Q & A's for Challenges and Opportunities for Home Decarbonization

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These Q&A's are a companion document to the LBNL report on Challenges and Opportunities for Home Decarbonization[1].

Q: What is the purpose of this report?
A: This report outlines emerging challenges and innovative strategies needed to achieve substantial CO_2 reductions in the US housing stock. Rather than presenting a guide to home decarbonization that includes well-established approaches and technologies, this report is focused on the emerging challenges that will need to be addressed in order to decarbonize large numbers of existing homes. It focuses on a segment of the buildings stock with direct emissions from fossil fuel use that will be difficult to decarbonize. The report identifies the home performance challenges to scaling up and the opportunities and innovation required to achieve DOE's building decarbonization goals.

Q: What is this report based on?
A: A combination of: a literature review of the state of the art, a survey of industry professionals, a database of over 1,700 projects, and input from stakeholders and practitioners. This report provides observations and recommendation from residential building researchers at LBNL.

Q: Who is the target audience?
A: It has been written to be used by a wide variety of stakeholders that are interested in addressing challenges to large scale decarbonization of homes. This includes federal and state energy and housing agencies, utility programs, manufacturers, nonprofit organizations, and local and tribal governments.

Q: What buildings are covered by this report?
A: This report focuses on decarbonization of the existing housing stock rather than new construction, including both owner-occupied and rented homes. Most of the specific analysis results in the report are for single family homes and LBNL is currently developing similar information for multifamily homes.

Q: Does this report summarize all DOE decarbonization-related programs?
A: No. The report is not intended to be a comprehensive overview, rather it focuses on barriers related to rapidly scaling home decarbonization not covered by existing programs and what the authors consider the most relevant potential new areas for R&D.

Q: What is the current cost to decarbonize a typical home with direct fossil fuel emissions?

[1] https://homes.lbl.gov/publications/challenges-and-opportunities-home

A: The authors estimate an average national cost of about $55,000 for about 70% reduction in carbon emissions. This is based on reported costs[2] for homes that currently use fossil fuel for major energy end-uses, i.e., heating and hot water. The authors estimate that the cost could be reduced to $40,000 for a typical home with a focus on the measures that give the most carbon savings for the least cost.[3] There is a significant cost to achieve substantial carbon emission reductions in the residential building sector - the "green price premium". Reducing this premium will require significant R&D from DOE and other innovators if the industry is going to rapidly get to scale and meet carbon reduction targets.

Q: Do the reported costs include rebates, tax credits or other cost reduction programs?
A: The analyses did not include these cost adjustments so as not to embed any biases for future policy developments on these topics.

Q: Will home electrification lower utility bills?
A: Because the cost of electricity and fossil fuels used in the home varies substantially from state to state, the switch to all-electric homes does not always result in lower bills, if all that is done is equipment and appliances switch. This is why energy efficiency measures, such as air sealing and insulating of the home and HVAC system, are recommended to reduce loads for heating and cooling systems, and are part of the most cost-effective approaches to home decarbonization. These load reductions can offset increases in fuel costs and make decarbonization more affordable. Another strategy to lower bills is to choose higher performance equipment, because the additional upfront cost can be small compared to total project costs. More research to reduce cost of equipment installation, envelope and thermal distribution improvements and project overheads will benefit consumers.

Q: How will the electrification of home heating, water heating, cooking and clothes drying impact CO_2 emissions?
A: Homes in states with high carbon content electricity[4] will find it very difficult to reduce CO_2 emissions by going all-electric without the use of rooftop solar PV. However, some of those states, such as Kentucky, already have a high proportion of homes using electric heat and would see little overall change in emissions. Nationwide, the vast majority of homes needing electrification will reduce CO_2 emissions and the average CO_2 reduction weighted by number of appliances in each state is about 45% for heating systems.

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[2] This dataset is limited by data availability and represents a snapshot of recent home upgrades that were selected to be focused on deep energy and carbon savings. There is considerable variation (at least +/- $35,000) in costs depending on home initial condition, home size, location, and the scope of the project, e.g., the most expensive project also included foundation insulation and window replacement not included in other projects. Similarly, project costs are lowered for newer homes that have relatively well-insulated envelopes, or in milder climates requiring lower capacity HVAC and Solar PV systems. The authors of this report note that subsequent discussions with stakeholders indicates that this cost seems reasonable to industry practitioners and is close to that reported in other studies: Less et al. (2014), Stebbins et al. (2020) and ACEEE (2022).

[3] This is based on optimizing measures from the cost data base to maximize carbon savings for a given measure cost. This optimized approach includes: 1) Air sealing and insulating the building envelope and thermal distribution system, 2) Replacement of fossil fuel end-uses with heat pumps for heating, cooling, and hot water, and 3) installation of onsite solar PV.

[4] Wyoming, Utah, Missouri, Kentucky, Indiana, and West Virginia.

Q: How much CO_2 reduction is currently being achieved per home based on the assumption for typical home decarbonization?
A: Typically, about 65-70%. This varies depending on the carbon content of electricity. In some states the saving can be close to 100%, but less so in others.

Q: Are there other climate impacts that need to be considered besides direct emissions from fossil fuel use in homes and indirect emissions from electricity use in homes?
A: Yes, there are two additional emission sources to consider. The removal of natural gas appliances and infrastructure results in less methane leakage from the storage and distribution system. Some studies have estimated that the leakage of methane has about the same contribution to climate change as the CO_2 from combustion. This will have a positive impact. However, there is a risk that leakage of refrigerant used in heat pumps, could increase as the number of heat pumps increases. This is primarily a concern for field-assembled equipment (mostly heating and cooling systems) and is less of a concern in factory-sealed products such as heat pump water heaters or air to water systems. The overall impacts are not well known, but are certainly significant because the global warming potential for common refrigerants[5] is about 2000 times higher than for CO_2. Both of these issues should be included in analyses of overall climate impacts of home electrification. In addition, there is considerable scope for reducing leaks in field assembled systems by requiring the use of better connections - e.g., brazing instead of flare fittings.

Q: What are some non-energy benefits of home decarbonization
A: Removing fossil fuel combustion from homes can improve Indoor Air Quality (primarily from unvented combustion) that may significantly improve occupant health according to preliminary investigations. Removing combustion also removes concerns about carbon monoxide and potential backdrafting of appliances when air sealing homes. There are also benefits in outdoor air quality that go beyond individual occupants to create benefits for whole communities. Research is under way to better quantify these health impacts. There are also potential safety improvements that are also being quantified - such as the use of induction cooking. Another issue is the potential increase in home value - that has previously been assessed for other energy efficiency-related measures but needs to be quantified specifically for decarbonization. Home resilience may improve. For example, by introducing cooling into homes that previously did not have it that makes homes safer during heat waves; integrating envelope improvements allows homes to remain occupiable for longer when energy distribution systems fail. Similarly, onsite Solar PV, thermal and battery storage all allow homes to function better in emergency situations.

Q: Why are electric panel replacement and service upgrades a challenge to home decarbonization?
A: When adding new electric circuits for electrifying a home it is possible to exceed the capacity of the home's electric service or of its main breaker panel. Increasing capacity costs thousands of dollars and wait times for utilities to upgrade the connection to a home can take many months. It is often possible to avoid this costly and time-consuming problem through use of lower power devices, technologies that remove the panel power constraint

[5] A notable exception is to use CO_2 itself as a refrigerant. This is done in some air to water heat pumps for heating only.

and through using electric codes intelligently. The National Electric Code (NEC) includes compliance paths that are rarely, if ever, followed. DOE is funding efforts to support simplification of the NEC to make it easier to use for home retrofits. The DOE EAS-E Prize is explicitly targeting this issue and there are products being developed to reduce the need for panel replacement.

Q: Are there any limitations or restrictions due to building and electric codes that are barriers to decarbonize homes?
A: For electric service and circuits, the National Electric Code (NEC) is the most significant. The NEC itself has a compliance path (NEC Article 220.87 - Determining Existing Loads) based on measuring actual home consumption, that can remove the need for costly and time-consuming panel and service upgrades. But this path often remains unused by electricians due to their unfamiliarity and the lack of clarity in the code language. Similarly, the NEC allows load control technologies, but these are not always accepted by local authorities. Other code restrictions (and sometimes manufacturers guidelines) may limit options for placement of outdoor units for heat pumps or require roof reinforcement for Solar PV. Overall, code restrictions, themselves, are not a very significant barrier and efforts are underway to improve the NEC for application to existing homes undergoing electrification. However, the application and interpretation of code requirements together with time delays for inspections can be significant issues.

Q: In addition to the first cost barrier, what are the most important barriers to achieving wide scale decarbonization of homes?
A: There are several key barriers identified by industry professionals and stakeholders:

1. Lack of consumer awareness and value proposition.
2. Lack of a suitable workforce. In most of the country it is very difficult to find a contractor to do the work.
3. Non-energy-related issues in homes add to cost, time and project complexity such as: deferred maintenance, structural damage, presence of asbestos, and space limits (particularly for heat pump water heaters and heat pump outdoor units).

Q: What are ways to increase consumer demand?
A: According to practitioners there are several important ways to increase demand.

1. Provide strong financial incentives, such as rebates and easy financing.
2. Improve the value proposition by emphasizing health benefits and increased home value.
3. Change cost discussions away from up-front costs to affordability (i.e., monthly payments), as is done with other large purchases such as automobiles.

Q: What can be done to deliver scalable and replicable upgrades to buildings in disadvantage communities, and low- and moderate-income households.?
A:

1. Develop portable solutions that renters can take with them (e.g. low-power plug-in products)
2. Develop drop-in and DIY products.
3. Emphasize health impacts in communities where health costs are severe burdens on both occupants and local public health programs.

4. Include increased home resilience - particularly opportunities provided by storage and envelope improvements which make homes habitable for longer during power failures.
5. Develop solutions that allow decarbonization without occupants having to leave their homes.
6. Develop solutions for multifamily and manufactured homes.

Communities may also need to consider policies to protect tenants from increased energy burdens when properties are upgraded.

Q: What can be done to prevent overloading the electric grid?
A: In general, the strategy is to reduce building electricity loads in order to avoid power system upgrades. For example,

1. Use lower power devices. More products are coming to market that have lower power consumption (operating off a standard 120V wall outlet) and have the ability to store electricity or thermal energy to retain capacity needed provide a service.
2. Use circuit sharing devices (e.g. for an EV Charger and a clothes dryer).
3. Install Solar PV to generate electricity on-site.
4. Install battery and/or thermal storage to operate during peak grid demand times.
5. Use lower power (7kW maximum) EV chargers and smart EV chargers that can switch charging away from peak times.
6. Use smart panels that limit a home's maximum power consumption.

Q: Does this report include utility regulations that would affect decarbonization affordability, such as future rate structures?
A: It does not directly address regulation, because rate structures are complex and highly variable and are continuously changing. The cost data supporting this report use national or state averages. This provides the baseline data that could be used to develop regulations without baking in existing regulatory assumptions.

References for Deep energy/decarbonization retrofits:

Amann, Jennifer, Rohini Srivastava, and Nick Henner. 2021. “Pathways For Deep Energy Use Reductions And Decarbonization In Homes.” b2103. American Council for an Energy Efficient Economy. aceee.org/research-report/b2103.
Less, Brennan D., and Iain S. Walker. 2014. “A Meta-Analysis of Single-Family Deep Energy Retrofit Performance in the U.S.” No. LBNL-6601E. Berkeley, CA: Lawrence Berkeley National Lab. https://doi.org/10.2172/1129577.
Stebbins, Gabrielle, Tom Perry, and Richard Faesy. 2020. “Zero Energy Now: 60%+ Total Energy Savings in Existing Buildings.” Proc. ACEEE Summer Study on Energy Efficiency in Buildings. American Council for an Energy Efficient Economy.