Integrating Health-Related Services into Electrification Upgrades: Feasibility Study for BlocPower

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Green & Healthy Homes Initiative®

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Executive Summary

Brief Overview

The Green & Healthy Homes Initiative (GHHI) worked with BlocPower to assess the feasibility of integrating health-related services into electrification building upgrades in Alameda County, CA. This comprehensive feasibility study analyzes payment mechanisms, operations, technical, and economic feasibility, and makes recommendations for next steps to improve the feasibility of bringing healthcare stakeholders into electrification projects.

This is a pioneering study: there have been no examples found of electrification projects utilizing healthcare funding. However, this study does affirm linkages between building electrification, health outcomes, and healthcare savings. Modeled estimates of health impacts and monetized healthcare savings from improvements in indoor air quality show potential for cashable savings that could offset part of electrification project costs, especially if projects focus on populations with asthma. This dovetails with recent policy changes in California that allow for reimbursement for some home-based asthma services.

At present, feasibility scores are in the low to moderate range, reflecting a nascent, untested-at-scale intersection of electrification and healthcare. There is nevertheless the potential to improve feasibility across each section. While some findings in this study are unique to this geography, there will be a need to further strengthen the evidence base behind the health benefits of electrification in any target geography. After this executive summary, we provide further details on the project background, target population, key takeaways for each feasibility category, and the path forward.

Overall Feasibility Assessment

There is an average feasibility score of 2.5 (out of 5) across payment mechanism (3), operational (2.5), technical (2.5), and economic feasibility (2). This indicates a moderate-to-low feasibility – there are promising policies and local service providers in California for linking healthcare and electrification, but there are no examples of these being integrated for an electrification project. Similarly, there is an evidence base that indicates electrification improves indoor air quality related health outcomes, and drives associated health savings, but further research will be needed to strengthen this case. The top priorities for improving overall feasibility are conducting further research on resident health outcomes after electrification, engaging California health plans about utilizing asthma related payment mechanisms for electrification, and piloting a healthy homes model with local service providers.

Background

This study assesses the feasibility of incorporating health-related services into BlocPower building upgrades. Each section evaluates in turn the feasibility of incorporating healthcare funding (payment mechanisms), healthcare referrals and operational partnerships (operations), the health impacts of electrification (technical), and the monetized health impacts (economic). The study is focused on Alameda County, California, although many learnings and takeaways from this study may be applied in other locations, including New York state.

Residential building electrification – replacing fossil fuel-fired home appliances with electric appliances – is steadily gaining momentum across the country. In fact, Alameda County, CA, is home to an early initiator of this trend; in 2020, Berkeley, CA, became the first city to ban natural gas in new residential construction.[1] Since then, dozens of cities have followed suit, largely by prohibiting gas appliance inclusion in new construction, but more recently, by restricting sales of gas appliances to existing buildings as well. Notably, in March 2023, the Bay Area Air Quality Management District (BAAQMD) approved a rule to ban the sale of nitrogen oxide (NOx)-emitting natural gas water heaters in 2027, NOx-emitting furnaces in 2029, and large commercial water heaters in 2031.[2] The press release for this announcement contained important insight into the decision; while much of the support for building electrification has been premised around mitigating climate change and reducing energy consumption, the BAAQMD's rule made the case for electrification primarily by referring to health impacts.[3]

Residential gas appliances are increasingly being borne out by research as posing health hazards to residents. In particular, the connection between gas stoves and asthma has been explored by recent studies, including a recent study finding that nearly 13% of childhood asthma cases in the United States (and 20% of the cases in California) can be linked to gas stove usage in the home. In early May 2023, a group of 11 Attorneys General from across the US called on the Consumer Product Safety Commission (CPSC) to "address the public health and safety dangers of gas stoves, highlighting the disparate negative impact on children and underserved, lower-income communities."[4]

While these trends are promising, the integration of health-related services into building electrification remains at a nascent stage. From a funding and operational perspective, there has yet to be any explicit healthcare funding invested in building electrification, and to our knowledge, no participation of healthcare stakeholders as funders or operational partners in electrification-focused projects (i.e., projects focused on electrifying the homes of patients).

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[1] https://kleinmanenergy.upenn.edu/wp-content/uploads/2022/06/KCEP-Economics-of-Building-Electrification-06-21-22.pdf
[2] https://thehill.com/policy/equilibrium-sustainability/3903555-san-francisco-bay-area-to-phase-out-natural-gas-furnaces-and-water-heaters/
[3] https://www.baaqmd.gov/~/media/files/communications-and-outreach/publications/news-releases/2023/barules_230315_2023_003-pdf.pdf?la=en
[4] https://oag.dc.gov/release/ag-schwalb-leads-11-attorneys-general-urging

From a research perspective, the evidence base on the health impacts of electrification remains sparse in terms of peer-reviewed studies that measure the effects of electrification on indoor health hazards and that track health outcomes.

Thus, the goal of this report is to add to the evidence base around building electrification and healthcare, and to make actionable recommendations to BlocPower around how to integrate health into electrification building upgrades. This report is meant to serve as a building block to drive further work, investment, and projects that center health and equity in building electrification.

Background on BlocPower

BlocPower is a clean energy leader creating smarter, greener, healthier buildings for all by reducing the barriers to money-saving, quality-of-life-improving green building upgrades. BlocPower provides engineering, financing and project implementation services, with a special focus in historically left out communities across the country. These communities, and their buildings, are underserved by traditional energy services companies because they are considered too small, too costly, or too risky. BlocPower's portfolio of projects include houses of worship, schools, non-profits, small businesses and multifamily buildings. BlocPower saves clients money, reduces greenhouse gas emissions, improves health and creates local employment opportunities.

Background on GHHI

The Green & Healthy Homes Initiative (GHHI), the nation's largest healthy housing organization, is a nonprofit organization headquartered in Baltimore dedicated to addressing the social determinants of health and the advancement of racial and health equity through the creation of healthy, safe, and energy efficient homes. By delivering a standard of excellence in its work, GHHI aims to eradicate the negative health impacts of unhealthy housing and unjust policies for children, seniors, and families to ensure better health, economic, and social outcomes for low-income communities of color. GHHI has supported dozens of projects around the country by providing capacity building and technical assistance services such as lead and healthy homes program design; healthy homes assessment and intervention training; asset and gap analysis; performance measurement and evaluation design; policy analysis; cost-benefit analysis; coordination of healthy homes and energy efficiency resources; and many more. GHHI is the recipient of the 2018 HUD Secretary's Award for Healthy Homes and the 2015 EPA National Environmental Leadership Award in Asthma Management.

Local Population Overview

This feasibility study focuses on Alameda County, California. Before evaluating the feasibility of integrating healthcare payments into building upgrades, it is important to set the context of the local geography and population. We note that BlocPower operates in other geographies across the country, and specifically that New York state is another market of interest. In the tables below, background data on New York is included for comparative purposes. Many findings in this report could be transferrable to New York; for example, the health impacts model could be updated with assumptions and data particular to New York.

Alameda County contains 14 cities including Oakland, Berkeley, Emeryville, Fremont, and Hayward. Oakland is the county seat with a population of 440,646. As Figure 1 shows, Alameda County's rate of Medicaid coverage (19.9%) and current asthma rate (8.7%) are slightly lower than both California and New York, although the rates of each vary significantly within each region's different census tracts. The current asthma rates in each of these locations indicates that slightly under one-in-ten adults has asthma, indicating that one barrier to integrating asthma services (and funding) into building electrification projects focused on the general population will be a relatively low representation of asthma patients among residents in a typical building. These dynamics and implications will be discussed in greater depth in the Payment Mechanism and Operational sections of this study.

Figure 1: Background Demographic + Health Information[5]

Data	Topic	Alameda County	California (State)	New York (State)
Demographic	Population	1,648,556	39,237,836	19,835,913
	% Black / African American	9.58	5.28	13.37
	% Asian	32.46	14.97	8.64
	% Hispanic or Latino	22.42	40.15	19.48
	% Non-Hispanic White	28.26	34.26	53.46
Health	Medicaid Coverage (% of residents)	19.92	26.65	27.67
	Mortality rate, all causes	565.1	630.7	661.4
	Current asthma (% of adults)	8.70	9.40	9.98

Alameda County's housing and environmental data show that the county ranks in the 59th percentile on the Lead Paint Environmental Justice Index, which is a weighted measure of lead paint exposure, compared to the 49th percentile for California and New York. However, Alameda County is lower on the Environmental Burden Index (which tracks exposure to air pollution and

[5] Sourced from Metopio: https://metop.io/i/2ft3iu68

other environmental hazards) at the 35th percentile, compared to the 50th percentile for California and the 58th percentile for New York.

Overall, Alameda County's split of 55% owner-occupied housing vs. 45% renter-occupied housing is on par with both states. 60% of housing units in Alameda County are single family homes, and conversations with Revalue.io indicate that many of the units they are servicing in Alameda County are single family units. 66% of housing units were built before 1979, compared to 56% overall for the state of California, which helps explain the higher Lead Paint Environmental Justice Index value in Alameda County (as consumer use of lead paint was banned by the federal government in 1978).

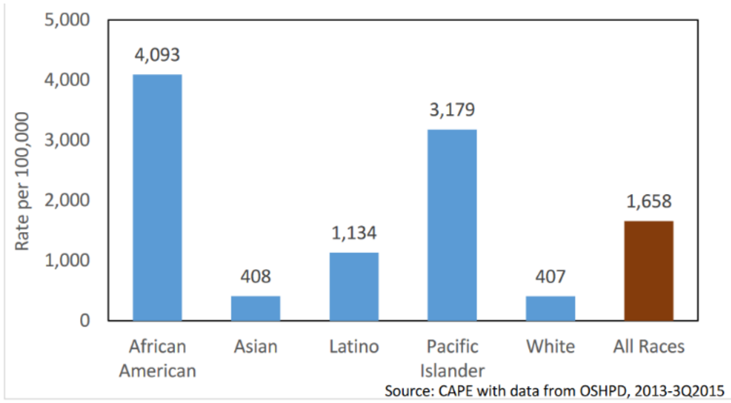
Figure 2: Background Environment and Housing Data[6]

Data	Topic	Alameda County	California (State)	New York (State)
Environ-ment	Lead paint Environmental Justice Index (percentile)	59.4	49.5	49.5
	Environmental burden index (percentile)	35.25	50.70	58.50
Housing	Owner-occupied housing (%)	54.63	55.87	55.39
	Renter-occupied housing (%)	45.37	44.13	44.61
	Severe housing cost burden (% of units)	17.82	19.93	19.46
	Single housing unit (%)	60.28	64.71	47.46
	2-4 housing units in building (%)	9.97	7.72	15.98
	5-19 units in building (%)	10.25	10.55	9.31
	20+ housing units in building (%)	18.08	13.39	25.16
	Built before 1979 (%)	66.13	56.48	74.57
	Median year structure built	1969	1976	1958

[6] Ibid

A 2018 report on Oakland's Housing Habitability and Health, written by the Alameda County Healthy Homes and Public Health Departments, sheds light on the intersection of racial, housing, and health inequalities in Alameda County.[7] To put a spotlight on asthma cases, over half of asthma-related Emergency Department (ED) visits in 2016 from children under 5 in Oakland

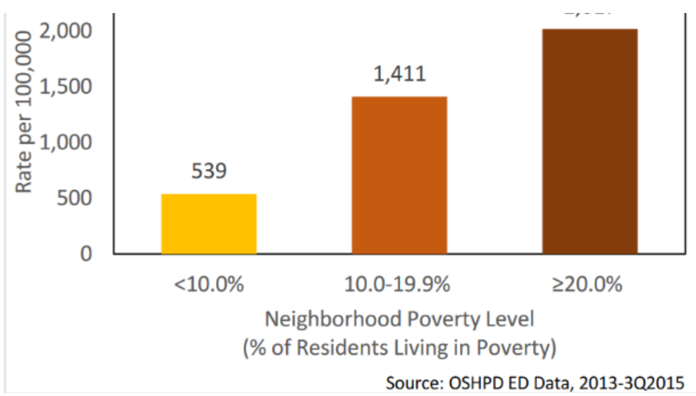
Figure 3: Asthma-related ED Visits from Children under 5 in Oakland



were African American children, despite African American children only making up 20% of the population under 5. Figure 3 shows that the asthma-related emergency department visit rate of African American children in Oakland is an order of magnitude higher than that of White children.

Furthermore, the report highlights that the higher a neighborhood's poverty level, the higher the asthma emergency department visit rate for children under 5. The asthma-related ED visit rate for neighborhoods with over 20% of residents living in poverty is over four times higher than the visit rate for neighborhoods with under 10% poverty.

Figure 4: Asthma-Related ED Visit Rate by Neighborhood Poverty Level in Oakland



[7] https://www.acgov.org/cda/lead/documents/news/health,housinginoakland.pdf

From a geographic perspective, higher rates of lead paint exposure and current asthma rates are found in Oakland and around its vicinity. Visualizations of lead paint indicators, current asthma rates, and the Medicaid population are found below.

Figure 5: Potential Lead Paint Indicator in Alameda County

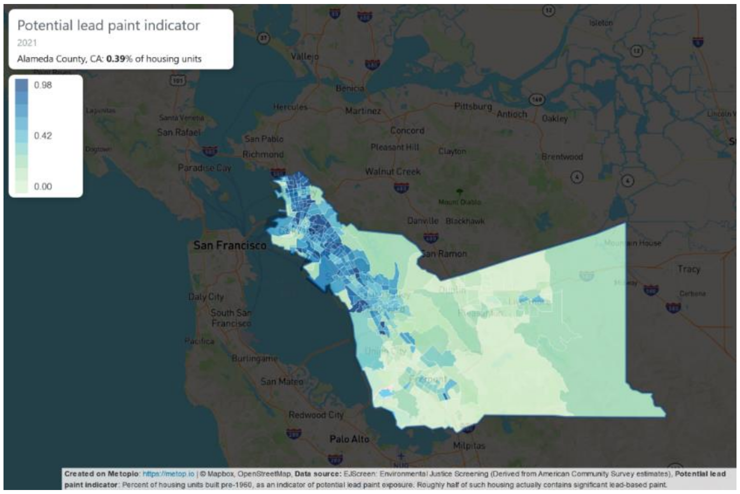


Figure 6: Current Asthma Rates in Alameda County

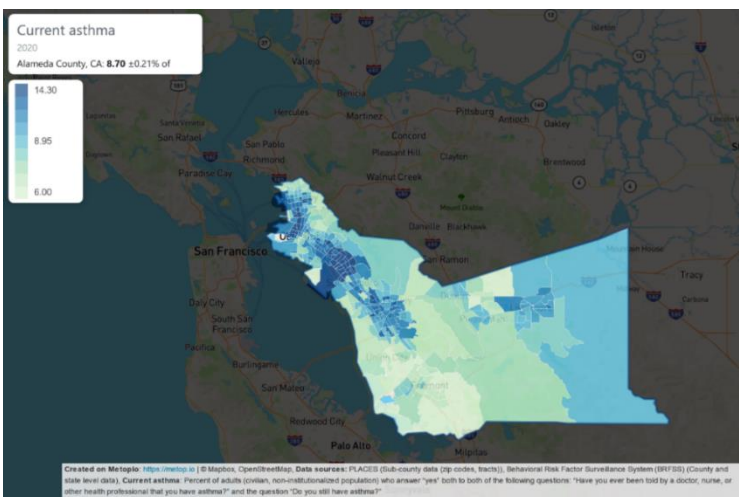
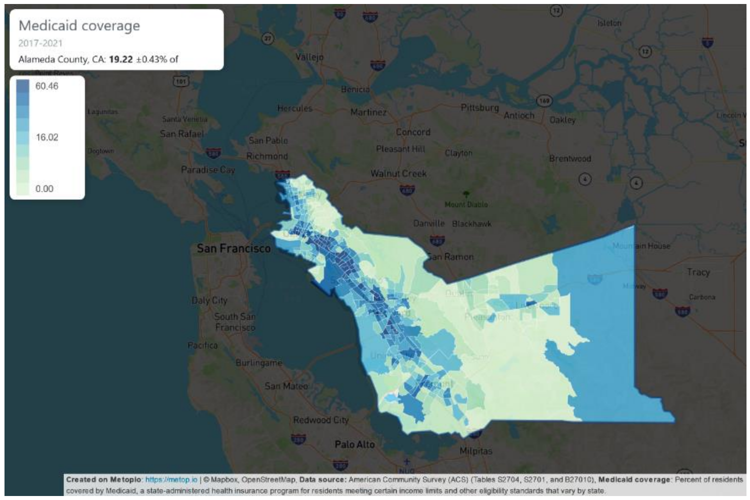


Figure 7: Medicaid Coverage in Alameda County



The specific target population for building upgrades will depend on program-specific factors, including healthcare payment mechanism (discussed in next section). For example, a program funded by a local hospital system might serve all residents within a certain geography, whereas programs sponsored by specific health plans would only target members of those plans. This feasibility study will evaluate possible payment mechanisms and operational considerations of integrating healthcare and BlocPower building upgrades, as well as the underlying technical and economic case for such programs.

Payment Mechanism Feasibility

As the evidence base develops for the health benefits of building electrification, so should the opportunities for healthcare payment mechanisms to fund BlocPower retrofits in Alameda County. GHHI reviewed possible payment mechanisms comprehensively, and ultimately included 13 different payment mechanisms for evaluation in this report. California has implemented innovative policy changes in recent years regarding healthcare funding for healthy housing programs. Mapping relevant payment mechanisms is also necessary as a precursor to braiding together funding sources for comprehensive healthy housing services in Alameda County. For some payment mechanisms covered here, additional policy advocacy and stakeholder engagement will be needed to achieve viability for electrification and decarbonization.

Key Findings

Traditionally, healthy housing services (including building electrification) are not reimbursable under state Medicaid programs, but California's healthcare system has demonstrated leadership in recent years by recognizing the significance of social determinants of health for underserved and vulnerable communities.

At present, the highest feasibility payment mechanisms that would link healthcare funding to BlocPower building upgrades are asthma-related, as California is pursuing a pioneering strategy that allows healthcare funds to cover home-based asthma care. These services include asthma self-management education, in-home environmental assessments for those with poorly controlled asthma, and environmental trigger remediation. The California Department of Health Care Services has secured a state plan amendment to add community health worker (CHW) services, asthma preventive services, and routine patient costs associated with participation in qualifying clinical trials as a Medi-Cal covered benefit in the Alternative Benefit Plan (ABP).[8] These new benefits combined with asthma remediation allowed by the Medi-Cal's Community Supports, which are new statewide services provided by Medi-Cal managed care plans as cost-effective alternatives to traditional medical services or settings, make possible the provision of comprehensive asthma services. The opportunity to braid BlocPower's building upgrades with educational and behavioral intervention services should be explored as a reimbursable asthma care program.

Other possible payment mechanisms for BlocPower have a feasibility rank of 2.5 or lower (out of 5), which signifies that they are not yet proven to be viable payment mechanisms in Alameda County, and/or that relevant stakeholders have not yet reached any commitments around these payment mechanisms. This section evaluates each payment mechanism along with its feasibility for BlocPower. GHHI has worked directly with states and stakeholders in several of these

[8] Department of Health Care Services Notice of General Public Interest. Release Date: June 1, 2022. https://www.dhcs.ca.gov/formsandpubs/laws/Documents/SPA-22-0019-Public-Notice.pdf

examples. For further background on feasibility scoring criteria, please reference the rubric in Appendix A.

It is also important to note that virtually all of these payment mechanisms are designed to serve individual patients based on their medical needs. This aligns with the majority of Alameda housing stock, as 60% of Alameda housing units are single family homes. However, there are considerations for individuals living in multi-family buildings. For example, if a multi-family building contains members of different health plans (as many buildings will, especially those with more units), then it would be difficult to persuade one of those health plans to find building-wide upgrades that would also benefit members of other plans. Alameda County actually presents more feasible conditions than other geographies in this regard because there is only one Medicaid plan serving the county, Alameda Alliance. Thus, buildings with high Medicaid enrollment would have those residents all as members of the same health plan. In order to determine which buildings meet this criterion, it would require working hand-in-hand with the health plan to identify where its members reside. GHHI has reached out to Alameda Alliance through different channels but has not yet secured a meeting to discuss potential collaboration. Partners have indicated that MCPs in general have limited capacity due to the rollout of In Lieu of Services across all topic areas addressing social determinants of health. We are hopeful that as MCPs continue to launch these services, there will be more opportunities to engage with them on aligning with electrification services.

Direct investment from hospital systems could be a more favorable approach than engaging health plans in this regard, as a hospital system will likely fund services for the entire geographic region it serves, not just select members of a certain health plan. However, depending on the payment mechanism, hospital-funded programs would likely still only serve a subset of the overall population, such as children and pregnant women (in a lead poisoning prevention program) or people with chronic asthma (in an asthma program). Thus, one of the core challenges in integrating healthcare into multi-family BlocPower building upgrades will be whether multi-family buildings that house residents with different health needs could be eligible for building-wide upgrades. These dynamics will also be addressed in the operational section but are worth keeping in mind when evaluating each payment mechanism and its feasibility for BlocPower.

Below, Figure 8 displays our feasibility scoring for each payment mechanism evaluated. Rankings are from 1 to 5, with 1 representing very low feasibility and 5 representing very high feasibility. After scoring and discussing each payment mechanism, this section concludes with the next steps for BlocPower.

Figure 8: Feasibility Scoring of Healthcare Payment Mechanisms for BlocPower

Payment Mechanism	Feasibility in Alameda County, CA
Medi-Cal Asthma Preventive Services	5
Medi-Cal In Lieu of Services / Community Supports - Asthma Remediation	3.5
Direct Administrative Payments (Reimbursement or PMPM)	2.5
Medi-Cal Managed Care	2.5
Hospital Direct Investment	2.5
Public-Private Healthy Homes Fund	2.5
CHIP HSI	2.5
Value-Based Purchasing	2
Climate-Related Health Expenses	1.5
Value of School Attendance	1

Analysis of Specific Payment Mechanisms

Medi-Cal Asthma Preventive Services

California has recently set policies that enable the provision of comprehensive asthma services, which makes the state a national leader in asthma-friendly policymaking. This includes both home-based asthma self-management education and environmental trigger reduction. This is significant because research demonstrates that the most effective asthma programs include a mix of self-management education and environmental trigger reduction. Despite this evidence, it is rare that Medicaid programs provide systematic payment pathways for both of these components.

California's state plan amendment provides reimbursement for asthma home-based asthma self-management education services while the In Lieu of Services provision provides a pathway for payment for environmental trigger reduction. This section and the next section will discuss these two payment pathways.

Effective July 1, 2022, California's state plan amendment 22-0003 adds asthma preventive services as covered services under Medi-Cal, which means that providers can now bill for these services just as other medical services can be billed for.[9] The scope of services are defined as those which are "consistent with the National Institutes of Health's Guidelines for the Diagnosis

[9] https://www.dhcs.ca.gov/formsandpubs/laws/Documents/SPA-22-0003-Pending.pdf

and Management of Asthma."[10] Generally, this includes the following services as described by DHCS:

- Basic facts of asthma's impact on the human body, including asthma control
- Roles of medications
- Environmental control measures
- Teaching individuals about asthma self-monitoring
- Implementation of a plan of care
- Effective communication strategies, including at a minimum, cultural and linguistic competency and motivational interviewing
- Roles of a care team and community referrals

Asthma preventive services may be provided by licensed medical provider or an unlicensed provider who holds proper certification.

Medi-Cal In Lieu of Services / Community Supports

California Advancing and Innovating Medi-Cal (CalAIM) is the Department of Health Care Service's (DHCS) multi-year Medi-Cal transformation project and is collectively made up of the state's 1115 demonstration waiver, consolidated 1915(b) waiver, Enhanced Care Management, state-approved in lieu of services, and state plan updates. A primary goal of CalAIM is to address members' social determinants of risk as a means to improve health outcomes and reduce health disparities.[11] In 2019 and 2020 RAMP, GHHI, and other stakeholders advocated for the inclusion of home modification as part of California Advancing and Innovating Medi-Cal's In Lieu of Services. As part of this 1115 demonstration, the State has created a preapproved list of 14 nonmedical in lieu of services (ILOS) that managed care organizations are strongly encouraged to offer as of January 2022.

One of the 14 services is "Home Modification Supports," which includes 1) Environmental Accessibility Adaptations (Home Modifications) and 2) Asthma Remediation. DHCS performed a literature review to determine ILOS services with a strong evidence base for efficacy and cost effectiveness. This review led to the inclusion of these home modifications in the ILOS menu of services. Up to $7,500 of home modifications may be provided per member.[12]

On January 1, 2022, the DHCS began implementing CalAIM— a framework that encompasses broad-based delivery system, program, and payment reform across the Medi-Cal program.[13] "CalAIM recognizes the opportunity to move California's whole-person care approach —first included in the Medi-Cal 2020 Section 1115 demonstration — to a statewide level, with a clear

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[10] Ibid.
[11] https://www.dhcs.ca.gov/provgovpart/Pages/CalAIM.aspx
[12] https://www.dhcs.ca.gov/Documents/MCQMD/ILOS-Pricing-Guidance-Updated-8-5-2021.pdf
[13] California Department of Health Care Services. CalAIM 1115 Demonstration & 1915 (b) Waiver. https://www.dhcs.ca.gov/provgovpart/Pages/CalAIM-1115-and-1915b-Waiver-Renewals.aspx

focus on improving health and reducing health disparities and inequities".[14] CalAIM provides new opportunities for MCPs to address social determinants of health. In particular, poor quality and unhealthy housing is covered as part of the introduction of a menu of pre-approved in lieu of services (ILOS).[15] Once the CalAIM initiative is fully executed there is flexibility for MCPs to provide benefits—which can include asthma self-management education, in-home assessment, and home modifications. This is achieved when MCP's contract with local service providers to deliver asthma trigger remediation and environmentally accessibility adaptations (EAA) to Medi-Cal beneficiaries and other low-income people in the state.[16]

Among the pre-approved ILOS there are two types of healthy home interventions - Environmental Accessibility Adaptations (EAAs - Home Modifications) and Asthma Remediation – which can now be funded by MCPs. Both EAAs and asthma remediation are payable up to a total lifetime maximum of $7,500 and the only exceptions to the $7,500 total maximum are if the Medi-CAL member's place of residence changes or if the condition has changed so significantly those additional modifications are necessary to ensure the health, welfare, and safety of the member or to enable the member to function with greater independence in the home and avoid institutionalization or hospitalization.

Based on GHHI's conversations with asthma providers, our understanding is that neither Alameda Alliance (the Medicaid Managed Care Plan [MCP] in the county) nor DHCS have provided a pre-determined list of reimbursable asthma remediation measures, such as gas stove replacement. The next step would be to clarify with both the state and health plan whether certain electrification measures like stove replacement can be reimbursable. If MCPs have the flexibility to determine which measures are reimbursable, then the inclusion of electrification measures would depend on contract negotiation with the asthma provider. If the inclusion of specific measures depends on policy guidance from the state, then stakeholders should lead this advocacy at the state level.

Asthma Remediation

As outlined in the DHCS Community Supports Policy Guide,[17] example asthma trigger remediations include the following measures shown below. A licensed healthcare provider must make the request to the member's health plan. The member must have poorly controlled asthma, which is defined as having an asthma-related emergency department visit or hospitalization or two urgent care visits in the past 12 months or a score of 19 or lower on the asthma control test.

- Integrated pest management
- Minor mold removal and remediation

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[14] *Ibid*

[15] California Department of Health Care Services. CalAIM. https://www.dhcs.ca.gov/provgovpart/Pages/CalAIM.aspx

[16] California Department of Health Care Services. CalAIM 1115 Demonstration & 1915 (b) Waiver. https://www.dhcs.ca.gov/provgovpart/Pages/CalAIM-1115-and-1915b-Waiver-Renewals.aspx

[17] https://www.dhcs.ca.gov/Documents/MCQMD/DHCS-Community-Supports-Policy-Guide.pdf

- Ventilation improvements
- Provision of supplies
- Other interventions that are medically appropriate and cost effective

Alameda County Public Health Department runs the Asthma Start program, which helps children with asthma gain control of their asthma. The program includes a team of social workers who provide home visits and asthma education. They also perform home assessments and are actively making requests to Alameda Alliance (the Medi-Cal health plan in Alameda) for approval of asthma remediation measures. In initial conversations, the health department has expressed interest in connecting their program with a network of contractors that could perform the work. A formal connection to Asthma Start could lead to a regular referral pathway to draw on asthma remediation dollars through Community Supports.

There may be other medical providers who are also requesting asthma remediation through Community Supports; GHHI is currently researching these potential partners. A statewide directory of asthma home visiting providers includes two other organizations in Alameda: 1) Breathe California of the Bay Area, Golden Gate, and Central Coast and 2) Roots Community Health Center.

Direct Administrative Payments (Reimbursement or PMPM)

MCPs have discretion as to how they spend their administrative budget, which is separate from the 85% of their budget which must pay for medical/healthcare services for their members. In Baltimore, GHHI's contract with Amerigroup for asthma home visiting services is paid for with administrative funding. Because MCPs must stay under a certain threshold for administrative spend, contracts using these funds are limited in scale. However, they could be used for a smaller program or pilot to prove out a larger investment that could then be counted as medical in the future using another mechanism.

Payments may be made on a retroactive reimbursement basis or a proactive Per Member Per Month (PMPM) basis. We have worked on healthy homes projects that have been funded by MCOs both ways.

Medi-Cal Managed Care

Managed Care Contract Provisions

States may incorporate quality improvement provisions in their Managed Care contracts that encourage or require Managed Care Plans (MCPs, otherwise known as Managed Care Organizations [MCOs] in other states) to address healthy housing or the social determinants of health broadly. An advantage of using this policy mechanism is that it requires relatively low administrative burden on the part of the state. These types of contract provisions may be set up in various ways, such as through a capitated payment separate from the MCO's premium (Pennsylvania) or a withhold payment that requires the MCO to demonstrate successful implementation of services or projects (Michigan). In both examples, MCOs are required to contract with community-based organizations to address SDOH and meet other specific goals set by the state.

State examples:

- **Louisiana's** most recent Managed Care Request for Proposals included a component for Value-Added Benefits, where MCOs were scored on their proposals to address eight topic areas for members, one of which directly addressed healthy housing. The RFP section for Value-Added Benefits (VAB) 2.6.3.1.6 required MCOs describe their plan for "identification and remediation of health-harming environmental factors related to an enrollee's shelter (e.g., infestations, mold…)." The VAB section of the RFP was worth 100 points of the total 1,500 possible points.

- **Michigan's** Population Health Management contract provisions require that MCOs work with community-based organizations and community health workers to address SDOH. In 2019 GHHI worked with Healthy Homes Coalition, Priority Health, and other stakeholders to set up a program in which asthma home assessments, home visits, and repairs were paid for as a project to mee the Population Health provision.

- **Pennsylvania's** HealthChoices contract includes a Community Based Care Management (CBCM) quality improvement program that allows MCOs to propose projects that address SDOH for their members. In 2017 GHHI worked with Health Partners Plans who used the CBCM program to fund community health worker home visits, home assessments, supplies, and integrated pest management for members with high utilization and cost for asthma.

In California, the boilerplate MCP contract includes provisions for In Lieu of Services (ILOS) that may cover nonmedical services including home modifications for asthma and home safety. ILOS has already been reviewed earlier in this report.

A second provision under the Quality Improvement System section states that MCPs must design and run two Performance Improvement Projects (PIPs) per year, which can be internal to the MCP or in concert with other MCPs. We note this provision because our home repair pilot project with local partners in Michigan was motivated by a Medicaid contract provision related to Quality Improvement as well.

The California contract itself does not go in depth into requirements or examples of projects but seems to leave discretion up to the MCP and DHCS (Department of Health Care Services, where Medi-Cal is housed), who may require an MCP to participate in one or more PIPs. To determine whether a PIP could be aligned with an investment in a home repair/upgrade project we recommend holding discussions with DHCS first, to see if PIPs are indeed a good potential option for involving MCPs in a project. The MCPs that serve Alameda County are Alameda Alliance, Anthem Blue Cross, and Kaiser. The next step would be initiating outreach to some or all of these MCPs in Alameda County.

Hospital System Direct Investment

It is well known that safe and healthy housing is a critical determinant of health. While some hospitals and health systems have been known to invest in new affordable housing developments, others have determined that there is a compelling case (and higher return-on-investment) to improve the quality of occupied housing, thereby improving the health and safety of residents. Investments in housing quality by a nonprofit hospital can be counted as community benefit for the purposes of maintaining nonprofit status.

In 2021, understanding the broad impact that housing conditions have on the community in terms of public health, education, crime, and economic opportunity, Lancaster General Hospital, part of Penn Medicine, partnered with GHHI to launch the Lead Free Families Initiative, a $50 million investment using hospital community benefit funds to conduct lead hazard control in Lancaster County, Pennsylvania, ensuring that children in 2,800 homes will be safe from lead poisoning. GHHI designed the program and is overseeing the lead hazard control work. The health system was awarded a $2 million HUD Healthy Homes Production Grant in order to address additional health, safety, and energy hazards and deficiencies in the homes.

Separately, in 2018, California-based Kaiser Permanente announced a $200 million Thriving Communities Fund that includes funding for a Housing for Health fund and a Supportive Housing Fund.

There are several hospitals and hospital systems in the Alameda area. Below is a list of the largest. GHHI recommends exploring existing relationships that may exist between the project team and individuals at these organizations, to socialize the project and discuss potential overlap with hospital priorities and funding interests.

- Alta Bates Summit Medical Center (Berkeley)
- Highland Hospital, Alameda Health System (Oakland)
- Kaiser Permanente Medical Centers, San Leandro and Oakland
- St. Rose Hospital, Hayward
- Washington Hospital, Fremont
- UCSF Benioff Children's Hospital, Oakland

We note that in 2022, UCSF Benioff Children's Hospital was an intended recipient of a $15 million donation from East Bay Community Energy, and the hospital had planned to use the funds to create an asthma program. Community groups, led by the Local Clean Energy Alliance, publicly opposed the plan, claiming that the funding should instead be directed to addressing the root causes of asthma through projects such as development of microgrids and building decarbonization.[18] Groups also took umbrage to the lack of competitive process to grant out the

[18] Community opposition to EBCE and Benioff project is summarized in the following two articles: https://www.localcleanenergy.org/August%202022%20Urge%20EBCE%20to%20Redirect%20%2415%20Million & https://dailycal.org/2022/09/27/controversy-over-ebce-proposal-to-use-surplus-funds

funds. It is unclear whether the original EBCE plans included any remediation of home-based asthma triggers; regardless, EBCE abandoned their plans for the Benioff donation. There may be an opportunity to engage EBCE about redirecting the $15 million to align with current energy, electrification, and health and safety home repairs. This may better align with community priorities while at the same time addressing asthma as EBCE and Benioff originally intended.

Public-Private Healthy Homes Fund

In 2020, GHHI began working with the Michigan Department of Health and Human Services (MDHHS) to design and create a statewide Lead Poisoning Prevention Fund (MDHHS administers the state Medicaid program, but the Fund sits outside the purview of Medicaid office). The goal of the fund is to provide affordable financing products to property owners to remediate lead hazards at scale. The fund is modeled after the state's highly successful Michigan Saves program, which provides affordable finance to property owners to install energy efficiency upgrades. Through Michigan Saves, the State leveraged its own investment of $8 million to secure additional private loan capital of over $300 million.

In 2021 MDHHS has secured $12 million of state dollars to seed the fund. This initial investment will establish a loan-loss reserve to attract additional private investment, similar to that of Michigan Saves.

In California, DHCS could consider a similar investment. An investment could be leveraged with private sector capital to provide a mix of affordable loans, forgivable loans, and grants for building modifications that improve resident health (including energy upgrades). The source of state funding is up for discussion. In Michigan, the state tapped its General Fund to seed the Fund. DHCS could consider something similar for a statewide model. Alameda could also consider a similar model at a local level using other sources of funding. One potential funding source could be California Climate Investments using cap and trade proceeds and programs designated for low-income communities such as the Transformative Climate Communities (TCC) grant program administered by the California Strategic Growth [19] TCC funds community-led projects that seek to reduce carbon emissions, and an electrification and healthy housing model could be a strong fit for this opportunity. The new funding round is expected this summer.

CHIP HIS (Children's Health Insurance Program, Health Services Initiative)

HSIs (a type of state plan amendment for CHIP) are often underutilized policy tools that states can use to leverage enhanced federal match to fund childhood asthma and lead-related issues tied to the home environment. This includes home repairs and upgrades that improve the health and safety of children; because there are strong overlaps between measures that address respiratory health and electrification (removal of combustion appliances that produce harmful substances), state investment under a CHIP HSI would present a strong leverage option for a portion of energy-related upgrade measures.

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[19] https://sgc.ca.gov/programs/tcc/

HSIs are funded under a state's CHIP administrative budget, which is made up of a federal share and state share based on an enhanced matching rate that varies by state—the Enhanced Federal Medical Assistance Percentage (E-FMAP). This federal matching rate is considered "enhanced" as it is higher than the FMAP for a state's Medicaid program. The administrative budget is limited to 10% of a state's total CHIP budget.

State Examples:

- In 2017 **Michigan** was the first state to implement an HSI to fund lead remediation, including lead service line replacement. Since then, several states have followed suit with similar programs. The Michigan HSI provides $23.8 million per year that is more flexible than the typical HUD lead hazard control grants, allowing the state and city agencies to expand the scale and scope of their lead poisoning prevention activities.

- Both **Maryland** and **Wisconsin** serve as unique examples because they are the only two states that have utilized the HSI to address both lead and asthma. With training support from GHHI, Maryland uses HSI funds to support environmental case management (lead and asthma) in addition to lead remediation. Wisconsin recently gained approval to use HSI funds to pay for home modifications that address both lead and asthma triggers.

It is possible for a new CHIP HSI to be budget neutral to the state while at the same time leveraging new federal investment; GHHI advised the State of Maryland in using this approach for its HSI in 2017. If California has existing state funds allocated to asthma or healthy homes programming outside of CHIP, the state can internally transfer those budget line item(s) into the CHIP administrative budget and count that amount as its share of a new HSI program. Doing this would then unlock new federal funds that could be applied to new programs and services.

Based on FY 2020 data, California's total CHIP budget was $3.866 billion, meaning its maximum administrative budget could theoretically be $386.6 million. The actual administrative budget was $56.7 million,[20] which left room for up to $329.9 million for CHIP HSI programs. Because California's Enhanced FMAP is 65%, the state share of that figure would be $115.5 million, and federal share would be $214.4 million. The next step would be to discuss this potential funding pathway with DHCS.

Value-Based Purchasing and Pay for Success Financing

For the past 25 years, New York has implemented a Medicaid Redesign Team 1115 Waiver that seeks to improve access, quality, and cost effectiveness of health services to New York's most vulnerable populations. One of the demonstrations in this waiver was the Delivery System Reform Incentive Payment (DSRIP) Program, which set up the state's Value Based Payment

[20] https://www.macpac.gov/wp-content/uploads/2021/12/MACStats-Medicaid-and-CHIP-Data-Book-December-2021.pdf

(VBP) Roadmap. The VBP Roadmap set requirements for New York MCOs to implement VBP contracts with community-based organizations to address SDOH.

GHHI supported the rollout of the VBP Roadmap by co-leading some of the "boot camps" hosted by the New York State Department of Health to explain the mechanics of how community-based organizations contract with MCOs for non-medical services, and how to evaluate those outcomes. The State used healthy homes as an example SDOH area that could be addressed by VBP.[21]

In 2022, GHHI launched an asthma program in NYC with Affinity by Molina Healthcare through an innovative model that combines outcomes-based financing with VBP to fund home-based services not typically covered by Medicaid fee-for-service. Third-party impact investors are providing over $4M to fund services provided by community-based service providers AIRnyc and Association for Energy Affordability. Leveraging VBP contracts, Affinity by Molina will repay the investors from cost savings created by the program's impact on medical utilization.

To incentivize these models, New York inserted language in its 2019 CMS-approved update to the VBP Roadmap encouraging the use of third-party financing models (also known as "Pay for Success") to address SDOH. The State also clarified that MCOs can classify SDOH expenses as medical costs.

New York likely has the most sophisticated VBP framework in the country, and other states are in various stages of developing similar value- or outcomes-based systems that enable retrospective payments based on effectiveness of medical and nonmedical services.

In California, DHCS's Value Based Payment Program[22] provides risk-based incentive payments to medical providers who meet or exceed preestablished metrics in the areas of behavioral health integration, chronic disease management, prenatal/post-partum care, and early childhood prevention. The most relevant metric to this project is "control of persistent asthma," where an incentive payment is provided for each member who has a diagnosis of asthma and is prescribed controller medication.[23] Unfortunately, there does not seem to be a good fit for aligning these incentive payments with home modification at this time. Despite this, a conversation with DHCS could reveal any future VBP plans that could support value-based

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[21] GHHI presentation from VBP Boot Camp:
https://www.health.ny.gov/health_care/medicaid/redesign/dsrip/vbp_bootcamp/docs/addressing_hr_factors.pdf
See Scenario C of VBP Bootcamp Class slides:
https://www.health.ny.gov/health_care/medicaid/redesign/dsrip/vbp_bootcamp/docs/2018-01-09/contracting.pdf

[22] https://www.dhcs.ca.gov/provgovpart/Pages/VBP_Measures_19.aspx#:~:text=%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8BValue%20Based%20Payment%20Program&text=These%20risk%2Dbased%20incentive%20payments,care%3B%20and%20early%20childhood%20prevention.

[23] https://www.dhcs.ca.gov/provgovpart/Documents/VBP_Policy_June_2019_6_11_19.pdf

payments that result from nonmedical services like building upgrades. Meeting(s) would allow provide an opportunity to demonstrate how New York's VBP system is producing creative ways that MCOs are investing in housing quality and other social determinants of health; this could serve as an example for future DHCS VBP policy.

In 2015 a group of Alameda stakeholders explored the feasibility of a Pay for Success feasibility study[24] that would capture cost savings (due to reduced hospitalizations and emergency department visits) from a home-based asthma intervention to pay for program cost. The project did not ultimately lead to a launched Pay for Success project.

Medicaid Funding for Climate-Related Health Expenses

One additional payment mechanism worth evaluating for feasibility is Oregon's recent Medicaid 1115 Demonstration waiver that makes particular climate-related health expenses eligible for reimbursement. While this was a pioneering, first-of-its-kind reform that has not materialized in other states, one can imagine similar motivations in California where both extreme weather events and compromised air quality have threatened residents in recent years. Oregon passed this reform one year after a heat wave killed nearly 100 people in the state; unfortunately, California is prone to both heat waves and wildfires, and during particular severe periods of wildfires in 2020, the Bay Area had the worst air quality in the world.[25]

The extent to which Oregon's waiver could cover, for example, BlocPower building upgrades, is still unclear. Oregon's Medicaid 1115 Demonstration waiver reads as follows:

> "Services authorized in this demonstration to address HRSN (Health-Related Social Needs) must be clinically appropriate for the eligible beneficiary. In Oregon, HRSN services will be provided for…individuals with a high-risk clinical need who reside in a region that is experiencing extreme weather events that place the health and safety of residents in jeopardy as declared by the federal government or the Governor of Oregon. The HRSN services approved for Oregon's demonstration include…clinically-indicated devices to maintain healthy temperatures and clean air during climate emergencies."[26]

The waiver will not be implemented until 2024.[27] Moreover, the actual waiver text above does not specify which equipment would be eligible, although news coverage suggests that both air filters and air conditioners would be included in the scope. Given that heat pumps have both

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[24] http://www.acgov.org/board/bos_calendar/documents/DocsAgendaReg_10_12_15/HEALTH%20CARE%20SERVICES/Regular%20Calendar/Pay_for_Success_Asthma_Initiative_Health_10_12_15.pdf
[25] https://www.latimes.com/california/story/2020-08-20/air-quality-danger-san-francisco-wildfire-smoke-ash
[26] https://www.oregon.gov/oha/HSD/Medicaid-Policy/Documents/2022-2027-1115-Demonstration-Approval.pdf
[27] https://apnews.com/article/health-oregon-portland-medicaid-medicare-f4980baa431dcab39bb58c73148c2677

heating and cooling capabilities, it is plausible that heat pumps could be reimbursable under this waiver, based on what we currently know. GHHI is reaching out to stakeholders in Oregon to learn more about the implementation of this waiver and will update accordingly.

Although this is a promising payment mechanism in Oregon, the pathway in California is more ambiguous given differences in each state's Medicaid waivers. California is already in the midst of its five-year 1115 Demonstration waiver which runs from 2021 to 2026, so the next opportunity to advocate for inclusion in California's 1115 Demonstration waiver is still several years away. Annual amendments to the waiver would not be a viable pathway to advocate for inclusion of climate-related health expenses, as these amendments can only apply to what is already included in the waiver.

Moreover, California is already pursuing an In Lieu of Services pathway (as explained above) for addressing health-related social needs. After speaking with an Alameda-based asthma program provider, GHHI learned that Medi-Cal will not be explicitly listing which home repairs and appliances are eligible, rather it will be up to individual MCPs and based on the care needs of each patient. Therefore, in California in the short term, the most promising opportunity remains to engage MCPs and local service providers about the eligibility of BlocPower upgrades under the ILOS program. For example, as the evidence base linking gas stoves and asthma strengthens, there could be an advocacy opportunity to push for reimbursement of stove electrification for asthma patients. As of now, stove replacement is not typically included in comprehensive asthma care (although ventilation/range hood repairs can be), so this is an area where more research and innovation could lead to the inclusion of electric stoves within reimbursable asthma-related home repairs.

Value of School Attendance

In California, the majority of funding for public schools is determined by a calculation that incorporates the individual school's three-year rolling Average Daily Attendance (ADA).[28] It is well documented that asthma is a significant driver of student absenteeism, and we therefore explore the potential financial value to public schools of preventing asthma-induced absenteeism.

Our research shows that asthma-related absenteeism does cost schools in terms of ADA funding, although the exact cost is uncertain. Calculating the ADA funding lost due to asthma is difficult, as school attendance data is not readily accessible. The only source to be found on this is cited in a 2022 article in *The Oaklandside*, which reports that, "According to a 2018 report by the Alameda County Public Health Department and Healthy Homes, "17% of Oakland's schoolchildren diagnosed with Asthma were chronically absent—missing 10% of the school year and reducing Average Daily Attendance by $894 per student per year." Extrapolating this data to 2022, and using Alameda County's population of 1.65 million, with 20.1% under the age of 18 and 13.6% of those children and teens diagnosed with asthma, this suggests 8,609 students

[28] https://www.cawsib.org/apps/news/article/1629780

who are chronically absent due to asthma. At a rate of $894 per student per year, this would total nearly $7 million in ADA funding across the county.

However, initial stakeholder engagement reveals that school systems may not be moved to act further despite the loss in funding. Conversations with the Alameda Healthy Homes Department, co-authors of that 2018 report, suggest that school districts within Alameda County have not proactively engaged county departments regarding asthma-related absenteeism. School districts may operate more conservatively regarding healthy housing due to capacity constraints, as well as reputational concerns. Despite losing an estimated $7 million annually from chronic asthma-related absenteeism, school districts in Alameda County are not discussing this problem publicly. Thus, while asthma-related absenteeism may be a compelling argument to use when lobbying both policymakers and building residents for home repairs, the feasibility of bringing school system funding into a healthy housing program appears low pending further research.

Conclusion & Next Steps

Given the multiple payment pathways that exist in California and other potential options that could be adopted, our feasibility scoring ranks Medi-Cal Asthma Preventive Services as the most feasible payment mechanism, followed by Medi-Cal In Lieu of Services / Community Supports as the second most feasible. The scoring reflects GHHI's conclusion that both payment mechanisms appear to be clearly defined and viable but have not yet been agreed to by the necessary parties, in this case local service providers in Alameda County such as Asthma Start. Other payment mechanisms are ranked as less feasible but may still be worth pursuing depending on BlocPower's assessment of opportunities in Alameda County.

To build on the conclusions in this section and work to improve the feasibility of payment mechanisms analyzed herein, the following next steps are recommended:

1) **Pursue the prospect of braiding asthma payment mechanisms with BlocPower services** by:

    a. Continuing to explore Medi-Cal policies (Asthma Preventive Services and ILOS/Community Supports) through stakeholder engagement. Initial outreach suggests that no asthma care providers in Alameda County are currently making use of ILOS payment mechanisms for home repairs. Continued education, engagement, and implementation assistance with organizations like Asthma Start will be needed for BlocPower to establish operational partnerships (discussed in next section).

    b. Building the evidence base between gas stoves and asthma toward the potential inclusion of stove replacement within reimbursable asthma-related home repairs. Research on cooking in low-income apartments in California found that range hoods were used for only 28% of cooking events.[29] Thus, further studies that elucidate the connection between gas stoves and asthma, including interventional studies that track health outcomes, would develop the evidence base constructively.

2) **Determine which other payment mechanisms are highest priority for BlocPower and approach healthcare stakeholders, namely MCPs and hospital systems, accordingly**.

3) **In discussions with MCPs, also gauge their interest in direct administrative payments for social determinants of health programs**. Additionally, perform outreach to DHCS to gauge interest in policies that would further expand resources for health-related home repairs, such as the CHIP HIS.

4) **Engage hospital systems in parallel with advancing MCP and DHCS discussions.** Since the funding mechanisms for home repairs by hospital systems and health will be very likely be different than those from the policy and MCP sides, discussions in those different sectors should not interfere with each other. As a starting point, the UCSF Benioff Children's Hospital in Oakland would be a promising target to engage, as the once-offered $15 million gift from EBCE to fund a pediatric asthma clinic there indicates potential for collaboration between the hospital and external energy and climate stakeholders.

[29] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7729668/

Operational Feasibility

Considering the payment mechanisms identified in the previous section, this section will focus on the operational feasibility of BlocPower incorporating healthcare stakeholders and health and safety remediation into its building upgrade programs. We begin this analysis by comprehensively reviewing health and safety hazards in the home and determining the extent to which weatherization and electrification would remediate each hazard. In general, health hazards that are already addressed by BlocPower building upgrades will require fewer operational partnerships or cross-training, and health hazards that are not addressed by electrification and weatherization will require some degree of additional training and/or partnerships in order to remediate them. Following this analysis, this section documents local service providers in Alameda County as well as key home repair funding programs, to evaluate the operational feasibility of braiding together funding sources. We propose a process flow for a healthy homes program in Alameda County where BlocPower could play multiple roles as a core project partner.

Key Findings

In order to braid and coordinate multiple funding sources for various healthy homes repairs in Alameda County, especially the asthma payment mechanisms identified in the previous section, operational partnerships will be needed. For example, asthma services in Alameda County are coordinated through Asthma Start, a program of the county health department. Patients with severe asthma in Alameda County would begin their comprehensive care journey with Asthma Start. Asthma Start provides home assessment, educational services, and other key social and behavioral interventions that comprise comprehensive asthma care. Utilization of Medi-Cal Asthma Preventive Services / In Lieu of Services would require coordination with Asthma Start to identify eligible patients with home repair needs, as Asthma Start would likely refer patients with such needs to BlocPower (or Revalue.io). However, Asthma Start has not begun implementing any of this Medi-Cal asthma-related funding, which would also require contracts with MCPs.

After mapping stakeholders across Alameda County, our proposed process flow (Figure 10) for what a healthy homes model could look like in Alameda County shows that an operating model that incorporates health-related services into building electrification is possible. However, our *Operational Feasibility* score is a 2.5 (out of 5) due to the fact that service providers do not have current plans to scale and coordinate comprehensive home repairs. Through outreach and engagement, it may be possible to increase the feasibility of a healthy homes operating model in Alameda County.

BlocPower Retrofits + Healthy Homes Interventions

Our operational analysis begins with an overview of health hazards present in the home. We evaluate which hazards are materially remediated by electrification and weatherization alone, and which hazards are only partially or not addressed by these upgrades and therefore require external service providers and partnerships if BlocPower is to seek integrating hazard remediation with electrification and weatherization.

Residential Health Hazard Identification and Interventions

Figure 9: Residential Health Hazards Overview[30]

	Hazard Type	Description	Health Endpoints	Source of Hazard	Home Repair Intervention	Educational / Behavioral Intervention	Remediated by electrification and/or weatherization upgrades? (Yes/Partial/No)
Indoor Air Quality	**Combustion Gases and Ventilation**	Pollutants (PM, O3, NOx, SO2, PAH, hydrocarbons, aldehydes, etc.)	Cardiovascular disease, cancer, adverse respiratory symptoms, chronic obstructive pulmonary disease, carbon monoxide poisoning hospitalization and death	HVAC, Water Heater, Gas Stove and Oven, other gas appliances	HVAC replacement (electric heat pump), appliance electrification, Weatherization (sealing and ventilation)	Install CO monitors	Yes
	Volatile Organic Compounds	Carbon-based chemicals from household items (e.g., formaldehyde, benzene)	Skin and eye irritation, asthma symptoms, pulmonary damage, ALS, VOC-related headaches, memory loss, sleep disorders, dizziness, neurological diseases with aging	Building materials (plywood, particleboard, fiberboard), appliances (gas stove), other household items (adhesives, sealants, carpets, cleaning products)	Appliance electrification, removal of VOC emitting products	Education on how to reduce VOC exposure	Partially (appliance electrification)
	Radon	Radon - Radioactive gas that enters through piping and compromised building foundations (prevalent in basements)	Radon-attributable lung cancer	Environmental (depends on region and geology)	Weatherization (cover exposed grounds in basements with vapor barrier, install radon mitigation system); ASHRAE compliant appliances	Education/awareness of radon exposure, home radon testing	No (WAP funds may not be used for radon-related remediation)
	Environmental Tobacco Smoke	Secondhand tobacco smoke	Respiratory illness, cardiovascular disease, cancer, pre-natal illness	Smoking inside the home, or smoke outside the home that enters the building	Weatherization (Insulation and Ventilation)	Education on smoking cessation, implementation of smoke free policies	No

[30] Adapted from GHHI publication, *Achieving Health and Social Equity Through Housing:* https://www.greenandhealthyhomes.org/publication/achieving-health-and-social-equity-through-housing/

Indoor Environmental Asthma Triggers and Allergens	**Biological and Unsanitary Conditions**	Mold, moisture, allergens, dirt + grime buildup	Asthma symptom days, asthma-related hospitalizations, asthma genesis, upper and lower respiratory illness	Water intrusion through walls and/or roof, objects within home, cleaning and washing behavior	Weatherization (Remove moldy objects from home, repair moisture intrusion points and insulation, exterior repairs, HVAC system repairs)	Distribute allergen impermeable bedding, education on cleaning protocols, dehumidifier use, carpet removal	Partially (weatherization and HVAC upgrades)
	Pest Management	Mice, rats, cockroaches, dust mites	Allergic reactions, asthma symptom days, asthma-related hospitalizations, rodent-related infections	Intrusion points, lack of cleaning, lack of pest management	Weatherization (sealing moisture intrusion points)	Integrated pest management, distribute allergen impermeable bedding, education on cleaning/washing protocols	No
Comfort & Safety	**Thermal Comfort**	Extreme heat or cold in the home	Thermal stress, exacerbations of COPD, increased mortality for those with chronic conditions	Poor home insulation, ventilation, and malfunctioning	Weatherization (improve insulation and increase ventilation)	Education on HVAC maintenance protocols	Partially (in cases where resident is experiencing thermal stress prior to upgrade)
	Unintentional Injury and Fall Prevention	Falls	Unintentional injuries (falls + other), hospitalizations and deaths	Tripping + fall hazards in home	Fall prevention (installing grab bars, fixing flooring transitions, installing better lighting, etc)	Education on home safety, maintenance, and repair protocols	No
	Fire Safety	Burns and thermal injuries	Fire-related injuries, hospitalizations, and deaths	Fire hazards in house, lack of functioning smoke detectors	Weatherization (repair faulty wiring)	Install smoke detectors	Partially (Weatherization can repair wiring that would otherwise cause electrical fires; more research needed on electrification + fire safety)
	Lead-based paint and lead-safe weatherization practices	Lead poisoning as a result of exposure to lead dust and/or chips	Childhood lead poisoning (increased risk of learning disabilities and behavior disorders), adult CVD	Exposed + peeling lead paint	Lead remediation (Encapsulation, enclosure, window replacement)	Education on lead safety practices	No

As shown above, our analysis concludes that a BlocPower building upgrade would definitively reduce concentrations of combustion gases and ventilation, due to the replacement of gas-fired appliances with electric appliances. However, all other hazards are only partially or not addressed by electrification and weatherization, including asthma triggers and allergens, which involve other educational, behavioral, and home repair interventions. This analysis of residential health hazards helps inform both the operational and technical sections of this study. For healthcare stakeholders to invest (financially or otherwise) in building upgrades, they will need confidence that the building upgrades truly improve health outcomes. Thus, the technical section of this report will focus on health outcomes where electrification and weatherization can remediate health hazards, namely indoor air quality. For other residential health hazards such as asthma triggers, BlocPower will require operational partnerships for some aspect(s) of remediation, whether it is referrals + identification of patients, provision of services (especially social work services such as behavioral counseling and asthma education), and other aspects.

To evaluate the operational feasibility of healthcare integration into home upgrades in Alameda County, GHHI has analyzed the landscape of service providers and provided an initial mapping of organizations and programs.

Operational Analysis of Alameda County Service Providers

GHHI's analysis of the home modification landscape in Alameda reveals a diverse group of service providers that have the capacity to deliver home modifications across the domains shown in Figure 9. Below is a set of Alameda organizations that deliver home modification services or services that could be part of a larger, comprehensive intervention model. There are likely additional organizations that could be part of this group as well; however, these listed appear to have the largest footprints in the area.

- **Alameda County Healthy Homes Department:** Lead hazard control and healthy homes supplementary repairs
- **Asthma Start (Alameda County Public Health Department):** Home-based asthma services, including home assessment and remediation of asthma triggers
- **Breathe California of the Bay Area:** Home-based asthma services, including home assessment and remediation of asthma triggers
- **Habitat for Humanity:** Critical repairs, minor repairs, accessibility upgrades
- **Rebuilding Together:** Safety modifications and minor repairs
- **revalue.io:** Energy efficiency upgrades, electrification, and weatherization
- **Spectrum Community Services:** Weatherization (no fuel switching)

Figure 10 summarizes current key home repair programs that exist in Alameda.

Figure 10: Home Upgrade and Home Repair Programs

Program	Administered by	Scope	Scale	$ per Unit
Health-E Home	EBCE, BlocPower, revalue	Incentives for EE upgrades and electrification	60 homes	$22k avg
BayRen	BayRen	Incentives for EE upgrades, electrification, weatherization	(data missing)	(data missing)
Weatherization Assistance	Spectrum Community Services	Grants for weatherization	200-250	Est. $5k-$10k avg

HUD Lead and Healthy Homes, Settlement Funds	Alameda County Health Department	Grants for lead hazard control	~50	Est. $10k-$20k avg
CalAIM Asthma Remediation	Alameda Alliance via Asthma Start, Breathe CA, TBD	Asthma trigger reduction	(data missing)	$7.5k max

Based on the review of service providers and funding sources, several takeaways emerge:

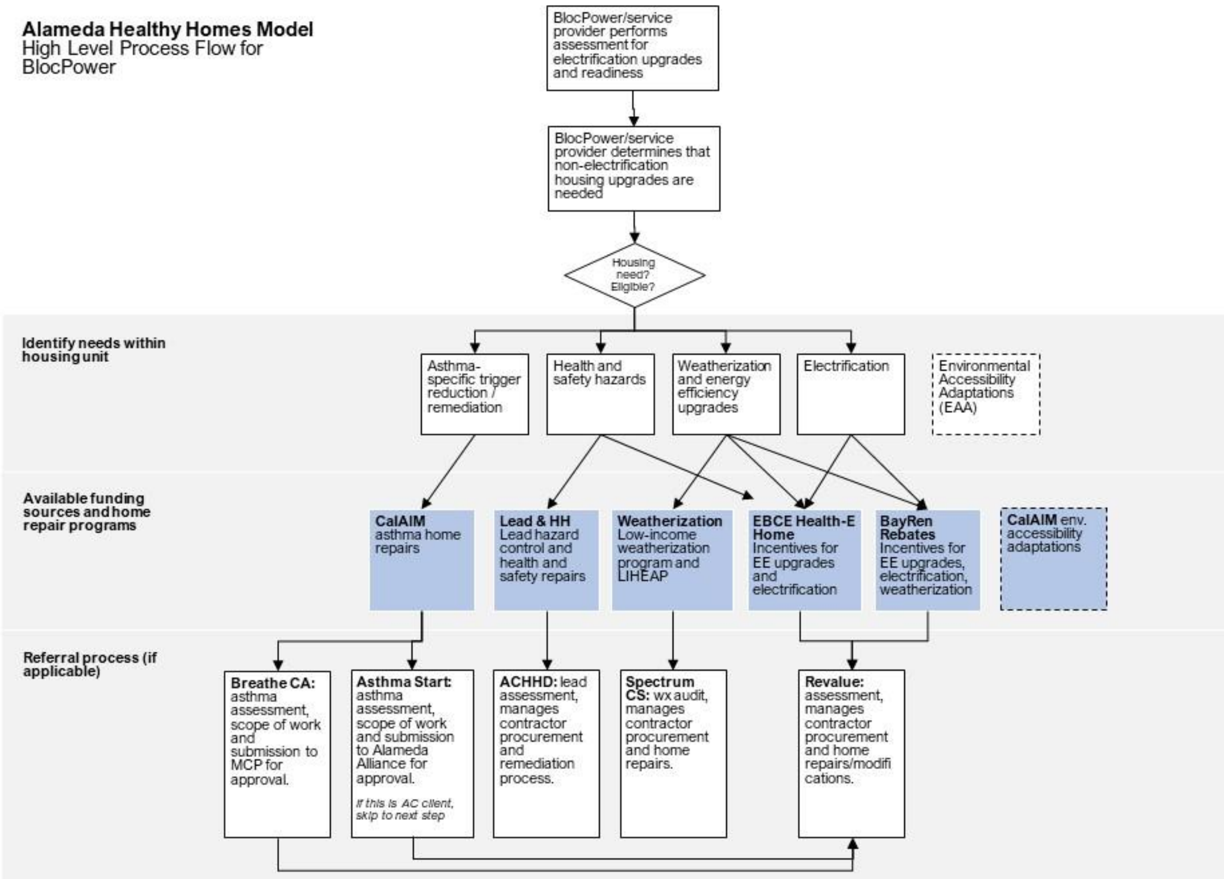
- Current electrification programs offer rebates and financing options for a large scope of home upgrade measures; however, current programming is limited in scale and the lack of grant funding may present gaps in equitable access to these types of home upgrades. Incoming funds through the Inflation Reduction Act will increase the availability of rebates and financing options.

- Weatherization is likely the largest of all available home repair programs, but the parameters of the Weatherization Assistance Program (WAP) limit its ability to address health and safety hazards and prohibits electrification of gas appliances. The expected increase in WAP services under the Bipartisan Infrastructure Bill (BIL) will further expand the reach of this program; however, stakeholders are concerned that this expansion will result in a proportional increase in deferrals due to the existing gap of health and safety dollars. There is a likelihood that WAP expansion may also undercut the push for building electrification by increasing the rate at which old fossil fuel appliances are replaced with new fossil fuel appliances, thus extending the longevity of these appliances.

- Programs that can address health and safety issues such as asthma and lead are limited in scale though the rollout of CalAIM services is still in its infancy, so there is still uncertainty around the rate of ramp-up.

To deliver a comprehensive and coordinated set of services alongside electrification building modifications, we recommend streamlining service delivery with existing home repair programs. Doing so would allow stakeholders to address other health, safety, and energy issues before or at the same time as performing electrification upgrades.

Figure 11: Draft High-Level Operational Flow for Healthy Housing Upgrades in Alameda County



Currently, Alameda service providers cross-refer between programs informally and on a case-by-case basis. Case studies are already emerging that demonstrate the value of leveraging one program's services to unlock other resources that would otherwise be deferred. Figure 11 above shows a draft process flow diagram of how Alameda housing units could be served by multiple home repair programs working in coordination:

- In a "no wrong door" approach, all Alameda home repair programs would use a common home assessment (or screening tool in addition to their program-specific assessment forms) to identify household needs that can be met through their own program(s) as well as others in Alameda.
- Identification of housing units for a potential combined intervention for electrification and whole home repairs could happen a number of ways:
    - **Existing / "real time" home repair clients:** As existing home repair/upgrade programs serve clients in their pipeline, program managers actively identify housing units that would be a good candidate for energy upgrades or health-related home repairs funded by other programs. This reflects more of an ad hoc

approach and is already happening to some extent in Alameda (and where a central coordinating organization could facilitate).

        - If a multi-family unit is served under this approach, a system-level protocol could be to perform a building-level assessment (and/or assessment of other housing units within the building) for broader upgrade/repair needs. The complicating factor for braiding healthcare funding under this approach is that families in different housing units may meet different eligibility criteria and be members of different health plans.

    - **Health plan / BlocPower cross reference:** Health plan identifies members who are at risk of home/indoor air quality related health issues. This list is cross referenced with BlocMaps or other BlocPower methodology to determine building addresses that are also strong candidates for electrification. Health plan provides some level of investment for home repair and building upgrades for those members identified and additional leverage may occur based on the need and eligibility of housing units served.

        - In multi-family buildings, the health plan would only insure the portion of residents who are plan members and who meet the plan's eligibility criteria. Level of health plan investment into building-level upgrades could be based on something like a fixed fee per, although Medicaid health plans would likely pay based on actual costs incurred. Commercial plans may have more flexibility in how their investment is structured.

    - **Hospital / BlocPower cross reference:** Similar to the previous example, a hospital identifies patients who are at risk of home- or indoor air quality-related health issues. This list is cross referenced with BlocMaps or other BlocPower methodology to determine building addresses that are also strong candidates for electrification. Hospital provides some level of investment for home repair and building upgrades and additional leverage may occur based on the need and eligibility of house units served. While health plan investment would be tied only to individuals who are covered under that plan, this is not the case for hospitals. Hospitals could provide funds using more of a general approach; for example, a percentage of the total cost of home repair and upgrade for a whole building regardless of it being a single- or multi-family building.

- Based on the needs of the household, they could potentially be eligible for multiple home modification programs, including electrification from BlocPower programs.
- Figure 11 depicts a model where each program is responsible for identifying the broader needs within a housing unit and coordinating referral(s) between other local organizations. While this is possible, it may create undue administrative burden for program managers at each of the organizations.
    - Ideally, the determination of available leveraged funding would be performed by a central coordinating organization to streamline this triage process. This could be performed within one of the organizations already providing local home repairs. Alternatively, this role could also be played by a centralized third party that has

regular, frequent touch points with all participating organizations. For example, in other sites across the country, GHHI has played the role of a third-party 'outcomes broker' who coordinates all participating organizations in a healthy homes program in a project management function.

- A central coordinating organization could help facilitate establishing a model as laid out in Figure 11. Model development could include service provider identification and engagement (in markets besides Alameda where new research would be required), capacity building around MOU development, process flow coordination, data sharing, and training to a common set of home assessment and implementation of electrification measures.
- If a household needs and qualifies for multiple services across different organizations, it is likely that each organization will need to perform their own home assessments based on specific program/funder requirements. If there is leeway in how home assessments may be consolidated and who performs them, there may be opportunities to create a shared, common home assessment form across different programs. A common, standalone screening tool could be adopted by individual programs as an "add-on" to existing home assessment forms to ensure that high-level health, safety, energy, and electrification readiness measures are checked across all programs.
- The creation of a scope of work could also potentially be consolidated between programs if flexibility is allowed. This would facilitate the procurement of contractors and coordination of work within a single home. In the absence of such flexibility, a central coordinating entity that oversees work across multiple scopes of work would help streamline the phasing and timeline for any given project.
- After home modifications—and any applicable home visiting services for asthma or other health issue areas—are complete by one or more programs, a quality inspection should be completed to ensure that all work has been performed correctly. This inspection could be performed by each individual program that has touched the home; however, it would be advantageous to arrange for a central entity to perform the quality inspection compared with the full scope of work that was completed across multiple programs.
- In Appendix B, a more detailed menu of services and coverage under each program is listed out. As it shows, the EBCE Health-E Homes program is the only funding source that covers all of electrification, weatherization, and health and safety hazard remediation. This shows the need for braiding of different funding sources to serve communities in Alameda County at scale, as well as the uniqueness of programs like Health-E Homes and the importance of advocating and fundraising for expansions of such programs.

The majority of services and programs shown on the flowchart are currently operational and therefore available for aligning with other home modification services. We are currently assessing how asthma remediation and environmental accessibility services through CalAIM can be incorporated as well. While the Community Supports policy went into effect last year, the Managed Care Plans (MCPs) are still in the midst of rolling those sets of benefits out through their provider network. From discussions with asthma program providers, our understanding is that existing asthma programs must submit applications to the plans to be able to access reimbursement for asthma remediation. We believe that reimbursement for asthma remediation services will be available later this year. EAA services may follow at a later date. Once providers and health plans finalize contracts for these services, the next step would be incorporating them into the broader, coordinated service delivery model.

Feasibility of Scaling

Workforce development: With new electrification funding that will flow from Inflation Reduction Act-related programs, as well as the tripling of the national Weatherization Assistance Program, the contractor labor pool will need to significantly increase to absorb the increased investment. And as these federal programs scale up, it will be imperative to center racial equity within workforce development initiatives. In conversations with revalue.io, we have learned that there is a shortage of minority- and women-owned contractors to perform electrification, weatherization, and health and safety remediation work. Revalue.io has said it is working closely with the National Association of Minority Contractors to this end. There are strong workforce programs currently operating in Alameda, including those led by revalue.io, the Cypress Mandela Training Center, and other local stakeholders. The Cypress Mandela Training Center stands out as a CBO that offers free 16-week training courses in skilled trade jobs and could be a potential partner if BlocPower were to expand its Civilian Climate Corps program to Alameda County. We recommend further analysis of how BlocPower could partner with existing workforce efforts to scale minority- and women-owned contractors to meet demand from increased funding as well as enhanced coordination of home repair services.

Service provider capacity building: revalue.io is the current implementer of the Health-E Homes program and also manages BayRen installations and other grant program measures. Scaling a coordinated model in Alameda would require an increase in staff capacity at revalue to lead system-level coordination across electrification and home repair programs. Capacity building would also be needed to train program managers on a unified approach to home assessment that incorporates electrification readiness, as well as scope prioritization and process flow that leverages city-wide programs.

Data systems: Currently, each organization manages their respective home repair programs distinctly from other programs. Program data is collected and maintained within each organization, and information sharing may occur informally when a referral is made. If systems-level coordination is to occur, a shared data system would facilitate cross-referrals, leveraging funds across programs to deliver holistic home repairs and upgrades, and knowledge of what measures are provided by multiple programs. There are examples of how other jurisdictions are using data platforms to address these needs; GHHI administers an Efforts to Outcomes (ETO) data platform in Detroit across eleven community partners to track home repair measures for the Detroit Home Repair Fund. Salesforce is also used in some jurisdictions to track similar home repair efforts.

Conclusion & Next Steps

Our operational analysis concludes that although there are service providers performing healthy housing services in Alameda County, braiding funding and coordinating services across different providers will require new, focused resources. The feasibility score of 2.5 (out of 5) could be improved by strengthening coordination and plans to scale between service providers. The following are possible next steps for BlocPower to pursue:

1) **Healthcare housing-identification pilot:** Engage local healthcare partner(s) on a pilot that identifies and funds comprehensive home repairs under a coordinated approach where households and housing units are cross-referenced by healthcare and BlocPower to create a lead list for housing upgrades and repairs. As described in the section above, this type of collaboration could occur at the health plan or hospital level. A hospital partnership would provide a more straightforward approach to serving multifamily buildings. GHHI could facilitate the engagement and socialization of potential hospital partners based on its previous work and current model with Lancaster General Hospital in PA (GHHI is administering a $50M program funded by the hospital for lead hazard control). GHHI could also support data analysis and has previously structured numerous data pulls of administrative healthcare data to identify high cost/risk patients who could benefit the most from health and safety home repairs.

2) **Pre-existing service provider + healthy housing pilot:** Even if a health plan or hospital system does not wish to formally join an electrification pilot, an additional next step could be piloting a healthy homes model in Alameda County with existing service providers. One possibility to fund the operations of this pilot could be raising philanthropic funds from a foundation or applying for a state or national grant. With sufficient funding for a third-party outcomes broker who can coordinate home repair service providers and various funding sources, a healthy homes pilot could rely on pre-existing referral streams (e.g., Asthma Start's asthma patients) and assess those referrals for comprehensive health and safety needs, including electrification. It is possible to scale down the coverage of the healthy homes pilot, for example a more modular version could focus just on asthma remediation and require initial partnerships with Asthma Start and Breathe CA when CalAIM reimbursement for asthma remediation becomes available. Such a pilot could also track health outcomes in an effort to strengthen the case for healthcare stakeholders to participate in future projects.

3) **Pursue service provider capacity building:** If launching a formal pilot is determined unfeasible or lacks sufficient funding, a third option is to simply continue engagement of Alameda service providers to socialize a coordinated home upgrade/repair model. GHHI has begun this process under a project with revalue.io but further work is required. Based on stakeholder input and feedback, next steps could also include formalizing cross-agency collaboration: establishing MOUs, aligning process flows, scopes of work, referrals, and common approach to assessing for common health and safety hazards alongside electrification readiness.

Technical Feasibility

The objective of the technical feasibility section is to estimate the quantified health impacts of residential building electrification using literature and modeling tools that are relevant for a healthcare audience. When engaging a health plan or hospital system about participating in an electrification program as a funder and/or referrer of patients, it will be important to show the expected health impact of that program using metrics and evidence that are resonant with the stakeholder. There are a range of health hazards and health endpoints that could pertain to electrification, but levels certainty and strength of evidence of supporting research to model health impacts vary widely. The health endpoints included in our technical model are all-cause mortality, asthma-related emergency room visits and hospitalizations, and incidents of myocardial infarction (heart attack), for reasons that will be detailed further in our analysis below. As part of this section, we also evaluate the evidence base around electrification and health, which continues to develop and is at an early stage for certain hazards/health endpoints.

Key Findings

Although the evidence base is increasingly growing to illustrate the link between indoor air quality, electrification, and health, there is still a paucity of tools and a nascent evidence base to make a health-centric case for electrification to health plans and hospital systems. Several models exist to estimate how changes in outdoor criteria air pollutants (ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM10 and PM2.5) impact population health, but no tools currently exist to estimate the indoor air quality-related health benefits of switching from gas appliances to electric. GHHI's technical model is an initial attempt to make these estimates for indoor air quality, but more research and investment will be needed to build robust tools with predictive accuracy for a wide range of building types and resident populations.

GHHI's technical model focuses on how electrification-related improvements in indoor air quality impacts mortality, asthma-related Emergency Room Visits (ERVs) and Hospital Admissions (HAs), and myocardial infarction (heart attacks). Our analysis shows a strong evidence base illustrating that reductions in nitrogen dioxide and carbon monoxide pollution indoors is linked to reduced mortality, avoided emergency room visits and hospitalizations due to asthma, and reduced myocardial infarction incidences. While particulate matter concentrations may be improved indoors due to building electrification, the evidence base is insufficient to include this pollutant in the model.

Gas stoves are the predominant driver of indoor air pollutants, as many homes lack ventilation and/or range hoods or fail to use them while cooking. Gas-fired water and space heaters are regulated to be vented outside and are therefore sources of outdoor air pollution, but in instances of malfunctioning ventilation, leakages, or backdraft, will release pollutants into the home.

To illustrate and estimate these health impacts, GHHI evaluated a hypothetical 60-building electrification program in Alameda County with its technical model. The building stock in this program is 60% single-family housing, and 40% multi-family buildings with 20 units each, yielding an estimated residential population of 1470. There are an estimated .00255 avoided deaths annually due to reduced NO2 exposure (equivalent to .17 avoided deaths per population of 100,000), .01063 avoided asthma-related Emergency Room Visits and .00062 avoided asthma-related Hospital Admissions, and no reduction in CO-related myocardial infarction due to a relatively modest exposure.

The estimates of mortality in the model appear consistent, if higher, compared to similar estimates of mortality (due to outdoor air quality) from the Bay Area Air Quality Management (BAAQMD) district around banning NOx-emitting water and space heaters. If the population of Alameda County were used as the program population in the model, this equates to 2.86 deaths avoided per year and 42.90 avoided over the course of 15 years. BAAQMD had reported 37-85 avoided deaths due to their proposed rule, and the Bay Area has nearly six times the population of Alameda County.

The case for avoided asthma emergency room visits and hospital admissions is weak when serving the general population, but if the model inputs are changed to characterize a 60-building program where each household has one member with severe asthma (one hospitalization per year), the model output indicates 2.02 avoided hospitalizations over 15 years. As the Economic Feasibility section will discuss, this could be a more significant figure for healthcare stakeholders. This finding illustrates challenges discussed in both the Payment Mechanism and Operational sections around how home-based asthma care programs are typically referral-based (so that the population served are known to have severe asthma) whereas BlocPower's model involves a building-by-building screening with usually limited data on the residents of each building.

There are myriad assumptions that go into the model, and the heterogeneity of each individual home and the residents in each home means that the smaller the number of buildings evaluated in this model, the less predictive accuracy it is likely to have. In speaking with researchers and developers of similar tools, a common sentiment is that it is simply too granular to make estimates and assumptions about indoor air quality without actual data from that building. Models like GHHI's, as well as EPA's COBRA and Harvard's CoBE tool are likely most useful in engagement with stakeholders evaluating a portfolio of buildings, so that the pooled health effects can be analyzed for a larger sample at the population health level.

Several residential health hazards, such as Volatile Organic Compounds (VOCs), Fire Safety, and Thermal Comfort, are likely improved by BlocPower building upgrades, yet there is currently insufficient research to model these impacts. Future research that strengthens the evidence base could result in these health hazards being included in health impact models.

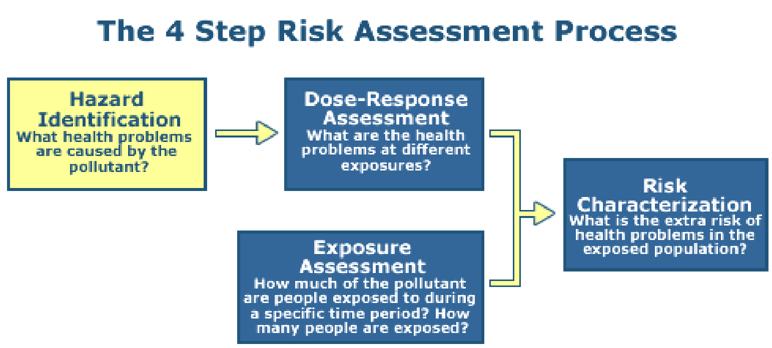
According to GHHI's feasibility rubric, the Technical Feasibility score is 2.5 out of 5, though there is possibility to improve this through future projects. The feasibility scoring is based on the fact that there is evidence from other populations about the relationship between indoor air pollutants and health outcomes, and separately there are limited studies on the intervention effect of electrification on indoor air pollutants. However, there is no direct, peer-reviewed evidence on the health outcomes for populations whose homes have been electrified. A stronger evidence base will help improve the feasibility score, and the Conclusion & Next Steps section makes recommendations about further directions for research.

Background and Methodology

To evaluate the impacts of BlocPower retrofits on health outcomes, our analysis synthesizes several bodies of literature into a spreadsheet-based model. The methodology follows the Human Health Risk Assessment process developed by the U.S. Environmental Protection Agency to characterize the magnitude and nature of risks to humans from chemical and other environmental stressors.

The four steps of this risk assessment framework are to: 1) Identify health hazards inside the home; 2) Assess the relationship between exposure to a hazard and the biological response[31]; 3) Determine how a BlocPower upgrade reduces exposure to air pollutants within the home, and finally, 4) Characterize the overall health risk mitigated after a BlocPower upgrade. Subsequently, in the economic feasibility section, we calculate the monetization of these health outcomes to generate financial metrics.

Figure 12: US EPA's Human Health Risk Assessment Framework



The design of the technical model presents fundamental questions about the scale at which to evaluate the health impacts of building electrification. As will be detailed later in this section, current tools for evaluating the health impacts of changes in building energy use are focused on outdoor air pollution and associated mortality, not indoor air quality, in part because evaluating the heterogeneity of individual buildings and their occupants produces much more uncertainty than estimating population-level health impacts. In other words, one can more reliably estimate the change in mortality across the entire Bay Area due to changes in outdoor CO and NO_2 concentration, than estimate the specific impacts on mortality for a family of four living in Oakland after stove replacement and heating and cooling electrification. Individual buildings vary widely in terms of the actual concentrations of pollutants experienced in each unit, and

[31] EPA. Conducting a Human Health Risk Assessment. https://www.epa.gov/risk/conducting-human-health-risk-assessment#tab-3

individuals vary widely in terms of their behavioral health risks and outcomes. However, BlocPower's interest (and the architecture of the BlocMaps software) is in a building-by-building electrification approach, and our objective in this study is to bridge this building-by-building electrification perspective with the traditional population-scale health approach of health impact models. The technical model can be scaled down to estimate health impacts for an individual building, but can also be scaled up to evaluate multiple buildings (e.g., a municipal electrification program).

For the purposes of demonstration, the model is pre-populated with a 60-building scenario, to mimic the East Bay Community Energy Health-e Homes program (although we used a 60/40 split of single-family to multi-family housing to reflect Alameda County's overall housing stock). We will return to this example throughout the following sections to illustrate the findings of the technical model for a specific cohort of buildings.

Hazard Identification: Background on Key Residential Hazards

The technical analysis begins by identifying which hazards are to be considered in the health impacts model. To build this list of hazards, we reference Figure 9 in the Operational Feasibility section to show the extent to which BlocPower building upgrades will remediate residential hazards, and layer in the strength of the evidence base found in our literature review. Throughout our analysis, we rely heavily on a UCLA study published in 2020 by Dr. Yifang Zhu and colleagues titled *Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California*.[32]

Figure 13: Residential Health Hazards and Supporting Research Base

	Hazard Type	Remediated by electrification/weatherization upgrade?	Existing studies on intervention effect of electrification/weatherization?
Indoor Air Quality	**Combustion Gases and Ventilation**	Yes	Yes (Paulin et al. 2014)[33]
	Volatile Organic Compounds	Partially (appliance electrification can reduce VOCs)	No (2022 study on benzene from gas stoves in California measured concentrations but did not perform interventions[34])
	Radon	No	No
	Environmental Tobacco Smoke	No	No

[32] https://coeh.ph.ucla.edu/effects-of-residential-gas-appliances-on-indoor-and-outdoor-air-quality-and-public-health-in-california/
[33] https://pubmed.ncbi.nlm.nih.gov/24329966/
[34] https://pubs.acs.org/doi/10.1021/acs.est.2c02581

Indoor Environmental Asthma Triggers and Allergens	**Biological and Unsanitary Conditions**	Partially (weatherization, appliance electrification and HVAC upgrades)	No
	Pest Management	No	No
Comfort & Safety	**Thermal Comfort**	Partially (only if resident is experiencing thermal stress before upgrade)	No (Tonn et al. 2014 evaluates thermal stress after weatherization, but highly dependent on climate zone and preexisting status of home HVAC[35])
	Unintentional Injury and Fall Prevention	No	No
	Fire Safety	Partially (more research needed)	Partially (research on weatherization and reduction in electrical fires, countered by research showing electrical stoves are associated with more fires than gas stoves[36])
	Lead-based paint and lead-safe weatherization practices	No	No

In order to build a model that estimates the health impacts of electrification, sufficient research is needed on both the health impacts of exposure to indoor air pollutants as well as the intervention effects (i.e., changes in concentration of air pollutants after building upgrades). Thus, our model analyzes the relationship between air pollutants produced by combustion gases, which have the strongest existing evidence base for both exposure assessment and intervention effects, and human health. Zhu et al. (2020) documents the likely exposure of California residents to indoor air pollutants; in terms of the intervention, Paulin et. al (2014) studies the intervention effect of stove replacement on NO_2 levels in the home, and we assume that replacement of gas-fired space and water heating systems will eliminate the backdraft-related emissions once buildings are electrified. Appendix B contains documentation and assumptions used in the model. The model also contains a lead module, based on GHHI's Lead Return-On-Investment (ROI) Calculator, which separately estimates the economic benefits and ROI of remediating lead hazards in the homes that BlocPower is also targeting for electrification.

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[35] https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_345.pdf

[36] https://www.nfpa.org/News-and-Research/Data-research-and-tools/US-Fire-Problem/Home-Cooking-Fires

Before proceeding with the exposure assessment, it is important to detail several home health hazards where the research base was insufficient to include in our model yet could be included in future models if research improves.

Volatile Organic Compounds (VOCs)

Volatile Organic Compounds refer to a variety of chemicals found in many products within the home. Two VOCs, formaldehyde and benzene, are particularly important to be mindful of as home health hazards related to gas-fired appliances.

Formaldehyde is one of the most common VOCs, which can be formed as a byproduct of combustion processes. Most literature focuses on formaldehyde emitted from smoking, wood burning, and building materials off-gassing, yet gas appliances and cooking activities are also a source of formaldehyde. Formaldehyde has been established as a human carcinogen by the WHO and International Agency for Research on Cancer, with evidence of it causing nasopharyngeal cancer and leukemia. There are also chronic and acute non-cancer health effects, yet because formaldehyde exposures are often alongside other VOCs and indoor air pollutants, it is more difficult to identify direct health effects of formaldehyde. Nevertheless, research suggests links between chronic formaldehyde exposure and lung disfunction, damage to the nasal passages, respiratory effects in children, neurotoxic effects, birth defects, low birth weights, and more.[37]

Research largely suggests that building materials are the primary sources of indoor formaldehyde emissions. It follows that most formaldehyde exposures in the home are likely chronic low-level exposures, rather than acute exposures driven by gas appliance usage. Thus, formaldehyde has not been included in GHHI's technical model.

Benzene is another VOC and known carcinogen associated with indoor air quality and natural gas appliances. Products that contain benzene include glues, paints, furniture wax, and detergents. Tobacco smoke is a major source of benzene exposure, as are emissions from fossil fuel combustion. A recent study found that gas stoves in California leak potentially hazardous levels of benzene into the home.[38] Chronic exposure to benzene can cause cancer, in particular acute myeloid leukemia (AML), and is also associated with reproductive issues in women. Beyond this study there are no experiments that we are aware of tracking levels of benzene before and after electrification. Further research is needed to strengthen the evidence base between gas appliances and VOC exposure.

Thermal Comfort

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[37] Zhu et al. 2020

[38] https://pubs.acs.org/doi/full/10.1021/acs.est.2c02581

Thermal hazards in the form of excessively hot or cool temperatures can cause thermal stress to increase for residents, which can have significant impacts on health and mortality.[39] Between 2010 and 2019, official California data cites 599 deaths due to heat exposure, although an *Los Angeles Times* investigation into potential undercounting of these deaths suggests that the true figure may be closer to 3,900.[40] Recent deaths in the Bay Area have also been linked to cold exposure.[41] While the homeless population is especially vulnerable to thermal stress, low-income housing with poor sealing, lack of heating and cooling, and/or malfunctioning heating and cooling systems are also at risk. This includes families without heating systems who may use gas stoves and ovens for heating during periods of cold temperatures. Oak Ridge National Laboratory's study on the health benefits of the Weatherization Assistance Program found that weatherization drove a 1.4% decrease in cold-related illnesses and a 1.1% decrease in heat-related illnesses for residents.[42] GHHI has published research on how heat waves disproportionately affect Black, elderly, and/or low-income and low-wealth communities, such as the 1995 Chicago heat wave where 75% of the 739 people who died did not have air conditioning.[43]

While a BlocPower building upgrade should remediate conditions for thermal stress by providing functioning heating and cooling, the literature on the health effects of indoor temperatures is inconclusive and therefore not included in GHHI's model at this time. A WHO systematic review published in 2018 found "there is no evidence published after 2003, which provides details on indoor temperature monitoring and allows for a direct link to be established between indoor air temperatures and health outcomes…including all-cause mortality, heatstroke, hyperthermia, dehydration or hospital admission.[44]" The study continues, "The problem of missing evidence has been noted by other authors and limits the ability to create evidence-based recommendations in this area." Until a stronger research base exists that outlines a significant relationship between indoor temperature and health, it is difficult to include thermal stress in a model assessing the health impacts of building electrification.

Fire Safety

Roughly 368,500 residential fires were reported annually in the US in the years 2017-2019, causing an estimated 2,770 deaths, 11,650 injuries, and $8.1 billion in property loss.[45] Fire risk tends to be higher in low-income housing due to faulty wiring, unsafe methods of space heating,

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[39] https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_345.pdf
[40] https://www.latimes.com/projects/california-extreme-heat-deaths-show-climate-change-risks/
[41] https://www.mercurynews.com/2022/12/16/two-more-bay-area-deaths-linked-to-cold-weather/
[42] https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_345.pdf
[43] https://www.greenandhealthyhomes.org/publication/air-conditioning-heat-vulnerability-and-racial-equity/
[44] https://www.ncbi.nlm.nih.gov/books/NBK535282/
[45] https://www.usfa.fema.gov/downloads/pdf/statistics/v21i2.pdf

and other causes.[46] There are a number of interventions covered by the Weatherization Assistance Program (WAP) that can reduce fire risk, yet conversely, we were not able to find any major studies measuring the impact of residential electrification on fire safety. There appears to be no research on the differences in fire risk between electric heat pumps and gas furnaces. Regarding stoves, a 2020 study by the National Fire Prevention Association found that electric stoves have a higher cooking fire risk than gas stoves; 80% of cooking fires were associated with electric stoves, despite 60% of American households having electric stoves.[47] However, the greatest explanatory factors cited in the study are that electric stoves are less obvious when turned on, and that electric coils take longer to cool down. Induction stoves should alleviate both risks significantly as the surface is cool to the touch, even when in operation. Thus, there is mixed evidence on how building upgrades impact fire safety; we can expect that repairing and upgrading wiring will improve fire safety, but more evidence is needed to demonstrate the fire safety of stove replacement and other appliance electrification.

In sum, we recommend further research into VOC, thermal stress, and fire safety hazards to further ascertain the relationship between those hazards and health. Compared to thermal comfort, benzene and fire safety are more likely hazards to yield significant relationships with health and BlocPower building upgrades.

Exposure Assessment & Dose Response

Having established the focus of GHHI's model as Combustion Gases & Ventilation (while also analyzing lead hazards using GHHI', we now turn to discussion of the exposure of building residents to pollutants, and the resulting dose response (the impact of different levels of exposure on health outcomes).

The combustion of fossil fuels inside the home produces pollutants such as CO, NO_2, NO_x, and PM. The main appliances typically responsible for these pollutants are water heaters, heating devices (e.g., furnaces), and kitchen appliances (stoves and ovens). For the purposes of this study, we presume that Alameda County residents with fossil fuel appliances are natural gas users, not any other fuel type. According to the California Energy Commission, only 0-1% of all California residents use a fossil fuel other than natural gas for space heating and water heating in multifamily units.[48] Especially in a county that is more urban and served by a gas utility (PG&E), it is fair to assume natural gas as the incumbent fossil fuel across the county.

Depending on the ventilation equipment for each appliance, pollutants can be vented outdoors or inside the home. Typically, space and water heating equipment have emissions ventilated outside the home, whereas kitchen equipment more commonly emits into the living space and

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[46] https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_345.pdf
[47] https://www.nfpa.org/News-and-Research/Data-research-and-tools/US-Fire-Problem/Home-Cooking-Fires
[48] https://www.energy.ca.gov/sites/default/files/2021-08/CEC-200-2021-005-PO.pdf

therefore has a more significant effect on indoor air quality.[49] However, faulty ventilation, backdraft, and or leakages can result in pollutants from space and water heaters being present in the home. A growing number of studies measure concentrations of indoor air pollutants from gas combustion in California residential buildings from cooking equipment, space heating, and water heating.

Findings from Zhu et al., 2020, synthesizes research on the impacts of gas combustion on indoor and outdoor air quality in California. The authors note several studies finding that gas stove usage in the home causes weekly and peak NO_2 concentrations that are in excess of the chronic California Ambient Air Quality Standards annual average limit (Appendix D) and the acute National Ambient Air Quality Standards 1-hour limit. NO_2 levels in kitchens and bedrooms have exceeded these standards in studies, especially in homes without ventilation/range hoods and with gas stoves with pilot lights. The researchers find that CO poses less of a health threat than NO_2 if appliances are operating properly. However, under certain conditions (lack of range hood, using a stove for heating, broiling conditions, full meal preparation), CO levels may exceed the peak CAAQS eight-hour standard, although not for a full eight-hour duration.

Zhu et al. 2020 does not include PM or formaldehyde in its scope for indoor air pollutants. Formaldehyde's exclusion has been addressed above, but one reason for PM's exclusion is that there is inconclusive evidence on the extent to which gas stoves are significant source of PM. Studies measuring PM2.5 emissions found that increases attributed solely to gas kitchen appliances (with no cooking of food involved, though sometimes a pot of water was heated) were negligible. Cooking itself can be a significant source of exposure to PM2.5 due to heating and combustion of food and cooking oil, resulting in indoor concentrations far in excess of the NAAQS 24-hour threshold of 35 µg/m3, but it is far from clear the extent to which stove electrification would lower those concentrations.

Figure 14: Combustion Gas and Ventilation Pollutants and Health Effects

	Health Effects	
Pollutant	**Acute**	**Chronic**
Nitrogen oxides (NO_x)	Decreased lung function, asthma exacerbation, respiratory infection, stroke	Premature mortality, lung and breast cancer, cough, shortness of breath, asthma, wheezing, respiratory illness in children
Carbon monoxide (CO)	Death, brain damage, seizures, memory loss, dementia, headaches, dizziness, nausea	Brain and heart toxicity, heart failure and cardiovascular disease, low birth weight
Fine particulate matter ($PM_{2.5}$)	Stroke, increased blood pressure	Premature mortality, bronchitis, asthma onset and

[49] https://ucla.app.box.com/s/xyzt8jc1ixnetiv0269qe704wu0ihif7

		exacerbation, low birth weight and preterm birth

Nitrogen oxides (NOx)

Nitrogen oxides are a family of poisonous gases that includes NO and NO_2, formed through combustion of fossil fuels such as natural gas. A report from Sierra Club and RMI estimates that gas appliances in California's homes and buildings generate four times as much NO_x as the state's gas power plants, and roughly two-thirds as much as all passenger cars in the state.[50] According to the 2016 US EPA Integrated Science Assessment (ISA), the medical literature suggests a causal relationship between chronic NO_2 exposure and respiratory effects, cardiovascular effects, cancer, and mortality, although an absolute determination was not made.[51] Nevertheless, a growing body of research points to the health impacts of NO_2 exposure. Several studies in recent years have found links between gas cooking related NO_2 and increased risk of children's asthma, wheezing, and other respiratory symptoms. Further, studies suggest that women may be at greater health risk from NO_2 exposure from gas cooking, due to cooking more frequently than men.

Acute NO_2 exposure can impair lung function, exacerbate asthma, and increase the risk of respiratory infection, especially in children. Acute exposure is associated with lung inflammation for individuals with asthma or chronic obstructive pulmonary disease (COPD) and is also associated with higher risk of hospital admission and mortality due to stroke.

Chronic NO_2 exposure is associated with premature death, as studies have shown relationships between chronic exposure and all-cause, cardiovascular, respiratory, and lung cancer mortalities, especially with patients with preexisting conditions.[52] Chronic NO_2 exposure also is associated with higher risk of lung and breast cancer, and there is evidence of impacts on pregnancy outcomes, including low birth weight. Overall, there is a strong and growing body of evidence on chronic exposure to NO_2.

Carbon monoxide (CO)

When ventilation and mechanical systems are functioning in gas appliances, the risk of dangerous exposure to CO should be minimal, as emissions from properly functioning appliances are negligible. However, when malfunctions occur, dangerous levels of CO exposure may follow. Excessive CO exposure can cause severe brain damage and result in long-term symptoms such as seizures, memory loss, and dementia. The acute symptoms of CO exposure include headaches, dizziness and nausea at low concentrations, and neurological damage and death at higher concentrations. In the United States, around 400 deaths annually are attributed to non-fire-related CO poisoning, with 13 to 36 of those deaths each year occurring in

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[50] https://www.spur.org/sites/default/files/Gas%20appliances%20and%20Smog%20(NOx%20Report).pdf
[51] https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=310879
[52] https://pubmed.ncbi.nlm.nih.gov/32590284/

California.[53] Long-term health effects of CO exposure are less well studied and understood, though evidence points to negative impacts on the brain and heart. Increases of 11.5 mg/m3 in ambient CO levels (nearly twice the World Health Organization suggested standard) are associated with increased risk of hospital admission for congestive heart failure. Additionally, other possible impacts of long-term exposure to CO include low birth weight and complications in pregnancy.

Particulate matter

Airborne particulate matter (PM) can be comprised of many different types of chemicals. Particles with a diameter of 2.5 microns or less, known as $PM_{2.5,\ are}$ produced from the combustion of fossil fuels. According to the World Health Organization's Global Burden of Disease project, $PM_{2.5}$ is associated with the greatest proportion of adverse health effects compared to all other common air pollutants.[54] Short-term exposures to $PM_{2.5}$ have been associated with premature mortality, increased hospital admissions with heart and lung causes, asthma attacks, bronchitis, and respiratory symptoms.[55] Long-term exposures to $PM_{2.5}$ are associated with premature death, especially for those with chronic diseases, and reduced lung function growth in children. Research sponsored by the California Air Resources Board (CARB) found that children living amidst high levels of $PM_{2.5}$ had slower lung growth, and smaller overall lung size by age 18, compared to children in communities with low $PM_{2.5}$ levels. Further, a CARB analysis found that $PM_{2.5}$ exposure causes between 4,200 and 6,700 premature deaths due to cardiopulmonary causes per year in California. In addition, $PM_{2.5}$ exposures contribute to roughly 2,800 hospitalizations for cardiovascular and respiratory diseases, and about 6,700 asthma-related emergency room visits annually in the state.[56]

PM concentrations inside the home can be attributed to cooking, household aerosol products, other appliances, and transportation of outdoor pollution into the indoor environment. Cooking can be a significant source of $PM_{2.5}$. According to Zhu et al. 2020, "although both gas and electric stoves generate particle emissions, gas stoves have been found to produce greater particle exposures." However, cooking methods and the type of food being cooked can also have a large impact on $PM_{2.5}$ emissions; in other words, cooking related $PM_{2.5}$ emissions are not solely caused by appliances. A study by Lawrence Berkeley National Laboratory found that many particles emitted by gas stoves are in the ultrafine range, otherwise known as Ultrafine Particles (UFPs). There is emerging evidence that UFPs are more harmful than $PM_{2.5}$ on a per unit mass basis, yet due to a limited research base and the small size of these particles, there have been no regulatory interventions to limit UFPs.[57]

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[53] https://ww2.arb.ca.gov/resources/carbon-monoxide-and-health
[54] https://www.thelancet.com/action/showPdf?pii=S0140-6736%2815%2900128-2
[55] https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health
[56] https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health
[57] https://www.iqair.com/us/newsroom/ultrafine-particles

As previously mentioned, Zhu et al. 2020 excluded $PM_{2.5}$ and UFPs from their study of gas appliances due to limited availability of data on indoor residential exposures and recommend future studies to build out the evidence base.

Technical Model Results (Risk Characterization)

GHHI's technical model seeks to characterize the change in health risk to residents after building electrification upgrades. The model focuses on stove replacement, space heating electrification, and water heating electrification as three core interventions that drive significant changes in concentration of indoor air pollutants.

Figure 15: Pollutants & Health Endpoints in GHHI Technical Model

Pollutant	Exposure Type	Reason for Inclusion	Health Endpoint
NO_2	Acute	Cooking with gas stoves can produce NO2 levels that exceed CAAQS, leakage/backdraft from space and water heating can contribute as well	All-cause mortality; asthma related ERVs and HAs
CO	Acute	Cooking with gas stoves can produce CO levels that exceed CAAQS, leakage/backdraft from space and water heating can contribute as well	Myocardial infarction (heart attack)

Our model focuses on Indoor Air Quality because there are no such models or tools widely available currently. This is in large part due to the difficulty in modeling the heterogeneity of indoor air quality health impacts, which depend so much on the particulars of each home as well as the profiles and health of residents in homes.

There are several existing tools that do focus on the health impacts of changes in Outdoor Air Quality, which also could be incorporated as complementary to GHHI's model. In particular, a team at the Harvard T.H. Chan School of Public Health has developed the Co-Benefits of the Built Environment (CoBE) tool, which like BlocMaps, is structured on building-level calculations.[58] The EPA has developed several tools including COBRA, AVERT, and BENMAP, but each of these looks at population-level health effects that are broader than a building-by-building lens.[59] In speaking with the development team behind the EPA's COBRA tool, they affirmed that COBRA is not useful for building-level assessments, because each building is too granular and involves too much heterogeneity that would increase uncertainty in results of

[58] https://cobe.forhealth.org/
[59] AVERT (https://www.epa.gov/avert), COBRA (https://www.epa.gov/cobra) , and BenMAP (https://www.epa.gov/benmap)

estimation of health effects at the building level. This illustrates both the importance and the challenges of trying to model building-level health impacts.

Figure 16: Outdoor Air Quality + Health Impacts Tools

Tool Name	Input	Pollutants	Outcomes	Comments
Co-Benefits of Built Environment (CoBE) *Harvard Chan School of Public Health*	Building-level energy consumption	PM2.5, SO2, NOx (outdoor)	Mortality	Building-level data upload is more compatible with BlocMaps, but tool is in beta mode and only focused on outdoor air quality.
Co-Benefits Risk Assessment (COBRA) *U.S. Environmental Protection Agency*	County-level % Reduction in Pollutants	PM2.5, NOx, SO2, NH3, VOCs (outdoor)	Mortality, heart attacks, asthma exacerbation, lost workdays	Unlikely to be helpful for BlocMaps because data resolution is county-level, developer says that building-level is too granular

Thus, GHHI's model seeks to fill a gap in the literature and existing tools by estimating the health impacts of electrification related to indoor air pollutants. Developing this model involved making many assumptions, which are detailed in Appendix C. At present, the model uses estimations of indoor air quality from Zhu et al., 2020, and dose response relative risk ratios from World Health Organization systematic reviews, to estimate how electrification will impact key health endpoints. The model could be improved by more specific and granular data on both the actual indoor concentrations of pollutants (e.g., using in-home measuring and monitoring) and the profiles of residents in buildings (e.g. engaging residents in research studies). Studies that track the relationship between electrification and health outcomes would provide the strongest evidence base. Nevertheless, the model is meant to be useful now as a starting point to estimate the health impacts of electrification, and especially if coupled with models like Harvard's CoBE tool, could illustrate to healthcare stakeholders and policymakers the health benefits to be realized through building electrification. By incorporating GHHI's lead calculator, the model can also illustrate the benefit of braiding lead hazard remediation with electrification services.

As mentioned earlier, the base scenario evaluated in the model is a 60-building program, modeled after the East Bay Community Energy Health-E Homes program.[60] We estimated a

[60] https://ebce.org/health-e-home/

breakdown of 36 single family homes and 24 multi-family buildings averaging 20 units per building, for a total of 480 apartment units and 526 homes overall. Using various population assumptions for the number of people in each type of home, we assume this program serves a population of 1470 (Appendix C). For each subgroup of single-family homes and apartments, we assume that half would receive water and space heater electrification along with stove replacement, and the other half would only receive water and space heater electrification (no stove replacement).

Because California mandates the venting of emissions from space and water heating, we only include pollutants from those appliances in instances where there is malfunctioning ventilation, backdraft, or some sort of leakage. We make conservative assumptions around the pre-existing ventilation and capture of pollutants from space and water heating in the units, estimating that 95% of units have fully functioning ventilation and capture (i.e., no backdraft of indoor air pollutants), 3% of units have 25% leakage/backdraft, and 2% of units have 50% ventilation/capture. These assumptions and inputs can all be customized, and in nearly all cases involve significant uncertainty. Appendix C provides an in-depth review of all key assumptions and inputs into the model.

Figure 17: Key Inputs and Outputs for GHHI's Electrification Model

Avoided Health Impacts	Annual Impact	Overall Program Impact (15 years)
NO2-related mortality, all causes	0.00255	.03825
NO2-related asthma Emergency Room Visits	0.01063	.15945
NO2-related asthma Hospital Admissions	0.00062	.0093
CO-related myocardial infarction	0.00000	.0000

Each of these outputs will be discussed further to explain their significance for technical feasibility.

NO2-related mortality, all cause

Mortality rates are generally reported per 100,000 people, especially general mortality metrics such as all-cause mortality. The scenario above estimates that for the program population of 1470, there is a .00255 reduction in NO2-related mortality on an annual basis, and a .03825 reduction over the 15-year program lifespan. Multiplying this for a population of 100,000, this would indicate 0.17 deaths avoided annually and 2.60 deaths avoided over the course of fifteen years. Scaling this up even higher to imagine a program that served all of Alameda County (1.8 million residents), this equates to 2.86 deaths avoided per year and 42.90 avoided over the course of 15 years. These figures fall in a similar range to the Bay Area Air Quality Management District's estimates of the impact of banning gas furnaces in the Bay Area, focused on Outdoor Air Quality using the EPA's BenMAP software, which ranged from 37-85 avoided deaths.[61] Given that the population of the Bay Area is nearly 7 times that of Alameda County alone, GHHI's estimate may be on the higher end of possible outcomes, but the exposures measured for indoor air pollutants are likely more acute than outdoor air pollutants, which could be an explanation for why GHHI's estimate is higher.

NO2-related asthma emergency room visits and hospital admissions

The estimated reduction in annual Emergency Room Visits (ERVs) and Hospital Admissions (HAs) due to asthma is 0.01063 and 0.00062, respectively. For a population of 100,000, this would mean the avoidance of .72 annual asthma-related ERVs (10.85 over a 15-year span) and 0.04 annual asthma related HAs (0.63 over a 15-year span). These figures alone would likely be less compelling to a healthcare stakeholder, as existing asthma programs in Alameda County seek to mitigate ERVs and HAs for dozens of patients a year; yet another way of interpreting these results is that an asthma-focused program that only served chronic asthma patients would yield a higher impact. GHHI's model assumes levels of asthma ERVs and HAs consistent with the general population in Alameda County, but many asthma programs (including GHHI's New York Healthy Homes Collaborative) are designed to refer patients who have a trigger event such as an asthma related ERV and/or HA, so that the program population is comprised of only patients with severe, uncontrolled asthma.

Modifying the asthma-related Hospital Admission rate to 0.3, indicating a population where roughly one member of each household served has severe asthma, shows 0.13545 avoided HAs per year for the program population of 1470, or 2.03 over the course of the 15-year evaluation period. These figures would be slightly more compelling for healthcare stakeholders, although would be unlikely to outperform traditional home-based asthma care services in terms of reducing hospitalizations. Nevertheless, if BlocPower is recruiting a healthcare stakeholder to participate in an electrification project, the takeaway is that serving a population with asthma will yield higher health benefits than serving the general population.

CO-related myocardial infarction

Given the assumptions and inputs as designed, the model did not yield any reduction in CO-related myocardial infarction. This reflects the research showing that CO levels exceed CAAQS less severely than NO2 from gas appliances. In a scenario with more instances of backdraft/leakage/ventilation malfunctioning among space and water heaters, CO levels would potentially register in the model as harmful enough to yield avoided incidences after electrification. Among the general population, incidences of CO poisonings from leaking appliances may be a more

[61] https://www.baaqmd.gov/~/media/files/board-of-directors/2023/bod_presentation_031523_v2_final_op-pdf.pdf?la=en&rev=31d959e50a20499eb034ee7e8d1f3997

salient concern than myocardial infarction, and further research could examine the link between CO concentrations and mortality (no WHO systematic reviews were found on this topic).

Conclusions and Recommended Next Steps

This technical section explores the integration of health and electrification building upgrades by seeking to define and quantify the health impacts of electrification. Through conducting a literature review and building an Excel-based model, our analysis shows that there is a strong evidence base linking electrification to reduced concentrations of nitrogen dioxide and carbon monoxide in the home, and as a result, lower mortality and avoidance of asthma related emergency room visits and hospitalizations. As the evidence base grows, a health impacts model could be developed to include benefits from reducing exposure to particulate matter and VOCs, as well as estimating benefits of improving thermal comfort and fire safety.

Our search yielded no existing tools to model the relationship between indoor air quality, building electrification, and health impacts. Other researchers who developed outdoor air quality-based tools note that this is a very difficult modeling exercise due to the heterogeneity of each individual home. GHHI's model uses data from UCLA and the World Health Organization to make assumptions for electrification-related health effects in California. Inputting a 60-building electrification program in Alameda County into GHHI's model shows an estimated 0.00255 avoided deaths annually due to reduced NO2 exposure (equivalent to 0.17 avoided deaths per population of 100,000), 0.01063 avoided asthma-related Emergency Room Visits and 0.00062 avoided asthma-related Hospital Admissions. If the population of Alameda County were used as the program population in the model, this equates to 2.86 deaths avoided per year and 42.90 avoided over the course of 15 years. For a program such as this that serves the general population, avoided deaths are likely to be the most significant and salient metric compared to avoided asthma hospitalizations and emergency room visits. Yet a program designed to serve homes with severe asthma patients would result in greater reductions in the use of acute care services – hospitalizations and emergency room visits – and their associated costs.

Recommended next steps include:

- **Strengthening the evidence base for evaluating the health impacts of electrification by pursuing future research studies**. The evidence base must be improved for a range of health hazards:

    - Indoor Air Quality monitoring in homes before and after electrification, such as WE ACT's *Out With Gas, In With Justice* 10-home pilot study, is critical to improving the accuracy and predictive ability of health impact models. Ultimately, more peer-reviewed studies will be needed, and BlocPower could explore whether partnerships with researchers and/or universities could yield pre- and post-electrification measurement and health outcomes tracking.

    - Fire safety, VOCs, and thermal comfort-related hazards are all likely mitigated to some degree by electrification, but the research base must be strengthened. In

Alameda County, fire safety and VOCs are likely more prominent hazards than thermal comfort, due to the relatively mild climate. Nevertheless, wildfires and extreme heat events periodically impact the region and if residents don't have pre-existing cooling systems, BlocPower's building upgrades could make a material health difference.

- **Socializing health impacts with relevant stakeholders to receive their feedback and develop further research plans accordingly**:
    - Avoided mortality is an important metric for all healthcare stakeholders concerned with the health and wellbeing of the populations they serve, but it can be an abstract and difficult-to-monetize metric, as will be discussed in the next section. Mortality will be important to discuss with local policymakers and municipal officials, and hospital systems serving a broad swath of Alameda County may also find it compelling. While health plans will be concerned with mortality as well, utilization-based metrics such as avoided asthma-related ERVs and HAs are more concrete and could be stronger foundations for engagement.

- **Exploring the integration of health impacts into BlocMaps through multiple avenues:**
    - Indoor air quality could be eventually integrated into BlocMaps using GHHI's model as a foundation, although the heterogeneity and lack of granular data on individual buildings will continue to limit the predictive accuracy. Nevertheless, estimates of health impacts using an assumption-based approach like the GHHI model can be an interim step. Even if specific calculations prove too uncertain to incorporate BlocMaps, a first step could be including data layers for asthma, lead, and other health hazards (addressed in the separate Building Data Collective deliverable), allowing users to visualize populations of highest need.
    - Outdoor air quality impacts of building electrification can be quantified with greater confidence and there are several existing tools to target for potential partnerships. In particular, the CoBE tool would be a strong candidate for partnership as it uses a building-level architecture and thus could integrate more smoothly into BlocMaps. In the near term, this is likely the most promising integration of any health impact assessment tool. GHHI's lead calculator could also be integrated into BlocMaps to provide lead-focused ROI estimates that could unlock the braiding of lead hazard remediation with electrification upgrades.

Economic Feasibility

After estimating the health impacts of electrification in the previous section, we now seek to monetize the savings from reduced mortality and avoided emergency room visits and hospitalizations. Using these monetized health impacts, we perform a cost-benefit analysis and assess the economic feasibility of whether the health savings from electrification would sufficiently incentivize healthcare stakeholders to fund or invest in projects.

Key Findings

Improved health outcomes caused by electrification's reduction in indoor air pollutants have valuable health benefits, although currently quantifiable benefits are insufficient to entirely fund an electrification program. Nevertheless, we identify areas where a public health stakeholder may be incentivized to partially fund electrification building upgrades.

Using the 60-building base scenario modeled in the technical section, our economic assessment finds $20,883 in annual program health value due to improved indoor air quality; over the 15-year evaluation period, this totals $313,741 in value, or $608.02 per home. 90% of health savings are driven by reductions in all-cause mortality, which are valued using the EPA's Value of a Statistical Life, described in the methodology section. These savings are significant, yet likely insufficient to attract a healthcare funder into an electrification program.

Electrification retrofits of buildings built prior to 1979 could also provide an opportunity to remediate lead paint hazards. To evaluate the economic case for lead hazard remediation, GHHI ran the same 60-building scenario through its Return-On-Investment for Lead Poisoning Prevention Calculator. The return-on-investment assessment for lead shows an overall IRR of 4.36% for lead poisoning prevention across health care, education, and the criminal justice sectors. This is a promising figure that indicates financial value (in addition to health and equity benefits) for remediating lead hazards alongside electrification building upgrades. Over 90% of lead-related health benefits are attributed to reductions in mortality risk. Policymakers and local officials with a cross-sectoral mindset may be more willing funders for these 'non-cashable' savings than healthcare-specific stakeholders, who will be most motivated to sponsor 'cashable' savings that reduce utilization costs.

One way to improve the economic feasibility of electrification is to serve a population with higher baseline costs, such as a population with at least one asthma related hospitalization per year. Designing a program in this way, the overall savings are $1.73 million, or $3,348 per home. 82% of these savings come from avoided hospitalizations, which is a more cashable saving from a health plan or hospital system perspective. While the overall savings would still be insufficient to fund an entire electrification project, it would be more feasible to bring in a healthcare stakeholder as a partial funder.

An additional opportunity to improve economic feasibility will be to expand the scope of health impacts analyzed in the model. Currently, only indoor air quality hazards have been studied due to limitations in the evidence base. Outdoor air quality hazards may also be integrated through a partnership with the CoBE tool developed at the Harvard School of Public Health. As the evidence base improves to allow the estimation of fire safety, VOCs, particulate matter, thermal comfort, and other home health hazards, the amount of modeled health savings from electrification will grow.

At present, the economic feasibility score of 2 (out of 5) reflects the fact that cashable savings have been identified, but it is unclear whether these savings can be sufficient to offset costs of the program. GHHI outlines what next steps can be taken to improve the feasibility score and advance healthcare participation in electrification projects.

Background and Methodology

The economic feasibility assessment has two objectives: 1) Estimate the financial value of electrification programs by monetizing the health impacts discussed in the technical feasibility section; and 2) Analyze the costs and healthcare benefits of electrification to evaluate the economic case for healthcare investment into electrification.

The monetization of health impacts requires making assumptions about the value of avoided mortality, asthma related hospital admissions (HAs) and emergency room visits (ERVs), and myocardial infarction among the target population. There is an important distinction between ‘cashable’ and ‘non-cashable’ impacts for these different health end points from a healthcare perspective. Cashable refers to instances where a health payer would directly realize cost savings through reduced utilization of health care services, such as fewer asthma related HAs and ERVs. Non-cashable refers to monetized health benefits that do not directly accrue to a healthcare stakeholder; mortality falls into this category because it is monetized using the Value of a Statistical Life (VSL), a figure from the US Environmental Protection Agency, which is derived using a Willingness to Pay methodology.

To illustrate this further, the EPA offers an example for how to think about VSL:

> Suppose each person in a sample of 100,000 people were asked how much he or she would be willing to pay for a reduction in their individual risk of dying of 1 in 100,000, or 0.001%, over the next year. Since this reduction in risk would mean that we would expect one fewer death among the sample of 100,000 people over the next year on average, this is sometimes described as "one statistical life saved.” Now suppose that the average response to this hypothetical question was $100. Then the total dollar amount that the group would be willing to pay to save one statistical life in a year would be $100 per person × 100,000 people, or $10 million. This is what is meant by the "value of a statistical life.” Importantly, this is not an estimate of how much money any single individual or

group would be willing to pay to prevent the certain death of any particular person.[62]

VSL is helpful to value reductions in mortality risk when conducting benefit-cost analyses, and it may also be useful in communicating with policymakers and the public, but it is non-cashable in the eyes of healthcare stakeholders and therefore more difficult to incorporate into the economic savings of a project. In other words, a health plan does not necessarily realize savings through reduced mortality risk, compared to more direct utilization metrics such as hospital admissions and emergency room visit that have a known cost.

GHHI seeks to quantify cashable savings wherever possible in order to make the most direct case for savings to health stakeholders. Myocardial infarction, for example, is non-cashable as a standalone metric, but we translate it into a cashable savings by using data on the cost of heart disease hospitalization. The base scenario evaluated in GHHI's model does not show changes in myocardial infarction incidences, and thus there are no associated savings incorporated into the current economic feasibility assessment, but a different scenario with higher levels of indoor CO would result in the inclusion of reduced myocardial infarction among health impacts.

The following values are used to monetize the health impacts of electrification:

Figure 18: Health Endpoints and Associated Monetized Values in GHHI Electrification Model

Health Endpoint	Value	Source	Cashable / Non-Cashable
All-Cause Mortality	$7,400,000	US EPA (Value of a Statistical Life)	Non-Cashable
Asthma Related Emergency Room Visit	$3,500	Alameda County Public Health Department[63]	Cashable
Asthma Related Hospital Admission	$16,545	Alameda County Public Health Department t[64]	Cashable
Heart Disease Hospitalization	$18,931	Cowper et al., 2019[65]	Cashable

For each health impact calculated in the technical model, the fractional value of each impact (reduction in mortality, reduced emergency room visits, hospital admissions,

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[62] https://www.epa.gov/environmental-economics/mortality-risk-valuation#means
[63] http://www.acgov.org/board/bos_calendar/documents/DocsAgendaReg_10_12_15/HEALTH%20CARE%20SERVICES/Regular%20Calendar/Pay_for_Success_Asthma_Initiative_Health_10_12_15.pdf
[64] http://www.acgov.org/board/bos_calendar/documents/DocsAgendaReg_10_12_15/HEALTH%20CARE%20SERVICES/Regular%20Calendar/Pay_for_Success_Asthma_Initiative_Health_10_12_15.pdf
[65] https://pubmed.ncbi.nlm.nih.gov/30975005/

incidences of myocardial infarction) is multiplied by the appropriate financial value. We evaluate these impacts over a 15-year period. To annualize the value of reductions in mortality risk, we calculate the average expected remaining lifetime for residents of Alameda County (Average Life Expectancy – Median Age) and divide the total mortality benefits by the number of years of expected lifetime. This annual value of reduced mortality risk is then spread equally across evaluation years. Hospital admissions, emergency room visits, and myocardial infarction-related hospitalizations are all calculated on an annual basis and assumed to remain at that same value (with inflation) for each year of project evaluation. The results of these calculations will be discussed in the following section.

After calculating the monetized health impacts, a cost-benefit analysis is performed to assess the economic case for the health benefits of electrification. GHHI uses the following assumptions as cost inputs:

Figure 19: Cost Assumptions for GHHI Electrification Model

Cost Type	Cost	Source
Building Assessment	$1,200	GHHI Assumption (lead calculator)
Heat Pump (Installed)	$18,842	TECH Clean CA[66]
HP Water Heater (Installed)	$7,054	TECH Clean CA[67]
Induction stove + electric oven (installed)	$2,231	Carbon Switch[68]

These inputs can easily be modified by BlocPower based on internal cost estimates. There are no other costs (direct, indirect, or maintenance) assumed in the model, which all could be added in to enhance the model. The assumption for a 15-year evaluation period is that all installation + equipment costs accrue in Year 0, with no ongoing annual costs. Thus, the cost-benefit analysis weighs the upfront costs of equipment and installation against the value from medical savings accrued over the duration of the period. To accommodate a range of analytical needs, both a discounted present value and a non-discounted total value are calculated for the costs and benefits over the project evaluation period.

Economic Impact Findings

The 60-building scenario evaluated in the technical section is once again the base scenario for the model. The model assumes a total impacted population of 1470, and a 15-year duration of the evaluation period. The outputs for both the electrification model and the lead calculator,

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[66] https://techcleanca.com/
[67] https://techcleanca.com/
[68] https://carbonswitch.com/induction-stove-costs-and-prices/

presented in the section below, show estimates of financial value associated with remediating home health hazards.

Electrification Model Outputs

The outputs for a 60-home program show roughly $20,883 in total annual health value due to improved indoor air quality; over the 15-year evaluation period, this totals $313,740 in value, or $608.02 per home.

Much of the financial value (90%) is driven by avoided NO_2-related mortality, with asthma-related ERVs and HAs comprising the other 10%. As discussed in the technical section, since the general population has relatively low rates of asthma ERVs and HAs (especially compared to a population with chronic asthma), the savings for these metrics are relatively low as well. The possibility of targeting a population with chronic asthma will be explored further in this section.

Figure 20: Summary of Financial Outputs from GHHI Electrification Model

Values in USD$			**Non-Present Value**		**Present Value**	
Avoided Health Impacts	***Annual Value – All Homes***	***Annual Value - Per Home***	***Total Program Duration Value***	***Total Program Duration Value Per Home***	***Total Program Duration Value***	***Total Program Duration Value Per Home***
NO_2-related mortality, all causes	18,879.93	36.59	283,652.53	549.71	242,963.8	470.86
NO_2-related asthma ERVs	1,570.48	3.04	23,594.97	45.73	20,210.38	39.17
NO_2-related asthma HAs	432.18	.84	6,493.01	12.58	5,561.62	10.78
CO-related myocardial infarction	-	-	-	-	-	-
Total Benefits	**20,882.59**	**40.47**	**313,740.52**	**608.02**	**268,735.80**	**520.81**

From a cost-benefit perspective, these figures will only defray a portion of the overall costs of electrification, although cost estimates are likely high and could be improved with more BlocPower internal data. For a project portfolio of 36 single-family homes and 24 multi-family buildings, electrification costs are estimated at $14 million, and the present value of health benefits related to indoor air quality improvements are estimated at $268,736 over 15 years. Even if costs are projected to be lower and benefits higher, the model suggests that health savings will only comprise a portion of the costs. Thus, approaching public health stakeholders as partial funders to electrification programs, to match the projected value achieved, is much more feasible than seeking to make a standalone economic case for the costs and benefits of electrification to a health plan or hospital.

To improve the economic feasibility of this model, one possibility is to target a population with higher existing medical costs, such as a population with chronic asthma. As discussed in the technical section, a program could be defined to serve only patients with one asthma related hospitalization, thus assuming an overall asthma HA rate of .3 to account for non-asthmatic members of households. With this targeted focus, the 15-year value of avoided HAs is $1,420,791, or $2,753.47 per home. The overall program benefits increase to $1,728,038 without altering costs (~$14 million), presenting a stronger financial picture than the general population program. While these asthma-related savings would still be insufficient to completely fund an electrification program, it would be much more attractive to engage a health plan or hospital system about a $1 million investment in the program, for example.

The model can also be complemented by other health impact estimates to improve overall attractiveness. For example, results from the Harvard CoBE tool (focused on outdoor air quality), could be added to indoor air quality related health savings to provide comprehensive outdoor and indoor air quality related benefits of electrification. Unfortunately, the CoBE tool is currently in beta mode and is restricted to internal use only. However, informal usage by GHHI indicates that the outdoor air quality related health savings from a 60-building electrification would be on the order of tens to hundreds of thousands of dollars for a 15-year period.

Lead Calculator Outputs

GHHI's Return-On-Investment for Lead Poisoning Prevention Calculator is designed to quantify costs and benefits of prevention, in order to finance projects at scale.[69] The calculator measures the benefits of lead poisoning prevention across sectors, including health care, education, and criminal justice.

This lead calculator has been added as module to the electrification model used in this feasibility study. As such, all figures from the lead calculator are treated as separate from figures in the electrification model. In practice, there could be more streamlining between the two models, such as lowering the overall assessment costs to reflect one comprehensive assessment instead of two unique assessments, but for the most part the costs and benefits of electrification and lead poisoning prevention should be accounted for separately from each other.

Using the lead calculator and the 60-building sample utilized throughout the study, we assume that 66% of homes will have lead hazards present, reflecting the percentage of homes in Alameda County built before 1979. With this assumption, there is a total benefit of $13,591 per home due to lead hazard reduction, and an internal rate of return of 4.36% overall for the program.

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[69] https://www.greenandhealthyhomes.org/publication/return-on-investment-calculator-for-lead-poisoning-prevention/

Figure 21: Lead Calculator Tool Outputs by Sector

Value from Prevention	Sector	Include?	**Per Person, $**	**% of Total**
Medical, short-term	Health Care	Yes	554	2.1%
Medical, long-term	Health Care	Yes	886	3.4%
Cardiovascular Disease Mortality	Health Care	Yes	23,955	92.0%
ADHD	Health Care	Yes	343	1.3%
Special education	Education	Yes	56	0.2%
Crime	Criminal Justice	Yes	239	0.9%
Total			26,033	100.0%

It is important to note that 92% of total benefits accrue through cardiovascular disease mortality risk reduction. There is a parallel here to the electrification model, where 90% of the benefits in the base case scenario were due to reduced all-cause mortality. As discussed then, mortality-related benefits are highly important to local policymakers and all healthcare stakeholders, but on their own are less cashable than direct, utilization-based health care savings.

Figure 22: Lead Calculator Tool Outputs, Financial Summary

	Summary	Total	**Per Home**	**Per Enrollee**
Present Value	Total Value of Benefits, PV	3,041,237.02	28,799.59	15,400.85
	Total Costs, PV	(1,606,044)	($15,209)	($8,133)
	Net of present values	1,435,193.02	$13,591	$7,268
	Return on Investment	89.36%		
	Internal Rate of Return	4.36%		
Non-PV	Total Value of Benefits	5,682,363.78	$53,810	$28,776
	Total Costs	(1,606,044.00)	($15,209)	($8,133)
	Net Benefits	$4,076,320	$38,602	$20,643

	Return on Investment	253.81%		

Conclusions and Next Steps

This economic analysis of the health impacts of electrification shows that improved indoor air quality does drive quantified healthcare savings, although likely only partial savings to cover the costs of an electrification program. The base scenario for a 60-building program shows $20,883 in annual program health value due to improved indoor air quality; over the 15-year evaluation period, this totals $313,740.52 in value, or $608.02 per home.

If the program were designed to target a population with elevated rates of asthma related hospital admissions, the overall savings would climb to $1,728,038, or $3,348.91 per home. This would still be insufficient to fund an entire electrification program that costs several million dollars for a 60-building target zone, but there would be a stronger possibility of bringing in a healthcare stakeholder as a partial funder than if the program was targeted to a general population. Thus, a key takeaway of this modeling exercise is that the higher the baseline healthcare costs of a population receiving electrification upgrades, the greater the savings will be. Specifically, a program focused on serving individuals with chronic, untreated asthma will achieve greater overall savings than a program focused on the general population.

The return-on-investment assessment for lead shows an overall IRR of 4.36% for lead poisoning prevention spread across health care, education, and the criminal justice sectors. Similar to the electrification health impact model, over 90% of health benefits are attributed to reductions in mortality risk. This leads to another conclusion that the majority of health savings currently modeled are non-cashable from a healthcare perspective. Programs with lower cashable savings will be less salient to healthcare stakeholders, although it is still worth engaging these stakeholders to understand their appetite for engagement and investment.

The economic feasibility score of 2 (out of 5) reflects the fact that cashable savings have been identified, but it is unclear whether these savings can be sufficient to offset costs of the program. To improve the economic feasibility score, next steps include:

- **Incorporating outdoor air quality and other health hazards into the overall health impacts assessment, to provide a comprehensive value of health savings from electrification.** Due to the current evidence base, our model focused narrowly on indoor air quality and associated health impacts, as other home health hazards do not have a sufficient evidence base to model accurately. Outdoor air quality tools such as CoBE would complement GHHI's model and provide a better picture of overall savings. Working directly with the CoBE team as their tool is in beta mode will be the most effective way to incorporate outdoor air quality related savings. The barriers to incorporating comprehensive health hazards into an electrification health savings model are largely technical, and improvements in the evidence base through additional research are critical next steps.

- **Considering program design focused on a population of residents with chronic asthma.** When the model estimates savings for an electrification program serving residents with chronic asthma, overall savings are more than 500% greater than a program geared toward the general population. What's more, 84% of total savings under a chronic asthma population scenario are cashable, attributed to reduced hospitalizations and emergency room visits. Thus, if BlocPower wishes to improve the economic feasibility without investing further in research and modeling, focusing on a high-cost population is an important strategy to consider.

- **Approaching state and local officials about funding the integration of electrification and lead hazard remediation.** GHHI's lead calculator shows an attractive IRR for lead hazard remediation, although the savings are spread across health care, education, and criminal justice sectors, and stakeholders siloed in any of those sectors are less likely to comprehensively fund work. In partnership with the Alameda County Healthy Homes Department, BlocPower could make the case for dedicated funding to ensure that homes receiving electrification upgrades also have lead hazards remediated.

Appendix A: Feasibility Scoring Rubric

	Very high feasibility 5	High feasibility 4	Moderate feasibility 3	Low feasibility 2	Very low feasibility 1
Payment mechanism	A clearly defined payment mechanism, including any applicable legislation, that has been used by similar projects exists.	A clearly defined payment mechanism exists that has not been used but has been committed to by the necessary parties.	A viable payment mechanism exists that is supported but not yet committed to by the necessary parties.	A possible payment mechanism exists but has not yet been discussed with necessary parties.	Payment mechanism is not readily apparent or does not have a reasonable chance of being advanced.
Operational	Service provider(s) has multiple years partnering to successfully implement and manage performance of the comprehensive intervention with a scale, population, and setting similar to that laid out in plans.	Service provider(s) has multiple years partnering to successfully implement and manage performance of most components of intervention at scale (or complete intervention on smaller scale) with planned population and setting.	Service provider(s) has multiple years successfully providing related services, but full intervention is a new endeavor. Team has strong plans in place to scale and manage performance in the planned population and setting.	Service provider(s) has no experience providing related services but has plans to scale and manage performance. Significant untested assumptions exist related to operational plans.	Service provider(s) has a history of not meeting performance management goals or intervention is completely new and team has weak plans in place to scale and manage performance.
Technical	Multiple independent, experimental or quasi-experimental studies and/or substantive operational data demonstrating achievement of the planned outcomes with the planned intervention, population, and setting.	Multiple studies and/or operational data demonstrating achievement of outcomes related to those in plans. Studies are non-experimental and/or non-independent. Intervention may not be as complete as one in plans but is near complete. Population and setting are similar to those in plans.	Plans for an evidence-based intervention aligned with established best practices that will be implemented for first time with partners who have been providing similar services for multiple years. Partners have at least demonstrated positive outcomes with self-reported data.	Plans for an intervention supported with evidence from other settings or populations with partners who have not provided similar services previously OR plans for a new intervention backed by little to no research with partners who have an established working history.	Plans for an intervention backed by no evidence with partners who have no history collaborating or providing similar services.
Economic	Significant evidence of the full intervention achieving measurable cashable savings, or outcomes that a potential payer values, substantially above all projected intervention and transaction costs with a population and setting similar to those in the plans.	Evidence of the intervention, or components of it, achieving some measurable cashable savings, and/or outcomes that a potential payer values, above all projected intervention and transaction costs with a population and setting similar to those in the plans.	Evidence of the intervention, or components of it, achieving outcomes associated with cashable savings, or outcomes that a potential payer might value, above at least the projected intervention costs with a population and setting similar to those in the plans.	Evidence of the intervention achieving outcomes associated with cashable savings, or outcomes that a potential payer might value, but unclear if savings/value outweigh projected intervention costs.	No evidence of the intervention achieving outcomes associated with cashable savings or producing value for a potential payer.

Appendix B: Menu of Services and Operational Feasibility

	Program Measure Description		Health-e Home	BayRen Rebates	Lead & Healthy Homes, Lead Settlement Funds	Asthma Remediation (CalAIM ILOS)	Weatherization	Other (CDBG, Philanthropy)
Implementer			- revalue.io	- revalue.io	- Alameda County Healthy Homes Dept	- Asthma Start (TBD) - Breathe CA	- Spectrum Community Services	
Income Qualifications			80% - 120% AMI +	Rebates based on income qualification for different measures	80% AMI (Owner Occ) 50% AMI (Rental, 50%+)	MAGI: 138% FPL for adults, 266% for children, 213% for pregnant women Non-MAGI: varies, Share of Cost	200% FPL (WAP) 60% AMI (LIHEAP)	
Other Qualifications						Medi-Cal member		
Financing Type			Grants, rebates, leases	Grants, rebates	Grants	Grants	Grants	
Capacity			60 total	(no data)	(no data)		200-250 per year	
Per-unit Budget			$16.7k in financing (avg) $4k-$15k in incentives (avg)	(no data)	(no data)	Up to $7,500	(no data)	
Home Repairs	Allergen	Carpet removal and flooring install			X	X		
		Carpet steam clean			X	X		
		IPM contractor			X	X		
		Gutter repair			X	X		
	Moisture	Landscaping re-grading	X		X	X		
		Mold major (>10ft2)			X	X		
		Mold minor (<10 ft2)	X		X	X		
		Plumbing major			X	X		
		Plumbing minor			X	X		
		Roof repair major	X		X	X		
		Roof repair minor	X		X	X		
		Venting, bathroom			X	X		
		Venting, dryer			X	X		

		Venting, kitchen			X	X		
	Indoor air quality	Air conditioners (window units)			X	X		
		Air conditioners (central)		X				
		Air purifiers			X	X		
		Dehumidifier			X	X		
		Furnace cleaning						
		Furnace filters	X (heat pump)		X	X		
		Furnace replacement	X (heat pump)	X			X (no fuel switching)	
		Gas stove/oven replacement	X (electric replacement)	X (induction replacement)			X (no fuel switching)	
		Hot water heater replacement	X (electric replacement)	X			X (no fuel switching)	
	Energy	Refrigerator replacement	?				X	
		Electrical / wiring upgrades	X					
		Weatherization / Energy eff.	X	X			X	
		Stove replacement	X					
		Heat pumps and mini splits	X	X				
		Heat pump water heaters	X	X				
		Electric dryers	X	X				
	Safety / injury	Asbestos	X		X			
		Lead	X		X			
		Structural	X		X			

Appendix C: Technical Model Notes + Assumptions

Documentation of Assumptions – "GHHI Assumption" refers to assumptions where no background literature was found and our staff made an informed estimate.

Assumption	Value	Description/Comments
Program Assumptions		
Total Number of Buildings	60	Based on the EBCE Health-E Homes Program
Number of Multi-Family Buildings	24	GHHI Assumption based on Alameda County having 40% multi-family building stock
Number of Apartment Units per building	20	GHHI Assumption based on 20+ unit being the largest category of multi-family buildings in Alameda County
Number of Single Family Homes	36	GHHI Assumption based on Alameda County having 60% single-family building stock
Average residents per apartment	2.8	Towncharts.com
Average residents per SFH	3.5	Towncharts.com
Years of Program Evaluation	15	Based on typical financing period for heat pump upgrades
% of Homes Built Before 1979	66%	Metopio
Cost Assumptions		
Assessment Costs	$1200	GHHI Lead Calculator
Electric Heat Pump + Installation	$18,842	TECH Clean CA
Electric Water Heater + Installation	$7,054	TECH Clean CA
Electric Stove + Oven + Installation	$2,231	Carbonswitch.com
Discount rate	2%	GHHI Assumption
Inflation rate	2%	GHHI Assumption
Health Assumptions: Baseline Data		
Baseline Mortality (per 100,000)	565.1	Metopio
Baseline Asthma ERVs (per 100,000)	2355.1	Metopio
Baseline heart disease hospitalizations (per 100,000)	290.9	Healthy Alameda County

Health Assumptions: Exposure Assessment		
NO_2 + CO from stoves and ovens		Zhu et al. 2020
NO_2 + CO from space and water heaters		Zhu et al. 2020
Space and water heater + ventilation		Zhu et al. 2020: A literature review conducted by LBNL found that while up to 50% of appliances tested were at risk of backdrafting, few instances of "sustained" backdrafting or spillage were recorded. There are several challenges associated with monitoring for backdrafting and spillage in homes. Due to the existing limitations, questions regarding the frequency, duration, and severity of backdrafting and spillage events remain to be answered.
Health Assumptions: Dose Response		
NO_2 / All-Cause Mortality		Orellano et al. 2020 (WHO Systematic Review)
NO_2 / Asthma-related ERVs and HAs		Zheng et al. 2021 (WHO Systematic Review)
CO + Myocardial		Lee et al. 2020 (WHO Systematic Review)
Intervention Effects		
Reduction in NO_2 due to stove/oven electrification	51%	Paulin et al. 2014
Reduction in CO due to stove/oven electrification	100%	GHHI Assumption (since CO is due to backdraft/leakage, assuming that building upgrades eliminates hazard)
Reduction in CO due to heat pump	100%	All modeled emissions from gas heaters are due to backdraft/ventilation. Thus, heat pump replacement should eliminate those emissions.
Reduction in NO_2 due to heat pump	100%	All modeled emissions from gas heaters are due to

		backdraft/ventilation. Thus, heat pump replacement should eliminate those emissions.
Reduction in CO due to HPWH	100%	All modeled emissions from water heaters are due to backdraft/ventilation. Thus, heat pump replacement should eliminate those emissions.
Reduction in NO2 due to HPWH	100%	All modeled emissions from water heaters are due to backdraft/ventilation. Thus, heat pump replacement should eliminate those emissions.
Health Impact Monetization Assumptions		
Value of a Statistical Life (VSL)	$7,400,000	US EPA
Value of avoided Asthma related ERVs	$3,500	Alameda County Public Health Department
Value of avoided Asthma related HAs	$16,545	Alameda County Public Health Department
Value of avoided heart disease hospitalizations	$18,931	Cowper et al. 2019

Appendix D: California Air Quality Standards (CAAQS)

Ambient Air Quality Standards

Pollutant	Averaging Time	California Standards [1]		National Standards [2]		
		Concentration [3]	Method [4]	Primary [3,5]	Secondary [3,6]	Method [7]
Ozone (O_3)[8]	1 Hour	0.09 ppm (180 $\mu g/m^3$)	Ultraviolet Photometry	—	Same as Primary Standard	Ultraviolet Photometry
	8 Hour	0.070 ppm (137 $\mu g/m^3$)		0.070 ppm (137 $\mu g/m^3$)		
Respirable Particulate Matter (PM10)[9]	24 Hour	50 $\mu g/m^3$	Gravimetric or Beta Attenuation	150 $\mu g/m^3$	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	20 $\mu g/m^3$		—		
Fine Particulate Matter (PM2.5)[9]	24 Hour	—	—	35 $\mu g/m^3$	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	12 $\mu g/m^3$	Gravimetric or Beta Attenuation	12.0 $\mu g/m^3$	15 $\mu g/m^3$	
Carbon Monoxide (CO)	1 Hour	20 ppm (23 mg/m^3)	Non-Dispersive Infrared Photometry (NDIR)	35 ppm (40 mg/m^3)	—	Non-Dispersive Infrared Photometry (NDIR)
	8 Hour	9.0 ppm (10 mg/m^3)		9 ppm (10 mg/m^3)	—	
	8 Hour (Lake Tahoe)	6 ppm (7 mg/m^3)		—	—	
Nitrogen Dioxide (NO_2)[10]	1 Hour	0.18 ppm (339 $\mu g/m^3$)	Gas Phase Chemiluminescence	100 ppb (188 $\mu g/m^3$)	—	Gas Phase Chemiluminescence
	Annual Arithmetic Mean	0.030 ppm (57 $\mu g/m^3$)		0.053 ppm (100 $\mu g/m^3$)	Same as Primary Standard	
Sulfur Dioxide (SO_2)[11]	1 Hour	0.25 ppm (655 $\mu g/m^3$)	Ultraviolet Fluorescence	75 ppb (196 $\mu g/m^3$)	—	Ultraviolet Flourescence; Spectrophotometry (Pararosaniline Method)
	3 Hour	—		—	0.5 ppm (1300 $\mu g/m^3$)	
	24 Hour	0.04 ppm (105 $\mu g/m^3$)		0.14 ppm (for certain areas)[11]	—	
	Annual Arithmetic Mean	—		0.030 ppm (for certain areas)[11]	—	
Lead[12,13]	30 Day Average	1.5 $\mu g/m^3$	Atomic Absorption	—	—	High Volume Sampler and Atomic Absorption
	Calendar Quarter	—		1.5 $\mu g/m^3$ (for certain areas)[12]	Same as Primary Standard	
	Rolling 3-Month Average	—		0.15 $\mu g/m^3$		
Visibility Reducing Particles[14]	8 Hour	See footnote 14	Beta Attenuation and Transmittance through Filter Tape	No National Standards		
Sulfates	24 Hour	25 $\mu g/m^3$	Ion Chromatography			
Hydrogen Sulfide	1 Hour	0.03 ppm (42 $\mu g/m^3$)	Ultraviolet Fluorescence			
Vinyl Chloride[12]	24 Hour	0.01 ppm (26 $\mu g/m^3$)	Gas Chromatography			

Appendix E: Medical Literature Base for Technical Review and Model

Particulate Matter (PM). PM-2.5 And PM-10
Long-term exposure to PM and all-cause and cause-specific mortality: a systematic review and meta-analysis (Chen & Hoek, 2020).
https://pubmed.ncbi.nlm.nih.gov/32703584/

ICD Codes: Health outcomes selected in relation to long-term exposure to PM2.5 and PM10 included (the 10th revision of the International Classification of Diseases (ICD-10) codes, version 2016 in brackets): all-cause mortality (A00 – Z99) and cause-specific mortality including circulatory diseases (I00 – I99), ischemic heart diseases (IHD, I20 – I25), J. Chen and G. Hoek Environment International 143 (2020) 1059742 cerebrovascular diseases (stroke, I60 – I69), respiratory diseases (J00-J99), chronic obstructive pulmonary diseases (COPD, J40 – J44, J47), acute lower respiratory infection (ALRI, J12 – J18, J20 – J22) and lung cancer mortality (C30 – C39). Natural-cause mortality or non-accidental mortality (A00 – R99) is mortality from all-causes except external causes such as accidents, suicide and homicide. We considered natural-cause mortality equivalent to all-cause mortality as natural cause mortality accounts for the majority of all-cause mortality and there is no clear evidence that air pollution is associated with accidental mortality. Equivalent definitions using ICD-9 or other versions of ICD- 10 were included.

Treatment Effects: For natural-cause mortality, the combined effect estimate across 25 studies was 1.08 (95%CI:1.06, 1.09) per 10 µg/m3 increase in PM2.5, which is slightly higher than the combined estimate of 1.06 (95% CI:1.04, 1.08) across 11 studies reported in a 2013 review used extensively by the European Environment Agency for European health impact assessment (Hoek et al., 2013). The previous estimate was based on studies predominantly conducted in North America with two studies from Europe (Beelen et al., 2008; Cesaroni et al., 2013). The evidence was strengthened by including new evidence generated in Asia (Tseng et al., 2015; Yang et al., 2018; Yin et al., 2017), North America (Bowe et al., 2018; Pinault et al., 2017), Europe (Beelen et al., 2014b; Carey et al., 2013), and longer follow-up (Cakmak et al., 2018; Di et al., 2017). For PM10, the combined estimate increased from 1.035 (95%CI:1.004, 1.066) reported in the Hoek, 2013 review to 1.04 (95%CI:1.03, 1.06) in the current review. The previous review was based on only 6 cohort studies while the updated combined estimate was based on 17 cohort studies.

Nitrogen Oxides and Ozones
Long-term exposure to NO2 and O3 and all-cause and respiratory mortality: a systematic review and meta-analysis (Huangfu & Atkinson, 2020).
https://pubmed.ncbi.nlm.nih.gov/33032072/

ICD Codes: Outcomes included in the review were mortality from all-causes (A00-Z99); respiratory diseases (J00-J99); COPD (J40-47) and ALRI (J12-J18, J20-J28). We included publication of prospective and retrospective cohort studies, published (or accepted for publication) journal articles in any language, conference abstracts and papers, letters, notes, and grey literature. Cohort studies were selected for the review as they are used in environmental epidemiology to assess associations between long-term (over years) concentrations of pollutants and risk of death.

Treatment Effects: For NO2 and mortality we assessed the certainty of evidence (adapted GRADE) from single pollutant models to be moderate for all causes (mean RR = 1.02 per 10 µ/m3), moderate for respiratory (mean RR 1.03 per 10 µ/m3); high for COPD (mean RR = 1.03 per 10 µ/m3; and moderate for ALRI (mean RR = 1.06 per 10 µ/m3). For studies reporting annual O3 metrics we assessed the certainty of the evidence from single pollutant models to be low for all-cause mortality (man RR = 0.97 per 10 µ/m3); and low for respiratory mortality (mean RR = 0.99 per 10 µ/m3). For peak O3 exposures we assessed the certainty of evidence from single pollutant models to be moderate for all-cause mortality (mean RR = 1.01 per 10 µ/m3) and low for respiratory mortality (mean RR = 1.02 per 10 µ/m3).

Short-term exposure to particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and ozone (O3) and all-cause and cause-specific mortality: systematic review and meta-analysis (Orellano et al., 2020).
https://pubmed.ncbi.nlm.nih.gov/32590284/
ICD Codes: The outcomes were classified using the International Statistical Classification of Diseases and Related Health Problems (ICD), and encompassed all-cause natural mortality (ICD-10: A00 to R99), cause specific mortality including cardio (ICD-10: I01 to I59) and cerebrovascular (ICD-10: I60 to I69), and respiratory mortality (ICD-10: J00 to J99) (WHO International Classification of Diseases (ICD) Information Sheet," n.d.). We defined an exposure-outcome combination as a pair comprising one of the pollutants selected, and one of the outcomes. Based on previous evidence, the exposure-outcome combinations that were analyzed included PM, NO2, and O3 – all-cause mortality, and PM – cardiovascular, respiratory, and cerebrovascular mortality.

Short-term exposure to sulfur dioxide (SO2) and all-cause and respiratory mortality: a systematic review and meta-analysis (Orellano, Reynoso & Quaranta, 2021).
https://pubmed.ncbi.nlm.nih.gov/33601225/
ICD Codes: The outcomes were classified using the International Statistical Classification of Diseases and Related Health Problems (ICD), and encompassed all-cause natural mortality (ICD-10: A00 to R99), and respiratory mortality (ICD-10: J00 to J99) (WHO, 2015).
Treatment Effects:

Table 2
Exposures, outcomes and pooled effect sizes.

Pollutant	Outcome	Number of effect sizes	RR (95% CI)	p-value	PI	Egger's test (p-value)
SO_2 (24-hour average)	All-cause mortality	36	**1.0059 (1.0046–1.0071)**	**<0.0001**	1.0025–1.0092	**0.016**
SO_2 (24-hour average)	Respiratory mortality	23	**1.0067 (1.0025–1.0109)**	**0.0018**	0.9976–1.0159	0.082
SO_2 (1-hour max.)	All-cause mortality	4	1.0016 (0.9930–1.0102)	0.6045	0.9952–1.0080	N/A
SO_2 (1-hour max.)	Respiratory mortality	3	**1.0052 (1.0013–1.0091)**	**0.0287**	1.0013–1.0091	N/A

RR, pooled relative risks; 95% CI, 95% confidence interval; p-value, significance of the association or statistical tests; PI, 80% prediction interval; N/A, not applicable (<10 studies); statistically significant results in bold.

Short-term exposure to ozone, nitrogen dioxide, and sulfur dioxide and emergency room visits and hospital admissions due to asthma: a systematic review and meta-analysis (Zheng et al., 2021).

https://pubmed.ncbi.nlm.nih.gov/33601224/

ICD Codes: Studies that fulfilled the following criteria were included: (1) Population: general human population (including subgroups at risk), of all ages, in developed and developing areas, both urban and rural; (2) Exposures: short-term exposure (from several hours to 7 days) to ambient O3, NO2 and SO2 expressed in a concentration unit (μg/m3, ppb); (3) Comparators: exposure to lower (lowest) levels of O3, NO2 and SO2 in the same population; (4) Outcomes: ERVs or HAs due to asthma, defined according to International Classification of Diseases (ICD), Ninth Revision (ICD-9) code 493.xx and ICD, and Revision 10 (ICD 10, code J45); (5) Studies: human epidemiological studies, comprising ETS and CCO studies published in peer reviewed journals in any language (abstract in English).

Treatment Effects: The pooled relative risk (RR) per 10 μg/m3 increase of ambient concentrations was 1.008 (95%CI: 1.005, 1.011) for maximum 8-hour daily or average 24-hour O3, 1.014 (95%CI: 1.008, 1.020) for average 24-hour NO2, 1.010 (95%CI: 1.001, 1.020) for 24-hour SO2, 1.017 (95%CI: 0.973, 1.063) for maximum 1-hour daily O3, 0.999 (95%CI: 0.966, 1.033) for 1-hour NO2, and 1.003 (95%CI: 0.992, 1.014) for 1-hour SO2. Heterogeneity was observed in all pollutants except for 8-hour or 24-hour
O3 and 24-hour NO2.

Short-term exposure to carbon monoxide and myocardial infarction: a systematic review and meta-analysis (Lee et al., 2020).
https://pubmed.ncbi.nlm.nih.gov/32634667/

“We included myocardial infarction as the only ischaemic heart disease outcome because it is not possible to accurately define the time of onset of other ischaemic heart disease outcomes such as angina which manifest over a period of months to years.”
Results: We evaluated 1,038 articles from the previous review and our updated literature search, of which, 26 satisfied our inclusion criteria. Overall, myocardial infarction was associated with exposure to ambient carbon monoxide concentration (risk ratio of 1.052, 95% confidence interval 1.017–1.089 per 1 mg/m3 increase). A third of studies were assessed to be at high risk of bias (RoB) due to inadequate adjustment for confounding.
Using an adaptation of the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework, the overall evidence was assessed to be of moderate certainty.
Conclusions: This review demonstrated that the pooled risk ratio for myocardial infarction was 1.052 (95% CI 1.017–1.089) per 1 mg/m3 increase in ambient carbon monoxide concentration. However, very few studies originated from low- and middle-income countries.