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DOE Deep Energy Retrofit Cost Survey

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Energy Technologies Area

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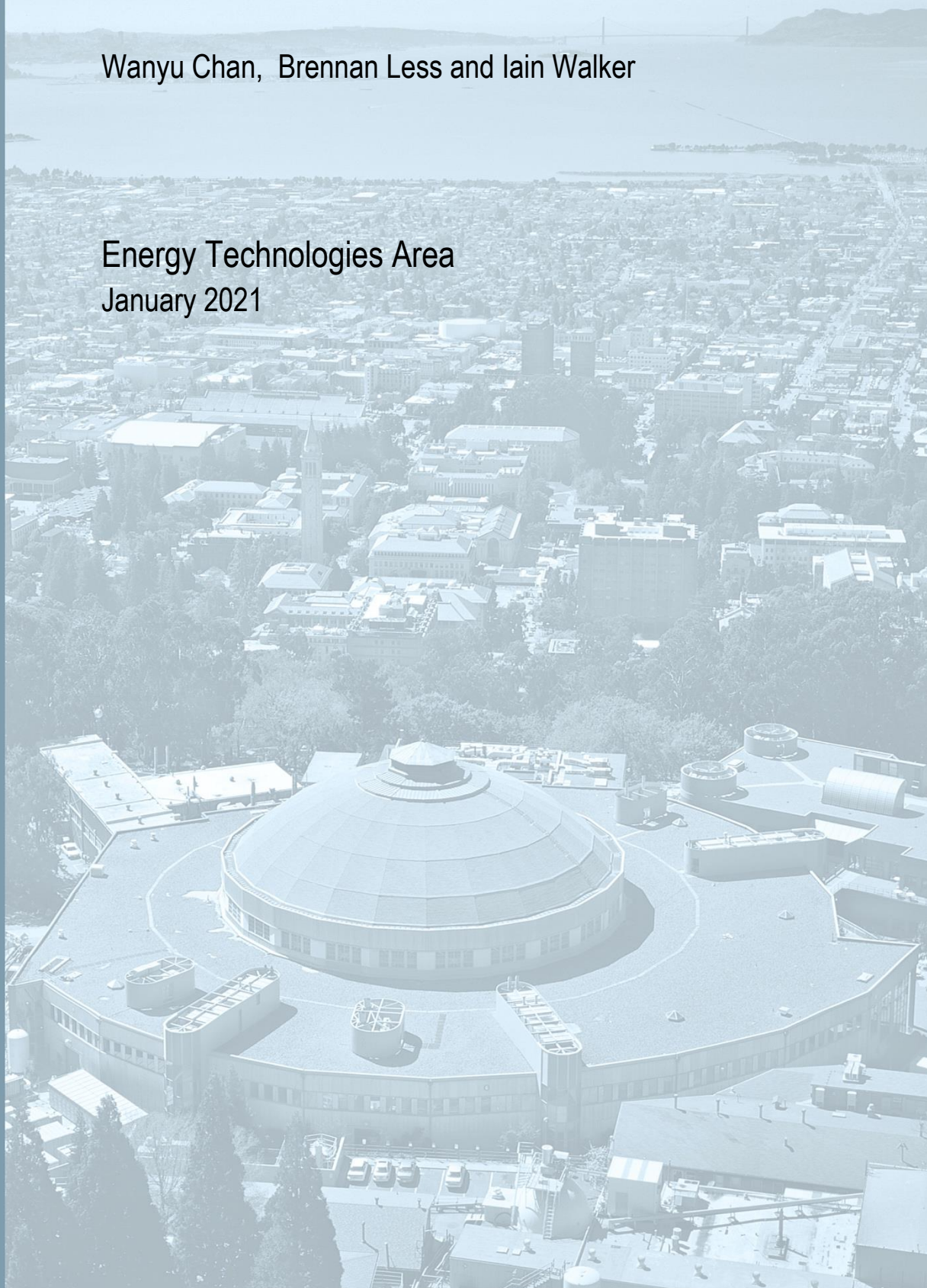

Disclaimer:

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1 Introduction

A survey was conducted by the Lawrence Berkeley National Laboratory on deep energy retrofit (DER) market drivers, opportunities, and challenges. The survey was part a research study sponsored by the U.S. Department of Energy to gather information on the costs of DER from home performance contractors and stakeholders. Cost data was gathered from DER projects that use a comprehensive, whole-home approach to drastically reduce energy use and improve performance. DER projects often aim at reducing energy use by 50% or more. In addition, these projects can improve home comfort and potentially benefiting occupant health. Yet, market adoption of DER has been limited. Major limiting factors include complex projects, high costs, perceived risks, extensive disruption, and unfamiliar work scopes to some contractors. In order to better understand what motivates and deters DER projects in today's market, a survey was conducted to gather this information, and to learn about promising approaches and technologies from the industry perspective.

Past surveys on homeowners and home energy performance professionals have studied the motivations and barriers of energy efficiency retrofits. Two surveys of home energy performance professionals (Palmer et al. 2013; McIlvaine et al. 2013) were conducted in recent years. The Resources for the Future (RFF) Home Energy Audit and Retrofit Survey was conducted in 2011 (Palmer et al. 2013) by recruiting energy auditors and retrofit installers through members of Efficiency First and Building Performance Institute (BPI) accredited contractors. The survey asked about the business and services that respondents provide, how often homeowners follow their recommendations to retrofit their homes, and the respondents' opinion on barriers faced by the industry. The survey found that not enough homeowners know about energy audits, but more importantly, it is the high cost of retrofits compared to low energy prices that is responsible for few energy audits and retrofits being completed.

The RESNET Deep Retrofit Industry Stakeholder Survey (McIlvaine et al. 2013) was conducted shortly after launching of the EnergySmart Home Performance Team program. The EnergySmart Team program involves a formal agreement among allied contractors who are engaged in high performance retrofits. Using this allied team approach, teams can pool their expertise and provide each other with customer referrals. The survey asked EnergySmart Team members and outside stakeholders on questions about market and technical barriers in performing home energy retrofits. Survey respondents identified lack of consumer awareness and lack of affordable financing for consumers as the leading market barriers to home energy retrofits. In their written comments, many survey respondents also echoed that the high costs of retrofit compared to low energy prices is a market barrier. Respondents found "certain housing characteristics that prevent effective retrofit" and "energy analysis software inaccuracy or limitations" are the two leading technical barriers. Their choices for technical barriers were reflective of the energy rater/auditor role played by the majority (78%) of the survey respondents.

In comparison to past surveys, this work aimed to gather inputs from a broader segment of the home performance industry to identify the opportunities and barriers faced by DERs from all perspectives. The survey asks for project costs to help breakdown the high costs of DERs. This survey is also motivated by a need to better understand the role of DERs in reducing energy use by the residential sectors and meeting climate goals. The survey is designed towards obtaining more substantive inputs from survey respondents by encouraging written comments, rather than setting the goal to reach a large number of respondents. We took this approach because DER is currently still a niche market, so it is more valuable to gather in-depth inputs from individuals who are performing this work rather than getting to the masses.

2 Method

We conducted an online survey to gather information from building energy professionals on their experiences and opinions on deep energy retrofits (DER). The survey took about 26 minutes (median response time) to complete. The survey asked questions about:

- What motivates and deters DER projects in today's market
- Promising strategies and technologies
- Non-financial aspects of retrofit measures that make them more or less desirable for homeowners and contractors

The research team sent email invitations containing the survey link to individuals from their professional contacts, including home performance, weatherization, and general contractors, home energy raters, mechanical/architectural designers, efficiency program managers, consultants, and researchers. The survey was advertised in the Home Energy magazine. The research team also posted promotional messages about the survey on the Building Performance Community Forum, and on other social media platforms.

At the end of the survey, respondents had the option to list their company names as a data contributor to this project (see Appendix A). The survey did not gather any personal identifiable information from the respondents.

The survey was organized such that questions that can be easily answered by most respondents, regardless of their roles, appeared first. Questions that asked about project costs of DER were placed at the end of the survey because not all survey respondents had this information. The main sections of the survey are described in Table 1.

Table 1 Survey questions organized by main sections of topic

Background information about past DER experiences of the respondent This section asked about the role of the respondent, what market (type of homes, geographical area) do they work in, and if they have been involved in certain DER programs.
Consumer perspective on DER projects This section asked questions about what motivate homeowners when seeking to perform a DER project, and what the important factors are being considered.
Home performance contractor perspective on DER challenges This section asked questions about barriers when performing DER and ways to increase customer demand.
Promising technologies and approaches to advance DER This section asked survey respondents to rate new technologies and approaches that are promising in their market.
Work scope and approaches to DER from past experiences This section asked for information about designing and implementing DER projects, how the respondents make decisions, and to identify non-construction tasks (e.g., customer acquisition) that they find the most time-consuming.
Project costs for performing DER This section asked for factors that drive project cost and timeline. It also asked for cost estimates of certain aspects of a DER project, such as project management, that are not often reported in cost bids. Respondents were asked to provide an estimate of overhead and profit margin if they are comfortable sharing this information.

In closing, survey respondents were asked to share one innovation in materials, equipment, or processes that in their opinion would greatly increase the performance adoption, and/or reduce the costs of DER. The survey was administrated using the Qualtrics software. The survey questions are provided in Appendix B.

3 Results

3.1 Survey Respondents

The survey was accessed by 95 participants, of which 73 of them filled out the survey. Among the 73 survey respondents, 55 completed and reached the end of the survey. Because most questions were optional, not all questions were answered by all survey respondents. Questions that asked for numerical inputs of cost or time estimates of specific tasks in a DER project received the fewest responses, partly because some of the survey respondents (e.g., program managers or researchers) did not have this information. Most other survey questions that asked

for the opinion of respondents based on their past DER project experiences received 60 or more responses. Respondents are encouraged to provide additional comments throughout the survey. Most of our respondents stayed engaged until the very end of the survey and provided lengthy responses to two open-ended questions.

77% of the survey respondents self-identified as having the following roles in DER projects: home performance contractor (25%), consultant (15%), program manager (14%), researcher (12%), and general contractor (11%). See Table 2 for the complete list of roles.

Table 2 Survey respondents' role in DER project

Roles	**Counts**
Home performance contractor	18
Consultant	11
Program manager	10
Researcher	9
General contractor	8
Engineer	6
Architect	3
Energy rater	3
Homeowner	2
Remodeling contractor	1
Weatherization contractor	1
Other	1
Total	73

Table 3 shows that survey respondents work in 23 states, representing most climate zones in the U.S. California was the state that had the most respondents, representing about a third (34%) of the total. Using ACEEE 2020 State Scorecard (Berg et al. 2020) as a way to sort states into groups, states that are ranked highly on their policy and program efforts to save energy and pursue efficiency (which goes beyond home retrofit programs but also include considerations of state building codes, vehicle emission standards, industry led appliance standards, etc.) were more heavily represented in this survey.

Table 3 Locations where study respondents' company most commonly work

States	Counts	ACEEE 2020 State Scorecard Ranking	Percentage
CA	24	Ranks 1-10	58%
CA, AZ	1		
NY	7		
MA	5		
MD	3		
CT	1		
MN	1		
CO	4	Ranks 11-20	16%
WA	3		
PA	2		
IL	1		
ME	1		
MI	1		
TX	3	Ranks 21-30	14%
AZ	2		
NC, AR, TN	2		
NC	1		
FL	1		
VA	1		
OH	2	Ranks 31-30	3%
AL	1	Ranks 41-51	4%
GA	1		
LA	1		
US nationwide	4		
Total = 73			

Both small and large companies were surveyed. When asked how many DER projects the survey respondents had been involved with in the past two years (2018 and 2019), about a quarter of them (26%) were only involved with a small number of projects (1 to 3), but approximately equal percentage (29%) were involved with a large number of projects (51+).

Table 4 Number of DER projects that the survey respondents were involved in the past two years (2018 and 2019)

Number of Projects	Counts	Percentage
51 or more	21	29%
31 to 50	2	3%
11 to 30	4	5%
4 to 10	13	18%
1 to 3	19	26%
None	14	19%
Total	73	

About half of the survey respondents worked in single-family homes market only (52%). Another (40%) also had some DER project experience in multi-family homes. Very few worked solely in

multi-family or other building types. This is to be expected because the focus of this study was on single-family retrofits.

Table 5 Types of homes which the survey respondent had experience with from past DER projects

Home Types	Counts	Percentage
Single-family only	38	52%
Mostly single-family, some multi-family	29	40%
Mostly multi-family, some single-family	2	3%
Multi-family homes	1	1%
Single-family and commercial / larger buildings	2	3%
Other	1	1%
Total	73	

About half of the survey respondents (53%) indicated that some of their past DER projects were conducted as part of a utility retrofit program. Table 6 shows the breakdown.

Table 6 Percent of past DER projects by survey respondents that were part of a utility retrofit program

% Projects in Utility Retrofit Program	Counts	Percentage
100%	16	22%
85% to 95%	6	8%
55% to 80%	5	7%
25% to 50%	7	10%
5% to 20%	5	7%
0%	32	44%
No response	2	3%
Total	73	

Survey respondents were asked to indicate programs that they had been involved in from past DER projects. A list of 13 programs were listed for survey respondents to select from (Table 7). Some survey respondents (N=24) also provided additional programs that they were involved in (Table 8). Ten survey respondents were involved in DER projects that were not part of any program.

Table 7 Programs that survey respondents indicated that they had been involved in from past DER projects

Program	Counts
Home Performance with Energy Star	22
Building America research study	15
Advanced Home Upgrade (Energy Upgrade California)	14
Thousand Home Challenge	11
EnerPHit (Passive House)	6
NYSERDA DER Pilot	5
Mass DOER Home MVP	4
MassSave DER Pilot	2
Clean Energy Works Oregon	1
TVA Extreme Energy Makeover	0
TVA Home Uplift / EnergyRight	0
VEIC DER Pilot	0
VT Zero Energy Now	0
Other	24
None	10

Survey respondents may select all that apply, so the total count does not sum to 73.

Table 8 Additional programs that survey respondents indicated that they had been involved in from past DER projects

Program Name	Counts
BayREN	4
PAYS®	3
CEC / IOUs funded research	2
EnergySmart Colorado	1
Holland Energy Fund	1
$ave, Ouachita Electric Corporation	1
Solar and Energy Loan Fund (SELF)	1
SMUD Programs	1
Boulder ETHIQ project	1
Build It Green / CALGreen	1
Zero net energy projects	1
PHIUS+ 2018	1
LEED	1
MCELIFT and multifamily programs	1
WAP	1
Not specified	3

3.2 Customer Perspective

This section asked questions about what motivates homeowners when seeking to perform a DER project, and what important factors were considered. Survey respondents reported that the main motivations of homeowners when seeking to perform a DER project are to: (1) improve comfort, (2) save money on energy bill, and (3) make home sustainable / green (Figure 1). While related to the goals of deep energy retrofits, reducing carbon emissions and reduced use

of on-site fossil fuel are less popular options, along with other benefits of retrofit projects, such as increase resilience and increase home value.

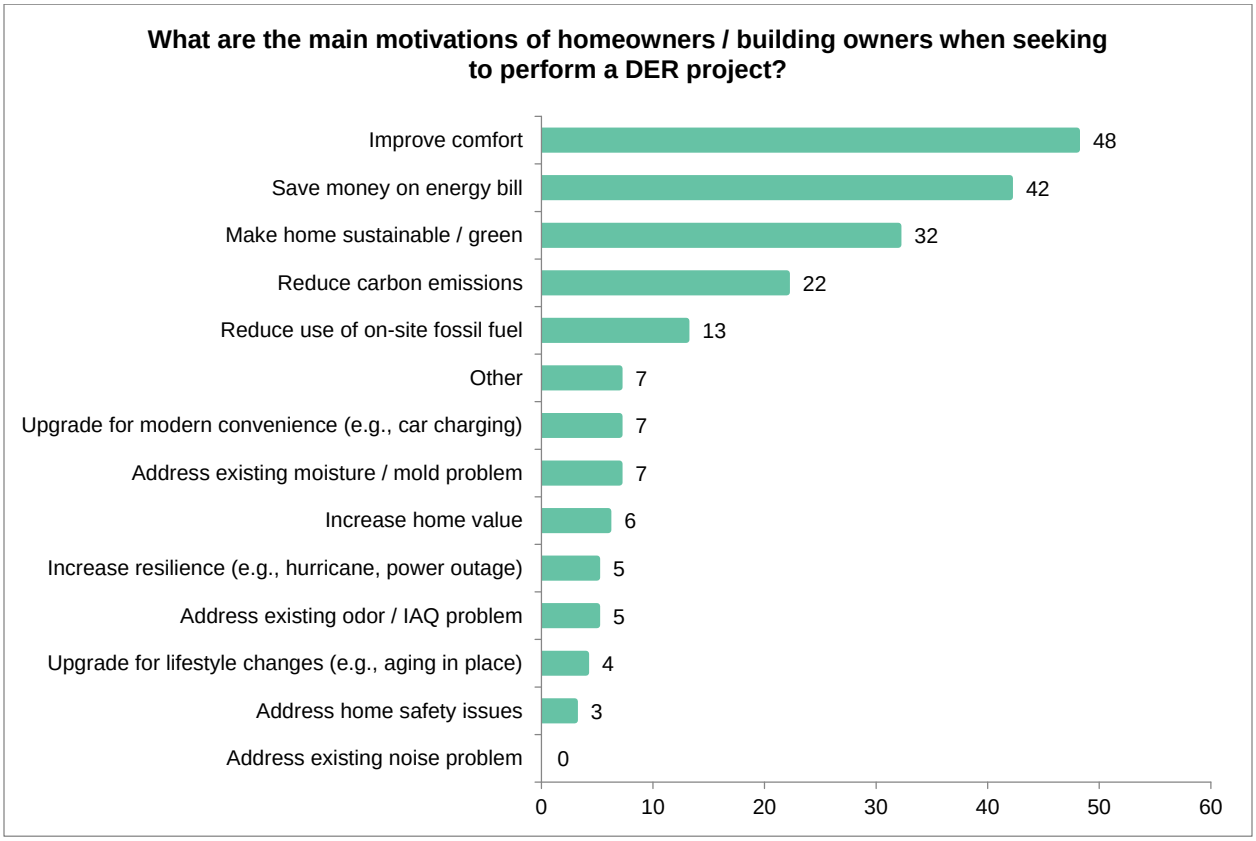

Figure 1 Main motivations of homeowners when seeking to perform a DER project. Total responses = 70.

From the viewpoint of survey responses, project cost was the factor that most often rated 4 or 5 out of 5 in terms of its importance when homeowners decide whether or not to proceed with a DER project (Figure 2). Other modeling priorities, financial payback, and availability of project financing are rated 4 or 5 out of 5 approximately 30% of the time. Factors that put the burden on homeowners, such as disruptiveness to life in the home, complexity of the project, and project timeline were least recognized by the survey responses as factors that homeowners considered in their decision making.

Other reasons for homeowners to seek DER include to take advantage of energy efficiency program incentives (N=3), and to address other existing problems (N=2) like ice dam and foundation failures. One survey respondent mentioned some homeowners have “interest in tech for its own sake”. Another survey respondent said homeowners performed DER to “improve home features”.

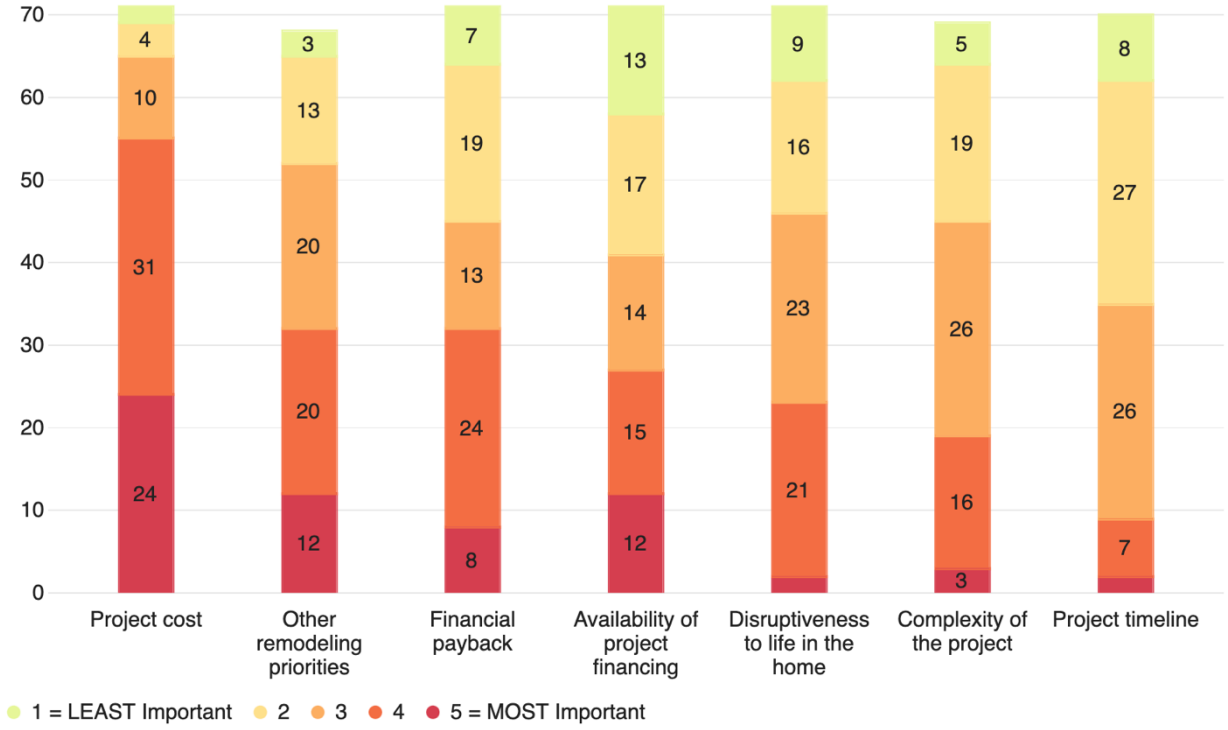

Figure 2 Importance of factors when homeowners decide whether or not to proceed with a DER project. Total responses = 71.

When it's time for costumers to decide whether to proceed with a project or not, they are mostly concerned about project costs. Factors like other remodeling priorities, financial payback, availability of project financing, disruptiveness to life in the home, and complexity of the project are also important. Somewhat less important to their customers is project timeline, as reported by survey respondents.

3.3 Industry Perspective

This section asked questions about barriers when performing DERs from the perspective of the study respondents and their experience from past retrofit projects. The survey also asked questions about ways to increase customer demand, which is one of the key barriers identified by study respondents when performing DER projects (Figure 3). Several study respondents provided responses that may explain the lack of customer demand, including:

> "*high hassle factor*"
> "*complexity presented to homeowner*"
> "*customer not trusting benefit worth cost*"

Lack of a reliable, trained home performance workforce was also a common barrier, followed by unforeseen conditions in existing homes and competition from companies performing non-DER work. One study respondent provided this comment on workforce:

> "*Lack of a reliable, trained home performance workforce who actually know what they're doing and aren't just going through the motions and applying flawed assumptions to qualify for incentive programs.*"

In comparison, fewer study respondents rated the steps of performing DER projects, such as work scope design and compliance with building code, as barriers. A few study respondents described practical challenges when performing DER projects: "*electrical upgrades*", "*scheduling*", and "*lots of toxic materials in existing buildings*". Overall, very few study respondents viewed lack of retrofit strategies, equipment / materials, or simulation tools as barriers. Two study respondents provided suggestions in their responses to overcome barriers, such as "*access to smart meter data*" and "*funding to resolve roadblocks"*.

Five survey respondents used "other" response to stress their view that cost is the biggest barrier to DER projects. One respondent provided this response:

> "*1. Low cost of electricity (lack of ROI for investment), 2. Other consumer priorities and 3. Complexity of putting together a value proposition that is compelling (even to us) ... (not to mention to the buyer)*".

To provide another perspective, another survey respondent provided a statistic that "*31% of homes close to poverty*" in the area that they work.

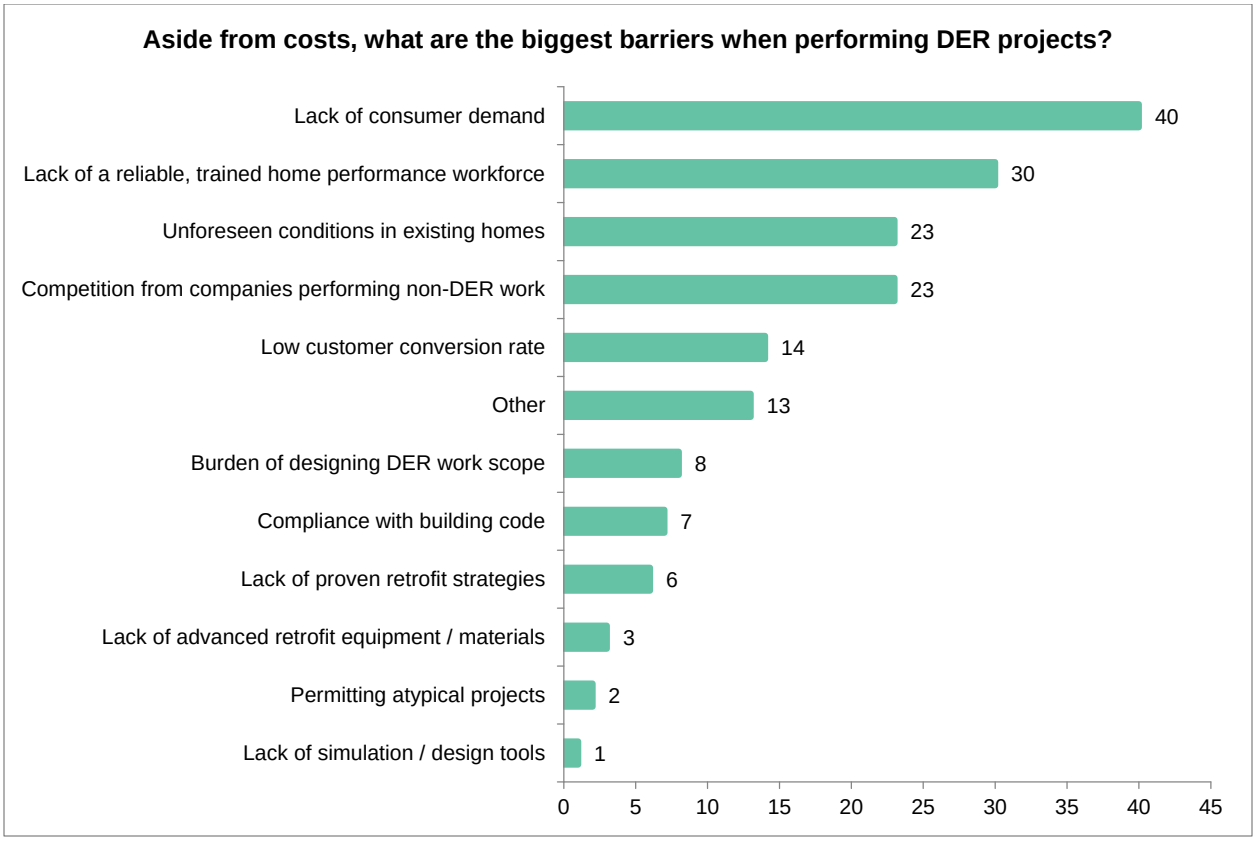

Figure 3 Biggest barriers faced by study respondents when performing DER projects. Total responses = 68.

Survey respondents considered providing strong financial incentives, such as through rebates and tax credits, is by far the most effective way to increase customer demand for DER projects (Figure 4). Similarly, lowering project costs and providing easier project financing were also seen to be effective. Linking DERs to increased home market value and health indoor environments and time of sale energy disclosures were other less popular suggestions.

Some responses were selected by only a few respondents, but may also be interesting avenues to pursue, such as improving the outcomes of DERs by improving energy savings or by using an approach called “energy bill guaranteed”, or reducing the burden on customers from project planning, project disruption and project timeline considerations.

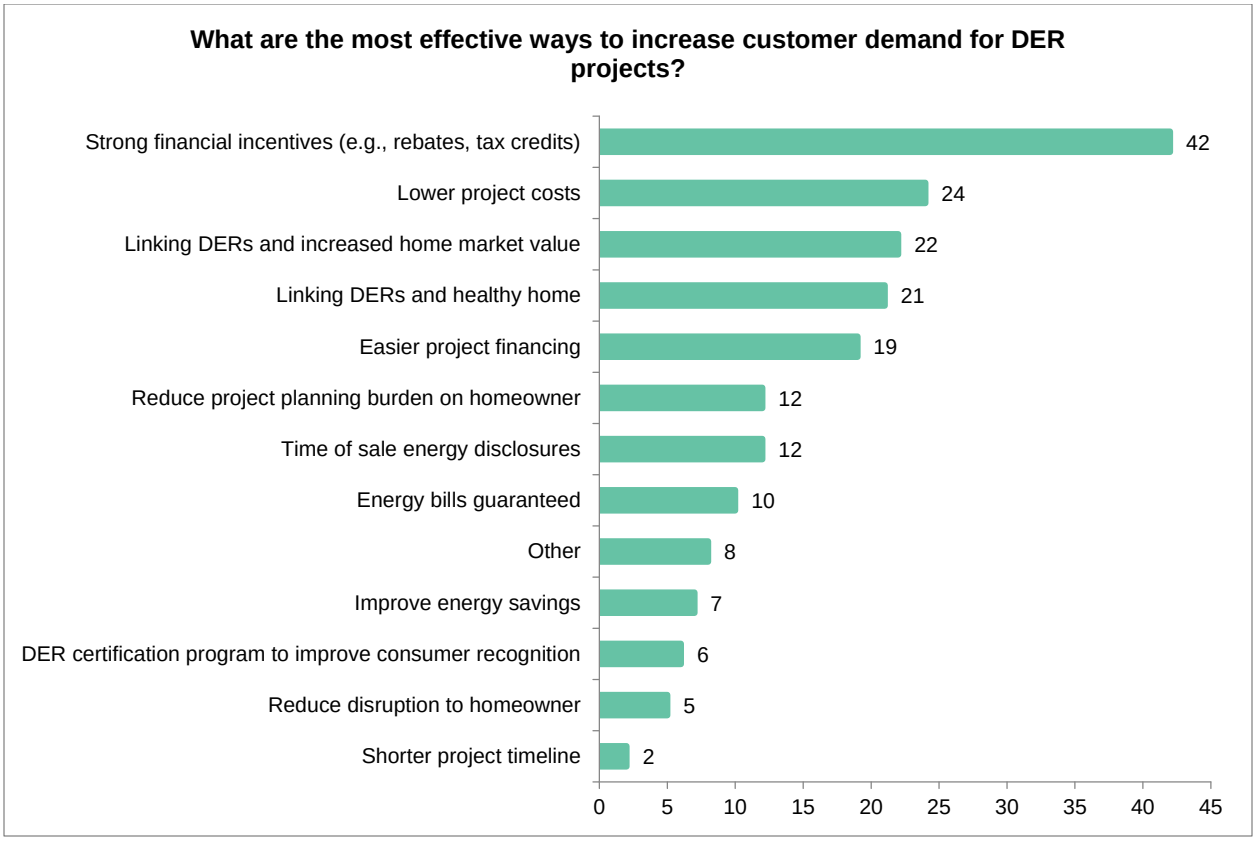

Figure 4 Effective ways to increase customer demand for DER projects. Total response = 68.

Several study respondents (N=3) suggested that providing customer education about DER is a way to increase demand. Letting customers know of low cost options, and connecting customers to trusted contractors directly were also mentioned.

3.4 Advanced Technologies and Approaches

This section asked study respondents to provide their opinion on new approaches and technologies for DER projects. The survey asked them to answer the questions from their perspective and based on the market that they serve.

Survey respondents identified the “one-stop shop” approach that encompasses energy audit, work scope, financing, permits, construction, and testing as the most promising overwhelmingly, followed by the concept of “energy plus healthy home” retrofits. There are three approaches that were rated similarly: (1) standard weatherization combined with heat pump and PV, (2) over-time DER aligned with equipment replacement / upgrade, and (3) home electrification retrofits. The two approaches that are viewed as less promising are ones that focus on building

envelope: (1) exterior retrofit with minimal disturbance inside home, and (2) pre-fabricated panelized envelope retrofits (e.g., EnergieSprong[1]).

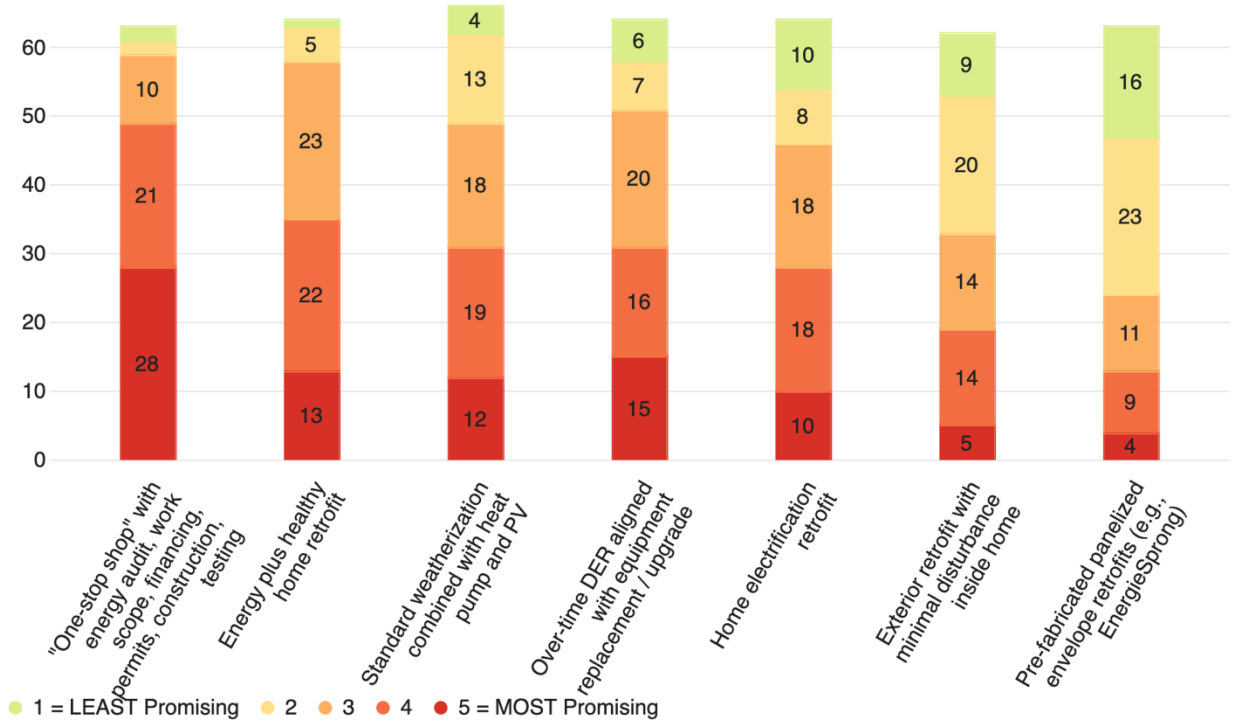

Figure 5 Rating of approaches for performing DER in your market. Total responses = 67.

Figure 6 shows the rating by survey respondents on advancements in DER technologies. Overall, heat pump technologies (integrated heat pump for space heating and hot water, cold climate heat pump) are rated by many respondents as promising technologies for DER. Smart ventilation and real-time indoor air quality monitoring are also highly rated. Other monitoring and control technologies like smart building controls, automated HVAC fault detection and diagnostics, and real-time energy monitoring also viewed by many survey respondents as promising.

Building envelope and window technologies are rated somewhere in the middle, including: Aeroseal for existing home envelopes, low global warming potential spray foam insulation, thin triple pane windows, super-insulation materials (e.g., aerogel, vacuum insulated panels).

[1] One study respondent pointed out that the benefits of EnergieSprong were not fully captured in the survey, which may have impacted its rating. "*The pre-fab EnergieSprong approach is not just about the panelized envelope, its more about developing minimally invasive prescriptive retrofit approaches that incorporate elements of offsite construction/pre-fab and can be installed quickly. That may include panels or not. But that approach has a lot of potential*".

The bottom five technologies that received the fewest votes are: alternative refrigerant (e.g., CO_2) heat pump, foundation insulation, advanced dehumidification, smart window coverings, and phase change materials in building envelope.

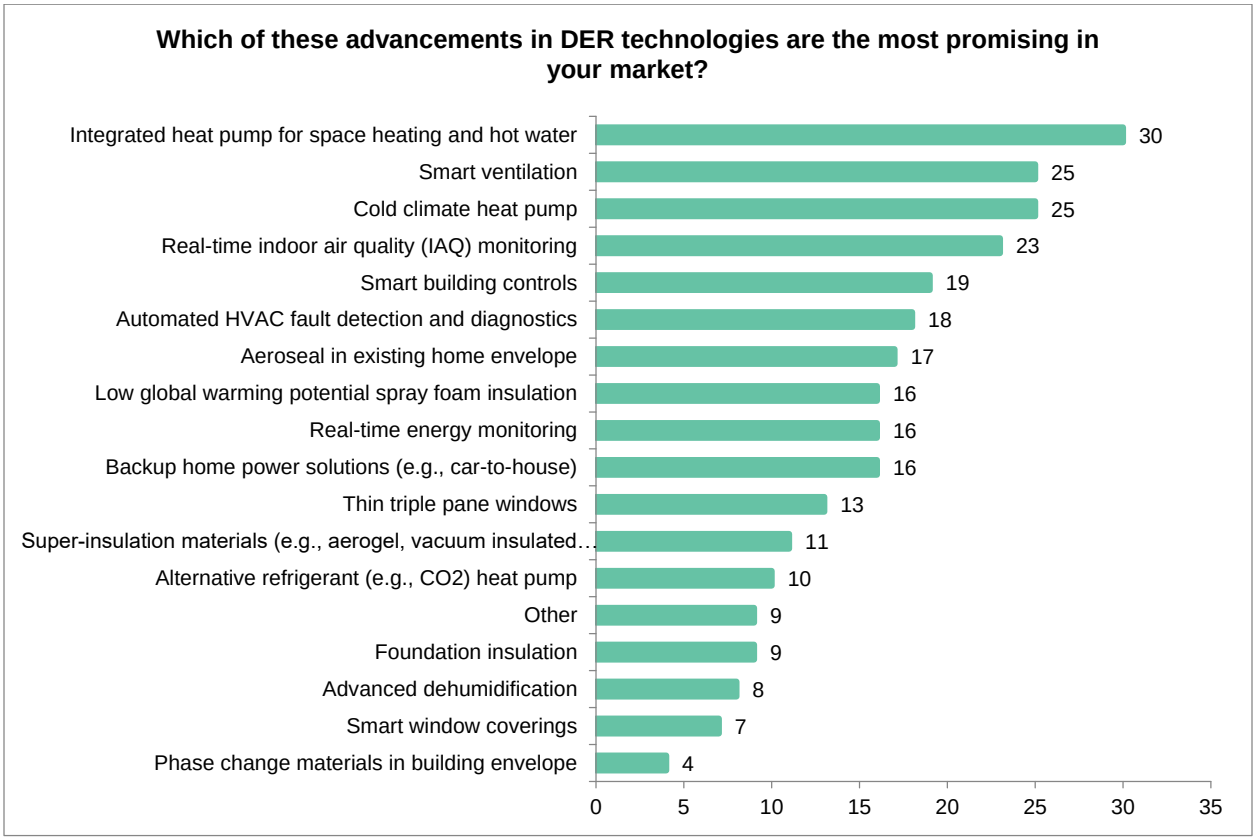

Figure 6 Rating of advancements in DER technologies. Total response = 67.

Many survey respondents also provided additional suggestions to promising approaches and technologies in their responses. Some suggested specific technologies such as smart meter data analytics and cool roofs. Others described alternative approaches like load shifting or neighborhood-scale solar thermal technology. There were some advocating for specifying or raising the requirements for energy efficiency retrofits using building codes or certification programs. However, others stressed the importance to create a "*profitable and repeatable business model*". The Pay As You Save (PAYS) approach was mentioned by several respondents. In addition, one study respondent provided this comment:

> "*streamlined process includes audit software and proposal simplification with costs (labor and material) as part of the process ... the objective is to make it easy to incorporate this DER effort with our standard consumer offerings .. so that this is just another offer that integrates with our existing process ... because it is sooooo different and much more complicated ... it seldom is worth the time to even offer to buyers. ... we must standardize and simplify the offering ... and make it accessible to more Home Advisors*"

The importance of educating homeowners and other professionals (e.g., architects, realtors) was also mentioned by a few survey respondents. One respondent put it in terms of making the benefits of DER more accessible to homeowners:

> "*We need to value the integrated offering of duct tightness, insulation, sealing, HVAC upgrade and then use advanced ventilation and smart controls which will report IAQ, Energy Use and present in a simplified but useful format*."

3.5 Work Scope and Approaches

This part of the survey asked questions about the approaches used by respondents to design and implement DER projects. Survey respondents provided information on how frequently they included different elements of work in their DER projects. The survey also asked questions about the different factors that are considered when making decisions on the work scope, and tasks that the survey respondents found to be most time consuming, aside from the construction work.

In deciding what retrofit options to include in a DER project, the leading factors that were recognized by many respondents as important to their decision making include: (1) customer preferences and needs, (2) energy savings, (3) health and comfort, and (4) cost (Figure 7). Even though study respondents expressed how overly important cost is to customers, it was not the number one or sole factor of consideration in determining retrofit options in a DER project. One study respondent added "*payback*" in their response.

These survey results summarize the challenge that there are a lot of different important factors to take into consideration when deciding between retrofit options for a given DER project. As one study respondent stated in their response:

> "*All of these are important factors that we consider when developing a scope*".

Perhaps it is because of this difficult decision making conundrum that only few study respondents selected "risks of call-backs / complaints", "profit margin", or "time to complete work" as factors that they considered, even though those are the factors necessary to enable a "*profitable and repeatable business model*", as commented by a study respondent earlier when asked about promising approaches for performing DER in their market.

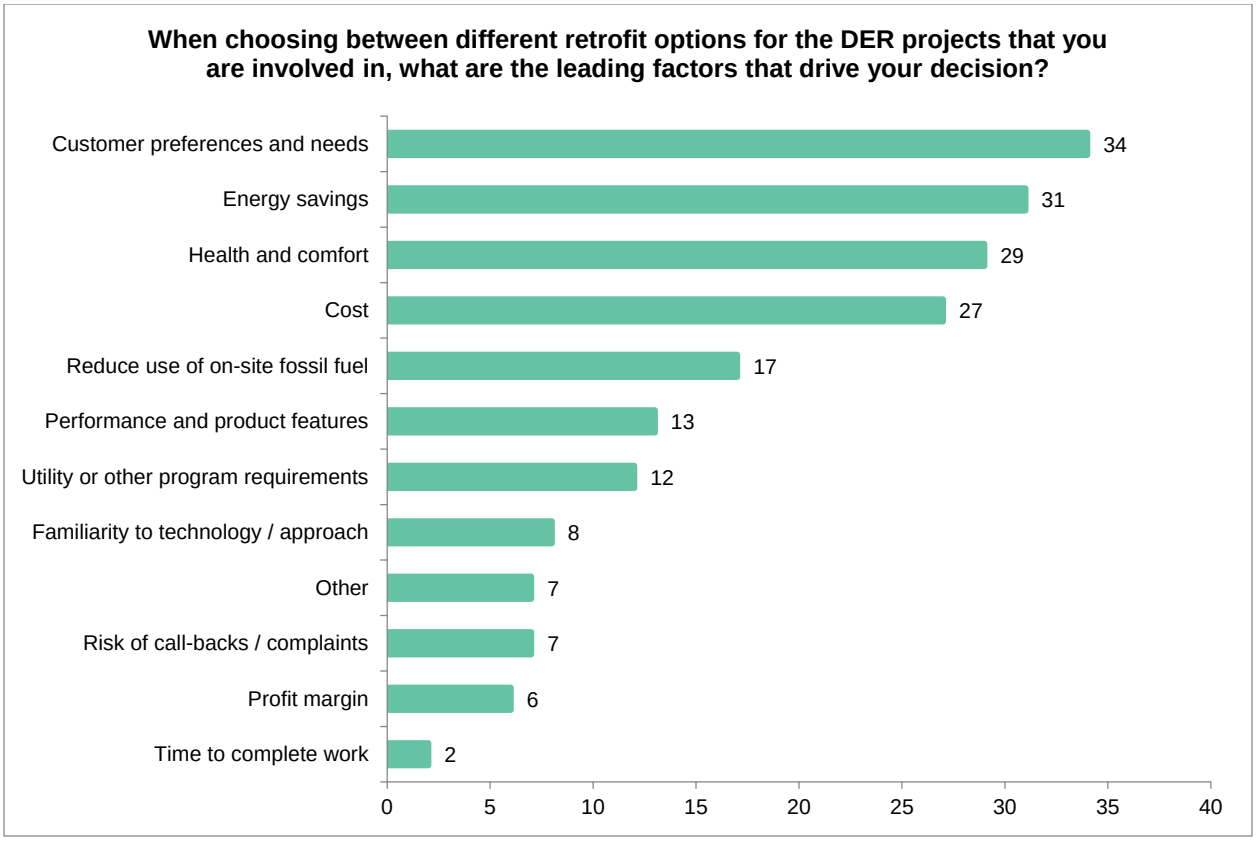

Figure 7 Leading factors to consider when deciding retrofit options for DER projects. Total response = 65.

Two study respondents also provided responses stating that embodied carbon is a factor that they considered in their decision making. Another two study respondents mentioned that the retrofit options have to work within the limit of the existing structure and building envelope. One study respondent mentioned an added problem that "*planning and zoning restricting good options*".

Figure 8 shows that for most survey respondents, their DER projects involved diagnostic testing such as blower door and duct blaster measurements. In contrast, professional design services from an architect or engineer, which tend to be costly, is commonly included as part of their DER projects by only a limited number of survey respondents.

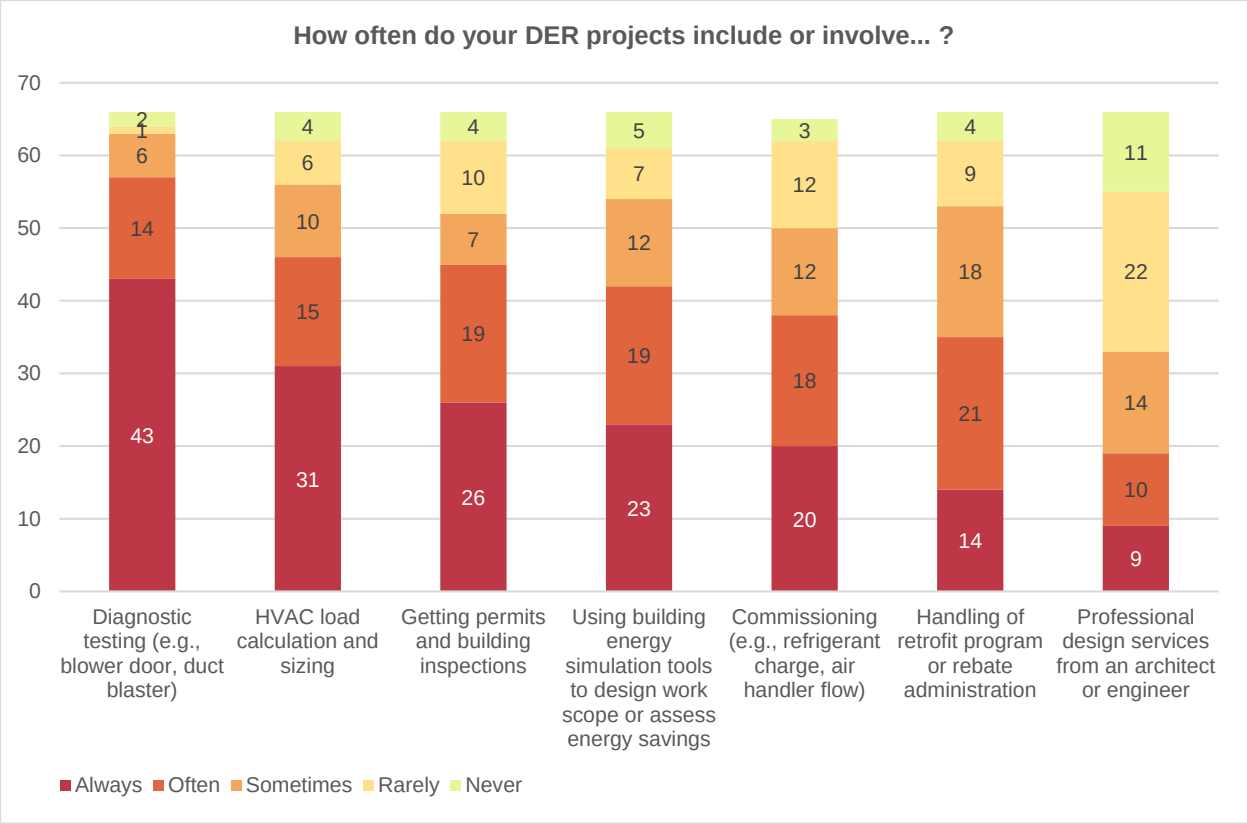

Figure 8 Frequency of work elements that are included or involved in DER projects.

From the perspective of the survey respondents, customer acquisition and work scope / proposal development are the two most time-consuming, non-construction tasks, followed by energy audit / initial site visit and program / rebate administration (Figure 9). These non-construction tasks that were considered as time consuming by study respondents contribute to the overhead costs of DER projects. Two survey respondents added "*customer education*" in their response. There were also two comments related to obtaining energy data and/or monitoring IAQ post retrofit.

In earlier part of the survey, only few survey respondents identified the burden of designing DER work scope as one of the biggest barriers when performing DER project (Figure 3). Yet, many more of them viewed it as a time consuming task based on their response to this survey question.

From Figure 3, many more survey respondents identified lack of consumer demand (N=40) as a barrier than low customer conversion rate (N=14). Based on this comparison, the cause of customer acquisition being a time consuming task may be driven more by the small number of customers who are interested in DER projects, and less because of customers deciding not to move forward with a project.

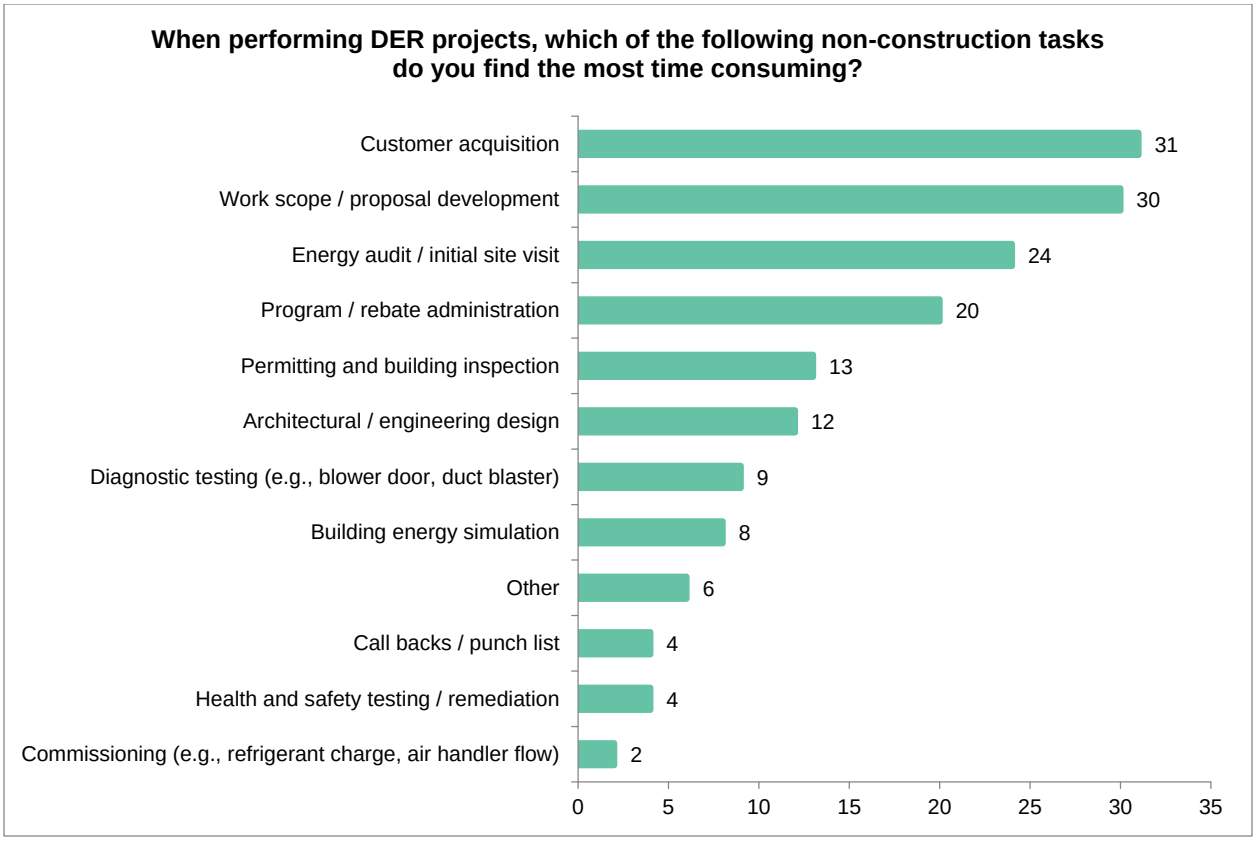

Figure 9 Non-construction tasks that survey respondents found to be the most time consuming. Total response = 64.

3.6 Project Cost Estimates

This section of the survey asked respondents for their opinion on the drivers that lead to cost variability in their DER projects. It also asked about the common causes of cost increases and project delays from their experience. Survey respondents were asked to provide an estimate of overhead and profit margin if they were comfortable sharing this information.

Even though costs of retrofits are often normalized by either dwelling size or the performance level of the retrofit[2], those factors are not always the leading causes of cost variability. Figure 10 shows that the two leading causes of cost variability identified by survey respondents were (1) existing condition of equipment or building elements, and (2) accessibility or complexity of the dwelling. Customer preference was another important driver for cost variability.

Among the list of existing problems stated in the survey question, more survey respondents selected moisture problems as an important driver of cost variability in their projects, compared

[2] One survey respondent provided an example where cost variability is driven both by the dwelling size and performance level of the equipment: "*number of HVAC systems which is tied to the size of dwelling and related to the target performance of the dwelling*".

to other types of problems such as asbestos, electrical, or structural. One survey respondent provided an example of a specific electrical problem: "*electrical feeder and panel too small*".

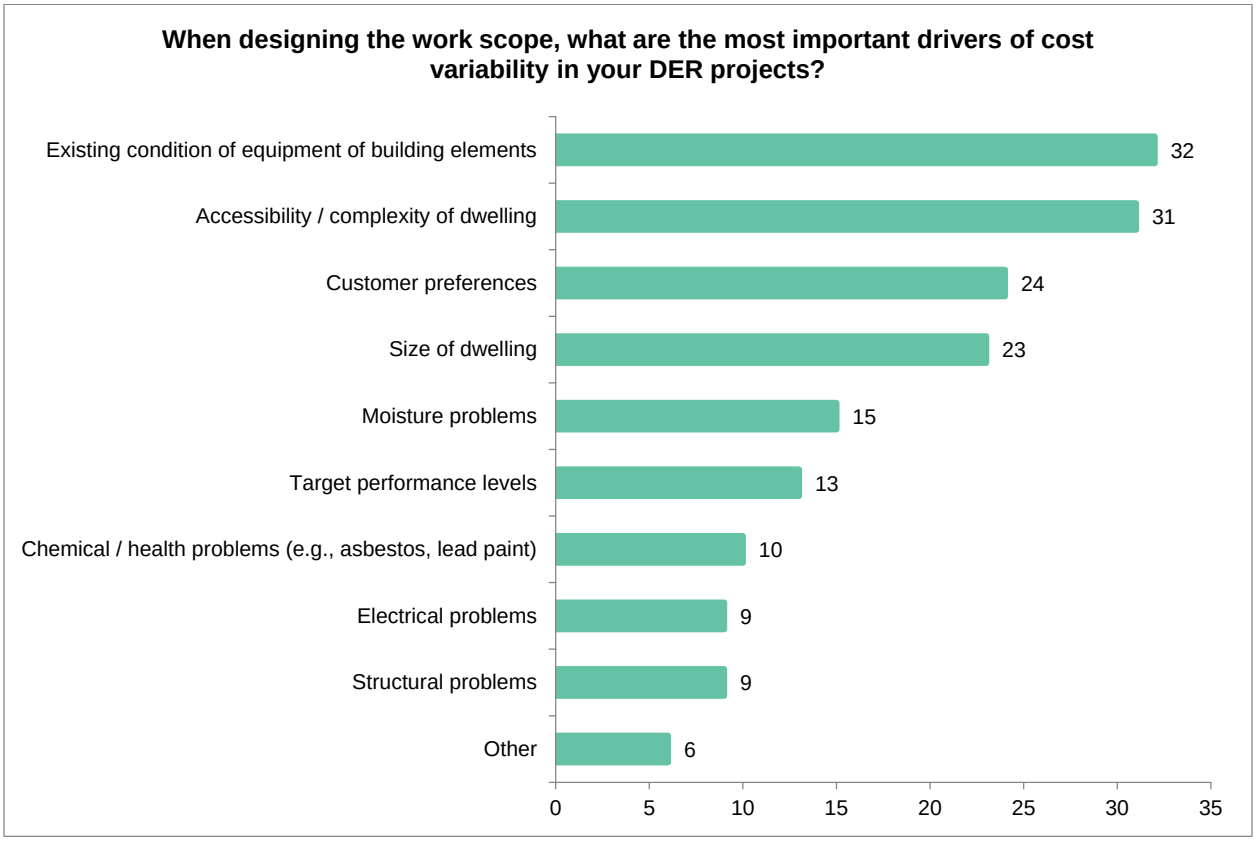

Figure 10 Important drivers of cost variability in DER projects. Total response = 63

Three survey respondents suggested other causes of cost variability: "*the home's energy profile"*, "*how it fits into the rebate program"*, and "*contractor resistance to best practice install and unfamiliar equipment & procedures"*.

The most common causes of cost increases were hidden problems that were not anticipated in the work scope. Among these hidden problems, the general description of "hidden problems with existing equipment or building elements" were selected most often by survey respondents (Figure 11), followed by hidden structural problems. Changes in customer preferences was also a leading cause of cost increase in DER projects. In comparison, only few survey respondents identified permitting / inspection issues as causes leading to cost increase in DER projects.

Overall, it appears that most survey respondents found that the quality of equipment or materials sufficient to support their DER projects. Very few survey respondents found defective equipment or materials to be a common cause of cost increases. Re-work due to installation errors sometimes can occur, and it was identified by 10 survey respondents as a common cause of cost increases in their DER projects.

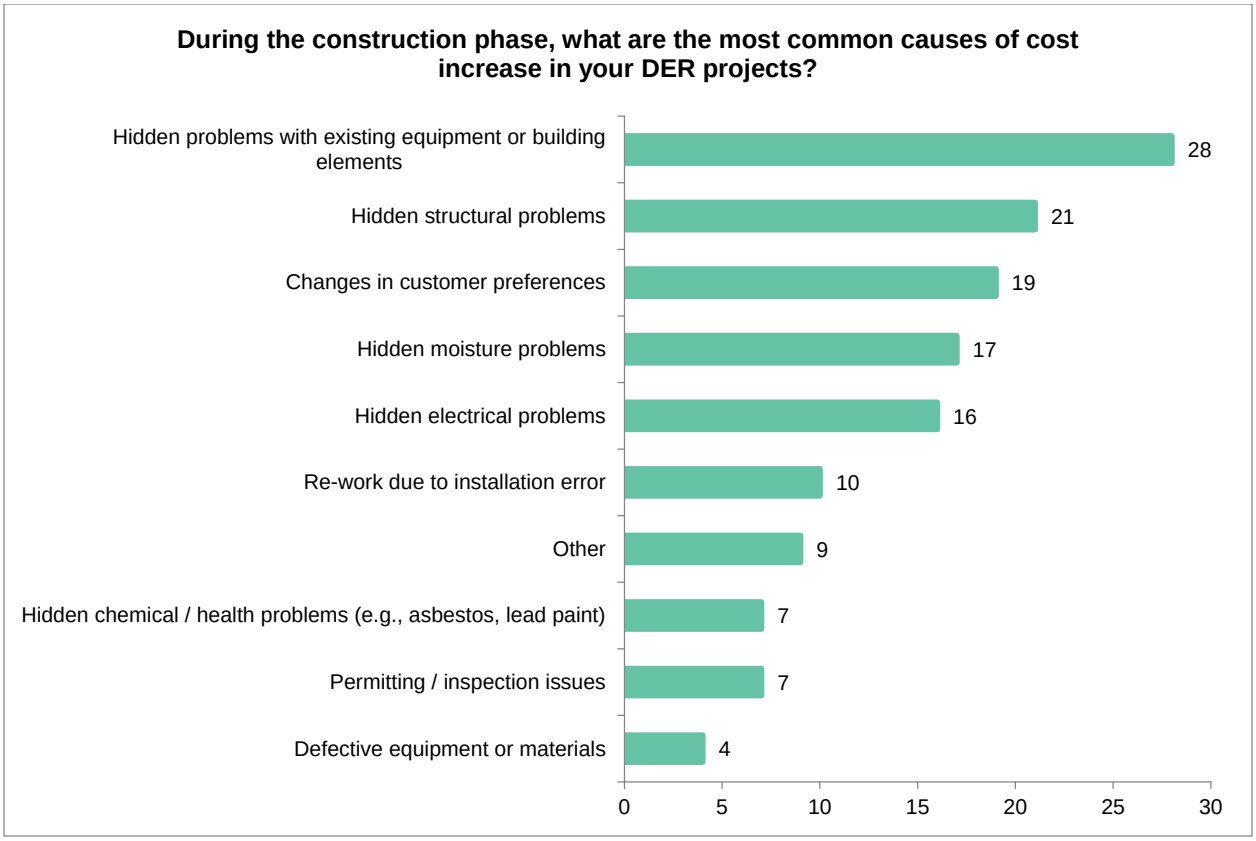

Figure 11 Common causes of DER project cost increase. Total response = 60.

A number of survey respondents responded that this question does not apply in their DER work because either "*our service is free to residents"*, or "*none, pre-negotiated fixed prices with contractors*". There was also one survey respondent saying that: "*99.9% of our change orders are to reduce cost*", in other words cost increase is uncommon in their work.

Program management was recognized by survey respondents as a challenge in DER projects. For example, Figure 12 shows that scheduling conflict is identified by survey respondents as a common cause of delays in DER projects. Many survey respondents also viewed changes in customer preferences as a cause of project delay, in addition to being a common cause of cost increases.

There are more survey respondents (N=16) identifying the consequence of permitting / inspection issues as causing time delays, than cost increase (N=7, see Figure 11). As one survey respondent put it: "scheduling program inspections and the correct results" are resulting in time delays, which would result in some cost increases.

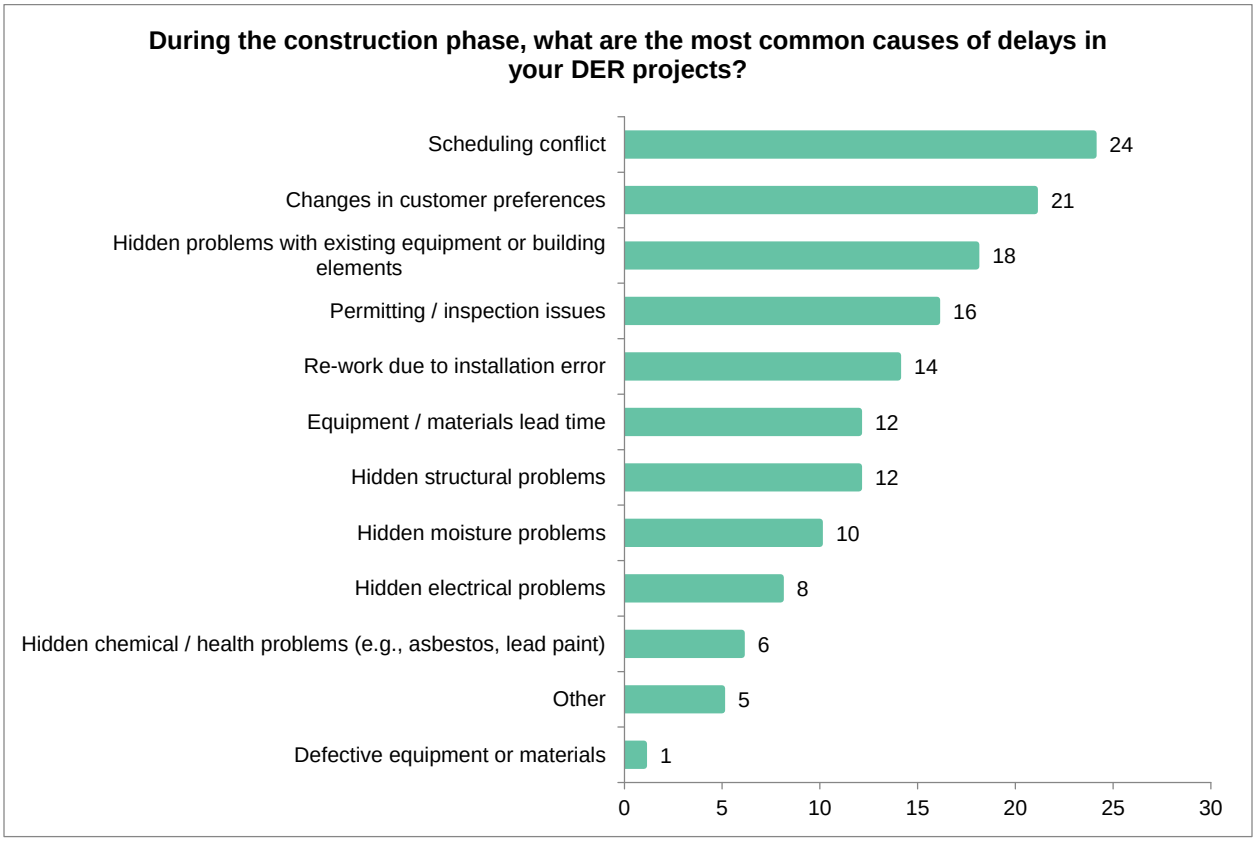

Figure 12 Common causes of DER project delays. Total response = 60.

3.6.1 Typical DER Project Costs

Survey respondents were asked to provide typical costs associated with performing different tasks, if applicable to the projects they are involved in. They had the option to provide data in cost ($), labor (hours), and/or as a % of project cost. Questions about cost data were asked in four groups:

[1] Typical operating costs in DER projects: home inspection / energy audit, HVAC load calculation / sizing, project management, customer management, traveling to and from job site.

[2] Typical costs of permits and inspections for DER projects: general building, mechanical / electrical / plumbing (MEP), window.

[3] Typical costs of professional design and engineering services for DER projects: architectural, mechanical engineer, structural engineer, civil engineer.

[4] Typical costs of diagnostic tests or commissioning for DER projects: envelope leakage (blower door), duct leakage (duct blaster), combustion safety, HVAC commissioning, ventilation fan airflow, infrared (IR) camera inspection, monitor energy use, monitor indoor environmental quality (IEQ).

About half of the survey respondents (N=39) provided cost data. Almost all home performance contractors who participated in this survey provided cost data (16 out of 18). Many others who provided cost data include consultants, program managers, and engineers (Table 9). California (N=8) and New York (N=7) are the two states with the most representation (Table 10).

Table 9 Role of survey respondents who provided cost data.

Roles	**Counts**
Home performance contractor	16
Consultant	6
Program manager	5
Engineer	4
General contractor	2
Energy rater	2
Architect	1
Homeowner	1
Remodeling contractor	1
Weatherization contractor	1
Total	39

Table 10 Locations of study respondents who provided cost data.

States	**Counts**	**States**	**Counts**
CA	8	CO	1
CA, AZ	1	GA	1
NY	7	IL	1
MA	4	MI	1
AZ	2	MN	1
MD	2	OH	1
NC, AR, TN	2	TX	1
WA	2	VA	1
AL	1	US Nationwide	2
Total = 39			

Table 11 shows the number of responses provided by survey respondents. Groups [1] and [4] received the most cost data. Fewer data were provided by survey respondents on professional design costs and permitting costs.

Table 11 Number of responses on cost data for different work items in DER projects.

Work Tasks	Counts	Work Tasks	Counts
[1] Home inspection / energy audit	36	[3] Professional – Structural	4
[1] HVAC load calculation / sizing	25	[3] Professional – Civil	2
[1] Project management	25	[4] Envelope leakage	19
[1] Customer management	16	[4] Duct leakage	11
[1] Traveling to and from job site	19	[4] Combustion safety	14
[2] Permits – General building	7	[4] HVAC commissioning	13
[2] Permits – MEP	10	[4] Ventilation fan airflow	13
[2] Permits – Window	2	[4] IR camera inspection	12
[3] Professional – Architectural	7	[4] Monitor energy use	9
[3] Professional – Mechanical	6	[4] Monitor IEQ	11

Figure 13 summarizes the cost ($) information provided by survey respondents. If a survey respondent provided a range, e.g., $1,000 to $1,500 for traveling to and from job site, the center point value (i.e., $1,250) was used in the analysis. Most survey respondents provided single values. The small number of range estimates provided by survey respondents tend to be narrow in their span as illustrated in the above example.

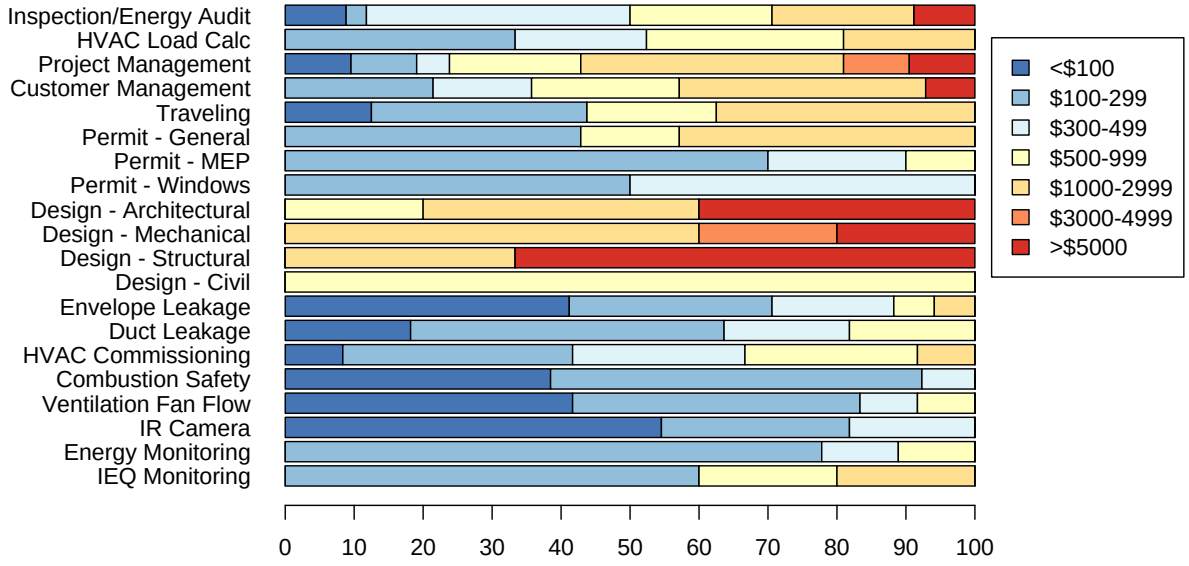

Figure 13 Ranges of cost data for the different work elements in DER projects.

Figure 13 shows the high costs of professional design and engineering services that are commonly upwards of $1000. Diagnostic tests or commissioning tasks are substantially lower in costs. However, they can add up if several diagnostic tests are performed as part of a DER project. Fewer data were available for pulling permits and inspections. Survey respondents reported a wide range of cost data in their response to general operating costs, such as project management, customer management, and home inspection / energy audit.

Table 12 to Table 14 provides central estimates (mean and geometric mean) and variability (standard deviation and geometric standard deviation) of the cost data provided by survey respondents. Summary statistics are shown only for work tasks where there are at least 5 responses after any outliners are removed. Table 15 shows the cost divided by number of labor hours, where mean values range between $90 to $140 per hour for different DER project tasks.

Table 12 Cost data summary of preforming different DER project tasks

DER Project Tasks	Counts	Cost ($)			
		Mean	Standard Deviation	Geo. Mean	Geometric Std. Dev.
Professional – Architectural	5	9600	12920	3204	6.0
Professional – Mechanical	5	2440	1915	1888	2.2
Project management	19	1734	2256	952	3.3
Permits – General building	7	1064	1052	558	3.8
Traveling to and from job site	16	837	876	409	4.2
Customer management	13	762	661	494	2.9
Home inspection / energy audit	30	634	473	498	2.0
HVAC load calculation / sizing	21	564	468	418	2.2
Monitor IEQ	10	426	373	291	2.6
Combustion safety	12	387	284	302	2.1
Permits – MEP	10	265	140	233	1.7
Duct leakage	10	260	155	222	1.8
Envelope leakage	17	233	283	142	2.7
Monitor energy use	9	228	128	198	1.8
Ventilation fan airflow	12	153	143	98	2.9
IR camera inspection	11	129	116	76	3.3
HVAC commissioning	13	122	93	83	2.8

Table 13 Labor hours reported for different DER project tasks

DER Project Tasks	Counts	Labor (hour)			
		Mean	Standard Deviation	Geo. Mean	Geometric Std. Dev.
Project management	20	12.8	11.4	9.4	2.3
Traveling to and from job site	16	11.8	15.8	5.5	3.7
Home inspection / energy audit	33	7.2	7.3	5.4	2.0
Customer management	14	5.9	5.1	4.4	2.2
HVAC load calculation / sizing	24	4.1	4.2	2.9	2.2
HVAC commissioning	12	4.1	3.4	3.2	2.0
Monitor IEQ	9	2.2	1.5	1.7	2.1
Monitor energy use	8	2.1	1.4	1.7	2.1
Duct leakage	10	1.8	1.1	1.6	1.7
Envelope leakage	16	1.5	0.8	1.3	1.7
IR camera inspection	11	0.9	0.4	0.8	1.7
Ventilation fan airflow	9	0.9	0.2	0.8	1.4
Combustion safety	12	0.8	0.4	0.7	1.6

Table 14 Costs for different DER tasks as a % of project cost

DER Project Tasks	Counts	% Project Costs			
		Mean	Standard Deviation	Geo. Mean	Geometric Std. Dev.
Project management	19	8.9	6.8	6.9	2.1
Traveling to and from job site	12	7.0	6.9	4.5	2.8
Professional – Architectural	5	5.8	2.7	5.3	1.6
Permits – General building	5	5.6	6.6	2.6	4.4
Customer management	9	4.1	2.2	3.4	2.0
Permits – MEP	6	0.8	0.7	0.4	6.0

Table 15 Estimated cost per hour of labor for different DER project tasks

DER Project Tasks	Counts	Cost ($) per Labor (hour)			
		Mean	Standard Deviation	Geo. Mean	Geometric Std. Dev.
Monitor IEQ	9	138	89	105	2.4
HVAC load calculation / sizing	18	137	56	126	1.5
Envelope leakage	16	136	140	97	2.2
Duct leakage	10	135	88	110	2.0
Monitor energy use	8	133	89	106	2.1
Customer management	13	131	80	109	1.9
Combustion safety	12	125	87	98	2.1
IR camera inspection	10	118	97	86	2.3
Project management	20	115	76	95	1.9
HVAC commissioning	11	108	68	87	2.1
Home inspection / energy audit	29	104	45	95	1.5
Ventilation fan airflow	11	100	64	83	1.9
Traveling to and from job site	12	90	65	72	2.0

3.6.2 Overhead and Profits

To help put in context how different cost components impact the overall project cost to customers, a number of home performance and general contractors responded to the questions that asked for their average overhead and average profit as a % of their total revenue from DER projects. They were asked to think about DER projects performed in the past two years (2018 and 2019). A few other survey respondents in other roles (e.g., architect, engineer) also provided this information. However, there were too few responses (less than 3) to summarize that data. Table 16 shows data provided by 10 home performance and 3 general contractors. There were two other responses from home performance contractors that were excluded from Table 16 because in those cases overhead + profit sums to 100%, possibly because the respondents misunderstood the question.

Table 16 Overhead and profit estimated as a % of total revenue

Contractors	States	Overhead as % of Total Revenue	Profit as % of Total Revenue	Overhead + Profit
Home Performance	AZ (N=2)	10%	15%	25%
		10%	18%	28%
	CA (N=2)	10%	30%	40%
		15-20%	50%	65-70%
	MD (N=2)	30%	20%	50%
		30%	30%	60%
	CO, IL, TX, VA (N=1 from each state)	40%	30%	70%
		45%	5%	50%
		52%	10%	62%
		60%	20%	80%
General	CA, MA, NY	10%	5%	15%
		12%	6%	18%
		15%	20%	35%

Among the 10 home performance contractors, the central tendency reported for overhead is 30% (same value for mean and median), and the central tendency (median) for profit is about 20% (mean = 23%). Overall, these values are higher than what were reported by the general contractors who responded to this survey. However, this observation is uncertain due to the very small sample size.

3.7 Closing Comments

In closing, survey respondents were asked to share one innovation in materials, equipment, or processes that in their opinion would greatly increase the performance adoption, and/or reduce the costs of DER. They were also invited to provide suggestions to improve this survey or more broadly our understanding of DER. All survey responses are listed in Appendix C, with some of the common themes summarized here.

Related to DER technologies, several survey respondents described their interests in heat pump technologies, others are interested in insulation and air sealing. The value of monitoring and diagnostics are recognized and emphasized by several survey respondents. There are many suggestions of programmatic approaches to advance the adoption of DER. One survey respondent pointed out the importance of developing a business model for DER projects:

> "*Repeatable process that can largely be done by entry level talent and plugs into an existing contractor network.*"

Some described the challenges they faced with zoning and building code as barriers. High project cost was a common concern raised compared to general contractors. Many survey

respondents shared the consensus that education of workforce and homeowners is also a barrier.

> "*Primary innovations are ready… high performance heat pumps (air and geo), smart ventilation, heat pump water heater, heat plump clothes dryer, and smart building controls… main barrier is education of homeowners, designers and installers and market penetration*."

There are two suggestions that point out the need to reframe the role of DER, each taking a different perspective:

> "*If you look at almost all DERs in terms of cost per ton of carbon avoided -- while also factoring in the embodied carbon of doing the project -- it quickly becomes clear they're not any sort of solution to the carbon emissions challenges we face. In fact, they're contributing to the problem in the short- and medium-term. Instead, do a couple of days of air-sealing and insulation upgrades, install heat pumps, and buy green power*."

> "*Think broader about DERs. They probably only make sense for 1-5% of homes (at least until a substantial portion of the cost can be recouped at resale). Think of homes like kids going to the school nurse hurt. 60-70% can probably be treated by the nurse. The next 20-30% needs to go to the hospital to see a doctor. And the worst cases go to the ICU (which are DERs). Ideally a system will provide a path for all three. That's what we're developing in HVAC 2.0. The problem in our opinion is mainly sales process. The technical stuff has been largely solved for 20 years*."

There are additional comments on the importance of making DER a viable business model for contractors. Survey respondents pointed out energy saving opportunities for DER projects to focus on, and where innovations in products can help improve outcome of such projects.

4 Summary

Survey respondents represent a diverse DER background and programs that they had experience with. But California and other states that focus more heavily on energy efficiency are over-represented in our sample. Homeowners are motivated by improved comfort and energy savings, some are also driven by green/sustainability, carbon reduction, which goes beyond energy efficiency. But when it comes to deciding whether to move forward with a DER project, cost is the most important factor. The biggest barriers faced by survey respondents were the lack of customer demand and lack of a reliable, trained home performance workforce, and not the more technical aspects of DERs, such as the retrofit strategies, equipment/materials, or simulation tools. Some respondents echoed past survey finding that the high costs of DERs compared to the low energy prices is a fundamental barrier to wider adoption.

Survey respondents considered providing strong financial incentives, such as through rebates and tax credits, is by far the most effective way to increase customer demand for DER projects. Far fewer survey respondents selected “lower project costs” or “easier project financing” in comparison.

Survey respondents viewed heat pump technologies as promising for DER projects, followed by smart controls, real-time monitoring and diagnostics. In terms of promising approaches to performing DER in their market, survey respondents identified “one-stop shop” as the leading approach, but beyond that, many approaches could also work, including: energy plus healthy home retrofit, standard weatherization combined with heat pump and PV, over-time DER aligned with equipment replacement / upgrade, home electrification retrofit.

While the importance of educating homeowners and other professionals such as realtors were mentioned by survey respondents, they are not widely recognized as a solution in itself to move the DER market. Rather, the notion of simplifying and standardizing DER approaches was more prominently reflected from respondents’ comments. Lacking standardization, coming up with a DER work scope becomes a difficult balancing act with so many different factors to be considered. Factors that are critical to the success of the DER business, such as profit margin and time to complete work, became secondary in importance.

DER projects have high overhead costs compared to home remodeling projects by general contractors. Survey respondents considered customer acquisition and work scope / proposal development as the two most time-consuming, non-construction tasks. The lack of customer interests in DER is at least partly due to the high costs of DER compared to the low energy prices. The lack of customer demands and the high costs of DERs are both fueling the problem of few DER projects being completed.

When survey respondents were asked about causes of cost variability and cost increase, the existing conditions of the homes are the main factors. Problems caused by accessibility or complexity of the structures, and any hidden problems with existing equipment or building elements are the leading reasons that lead to the high costs of DERs. In addition, cost data provided by survey respondents suggest that project management, customer management, and traveling to/from job site all contributed substantially to the overhead costs.

In closing, survey respondents commented on the need to define the role of DER in reaching carbon reduction goals. While innovations in technologies, such as heat pumps, monitoring and diagnostics, will continue to improve the energy savings of DER projects, a viable business model is vital to wider its adoption.

5 References

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Appendix A: List of Survey Participants

We would like to express our appreciation to all of our survey participants for their time and thoughtfulness in their responses. Here is the list of survey participants who opted to list their company names as a data contributor to this project.

A George Beeler, Architect	Petaluma, CA
AAA Air Care	Dothan, AL
Az. Energy Efficient Home	Phoenix, AZ
Berges Home Performance	Cleveland, OH
BIRAenergy	Stockton, CA
Build Equinox	Urbana, IL
Building Energy Experts	Crystal Lake, IL
Byggmeister, Inc.	Newton, MA
Calnan's Energy Systems, Inc.	Waltham, MA
Decumanus Green Design/Build	Lenox, MA
Design AVEnues LLC	Petaluma, CA
ELEM3NTS-E3, Inc.	San Jose, CA
John Craig Construction, Inc.	Sonoma, CA
MA DOER	Boston, MA
Minnick's	Laurel, MD
The Levy Partnership	New York, NY
Think Little	Charlottesville, VA
United Way of Long Island	Deer Park, NY
Wise Home Energy	Rochester, NY

Appendix B: DOE Deep Energy Retrofit Cost Survey

Start of Block: Introduction

Welcome to the Lawrence Berkeley National Laboratory Deep Energy Retrofit (DER) Survey!

We are conducting this survey to gain a better understanding of the market drivers, opportunities, and challenges of DER in order to broaden its adoption. This study is sponsored by the Department of Energy.

In this survey, we are interested in:
- What motivates and deters DER projects in today's market
- Promising strategies and technologies
- Non-cost aspects of retrofit measures that make them more or less desirable for homeowners and contractors

This survey will take about 20 minutes to complete. You can stop responding to questions at any point and responses up to that point will be saved.

This survey does not ask for your name or contact information. However, when you reach the end of the survey, you have the option to list your company name as a data contributor to this project. The data contributor list is separate from the survey, so your responses will remain anonymous.

If you have questions about this survey, please email us at ProjectDERCosts@lbl.gov.

If you wish to participate, please indicate that you have read the above information about the survey, you are at least 18 years of age, and you voluntarily agree to take part in this survey.

- ○ Yes, I agree to participate
- ○ No, exit survey

End of Block: Introduction

Start of Block: Background

For this study, we define deep energy retrofit (DER) to mean projects that use a comprehensive, whole-home approach to substantially reduce energy use and improve home performance. DER projects often aim to reduce energy use by 50% or more.

Which of the following best describes your role in a DER project? *Required

- ○ Home performance contractor
- ○ General contractor
- ○ HVAC contractor
- ○ Insulation contractor
- ○ Remodeling contractor
- ○ Weatherization contractor
- ○ Energy rater
- ○ Engineer
- ○ Consultant
- ○ Architect
- ○ Program manager
- ○ Researcher
- ○ Other _____

Where does your company most commonly work? *Required

- ○ City / Metropolitan Area _____
- ○ State _____

How many DER projects have you been involved with in the past two years (2018 and 2019)? *Required

- ○ None in the past two years
- ○ 1 to 3
- ○ 4 to 10
- ○ 11 to 30
- ○ 31 to 50
- ○ 51 or more

Which type(s) of homes do you have experience with from past DER projects?

- ○ Single-family homes only
- ○ Mostly single-family homes, some multi-family homes
- ○ Mostly multi-family homes, some single-family homes
- ○ Multi-family homes only
- ○ Other _____

Which of the following program(s) have you been involved in from past DER projects? Select all that apply.

- [ ] Advanced Home Upgrade (Energy Upgrade California)
- [ ] Building America research study
- [ ] Clean Energy Works Oregon
- [ ] EnerPHit (Passive House)
- [ ] Home Performance with Energy Star
- [ ] MassSave DER Pilot
- [ ] Mass DOER Home MVP
- [ ] NYSERDA DER Pilot
- [ ] Thousand Home Challenge
- [ ] TVA Extreme Energy Makeover
- [ ] TVA Home Uplift / EnergyRight
- [ ] VEIC DER Pilot
- [ ] VT Zero Energy Now
- [ ] Other _____
- [ ] ⊗ None

*

Approximately what percent of your past DER projects were part of a utility retrofit program?

- ○ Enter % (0 to 100): _____

End of Block: Background

Start of Block: Customer Perspective

Customer Perspective

We are interested in understanding how homeowners / building owners view deep energy retrofit (DER) projects. Please answer these questions from your interactions with them from past DER projects.

What are the main motivations of homeowners / building owners when seeking to perform a DER project? Select up to THREE.

- [ ] Save money on energy bill
- [ ] Make home sustainable / green
- [ ] Reduce use of on-site fossil fuel
- [ ] Improve comfort
- [ ] Address existing moisture / mold problem
- [ ] Address existing odor / IAQ problem
- [ ] Address existing noise problem
- [ ] Address home safety issues
- [ ] Increase resilience (e.g., hurricane, power outage)
- [ ] Increase home value
- [ ] Upgrade for modern convenience (e.g., car charging)
- [ ] Upgrade for lifestyle changes (e.g., aging in place)
- [ ] Reduce carbon emissions
- [ ] Other _____

Please rate the following factors, with 1 being the LEAST important and 5 being the MOST important, when homeowners / building owners decide whether or not to proceed with a DER project.

	1 = LEAST Important	2	3	4	5 = MOST Important
Project cost	○	○	○	○	○
Project timeline	○	○	○	○	○
Complexity of the project	○	○	○	○	○
Disruptiveness to life in the home	○	○	○	○	○
Other remodeling priorities	○	○	○	○	○
Availability of project financing	○	○	○	○	○
Financial payback	○	○	○	○	○

End of Block: Customer Perspective

Start of Block: Contractor Perspective

Home Performance Industry Perspective

We are interested in challenges faced by the home performance industry when performing deep energy retrofit (DER) projects. Please answer these questions from your perspective and experiences from past retrofit projects.

Aside from costs, what are the biggest barriers when performing DER projects? Select up to THREE.

- [ ] Lack of consumer demand
- [ ] Low customer conversion rate
- [ ] Burden of designing DER work scope
- [ ] Competition from companies performing non-DER work
- [ ] Lack of a reliable, trained home performance workforce
- [ ] Lack of advanced retrofit equipment / materials
- [ ] Lack of proven retrofit strategies
- [ ] Lack of simulation / design tools
- [ ] Unforeseen conditions in existing homes
- [ ] Permitting atypical projects
- [ ] Compliance with building code
- [ ] Other _____

What are the most effective ways to increase customer demand for DER projects? Select up to THREE.

- [ ] Lower project costs
- [ ] Shorter project timeline
- [ ] Reduce disruption to homeowner
- [ ] Improve energy savings
- [ ] Easier project financing
- [ ] Linking DERs and increased home market value
- [ ] DER certification program to improve consumer recognition
- [ ] Time of sale energy disclosures
- [ ] Linking DERs and healthy home
- [ ] Reduce project planning burden on homeowner
- [ ] Energy bills guaranteed
- [ ] Strong financial incentives (e.g., rebates, tax credits)
- [ ] Other _____

End of Block: Contractor Perspective

Start of Block: Advanced Approaches

Advanced Technologies and Approaches

We are interested in your opinion on new approaches and technologies for deep energy retrofits (DER). Please answer these questions from your perspective and the market (e.g., location, home types) you serve.

Please rate the following approaches, with 1 being the LEAST promising and 5 being the MOST promising, for performing DER in your market.

	1 = LEAST Promising	2	3	4	5 = MOST Promising
Standard weatherization combined with heat pump and PV	○	○	○	○	○
"One-stop shop" with energy audit, work scope, financing, permits, construction, testing	○	○	○	○	○
Home electrification retrofit	○	○	○	○	○
Exterior retrofit with minimal disturbance inside home	○	○	○	○	○
Pre-fabricated panelized envelope retrofits (e.g., EnergieSprong)	○	○	○	○	○
Over-time DER aligned with equipment replacement / upgrade	○	○	○	○	○
Energy plus healthy home retrofit	○	○	○	○	○
Other	○	○	○	○	○

Which of these advancements in DER technologies are the most promising in your market? Select up to FIVE.

- [ ] Advanced dehumidification
- [ ] Automated HVAC fault detection and diagnostics
- [ ] Cold climate heat pump
- [ ] Alternative refrigerant (e.g., CO2) heat pump
- [ ] Integrated heat pump for space heating and hot water
- [ ] Backup home power solutions (e.g., car-to-house)
- [ ] Smart building controls
- [ ] Smart ventilation
- [ ] Real-time energy monitoring
- [ ] Real-time indoor air quality (IAQ) monitoring
- [ ] Thin triple pane windows
- [ ] Smart window coverings
- [ ] Foundation insulation
- [ ] Aeroseal in existing home envelope
- [ ] Phase change materials in building envelope
- [ ] Super-insulation materials (e.g., aerogel, vacuum insulated panels)
- [ ] Low global warming potential spray foam insulation
- [ ] Other _____

End of Block: Advanced Approaches

Start of Block: Work Scope and Approaches

Work Scope and Approaches

We are interested to learn your approaches to designing and implementing DER projects. Please answer these questions from your perspective and experiences from past retrofit projects.

When choosing between different retrofit options for the DER projects that you are involved in, what are the leading factors that drive your decision? Select up to THREE.

- [ ] Cost
- [ ] Energy savings
- [ ] Health and comfort
- [ ] Familiarity to technology / approach
- [ ] Time to complete work
- [ ] Customer preferences and needs
- [ ] Profit margin
- [ ] Risk of call-backs / complaints
- [ ] Reduce use of on-site fossil fuel
- [ ] Utility or other program requirements
- [ ] Performance and product features
- [ ] Other _____

How often do your DER projects include getting permits and building inspections?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

How often do your DER projects involve using building energy simulation tools to design work scope or assess energy savings?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

How often do your DER projects involve the handling of retrofit program or rebate administration?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

How often do your DER projects include professional design services from an architect or engineer?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

How often do your DER projects include HVAC load calculation and sizing?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

How often do your DER projects include diagnostic testing (e.g., blower door, duct blaster)?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

How often do your DER projects include commissioning (e.g., refrigerant charge, air handler flow)?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

When performing DER projects, which of the following non-construction tasks do you find the most time consuming? Select up to THREE.

- ☐ Customer acquisition
- ☐ Energy audit / initial site visit
- ☐ Work scope / proposal development
- ☐ Architectural / engineering design
- ☐ Health and safety testing / remediation
- ☐ Diagnostic testing (e.g., blower door, duct blaster)
- ☐ Commissioning (e.g., refrigerant charge, air handler flow)
- ☐ Permitting and building inspection
- ☐ Program / rebate administration
- ☐ Building energy simulation
- ☐ Call backs / punch list
- ☐ Other _____

End of Block: Work Scope and Approaches

Start of Block: Project Costs

Project Cost Estimates

In this section, we are asking questions about project costs for performing deep energy retrofits (DER) from the view of the home performance industry.

When designing the work scope, what are the most important drivers of cost variability in your DER projects? Select up to THREE.

- [ ] Structural problems
- [ ] Electrical problems
- [ ] Chemical / health problems (e.g., asbestos, lead paint)
- [ ] Moisture problems
- [ ] Size of dwelling
- [ ] Existing condition of equipment of building elements
- [ ] Accessibility / complexity of dwelling
- [ ] Target performance levels
- [ ] Customer preferences
- [ ] Other _____

During the construction phase, what are the most common causes of cost increase in your DER projects? Select up to THREE.

- [ ] Hidden structural problems
- [ ] Hidden electrical problems
- [ ] Hidden chemical / health problems (e.g., asbestos, lead paint)
- [ ] Hidden moisture problems
- [ ] Hidden problems with existing equipment or building elements
- [ ] Changes in customer preferences
- [ ] Permitting / inspection issues
- [ ] Defective equipment or materials
- [ ] Re-work due to installation error
- [ ] Other _____

During the construction phase, what are the most common causes of delays in your DER projects? Select up to THREE.

- [ ] Hidden structural problems
- [ ] Hidden electrical problems
- [ ] Hidden chemical / health problems (e.g., asbestos, lead paint)
- [ ] Hidden moisture problems
- [ ] Hidden problems with existing equipment or building elements
- [ ] Changes in customer preferences
- [ ] Equipment / materials lead time
- [ ] Scheduling conflict
- [ ] Permitting / inspection issues
- [ ] Defective equipment or materials
- [ ] Re-work due to installation error
- [ ] Other _____

Page Break

For the following set of questions, please consider a typical DER project with a total cost that is somewhere in the middle from your past experience.

You may provide estimates in terms of the typical cost, the time involved in performing that task, or as a percentage of the total project cost. You may skip a question if it does not apply to your DER projects.

What is the typical cost of performing a home inspection / energy audit for your DER projects?

- ○ Cost ($) _____
- ○ Labor (hours) _____

What is the typical cost of performing a HVAC load calculation / sizing for your DER projects?

- ○ Cost ($) _____
- ○ Labor (hours) _____

What is the typical cost of project management for your DER projects?

- ○ Cost ($) _____
- ○ Labor (hours) _____
- ○ % of Project Cost _____

What is the typical cost of customer management for your DER projects?

- ○ Cost ($) _____
- ○ Labor (hours) _____
- ○ % of Project Cost _____

What is the typical cost of traveling to and from job site for your DER projects?

- ○ Cost ($) _____
- ○ Labor (hours) _____
- ○ % of Project Cost _____

Where applicable, what are the typical costs of pulling permits and inspections for your DER projects?

	Cost ($)	% of Project Cost
General building		
Mechanical / Electrical / Plumbing		
Window		
Other		

Where applicable, what are the typical costs of professional design and engineering services for your DER projects?

	Cost ($)	% of Project Cost
Architectural		
Mechanical Engineer		
Structural Engineer		
Civil Engineer		

Where applicable, what are the typical costs of diagnostic tests or commissioning for your DER projects?

	Cost ($)	Labor (hours)
Envelope leakage (blower door)		
Duct leakage (duct blaster)		
Combustion safety		
HVAC commissioning		
Ventilation fan airflow		
Infrared camera inspection		
Monitor energy use		
Monitor indoor environmental quality (IEQ)		

Page Break

Before we end this survey, we want to get a sense of the overhead rate and profit margin for the home performance industry when performing deep energy retrofit (DER) projects. This information will help us understand how different cost components impact the overall project cost to consumers. If you are comfortable doing so, please share with us your estimates from DER projects in past two years (2018 and 2019).

What was the average overhead as a percentage of your total revenue from DER projects in the past two years (2018 and 2019)?

○ % of Revenue _____

What was the average profit margin as a percentage of your total revenue from DER projects in the past two years (2018 and 2019)?

○ % of Revenue _____

End of Block: Project Costs

Start of Block: Closing

Congratulations! You have reached the end of the survey.

Thank you for your time and valuable input. Your responses have been recorded. If you wish to change any responses, you can click back through the survey to do so.

Please share one innovation in materials, equipment, or processes that in your opinion would greatly increase the performance, adoption, and/or reduce the costs of deep energy retrofits (DER).

Innovation in DER:

_____

_____

_____

_____

_____

If you have suggestions to help us improve this survey or more broadly our understanding of DER, please let us know here:

_____

_____

_____

_____

_____

End of Block: Closing

Appendix C: Additional Comments from Survey Respondents

In closing, survey respondents were asked to share one innovation in materials, equipment or processes that in their opinion would greatly increase the performance, adoption, and/or reduce the costs of deep energy retrofits (DER). Here are their responses categorized by topics.

Comments related to DER technologies:

“Heat Pumps”

“Air source heat pump tech & consumer education.”

“plug and play heat pump systems that don't rely on field-installed/charged refrigerant lines”

“Low/zero-GWP refrigerants”

“ Making it easier for Air to water heat pumps to be used. Stumbling block is the CEC T-24 compliance credit. If AWHPs were treated the same as other HPs like Air to Air or Geo, that would open the market up. And allowed to use their benefit of EERs of over 20, but they are only allowed 11.7. Given benefit of DHW capacities and efficiencies, currently they are not given much credit.”

“Plugs loads (including pools, spas, wine coolers, instahot dispensers, game consoles, heated towel racks, etc) are often the biggest energy consumers in modern homes. We focus on identifying and mitigating these loads as a free service for residents. We are paid per MMB saved by PG&E.”

“Low cost air tight storm windows, operable, interior installation”

“System to add 2" of exterior insulation without bucking out windows.”

“quick, inexpensive, long-lasting, low-GHG, non-toxic spray air sealing process for crawl spaces & attics”

“Carbon sequestering insulation materials.”

“The adoption and or mandate of super insulated roofing systems where applicable as well as solar roofing.”

Aeroseal, but I shy away from it typically. Cold climate heat pumps incentives thru NYSERDA and local climate incentive programs are the single biggest help to DER and residential electrification.”

“Refuse to support use of any foam insulation. Replace with more education, rebates on the use of mineral wool. Education of building departments, architects and builders on high performance building technology. Google: high performance homes simplified by Scott mills“

“Best I can offer is the article we published in JLC or Fine Home Building... DER in Ohio, that we did with EHW.”

Comments related to monitoring and/or diagnostics:

“BIM and IAQ monitoring w remediation strategy built in (ie, panasonic cosmos system)”

“The implementation of diagnostics (pre- and post- retrofit audit, inspection, verification, testing, commissioning) as set point for all DER.”

“Continuous commissioning for central water heating systems. One m month before determining the job scope and then monthly monitoring forever. Think of this as part of the warranty and essential to customer satisfaction. Also to measurement and verification for utility programs.”

“Quick HVAC Commissioning tools (MeasureQuick)”

Comments related to program approaches:

“Repeatable process that can largely be done by entry level talent and plugs into an existing contractor network.”

“One stop shop program model including: transparent pricing, easily accessible low cost financing, trusted contractors with Quality Assurance.”

“Neighborhood approach to recruitment. Proven effective in BIRA/DOE/SMUD Pilot.”

“If a percentage of bank owned properties require some DER's. Scale, need to try and fail more and faster until we get to more of the ideas which are harder to kill. Increase educational requirements for contractors”

“Revised zoning codes to allow for multiple units within existing single family homes would drive this industry forward quickly. This would allow existing homes to be more affordable to purchase and renovate by families, and leave more $ available to take on DER's to upgrade existing building stock to high performance and better quality, more durable products. Zoning regs currently still kill many of the most cost-effective DER solutions (and cities don't want to acknowledge this!)”

“My DER projects are most often made more complicated by local zoning regulations. Cities restrict where I can place outside compressors for HP's, or how much exterior insulation I can add to side yards or roofs, due to height and setback encroachment issues. These are capricious limitations that should not be limiting our industry's ability to mitigate climate change. I'm also grossly limited by the number of high performance ventilation products available in California. We simply don't have enough options for smart, integrated HVAC that will make DER's faster and cheaper. Primarily these are related to ventilation, where the bath fan is the default provider of supposed 'fresh air' in a state where the air is increasingly neither 'fresh' nor healthy to breathe”

“The improvement needed is in assessment diagnostics that roll to cost analysis and proposal development and then the presentation of the project value to the consumer. This must be easier, simpler and integrate with our core HVAC / Plumbing service and replacement business. We used to offer a lot of DER and find that the time invested does not generate sufficient sales to justify the investment in time, training and knowledge. So, we offer parts of a DER on most jobs and mostly that incorporates the pieces of the puzzle that blend with our standard offering and make sense to our "Comfort Advisor" core. If we offered DER more … we would sell (a lot) more. But, our Advisors only get paid on closed deals and the company only gets paid on closed deals so many DER potential projects never get offered. About 1/3 of our replacement AC work includes one or more elements of whole building improvement. Another 1/3 of our replacement AC work includes 2-5 steps of leading to a DER. The final 1/3 only gets equipment replacement.”

“In most cases, bundling envelope and HVAC measures such as sealing ceiling drywall, replacing insulation, improving or replacing ductwork, correct sizing of return ducts and grilles, and coil inspections.”

Comments on project costs:

“The cost to be in the program is too high when compared to "normal contractors" It is hard to make money doing DER when the program people require all the checks and balances to protect the consumer but very little thought has been given on how to make the industry profitable and thus sustainable.”

“a better rebate program that can involve energy assessments as first to improve the knowledge of the customer/homeowner and help them in the final cost - the contractors for market reasons will follow the demand”

“Using stimulus money to make all homes electrification ready.”

“The City of Holland has a dedicated fund (Holland Energy Fund) to support our 40 year Community Energy Plan. We offer 10% grants towards residential retrofits. Our average project is $18,000. Average Grant $1,800. We also offer up to 15 years on-bill (Electric Utility) financing and rebates from Electric and Gas Utility. City has a dedicated Residential Energy Advisor to guide homeowners and be liaison with contractor.”

Comments on education:

“Primary innovations are ready....high performance heat pumps (air and geo), smart ventilation, heat pump water heater, heat pump clothes dryer, and smart building controls....main barrier is education of homeowners, designers and installers and market penetration.”

“Knowledge & understanding to effectively reach goals while doing less.”

“Qualified workforce.”

“All buildings have publicly visible real time energy use indicators comparing to comparable buildings.”

“As a homeowner who underwent this journey to net zero almost all by myself, a comprehensive website that shows the road-map, allows for evaluating DER choices and points to a set of local contractors or installers that can do each part of the retrofit would have been very helpful.”

Survey respondents also provided other suggestions to either improve this survey or more broadly our understanding of deep energy retrofits.

Role for DER in reducing residential energy use:

“Think broader about DERs. They probably only make sense for 1-5% of homes (at least until a substantial portion of the cost can be recouped at resale). Think of homes like kids going to the school nurse hurt. 60-70% can probably be treated by the nurse. The next 20-30% needs to go to the hospital to see a doctor. And the worst cases go to the ICU (which are DERs). Ideally a system will provide a path for all three. That's what we're developing in HVAC 2.0. The problem in our opinion is mainly sales process. The technical stuff has been largely solved for 20 years.”

“I was unable to express that DER are very niche in our location. Paybacks drive almost every customer decision to perform an energy retrofit. Low energy costs & lack of incentives have driven demand to 0 in the past few years.”

“Our typical customer is driven by a desire for a healthy home environment with energy as a secondary benefit”

Carbon reduction over the life cycle of the home:

"If you look at almost all DERs in terms of cost per ton of carbon avoided -- while also factoring in the embodied carbon of doing the project -- it quickly becomes clear they're not any sort of solution to the carbon emissions challenges we face. In fact, they're contributing to the problem in the short- and medium-term. Instead, do a couple of days of air-sealing and insulation upgrades, install heat pumps, and buy green power."

"there should be an element of life cycle cost in the DER project"

"I hate to admit being jaded in thinking my answers or opinion ultimately matter so I will entertain the opposite here. Having the insight of a WAP agency where extremes are the norm, it is difficult to ignore how much the disparity in income and urgency will forever be an uphill battle. We truly need to adopt a carbon tax/dividend to shift that."

Enabling contractors to do their work:

"Make sure the contractors are making money if they are participating in the programs. The consultants and program people are guaranteed to make money but the risk fall on the Contractors."

"Questions regarding partnership with other contractors to provide a better DER."

DER work scope:

"Broaden your scope beyond just traditional HVAC retrofits. Home energy use has changed, and the low hanging fruit today (at least here in CA) is plug loads, not duct sealing or LEDs."

"Add more about hot water, particularly for MF. Largest remaining central system. Most complex. Generally very inefficient plumbing. Switching to heat pump water heating is more complex than most realize. And, it does't solve the underlying problems in thee plumbing."

Product innovations:

"Retrofits are the challenge of our era, but until our industry learns how to build NEW buildings properly, we'll keep growing the pile that need retrofitting. If we can't source products that are sufficiently high performance for new buildings, we won't be able to cost-effectively deliver good retrofits. Please get back to first principles, aim for ambitious targets and stop dinking around with incremental improvements (like thin-film triple glazing...) Also, please look at other energy models that have more granular inputs than the tired old blunt instruments you've been using... The world needs fast, bold action, and LBNL has only been chipping away at the edges, without making much headway. Please also look beyond our borders to countries already making highly innovative products? California is now a third-world building product market (unless you need an expensive thermostat.)"

Other comments and suggestions:

"It would be useful to define DER at the very first. What I think a DER is and what you think a DER is … may not be the same."

“Explain what you mean by DER. I input we have done 3 in the past 2 years. After answering questions I realized that alot of the home performance projects we conduct (including electrification) seem to be considered a DER. So I'd like to change my answer to 30 DER's in the past 2 years.”

“Have your set of questions be more targeted to the participant role in the DER process.”

“Not a suggestion, but a qualification: Our involvement does not extend to contracted home improvement work. Suggest interviewing home improvement contractors such as members of the Ring 4 Club and PG&E Comfortable Home contractors who have cost data and greater experience with homeowner interactions. Utility and CCA program managers may also be a good resource.”

“I would love the chance to submit actual project costs an offer additional insights. Given the current landscape that will not be possible until I have regained access to our database which offers a highly accurate breakdown of funding.”

“it will be nice to understand how long it will be and you could eliminate some questions...short a little bit”

“I hope to come back and add cost data but it is time consuming to do it accurately.”

“I did not answer several questions because we are a rebate program, not a contractor and we don't have information on contractor pricing for various labor categories.”

“Have box for additional information in each response”

“Pictures would be nice”

“Keep up the good work”

“This was thoughtful and thorough, thank you. Stay safe out there :)”