



Architects, Engineers, and Contractors- Key to Moving towards a Zero Carbon Future

Preprint

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National Renewable Energy Laboratory

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Architects, Engineers, and Contractors—Key to Moving towards a Zero Carbon Future

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ABSTRACT

Many building owners have set energy or carbon goals, often citing targets of carbon neutrality in the next 10 to 30 years. These goals need to be translated into actions with designers and contractors being key to designing solutions that meet energy and carbon goals.

As a voluntary program, the Design and Construction Allies (“Allies”) as part of the U.S. Department of Energy’s Better Buildings Initiative was formed to identify barriers to the adoption of zero energy and zero carbon buildings (ZEZC). The goal was to understand why all buildings are not designed with ZEZC in mind. Currently the Allies program consists of 25 leading architecture, engineering, and construction firms seeking actionable steps to deliver buildings with the ZEZC goal. In the first year, Allies have articulated numerous barriers and have implemented working groups to address key challenges.

This paper documents program formulation and engagement strategies as well as the identified barriers and related recommendations for the design and construction community to shift towards ZEZC as a normal design and construction outcome. The Allies identified two major topics to address: (1) providing guidance and knowledge to clients such that they will be active in creating ZEZC, and (2) gathering knowledge related to embodied carbon, so action can be taken to reduce this source of carbon emissions. Each of these working groups has refined the barriers and created solutions that have been tested by the Allies themselves. The rapid identification of barriers and subsequent creation of deployable solutions demonstrates that swift change is possible.

Introduction

Buildings comprise the most energy-consuming sector of the economy—and most of the energy they consume is fossil fuel based. This energy use, coupled with embodied emissions from construction materials and the high greenhouse gas potential of leaking refrigerants in buildings, results in buildings being responsible for approximately forty percent of worldwide greenhouse gas emissions (EIA 2021; UNEP 2021). Many building owners recognize the need to reduce carbon emissions and have publicly announced carbon reduction goals. These owners also recognize the strong connection between energy consumption and carbon emissions and have strived to reduce energy consumption, install renewable energy, purchase renewable energy, or procure carbon offsets—especially at a portfolio level. In the past ten years, over 345 organizations have set energy goals through U.S. Department of Energy’s (DOE) Better Buildings Initiative (DOE 2021a).

In 2022, DOE introduced the Better Climate Challenge, through which more than 110 organizations have committed to an operational GHG emissions reduction target of fifty percent in ten years (DOE 2022a). This carbon challenge, like the original energy challenge, is focused

on energy efficiency and electrification first. After that, strategies to be considered include on-site renewables, grid interactivity, off-site renewables, renewable energy certificates, and other carbon-free energy purchases (DOE 2022b). Some owners have expressed that while they purchase offsets today for a portion of their emissions, they would like to continue to move towards energy efficiency, on-site renewables, and off-site renewables for their carbon solutions. They would also like to use on-site storage (e.g., batteries, hot and cold water, thermal mass in the building) to shift electricity usage from the grid to times of lower emissions.

As fossil fuels remain a significant energy source for heating and electricity generation, reducing energy often reduces carbon. Balancing energy consumption with renewable energy generation introduces the concept of a zero energy building. In simple terms, when buildings are electrified and renewable energy balances the total energy load of the building, this balance can be considered a zero carbon building¹ (Torcellini 2006; Torcellini et al. 2020a). As the owners move their buildings towards zero carbon, there is also more interest in aligning consumption with low-carbon energy production (Torcellini et al. 2020a). These concepts focus on the operational life of the building. The approach emerging is focused on moving to less energy consumption, more renewable energy generation, and lower carbon emissions overall. In this paper the term zero energy and zero carbon buildings (ZEZC) will be used to represent this concept of a “zero” building. Although the concept is still in its infancy, the carbon expended to create and maintain a building—also called “embodied carbon”—is also important, and in some cases, owners may also want to consider this carbon expenditure as part of the energy balance of the building. This can be challenging as it is difficult to export more energy than is purchased through the electric meter due to net metering rules, as is purchasing more renewable energy than is needed by the building from outside sources.

As owners strive to reduce energy and carbon, many have achieved some level of efficiency with operational changes; in addition, building owners procure offsets or renewable energy certificates to meet carbon goals. As building owners move towards deeper energy efficiency measures and on-site renewable strategies, design expertise is needed. Few building projects that change the physical appearance of the building, require upgrades of equipment, or involve working with the structure of the building move forward without design and construction professionals—the “trusted advisors” for projects. As a result, a key component to achieving deep energy and carbon reduction lies with the decisions made by members of the architecture, engineering, and construction (AEC) community.

The AEC professions recognize their impact in shaping the future of the built environment. Several aspirational goals have been set, including:

- Architecture 2030, an effort that aims to “achieve a dramatic reduction in the energy consumption and CO₂ emissions of the built environment by 2030 and a complete phase-out of fossil fuel CO₂ emissions by 2040” (Architecture 2030 2022)
- Structural Engineers 2050 Commitment Program (SE2050), “designed to ensure substantive embodied carbon reductions in the design and construction of structural systems by the collective structural engineering profession,” with a goal that “all structural engineers shall understand, reduce, and ultimately eliminate embodied carbon in their projects by 2050” (Structural Engineering Institute 2022)

¹ For a comprehensive definition of zero energy buildings, please refer to the following references: (Torcellini 2006; Torcellini et al. 2020a)

- The Mechanical, Electrical, and Plumbing (MEP) 2040 Challenge, stating “all systems engineers shall advocate for and achieve net zero carbon in their projects: operational carbon by 2030 and embodied carbon by 2040” (Carbon Leadership Forum 2021).

These initiatives are helpful in moving the industry towards ZEZC and achieving a substantial reduction in carbon emissions from the building sector. It represents the “what,” that is, the concept that emissions need to be reduced. While these goals have been articulated, many in the AEC community are asking for the “how,” driven by commitments that clients have made for emissions reduction. This “how” is the strategy to deploy and implement identified solutions.

DOE's Better Buildings Initiative created the Design and Construction Allies (Allies) to help the AEC industry identify barriers and challenges to ZEZC and to work collaboratively to create and implement solutions. The overall goal is to enable the routine design and delivery of ZEZC. Through this initiative, DOE is partnering with leading AEC firms to understand barriers to advanced levels of energy efficiency and carbon savings, to provide transparency in their approaches for others to follow, and to educate the market about creating and delivering high levels of energy efficiency and carbon savings within current market conditions. The following sections document the evolution of this program, from concept to engagement to the identification of barriers and related recommendations which will help the design and construction community to shift towards ZEZC as a normal design and construction outcome.

The Reasoning for the Allies

Building owners rely on AEC firms for their expertise when it comes to decisions regarding the design, performance, or functioning of their buildings. Most elements of the delivery process of a building project from design through construction, such as budgeting, design concept development, and aesthetics, are accomplished with varying levels of coordination between AEC professionals and building owners. Areas that require a high level of expertise, such as HVAC design, remain more challenging for the AEC community to directly involve clients in the input process.

DOE's Better Buildings has over 900 partners of whom more than 345 have energy goals (DOE 2022c). Owners need access to the expertise of AEC professionals to achieve their energy and carbon goals.

The Better Buildings Initiative identified a gap in addressing the design and construction community which is critical to the success of the owners. This became the focus of the Allies program.

Formation and Planning

The Better Buildings Initiative supports owners to catalyze energy efficiency and emissions reduction progress through technical assistance, resources and solutions, and overcoming market barriers through engaging outside expertise. The Better Buildings Financial Allies, started in 2017, is one example of this model of support. In the Financial Allies program, financial firms commit to providing financial instruments to help owners achieve their energy goals. The metric of success for this program is the amount of financing that has been issued to building owners to help further their energy goals. The incentive for the financial allies is to increase their market offerings and their financing business. Financial Allies are required to sign a non-binding agreement that includes sharing profile information about their company to be

included on DOE's Better Buildings Solution Center, a commitment to invest or finance at least \$25 million in new financing, and a pledge to maintain a dedicated energy efficiency or renewable energy financing line of business. In addition, Financial Allies commit to annual reporting towards their established goal. When financial institutions meet their goals, they gain a Goal Achiever designation.

The Design and Construction Allies have a similar design. Member organizations sign a non-binding agreement that includes a commitment to sharing company profile information, participating in Ally meetings and working groups assigned to solve specific problems, and providing DOE with updates on progress towards their measurable goals.

These goals are an important part of the effort. Allies must commit to goals for integrating elevated levels of energy efficiency and renewable sources into designs, sharing strategies that work and the barriers encountered, and setting measurable goals to show progress towards ZE2C. They also commit to annual reporting towards the goal that they have set.

A draft agreement was developed in August 2020, and six architectural firms were interviewed to gauge interest in the effort. A preliminary list of firms was developed based on the attendance list of the 2020 Better Buildings Summit as it represented design firms that had a connection to clients involved in Better Buildings. Based on this input, the following framework was used in launching the program:

- Recruit and engage fifteen to twenty leading firms, a range chosen in order to facilitate effective group discussions and brainstorming to represent the AEC industry, while not being so large as to stymie effective dialogue
- Host quarterly calls for peer sharing and developing solutions
- Identify barriers and solutions to the design, construction, and operation of ZE2C
- Identify and recommend projects that DOE and their technical support could execute to help Allies as well as the entire AEC community
- Create an engagement schedule including on-boarding meetings, kick-off virtual meeting, and quarterly meetings
- Create and prioritize research questions, market transformation barriers, and resource development opportunities.

The starting question for the Allies was: "What is stopping you from routinely delivering ZE2C buildings?" The answer to this question was documented starting with the initial kickoff call on October 28, 2020, and this theme is carried forward to each meeting to keep the focus on the "how." Ally responses to this question were used in formulating the identified barriers. To start the program, DOE hosted monthly group calls in the first two quarters to establish, refine, and prioritize the barriers. Table 1 shows the planned program schedule for the first two years.

An essential element of the program design is determining the value to the Allies. The inaugural Allies clarified the following value proposition for participation:

- AEC community access to DOE and national laboratory knowledge
- Opportunity to pilot new tools and solutions
- Recognition for exceptional projects and achievement of energy and carbon goals
- Exposure to Better Building partners through the Better Buildings website profiles
- Participation in a peer-to-peer network to share and develop ideas.

Table 1. Program timeline for first two years

Project Quarter (Starting October 2020)	Activity for Quarter
Q1 (October 2020)	Recruit Allies Set metrics and goals Share company profile Identify barriers
Q2 (January 2021)	Prioritize barriers Create two working groups to address barriers Create website and Ally profiles
Q3 (April 2021)	Create workplans for two working groups Implement workplans
Q4 (July 2021)	Develop first draft of solutions in working groups
Q5 (October 2021)	Iterate on solutions
Q6 (January 2022)	Finalize first set of solutions and field test with AEC and clients (beta versions of solutions) Prepare progress report towards individual Allies goals
Q7 (April 2022)	Complete first round of solutions and sunset or retask first two working groups
Q8 (July 2022)	Launch next set of working groups and phase two recruitment

Program Workflow

The Design and Construction Allies program workflow is shown in Figure 1. The National Renewable Energy Laboratory (NREL) leads the Allies through incremental monthly feedback sessions, in working group meetings, and throughout the solution development process. First, goals were set for the overall effort, then barriers were determined and ranked. Barriers were also evaluated based on whether this group was the right entity to solve them. Working groups were then established to address some of the barriers. The working groups develop resources that address the barrier, and the Allies incorporate the resource within their firms’ internal workflows for testing. They then report back to working groups on the effectiveness of the solution at addressing the barrier at hand. The feedback loop may result in revisiting the barrier and pivoting the developed solution to improve effectiveness and impact at addressing the barrier. The last step involves a collaborative effort between all Allies to disseminate and scale the solutions to ensure access and adoption of the resources to the broader AEC community. In Figure 1, The green “checked” boxes indicate completed portions of the program to date, which occurred as part of the program formulation and formation of the working groups.

In the following sections, we describe each portion of the program workflow in Figure 1 in more detail, as well as progress to date and/or planned activities.

Setting Goals and Metrics

Reporting metrics is an important aspect of the program, as both DOE and the Allies sought to show progress. The key metrics identified by the Allies were:

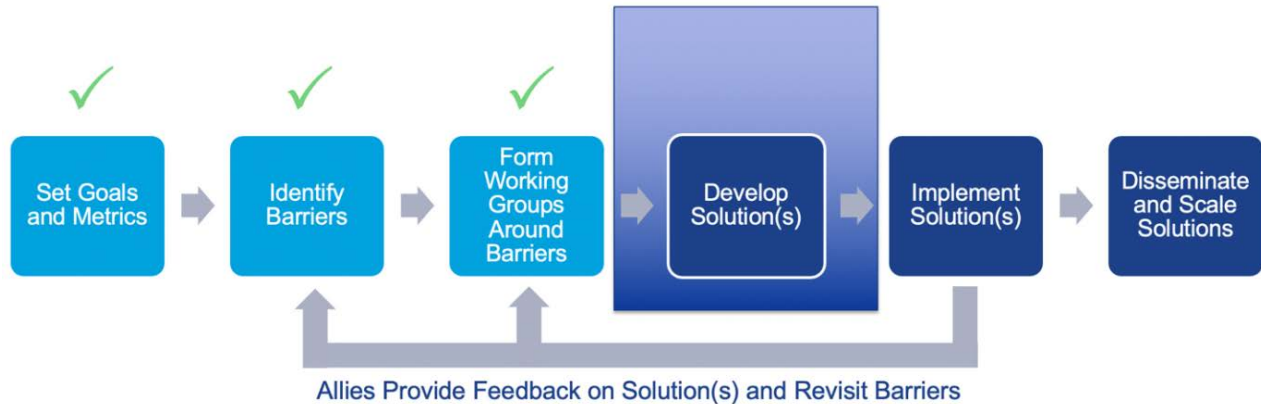


Figure 1. Schematic describing approach.

- Percentage of building projects designed or constructed targeted as Zero Energy Zero Carbon/Ready² (ZEZC/R)
- Number of building projects designed or constructed targeted as ZEZC/R
- Percentage of building floorspace designed or constructed targeted as ZEZC/R
- Total building floorspace designed or constructed targeted as ZEZC/R.

Allies requested that metrics be consistent with American Institute of Architects (AIA) 2030 reporting and other reporting databases to prevent added efforts within their firms. Different sized firms had different priorities for the metrics. Smaller firms preferred to report a percentage of the buildings designed to ZEZC while larger firms preferred to report total impacted building floorspace area.

After signing the program agreement, the Allies set goals for their firms to achieve ambitious ZEZC/R targets relative to their current operations. The Allies were required to set quantifiable and measurable targets. Table 2 summarizes the goals set by the Allies to date, and that have been publicly released on the Design and Construction Allies program webpage (Better Buildings 2022). We anticipate at least nine additional firms to publicly release ZEZC/R goals by January 2023. Setting public goals is a requirement for firms to be listed on the website as participants.

Identifying Barriers

Next, the Allies focused on naming current market and technical barriers associated with design and delivery of routine ZEZC buildings within current market conditions. Allies created a list of barriers and prioritized these barriers on a scale of one to five, with five being the most significant. The scoring results are shown in the Figure 2 and indicate that the top three barriers are *Perceived First Costs*, *Customer Demand*, and *Risk Aversion to New Technologies*. The lowest scored barrier was *Technology Limitations*.

² DOE defines zero energy ready (ZER) as a high-performance building that is energy efficient enough to allow renewables, if installed, to offset total annual energy consumption (DOE 2022d).

Table 2. Goals set to date by Allies

Firm Number	Goal
1	Design and/or deliver one million square feet of Zero Energy/Ready (ZE/R) space by Earth Day 2024 (April 22, 2024).
2	25% of building floorspace to be designed and delivered to Zero Energy by 2030. 35% of building floorspace delivered to ZE/R by 2030.
3	In the past ten years, firm has designed and built 1.3 million square feet of zero energy buildings and installed 75 MW of solar. In the next ten years, firm hopes to design and build ten times as much; as of 2021 the company has 3.1 million square feet under construction and 2.1 million square feet in design.
4	40% of designed square footage among all building types to be ZE/C by 2025.
5	95% of projects to receive a net zero analysis starting in 2022 and 15% of projects designed to be net zero by 2024.
6	60% below energy use intensity benchmark for average of all new designed projects in 2022. 25% of building floorspace to be Net Zero Energy/Ready by 2025. 50% of building floorspace to be Net Zero Energy/Ready by 2030.
7	Deliver 25% of new building projects as ZE/R by 2024.
8	100% of projects to be carbon neutral by 2030.

Source: Better Buildings (2022)

Initial perception of capital or project cost is often cited as the key inhibiting barrier to ZE/C (Torcellini et al. 2020b); however, this barrier is mixed with how design decisions are made and trade-off analysis that occurs between the design team and the client. The second most challenging barrier is a lack of client demand. This barrier encompasses the idea that designers and contractors do not feel that clients ask for ZE/C or even buildings with significantly reduced energy loads.

A session at the DOE 2021 Better Buildings, Better Plants Summit asked participants of their plans to build a ZE/C building within the next five years, and half of the building owners stated that it was highly likely or definite. Another forty percent said that it was a possibility. The same owners, however, also noted that they were not confident they would be able to hire an adequate design and contracting team, with only fifteen percent saying that those services “certainly” could be procured. When the designers were asked what they wanted to see from owners, they wanted owners to be more knowledgeable about ZE/C and wished that more owners would establish stretch energy goals and would have more of a desire to pursue ZE/C (DOE 2021b). There is clearly a need to connect designers and contractors that want to achieve ZE/C with clients that have those aspirations.

The third barrier is an apprehension about incorporating new technologies that might be required to achieve ZE/C. These first three barriers all relate to the relationship between the designers, contractors, and clients.

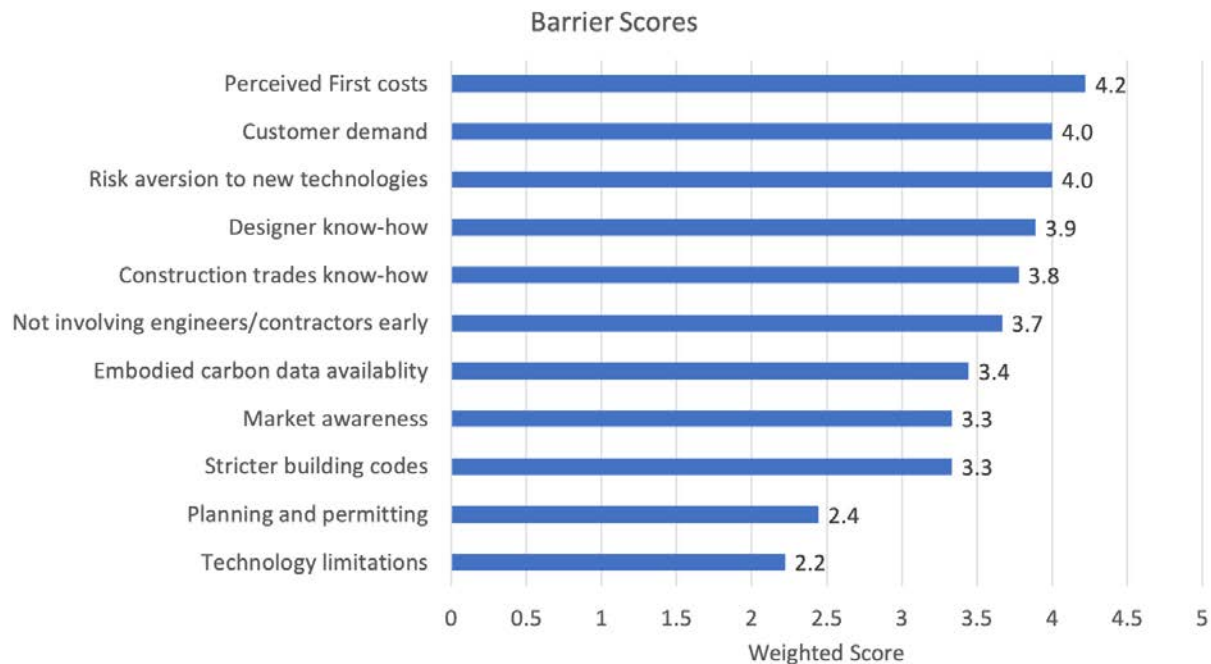


Figure 2. Barriers identified by the Design and Construction Allies for routinely delivering ZEZC buildings.

Working Groups

Recognizing that the barriers identified in Figure 2 are often intertwined, and keeping in mind that the focus of the working groups is to address top ranked barriers that (1) are real, (2) can make substantial impact if addressed, and (3) can be addressed by the group/forum, the Allies developed working groups to address the highest ranked barriers.

Based on the results of the barriers analysis and evaluating the strengths and interests of the Allies, two working groups were established. The first group was to address “Cultivating Client Demand” and develop resources that explored the relationship between the AEC community and the clients. While this is a broad topic, the first six barriers could be addressed by this group. The second working group is also a broad topic, only addressing embodied carbon and integrating this concept into the design and delivery process of buildings. Interestingly, this topic is outside the boundaries of achieving ZEZC from an operational point of view but was seen as a topic of relevance. As of May 2022, some of the firms have opted to participate in both working groups using different staff members on each working group.

Develop Solutions

The Allies program aims to provide rapid resource development while delivering viable and useful solutions to the AEC community. DOE manages the resources development, NREL leads the resource development, and the Allies provide direction and feedback on the resources. NREL coordinates monthly workshops during resource development to obtain feedback and gain input from Allies. Between workshops, NREL researchers weave together Allies’ feedback, real-world examples, and other insights to create compelling solutions with the end goal of publication and implementation by the Allies.

Prioritized Solution Pathways for Working Group 1: Cultivating Client Demand. The allies participated in a polling exercise to gain a better understanding of the most useful solutions that they could leverage within their firm. The collected information was used to prioritize the resource development pathways. The results of the poll are shown in Table 3 and illustrate that a guide to ZEZC financial incentives would be most useful to the Allies and the broader AEC community as a first product. It would engage owners, especially the financial decision makers, as well as show the value of the Allies to the clients.

Table 3. Tallied Ally votes for solution development pathways for Working Group 1

Resource Title	Number of Votes (High to Low)
Guide to ZEZC financial incentives	6
Heat pump design guide	3
Pathways for getting clients to say “yes”	2
Guide to low budget ZEZC buildings	1
Resources for AECs working with clients on ZEZC goals	1

The goal of the ZEZC financial incentives guide is to equip designers and contractors with information on key technical requirements, eligibility, and other aspects of federal incentives related to high-performance buildings to (1) raise awareness of performance thresholds that trigger incentives, (2) share with their clients to move them toward ZEZC, and (3) bring added value to clients by helping them access information that could positively impact their projects’ cashflow. The resource will include the following elements:

- Opportunities for both renovations and new construction
- Federal incentives opportunities
- Case studies that feature the financial incentives’ applicability, impact, and stacking opportunities.

Prioritized Solution Pathways for Working Group 2: Integrating Embodied Carbon. The Allies participated in a polling exercise in Working Group 2 to gain a better understanding of the most impactful solutions that they could leverage and to prioritize the resource development pathways for the group. The results of the poll are shown in Table 4 and illustrate that life cycle assessment (LCA) educational materials, case studies, and an overview of available tools for LCAs would be most useful to the Allies and the broader AEC community.

The goal of the deliverable is to point the AEC community to useful resources that will result in design and construction decisions to reduce embodied carbon. The resource will include the following elements:

- Educational materials that familiarize designers and contractors with embodied carbon and LCAs
- Case studies that focus on design changes from LCA findings
- Examples of readily available, cost-effective design/construction steps to lower embodied carbon
- Overview of LCA tools.

Table 4. Talled Ally votes for solution development pathways for Working Group 2

Resource Title	Number of Votes (High to Low)
Education materials on embodied carbon analysis	3
Case studies for data and analysis process	3
Overview of available databases/tools and guidance	3
Overview of material categories	0
Pathways to get commercial building owners/clients to consider LCA	0
Benchmarks using DOE building prototype models	0

Implement Solutions

Once the “beta” resources have been developed by the working groups, the Allies will integrate the resources into their firms’ internal workflows and provide feedback to working groups by answering questions such as:

1. How was the resource used?
2. Was the resource useful for addressing the barrier?
3. Does the resource have the appropriate format? If not, how could we improve the format to maximum its effectiveness?
4. Are there derivative works including different media that would be helpful?

The feedback will be used to continue to enhance the resources by cycling back to the working groups. The working groups will also develop metrics to measure the impacts of the resource within their firms, for example, the number of projects that leverage the resource or the total reduction of project costs/energy/carbon due to the resource. At this point the resource will be finalized and available for widespread dissemination.

Finally, this step includes identification of other barriers that arise from solving the current barrier addressed. Many times, barriers go unseen, as other barriers mask larger issues. These issues will be captured and reprioritized. It may be that one working group sunsets and a new one with a different focus starts, or the same working group feels qualified to tackle the barrier.

Disseminate Information and Scale-up

After implementation of the solutions by the Allies, program efforts will be dedicated towards information dissemination, and distribution of the resources to the broader AEC community. Information dissemination activities will include presentations at pertinent conferences venues (i.e., AIA, ASHRAE, ACEEE) and participation in Better Buildings webinars and summits. Allies will be encouraged to help disseminate materials and to continue to receive feedback.

Engagement

Figure 3 shows the level of engagement over the first eighteen months of the program. The level of engagement has been consistent with high repeat participation. This demonstrates the value of the program for the participants and the need for such a program.

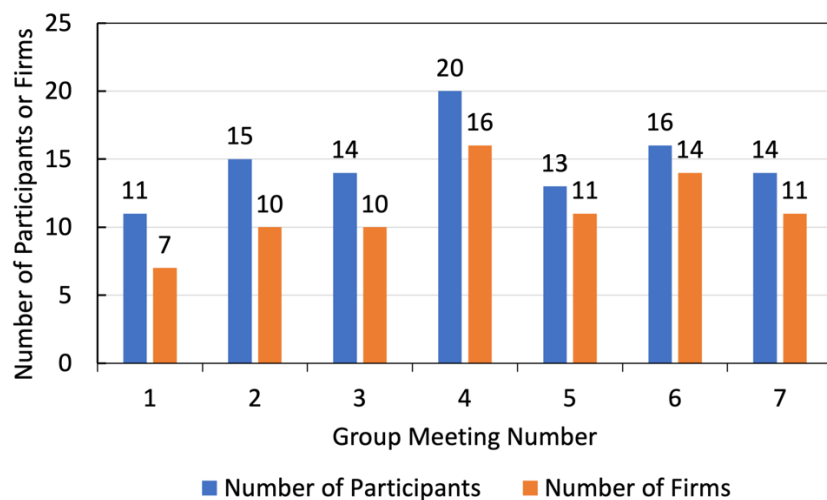


Figure 3. Number of participants and firms that engaged in each group meeting to date.

Conclusion

Architects, engineers, and others associated with designing buildings, coupled with contractors who implement the plans of the designers, have a tremendous potential to create ZEZC. While clients provide the financial resources and sometimes high-level goals around energy or carbon performance, they rely on the AEC community for expertise. The AEC community is often the trusted adviser to implement the plans and goals of the building owners. To this end, the AEC community provides the actions or the “how” to create these buildings while the clients sometimes provide the goals or the “what.” The AEC community, however, struggles with solution pathways that are on the edge—such as very deep retrofits, ZEZC new construction, and decarbonization of buildings. Many of the barriers seem insurmountable and may change workflows or have financial implications, or the knowledge to solve these problems is not well established.

DOE created a mechanism through the Better Buildings Initiative to drive down the barriers facing clients and the AEC community. The Better Buildings Initiative already has extensive programs to work with clients, but there is an industry gap in addressing the parties that often provide the solutions to owners. The Design and Construction Allies program addresses this gap. The program works with Ally members to identify the barriers and work through solutions to these barriers.

An initial cohort of twenty-five AEC firms are participating in 2022 and have identified and prioritized barriers. Two working groups have been formed and resources have been created to address the first round of barriers. These resources are currently being field tested by those companies. The quick turnaround and rapid development techniques help keep the program

nimble and provide viable solution pathways to the AEC community. The Ally members have a high rate of engagement over the first eighteen months of the program indicating the continued value in participating.

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