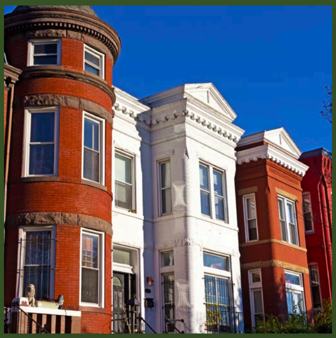
# INNOVATIVE BUILDING TECHNOLOGY GUIDE

SELECTING THE BEST SOLUTIONS FOR YOUR PROJECT



U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

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# Innovative Building Technology Guide

Selecting the Best Solutions for Your Project

Prepared for:
U.S. Department of Housing and Urban Development
Office of Policy Development and Research
Washington, D.C.

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# Disclaimer

# Preface

More than $400 billion are spent each year to power the residential and commercial buildings in the United States. This amount is nearly 70 percent of all electricity consumption, about 40 percent of the nation's energy bill, and contributes to nearly 40 percent of the carbon emissions in the country.[1] Although these numbers may seem alarming at first, they also highlight a significant opportunity. Improving the efficiency of our buildings does more than just save money and energy; it supports the creation of new jobs, reduces pollution, and supports the local and national economies.

The shift toward more efficient and sustainable buildings has been accompanied by increased emphasis on resiliency and durability. In just the past 10 years, significant changes have been made in construction and design methods—focusing on stronger, safer, and more durable buildings. Our buildings need to stand up to natural hazards, moisture, pests, occupants, and other elements that can undermine the performance of the structure. The efforts made toward improving energy efficiency will be realized only if the building is designed to endure these various conditions.

The affordability of our buildings also stands to improve greatly from increased efficiency and new construction methods. Energy, construction, and maintenance costs can contribute substantially to the financial burdens of buildings, rendering them unaffordable to many owners or tenants. Implementing energy-efficient strategies results in lower energy consumption and lower utility bills for owners and tenants. Improved construction methods and practices produce higher quality and more durable buildings that can decrease construction costs and future maintenance and repair needs.

This increased emphasis on constructing buildings to a higher standard has resulted in significant investments in research and development of innovative building technologies. The landscape of building products, materials, components, and systems has increased substantially in recent years. These advancements have paved the way for the new design and construction methods that make buildings stronger, safer, more durable, and more efficient. Many options are currently available to building owners and decisionmakers when investigating new technologies that can improve their buildings.

This document, *The Innovative Building Technology Guide,* is important today to assist in the decisionmaking process. Just as no two buildings are the same, different technologies, products, systems, and building components differ in the types and quantity of benefits they offer and the impact their advantages can have on a specific building. It can often be overwhelming and confusing for owners and decisionmakers to determine which technologies are the best fits for a given project. No one-size-fits-all solution exists to improve building construction efficiency and, thus, key decisionmakers need to be educated—not only about what options are available to them, but also about how to evaluate these options in relation to their project. By developing this guide, we provide a valuable resource that will assist building owners and operators, design professionals, and other decisionmakers through the process of identifying, evaluating, and ultimately implementing the technologies that best fit their needs.

[1] http://energy.gov/eere/buildings/about-building-technologies-office

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# Chapter 1. Introduction to the Innovative Building Technology Guide

Organizations and agencies that own, manage, upgrade, and operate assisted housing facilities (or other non-market-rate housing) are often key decisionmakers regarding systems, materials, equipment, and technologies that will be incorporated into new construction and renovation projects. Although design and building professionals, such as architects, structural and mechanical engineers, and building/trade contractors, often provide guidance regarding building systems and materials, HVAC (heating, ventilation, and air-conditioning) and water heating equipment, recommendations often revolve around those technologies that are most familiar and have the lowest first costs. Opportunities to enhance building performance and reduce operating costs over time are frequently lost due to lack of adequate consideration of newer, less well-known technologies. For existing buildings, this tendency is often exacerbated by the additional constraints of space, other existing systems in the building, scope of the renovation project, and occupancy; a typical scenario is simply to replace in kind. Project schedule also drives the decisionmaking process and, far too often, selections are made hastily.

This Innovative Building Technology Guide is designed to assist building owners/operators and design professionals through a process that encourages thorough and rational consideration and comparison of multiple technologies to select the best fit to fulfill a given purpose(s). Upfront economic costs will be only one of multiple economic considerations. Life-cycle analysis, return on investment, and total monthly operating expenses (cashflow)—including utility bill costs, and principal and interest payments on financing—will be important considerations. Tools and methodologies to analyze and compare performance of different system options will provide assurance regarding maintenance schedules and costs, longevity, and documentation that the equipment or products function as expected. Tools that aid in review and understanding of local code compliance, in compliance with possible green standards or high-performance programs, and in verification that selected technologies will be compatible with one another are important metrics to ensure feasibility and constructability in all homes and categorized specifically based on climatic, disaster, and other weather concerns.

## About the Guide

The building technologies landscape is extremely broad and encompasses a wide variety of components and systems that make up a building or home. This broad landscape makes creating a comprehensive guide, like this one, challenging. The authors must take into consideration that the level of understanding and knowledge about buildings, the components and systems that they encompass, and new technologies varies greatly from person to person. For that reason, it is the intention of the authors that this guide be relevant to the masses.

When integrating an innovative technology into a project or building, a building professional needs to consider three major types of analysis. (1) An economic analysis would be performed to determine and identify all costs associated with the technology and project to make the most cost-effective decision. (2) A feasibility analysis would be performed to determine if a particular technology is applicable and compatible with the project or building. (3) Finally, a performance analysis would help determine whether the technology will achieve the goals and objectives of the project.

The guide is structured around these three major evaluation channels, or considerations, each one headlining a different chapter. Although these three types of analysis provide a framework for a comprehensive evaluation of building technologies, it is also important to understand how they tie into overall project management. Project management structures have many different variations, but most generally incorporate very similar components. For purposes of this guide, we identify four different phases of a project management structure: conceptual, scoping, design, and implementation. These phases outline a general timeline for a project; however, it is important to remember that economic, feasibility, and performance considerations are critical throughout the life of a project. Instances will occur when certain evaluations and considerations will need to be revisited again during different phases of the project.

The four project decision phases identified by this guide include—


## Using the Guide

The following illustration (on page 3) offers the reader a depiction of the structure of this guide. Economic, feasibility, and performance considerations discussed in chapters 2, 3, and 4, respectively, are represented by the columns. The rows are decision phases that are common across each of the considerations. Each row is a subsection in the chapters on the considerations. Furthermore, this illustration is used throughout the guide to help orient the reader as to what consideration and phase is being discussed in that subsection.


Decision Phases
Economic Considerations
Feasibility Considerations
Performance Considerations
Conceptual Phase
Funding Sources and Incentives
Occupant and Program Needs
Desired Performance Attributes
Scoping Phase
Budget Priorities
Local Zoning and Building Codes
Project Selection and Review
Design Phase
Cost/Benefit Analysis and Optimization
Compliance
System Integration
Implementation Phase
Operational and Maintenance Costs
Construction Trades and Schedules
Verification

## Background on Building Innovation

In regard to technology, innovation means finding a better way to do things or improving something that already exists. Innovation is what drives progress in all industries. Can you even imagine our lives without it? Automobiles were a rich man's toy at the beginning of the 20th century until, through innovation, Henry Ford developed the Model T. Fast forward to the present and we have cars that can be plugged into electrical outlets, drive hundreds of miles, and accelerate to speeds of more than 200 miles per hour. We have clearly come a long way since the horse and buggy. Innovation is responsible for this progress.

The same can be said about the building industry. Shelter is an essential part of human life. Our early ancestors built structures with their own hands from the natural resources available to them. Early Americans built log cabins, a construction method that was advanced for the time. The Industrial Revolution paved the way for faster construction through factories, improved manufacturing, and more durable structures with the creation of new building materials such as steel and concrete. These new capabilities, coupled with the explosion of the global population, the demand for strong, safe, and quickly constructed buildings drastically increased.

According to a report by the World Business Council for Sustainable Development, the building sector accounts for an estimated 40 percent of global energy consumption. In addition, in 2007, HUD determined that more than 6 million households in the United States lived with either moderate or severe housing conditions. These statistics are alarming; however, they also offer a great opportunity for improvement. Most of today's buildings will be used for the foreseeable future, and, without investing in these technologies as opportunities arise, we are not only missing out on short-term benefits but also on long-term ones. The sooner we invest in innovative technologies and systems, the sooner we can reap the performance and economic rewards.

Source: Energy Efficiency in Buildings: Transforming the Market, World Business Council for Sustainable Development, August 2009

Technological advancements continue to offer the opportunity for further advancements in building performance. Today, the market places increased emphasis on constructing sustainable and energy-efficient buildings. New technologies and innovations enable us to construct buildings that consume a low amount of energy and, in some cases, even generate their own. Manufacturing improvements, new materials, improved construction methods and best practices, understanding building science, and renewable energy technology are some areas that provide the ability to construct high-performance buildings.

Many different building components have seen significant growth in regard to technological advancements that offer great benefits to the building industry. Insulation used to consist of straw and mud being stuffed between the spaces of the walls of structures. Over time, new materials, such as fiberglass, cellulose, and foam insulation types, were developed; all of these materials have continued to improve the thermal performance of our buildings. Similarly, in the 18th century, a fireplace was the main source of heating for a building. When Benjamin Franklin invented the Franklin stove, he was innovating. His stove used half the wood a normal fireplace used while generating twice as much heat. Today we have extremely efficient whole-house heating systems that incorporate air-conditioning and ventilation that provide improved comfort at the touch of a button.

The building industry plays a major role in regard to global energy consumption. Whether we live or work in buildings, they are essential to the global population. Innovative building technologies enable us to construct stronger, safer, and more efficient structures. Many of these technologies too often do not experience a high level of market adoption for a wide variety of reasons, however, including high upfront costs, low awareness levels, and a lack of knowledgeable and qualified professionals.

## Evaluating Building Innovations (Economics, Feasibility, and Performance)

This document intends to provide a guideline for building owners/managers and design professionals to identify the "best fit" technology for a given purpose by comparing and analyzing them through three main evaluation criteria. The primary evaluation considerations identified in this guide are economic, feasibility, and performance. Study each consideration closely, because decisions that are made regarding innovative technologies have a significant effect for each consideration. Examining only one of these considerations can be detrimental to a project because it may compromise the needs and resources of another. For example, if a building owner is looking to upgrade the HVAC system and looks into only the performance characteristics of a technology, a decision made on that one analysis may result in going over budget or not being in compliance with local codes. In this case, the technology would most likely not be the "best fit." Similarly, if the building owner looks only at the economic considerations of the equation, he or she may miss out on some significant performance characteristics that could ultimately provide savings, increased efficiency, and improved comfort and durability of the building. In either case, the need for evaluating technologies for each of the three primary evaluation considerations identified in this guide is essential to making the best decision for your project.

> We have divided project management into four phases as a way of organizing some considerations you will want to take into account. Keep in mind, however, that you may need to revisit some of these considerations throughout the entire planning and construction process. For instance, during the implementation phase, you may become aware of an additional source of funding that will enable you to expand the scope of the project somewhat or you may learn of a new product or technology you would like to use and need to verify code compliance.

For purposes of this guide, an economic analysis includes all costs associated with the technology and project. Financial considerations are often the driving factor in the decisionmaking process and extend far beyond the initial (first) cost of the technology. Other costs associated with a project include operation, maintenance, and replacement costs and expected or estimated savings (energy and cost). Other economic considerations that are likely to be impacted by integrating these technologies are increased value of the building and indirect cost or savings (those not immediately attributed to the technology but are affected by it). In addition to evaluating these costs, identify any potential funding sources and incentives available for specific technologies. One might be motivated to invest in a newer, more efficient technology if a certain government agency or group is providing financial support.

Feasibility pertains to how applicable a technology is for a given project. In many cases, feasibility considerations are accounted for automatically. Examining elements of feasibility helps a project in various ways including; maintaining a schedule, staying within budget, avoiding roadblocks, and quality assurance. Often times these considerations are "automatic" or "givens" that are not necessarily analyzed in depth. If you know you cannot displace an entire building of tenants for a long period of time, a deep retrofit is probably not possible. If a technology is not practical, you are not going to waste much time evaluating it. Not all feasibility considerations are automatic, however. In other cases, a more indepth look at the various characteristics of the project and technology is necessary to evaluate its practicality. Aspects of feasibility that should be considered for any project include; requirements from funding sources, local codes and ordinances, compatibility with existing building components, climate and geographic appropriateness, and availability of associated resources.

The third primary evaluation consideration—performance—is tied directly to how effectively a technology will accomplish the objectives of the project. Performance is a broad category that encompasses different elements for different technologies and projects. Performance can be analyzed by evaluating technologies in regard to desired attributes, such as energy efficiency or disaster resistance. It can also be analyzed by type of building component, such as lighting or HVAC equipment. Evaluating a technology's performance depends on primary goals and objectives identified at the beginning stages of the project. In addition to ensuring that you meet these objectives, a performance evaluation will provide a level of quality assurance and help save time and money in the long run by specifying a tested and certified technology.

Keep in mind that most zoning ordinances distinguish among areas zoned for different types of residential occupancy. Among these types may be—

- Single-family homes.
- Multifamily buildings up to X units.
- Multifamily buildings with more than X units.
- Group homes.

Some jurisdictions are developing ordinances related to communal ownership of homes and the definition of family.

Each of the three evaluation considerations alone is individually significant; however, to make sure the best choice is made, all three must be accounted for. A technology that fails to meet the requirements of only one of the criteria is not going to be the optimal choice for your project.

## Starting Considerations and Project Context

Within the context of any given project, a variety of unique elements need to be taken into account when deciding whether to integrate a new technology into your building. These various elements can take on many different forms. In addition to the role the building plays in the project, existing systems and assemblies, site conditions and location, the anticipated scope of work, occupancy characteristics, and even billing structure (as it pertains to split incentives) all play significant roles in how a building will perform and be affected by new building technologies. Each of these various elements will determine whether a particular technology will properly fit into your project.

For instance, a building owner who is looking to replace the old furnace and air-conditioner might immediately look into using heat pumps. If the electrical service is not large enough to handle the load in the winter, however, a heat pump is not a feasible option. Similarly, a building being occupied by senior citizens is probably not a prime candidate for a high-technology, interactive programmable thermostat. Each project will have its own unique set of characteristics that will need to be addressed and considered when determining whether a certain technology is feasible.

**Example: Replacing HVAC**

The building owner has planned to replace four centrally metered heat pumps in a 12-unit apartment building with dedicated high-efficiency minisplit heat pumps for each apartment. The units were ordered as soon as construction got under way so they would be on site in time for prompt installation. When the electrician began his rewiring work for the project, he reviewed the electrical specifications for the new HVAC equipment and realized that the current 60 amp electrical service feeding each apartment was not adequate to power the new heat pumps. This problem delays construction while the design team and building owner decide whether to upgrade all the electrical entrances or redesign the HVAC system.

**Lesson Learned:** Interference of the project schedule nearly always entails higher costs and impact on the budget. Therefore, in the very early stages of project planning, the building owner should have considered all relevant elements related to feasibility to ensure that the decisions he made were practical, reasonable, and doable. If the building owner had consulted electrician regarding the innovative HVAC technology, the conflict with the existing electrical services probably would have been discovered much sooner. In addition to construction delays and unexpected higher costs, decisions made in haste are often not as carefully considered.

### *Why are these considerations important to your project?*

Assume you are the general manager of a professional baseball team. It is your job to put together a team that will succeed on the field, while remaining under the constraints of the team budget or league salary cap. Building a winning team takes a lot more than 11 baseball players simply signing contracts. Players specialize in different positions, excel at different aspects of the game, and provide a variety of different characteristics. To effectively do your job, it is critical to consider all these different elements when piecing the team together. You will probably also want to consult with all the members of your staff who can provide unique knowledge and perspectives on the different players you are considering. Together, you can best piece your team together based on your needs, your budget, your fan base, your opponents, and many other elements that will ultimately define your success. By considering all these different elements during the off-season, you are more likely to avoid, or at least minimize, the effect of potential issues (slumps, injuries, and so on) that could lead to an unsuccessful season.

Just as with a baseball team, a number of different elements affect a building. As stated previously, these elements can be within the building or can be related to the whole building makeup. Identifying all the various characteristics associated with your building and using them to evaluate the applicability of an innovative building technology are enormously beneficial actions for you as a decisionmaker. Considering these elements can help you identify, early in the process, those technologies that will be viable options for your project. It is important to have all the trades who will be involved in the installation of a new technology review the specifications well ahead of procurement and installation. In addition to your design professional(s) and contractor(s), personnel from facilities and maintenance, security, resident life, healthcare services, and others on the building staff will have different perspectives regarding elements that may make a particular technology a good, impractical, or unsuitable choice. After you have identified your constraints and requirements, you can begin evaluating these technologies on a higher level with regard to economics, feasibility, and performance. The following table outlines some benefits of identifying and analyzing the specific characteristics related to your building.

| Maintain a Schedule | Stay Within Budget | Avoid Roadblocks | Implement Quality Assurance |
|---|---|---|---|
| If you find that a particular technology is not feasible after you are well into the implementation phase of your project, work can come to a grinding halt. | Discovering a technology is the wrong choice after you are well into a project can result in higher costs and can delay the schedule. Whether paying an architect for redesign or a contractor for rework or simply having to select a more expensive technology, project costs can increase quickly. | By considering economics, feasibility, and performance up front, you will be able to resolve any conflicts that could be encountered ahead of time. | Considering various elements during the conceptual, scoping, and design phases will help to ensure that the technologies you select are suitable for the application and, thus, will perform as anticipated. |

### ***Questions To Ask***

Depending on the main objectives of your project and the specific characteristics of your building, you can ask a number of different questions to help identify the constraints and requirements when integrating new building technologies. These questions will vary in regard to the specifics of your project. Often, one question can lead to another, and can help guide you through a filtering process.

The following are some different types of feasibility considerations that may be applicable to your project. These questions will be important to ask yourself, your design professionals, your builder, the local code official, or your HUD point of contact.

**What are the HUD (or other funding source) regulations regarding eligible improvements?**

- Do equipment and appliances have to be ENERGY STAR labeled?
- Is there a preference for or advantage to using sustainable materials?
- Am I permitted to swap out existing gas water heaters with electric water heaters?
- Can I replace the windows in my building if there are strict requirements regarding the Savings-to-Investment Ratio that must be achieved?

**Is the improvement or technology suitable, given the current scope of my project?**

- Is adding wall insulation realistic in my masonry building if I am not planning or able to remove the existing interior wallboard?
- Are minisplit heat pumps a viable option if it means I will also have to replace the electrical service to every apartment unit?

**Is the technology suitable, given the building type, and compatible with other existing systems and assemblies?**

- Is rigid foam insulation a viable option for wall insulation if there is a vapor retarder behind the existing drywall?
- Is a gas tankless water heater a viable option if a new, larger gas line will have to be run from the street?
- Is replacing an old steam boiler with a higher efficiency hot water boiler compatible with the distribution system?

**Is the technology well suited to residents or occupancy of the building?**

- What is the learning curve associated with the technology?
- Is it realistic to expect the residents to use the technology appropriately to achieve anticipated performance and savings?
- What are the consequences if the technology is not used appropriately?

**Is the technology well suited to my climate?**

- Will a night-time ventilation system perform well in my cold climate?
- Does my climate receive enough sunshine to make a photovoltaic system viable, given the return on investment that I am looking for?

**Is the technology code compliant with the building and zoning codes in my jurisdiction?**

- Is an unvented attic allowed by the building code in my jurisdiction?
- Is an unvented crawlspace allowed by the building code in my jurisdiction?
- Am I permitted to insulate the exterior of my foundation with rigid foam insulation?

**Are the resources to support the technology readily available? Will they be available for the long term?**

- Are there examples of the technology in use in my area?
- Is the technology reasonably available in my area?
- Is skilled labor available for the installation?
- Are adequate service technicians or maintenance staff available?

# Chapter 2. Economic Considerations

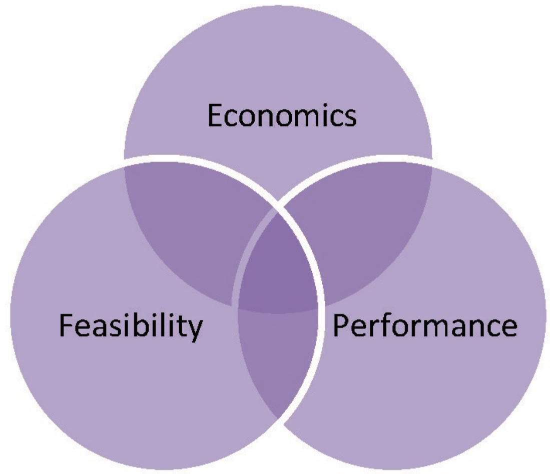
## Economic Top 5

1. What do you want to do and what do you have to do?
2. What is your budget?
3. Compare options with equal performance to optimize costs.
4. Choose an analysis method that will give you an accurate look at all the costs and benefits.
5. Keep in mind that many innovations have a cost and value beyond the initial purchase.

## Introduction

We are all aware of the importance of cost when making any investment. Regardless of the product or service, cost is certainly something that all of us consider. These economic considerations are especially important in regard to innovative technologies for your construction or renovation project. They are likely to be central to your decisionmaking process. Although facility needs or funding opportunities may be the initial driver to actually get a project's conceptual and planning phases rolling, usually it is the project budget that frames the boundaries and overall scope. Throughout the planning and design phases, it is likely that you will move back and forth between performance goals, feasibility considerations, and economic analysis, often in multiple iterations related to any one technology or a set of technologies. Sometimes something that may seem impractical economically at the first pass can be refined or revised so that both the advantages offered by the technology and its economic cost fit both the project goals and the budget.

Let us start with a basic example of how you might incorporate an economic analysis in a project: the architect for your new housing project suggests using spray foam insulation for the exterior walls. After contacting an insulation contractor you learn it will cost three times as much as fiberglass and twice that of dense packed cellulose. Even factoring in the added benefits (thermal performance, improved air sealing, and moisture resistance) the cost simply will not fit in your budget. Although you know you cannot afford the upgrade, you still have a desire for some high-performance characteristics associated with the spray foam. Your insulation contractor suggests blowing one inch of spray foam against the structural sheathing and filling the rest of the cavity with a lower cost insulation material to achieve the code-required levels. This compromise adequately addresses your economic and performance considerations.




Building owners, managers, and decisionmakers need to economic analysis is a critical element to decisionmaking, it is directly tied to other evaluation tools. Performance analysis is necessary to identify the benefits of different products and systems and value them accordingly. Feasibility analysis is also critical to an economic analysis. If a particular technology is not well suited to your climate, an economic analysis of these alternatives would be irrelevant.

To ensure that your economic projections are as accurate as possible early in the decisionmaking process, make sure you obtain pricing estimates that are as accurate as possible. If you have a contractor and subcontractors on board, request cost estimates from them because they will be performing the work and are likely to have the most realistic cost information. If you are still looking for a contractor, be sure to get multiple estimates. Vetting multiple contractors will give you assurance that the pricing is fair and reasonable. Always obtain several references for a similar type and scope of work before selecting a contractor. Keep an eye out for potential conflicts of interest—for instance, a contractor who tells you that you must replace the windows in your building and is a distributor for a particular window manufacturer has a conflict of interest.

**How To Identify Reliable Sources of Information:**

- Recommendation is from a trusted source.
- Recommendation is from your design professional.
- Recommendation is from an independent third party source.
- User review trends are positive

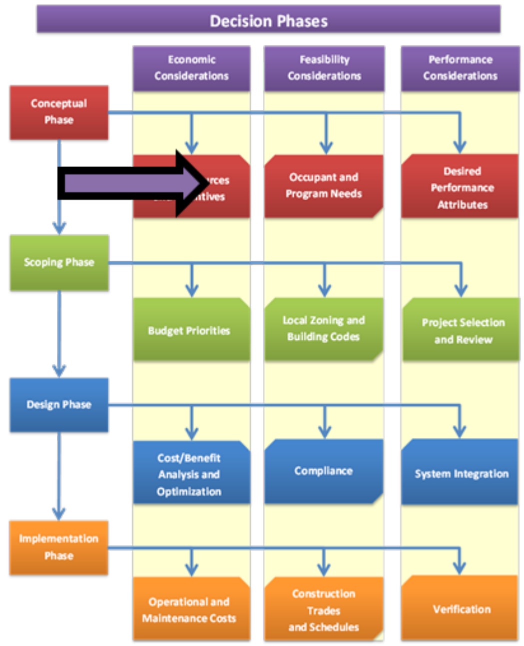
As will become evident in the discussion of different types of economic analysis, the evaluation will usually involve comparisons. You often will be comparing different technology options and weighing performance characteristics, the extent of feasibility, and economic costs and savings.

As with the overall project, economic decisionmaking on building innovations are broken down into four major project phases. These phases are intended to outline the thought process for adopting and analyzing innovations from an economic point of view, starting with deciding what is required for the project, proceeding to determining the size and extent of the project, choosing a method and conducting a thorough economic analysis, and finally considering costs that will affect the building owner or operator beyond the implementation of the innovation.

| | |
|---|---|
| **Conceptual Phase**<br>Funding Sources and Incentives | • Identify funding source and scope<br>• Idenify any requirements tied to funding |
| **Scoping Phase**<br>Budget Priorities | • Idenify Must have/want to have items and perform prioritization<br>• Plan size of project based on available budget |
| **Design Phase**<br>Cost/Benefit Analysis and Optimization | • Review cost/benefit analysis methodology options and perform analysis<br>• Perform cost optimization |
| **Implementation Phase**<br>Operational and Maintanence Costs | • Plan for continued costs based on building use<br>• Plan for maintanence of system |

## Conceptual Phase—Funding Sources and Incentives

Economic considerations in the conceptual phase mostly revolve around how the funding for the project is allocated, and what requirements are tied to that allocation. The funding source will often have specific requirements, and may be targeted for a specific purpose, or may be more general. For example, a project funded by a nonprofit elderly advocacy organization might be targeted at technologies to allow for aging in place. During the conceptual phase, clearly defining the source (or sources of funding), what that funding can be used for, and what must be achieved by the funding will help identify what innovations can be included in a project. The following chart outlines key questions that will help categorize the funding and drive characterization of the options for using the funding.




| Is the funding specific or general? | What is the funding source? | Are incentives available? | Who benefits? |
|---|---|---|---|
| Funding is tied to specific work and is limited in scope | Federal, state, or local government | Based on scope | Building owner |
| Funding is general program funding | Commercial or private interest | Multiple tiers | Occupants |
| | Nonprofit organization | Multiple sources | Advocacy organization |
| | Funding is mixed | | |

An apartment building might be renovated for specific reasons, such as improvements to outdated ventilation systems in the building for the purpose of limiting building owner liability. Conversely, a general pool of funding may be available for building improvements each year, and the building owner may look for what incentives make a specific improvement economically viable.

Conceptual Phase

### Funding Sources

A funding opportunity may often be the initial driver that moves your project into the conceptual and design phase. Agencies such as HUD or the U.S. Department of Energy (DOE) may award grants and financial support for projects that help encourage more widespread adoption of innovative technologies and energy-efficient practices. Often such awards may be tied to requirements to meet a higher standard of performance or include products that carry a particular designation—examples being ENERGY STAR, WaterSense, or Federal Energy Management Program (FEMP)-Designated certifications. It is important to identify the program or grant requirements and include them in your key analysis from the beginning, because they will need to be addressed throughout the project.

Make sure you are very familiar with the funding structure and program requirements that apply to your project. Depending on the specific program—whether it is one of HUD's many programs, a grant using a state or national program, or tax credits through the Internal Revenue Service, specific requirements will apply regarding eligible costs, allowable rents, timeline if repayment is required, and a host of other guidelines. This process can be especially complicated if you are leveraging funds through multiple sources.

### Incentives

When considering the initial cost of a technology, be sure to investigate any incentives or rebates that may be available. Innovative technologies are often given a boost by federal, state, and local governments or utility companies when these entities perceive an overall advantage to getting the technology more widely adopted in the marketplace. These incentives are certainly available with renewable technologies but may also hold true with other technologies, such as lighting, high-efficiency equipment and appliances, and energy retrofits. As they roll out new products, manufacturers may give discounted pricing on certain items. A good place to start your search for available incentives is www.dsireusa.com. DOE's website, www.energy.gov, also provides a list of available incentives for each state.

Incentive programs are widely varied of on multiple levels. For example, in the state of Maryland, Baltimore Gas and Electric (BGE) offers a variety of discounts and rebates to increase energy efficiency in homes and buildings through its Smart Energy Savers Program. If your project includes replacing and upgrading your HVAC equipment, the program offers up to $900 in rebates for ENERGY STAR-certified heating and cooling equipment. Similar incentives are available for a variety of other building components. These incentives not only help offset the initial cost of a project but also will begin paying for themselves through the savings achieved after they are installed. Remember to check with your local utility company to see what it offers.

Most HUD-subsidized housing will be eligible for weatherization assistance at low or no cost. Check out what weatherization services may be available for your property.

### Reserve Funds

Many HUD grants, mortgages, or insured funds carry a requirement that a reserve fund be established to defray future replacement costs. The building owner makes monthly contributions to the reserve fund to offset the replacement of equipment, major appliances, and other major repairs/replacements such as roofs, sewer lines, and plumbing fixtures. Minor repairs, such as interior painting, are usually not eligible for use of these funds. HUD will usually maintain control over the fund and issue approvals for withdrawal on a case-by-case basis. HUD will also make recommendations regarding the amount of monthly contribution based on the age, condition, size, and location of the building.

If you have received funding from HUD or another government agency to initiate a project, inquire about any requirements for and regulations regarding reserve funds. Even if an agency does not require that you set up a reserve fund, setting up your own fund to help cover future replacements, anticipated or not, would be an important thing to do. The reserve fund provides at least a partial safety net to respond quickly to building needs.

### The Split Incentive Problem

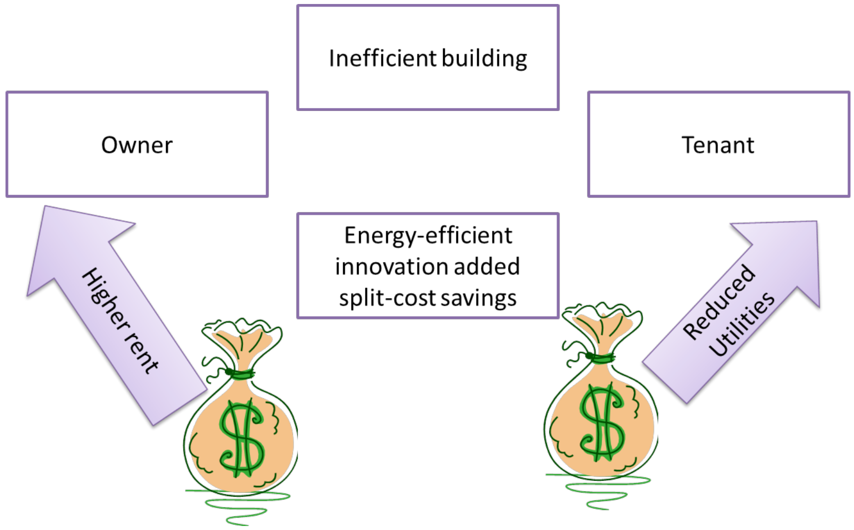
Split incentives arise when the “investor” and the “beneficiary” of the investment are split between different parties. Regarding rental housing and energy-efficient technologies, this situation can arise in a number of ways. If the building owner pays the utility expenses for the tenants, the tenant has little incentive to monitor or reduce his/her energy consumption. He/she is probably not even aware of magnitude of the energy bills for his/her apartment. The building owner has little incentive to invest in more efficient equipment, appliances, or efficiency upgrades because of the uncertainty regarding the savings he will actually realize. The tenant still controls the thermostat, lights, windows (open or closed), and so on.

When the tenant pays the utility bills, they have little incentive to make energy improvements because they do not own the building. It is likely that they will not live in the building long enough to see a return on any investment via monthly bill reductions. The building owner similarly has no incentive to upgrade aging equipment or make other energy improvements like better windows or air sealing because he/she will not recognize the direct benefit of lower monthly bills.

Types of available funding may also give rise to split incentives. Often an agency such as HUD will provide support to low and moderate-income tenants for a portion of their utility expenses. It may be a percentage or a flat amount per month. Public housing owners are also usually limited in the rents they can charge (for example, no more than X percent of monthly income). In each case, such a funding structure is likely to discourage energy conservation and energy-efficiency upgrades.

### Split Incentive Solutions

Although solving the split incentive issue has no one-size-fits-all approach, several examples provide common ways to address it. One such approach is a “green lease,” which can take a number of forms. For example, an agreement may be made between the building owner and tenant stating that the owner would make energy improvements (upgrading HVAC equipment) and the tenant would agree to operate the equipment within certain restrictions (maintaining minimum and maximum thermostat settings). For situations in which the tenant pays the utility bills, another possibility might be to permit an increase in rent based on anticipated energy savings. The owner would recoup some of his investment through higher rent, but the tenant would realize a net savings because of lower monthly bills. The increased rent is typically no more than 80 percent of the predicted savings to protect against underperformance. See http://daily.sightline.org/2009/04/27/split-incentive-stalls-energy-efficiency-in-rental-housing/.



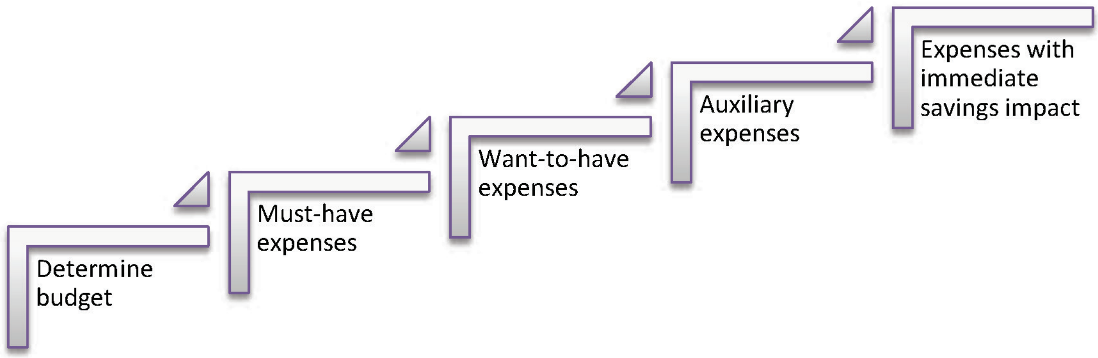

Another option might be for the owner/landlord to pay up to a certain amount for utility expenses. If a tenant exceeded that amount, they would either make up the difference or incur a penalty. Neither one of these options comes without some issues to overcome. In the case of an existing building, determining some type of initial energy use benchmark is required to determine the savings achieved. It would likely be necessary to continue to monitor energy consumption, preferably on a unit-by-unit basis.

Although these agreements are all possible ways of helping to solve the problem of split-incentives, a critical component to all of this discussion is tenant education. Tenants need to be informed on certain operational guidelines, such as setting desired maximum and minimum thermostat settings, turning out lights in unoccupied rooms, and operating windows properly. Energy monitors may be an option, but tenants will have to be shown how to use them and what the readout means. Again, some form of energy monitoring is recommended to be able to verify energy use on a per unit basis. It is also likely that building staff will need to perform periodic checks to ensure tenants are following the recommendations and to reinforce conservation measures.

Scoping Phase

## Scoping Phase—Budget Priorities

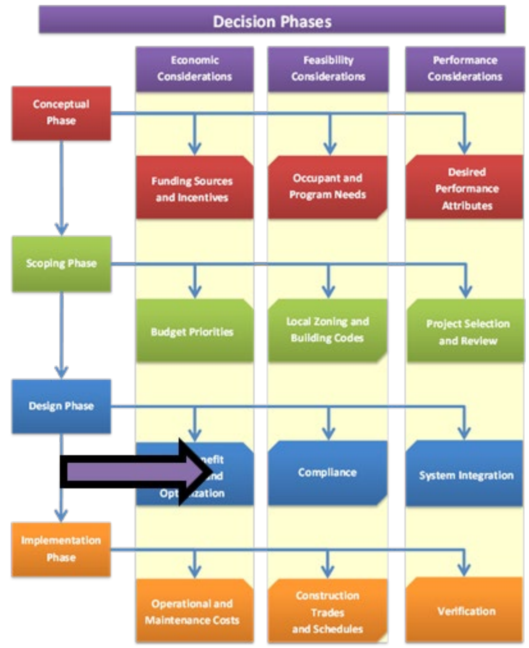
After exploring and understanding the requirements tied to the funding source for the project, the next step is to move on to the scoping phase, identifying budget priorities within the project and exploring what innovations can fit within those budget priorities. The following steps describe, at a high level, the process for determining budget priorities:



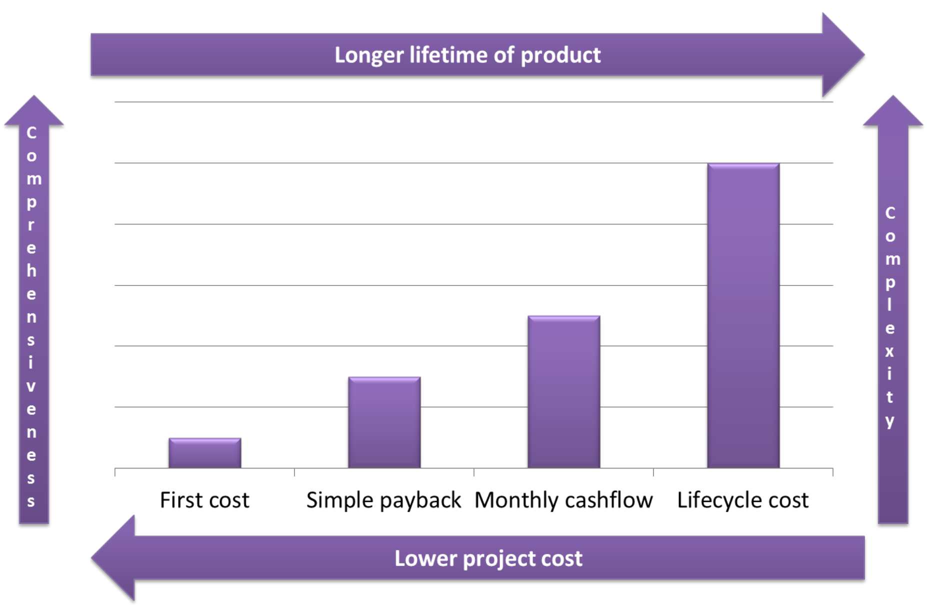

| General Steps | Example—New Building |
|---|---|
| **Step 1—**Determine general budget size and flexibility. | **Step 1—**Budget sized for construction of new three-story apartment building with 20 units and a management office. |
| **Step 2—**Identify "must-have" expenses needed to achieve goals of the project within the limitations set in the conceptual phase. | **Step 2—**All construction items required by local code and by funding source for desired size of building estimated. For example the project requires 100-percent-accessible units because of funding source requirement. |
| **Step 3—**Identify "want-to-have" items that will help make the project a success. | **Step 3—**The building manager wants to cut energy costs and therefore will use innovative construction details to limit air leakage and will add ultra-efficient HVAC units. |
| **Step 4—**Identify any auxiliary expenses that become necessary because of "must-have" or "want-to-have" expenses. | **Step 4—**Because of building air leakage reduction, increased ventilation is a necessary auxiliary cost. |
| **Step 5—**Identify which expenses will have an immediate savings impact on the budget through optimization, incentives, or other means. | **Step 5—**Lower heating and cooling needs because of reduced air leakage allows for smaller, less expensive HVAC units, creating an immediate cost benefit and allowing for budget flexibility for other building attributes. |

## Design Phase—Cost/Benefit Analysis and Optimization

Building owners, managers, and decisionmakers can use a number of different methods to perform an economic analysis that range from very simple to very complex. The type of analysis performed varies relative to the desired measure, product or system, and end use. For example, when debating between two types of air-conditioning units, a building owner could perform a simple cost-benefit analysis, such as payback period, and get a relatively useful comparison for making a decision. By contrast, if a building is in its initial design phase or undergoing an extensive retrofit, a more complex economic analysis, such as a life-cycle cost analysis or value engineering (VE) approach, would provide a more relevant measure of comparison for project alternatives. In the case of some innovations without clear paybacks, first cost, or value, may also be the main driver for decisionmaking.




Depending on the complexity necessary to perform an economic analysis, you may want to consider hiring an outside consultant to assist with this analysis. An energy analysis regarding annual energy consumption may require the use of specialized software to gain a reasonably accurate picture of the costs and savings associated with different technologies. After the building characteristics are entered, it is then fairly simple to enter different levels of insulation or equipment efficiencies and optimize first costs versus long-term savings. As demonstrated in the graphic that follows, the rigor of the economic analysis may be driven by factors such as the size of the project or the lifetime of a project. For example, an innovation that provides both high-performance insulation and structural durability might be better analyzed using a lifecycle cost. Such an innovation is likely a large project, and the innovation lifetime likely matches the life of the building. Conversely, replacing toilets with low-flow fixtures may be an easier decision. Simple payback based on reduced water use might give a less comprehensive answer than lifecycle analysis, but may be more appropriate for a low-cost project.



Design Phase

You may want to look at several different types of economic analysis. This section deals with relatively simple methods to more complex forms of analysis. Of course, keep in mind any particular economic requirements that the funding source may have, such as a payback of no more than X years. These limits may be identified in the conceptual phase.

### First Cost/Initial Cost

The first (or initial) costs include those incurred during the design and construction phase of a project. Considering first costs is the simplest form of economic analysis. Product X has a price tag $500 less than product Y. Choosing Product X on this basis would be using first cost to drive your economic decisionmaking.

For most building projects, this analysis will entail a number of components including architect/engineering fees, product/material costs, and labor/installation costs.

Although technology costs will certainly need to fit within your overall project budget, be sure to look ahead at how that technology or set of technologies may impact the total operating costs of your building over time. For instance, an energy-efficiency package to achieve 30 to 40 percent above code minimum may cost approximately 15 to 20 percent more than the standard package. Using a more complex economic analysis than first costs, however, such as considering the monthly savings, may alter the economic outlook for an innovation.

Another consideration in first cost is comparing the first cost at initial construction with a renovation cost. Keep in mind the possibility to install the capacity for a certain functionality to be achieved at a later date. For instance, although you might decide not to install grab bars in tubs now, the blocking and support can be installed inexpensively to provide easier retrofit in the future.

First cost may be the most appropriate economic analysis at times. These decisions may be driven by an immediate need to repair or replace items in a building while having limited flexibility. For example, if a water heater breaks and a building owner must restore domestic hot water service to tenants quickly, but they have a limited and inflexible budget for the remainder

***Case Studies***

## It Costs Less….for Now

In a low-income housing renovation program, the decision was made to replace an aging furnace with electric strip heat because it was the least expensive option. As it turned out, a resident could not afford the monthly electric costs associated with using the electric heat. So, she used the gas range instead. This option may or may not have been an actual cost saver for the resident, but it certainly posed health and safety concerns. In addition, the cost of the electric strip was lost because the technology was not used.

Renovations to a senior citizen housing development included replacing windows. The facility manager decided to go with the lower priced window that still had the same thermal performance as higher priced windows. The windows were so difficult to open that the residents could not operate them.

***Lesson Learned***

## The Dangers of Initial Cost

It is often tempting to let the first cost of a technology take priority in your considerations. Making a decision solely based on upfront cost, however, is not necessarily the best strategy.

of the year, they may be forced to choose a water heater based on first cost as budget permits, despite the fact that a more innovative unit might be overall more cost effective when considered on a lifecycle-cost basis. Another time might be when choosing between two objects of equal performance. For example, if a building owner has to replace a doorknob on an exterior door and must choose between two doorknobs of equal durability and functionality, making that choice based on first cost may be the most reasonable analysis.

### Simple Payback

The payback period is a useful and simple tool for evaluating the cost-benefit of a certain project and can be easily calculated and understood by most users, depending on the technology. Regarding buildings and building systems, simple payback is generally used for smaller, less costly projects (such as lighting improvements) and simple equipment comparisons (such as air-conditioner units and appliances). The simple payback method does not account for various financial parameters, such as inflation, discount rates, and net present value.

Because innovative products tend to have a higher initial cost than conventional ones, users need to be able to determine the amount of time it will take for an investment to pay for itself. Calculating the payback period for a product or building system can determine, with relative accuracy, at what point the savings accrued from an investment will cover the purchase price. Although simple payback does not account for more complex financial variables, such as inflation, discount rate, and net present value, it does provide one perspective for economic evaluation. The annual savings and life expectancy for a product or system need to be determined before the simple payback calculation can be performed. The example that follows shows how you could use a payback calculation for a lighting project.

#### Simple Payback = Initial Incremental Cost / Annual Savings

- Annual electricity savings = (daily hours x 365 days/year) x watts saved x cost
- For example, if a 100-watt incandescent bulb is replaced with a 25-watt compact fluorescent lamp (CFL) bulb, the savings would be—
- Annual electricity savings = [(6 hours/day x 365 days/year) x (100 – 25 watts)]/1,000 Wh/kWh = 164 kWh/year.
- Assuming $0.08/kWh, the annual savings realized with the CFL bulb is $13.14.

***To calculate the payback, assume that the 25-watt CFL used in this example costs $15.00 and a standard bulb costs $3.00. Using the simple payback calculation we can determine that the payback period for this product will be:***

***Simple payback = $12.00 / $13.14 = 0.9 years***

Design Phase

These simple examples leave out a lot of elements that are likely to impact your investment. Factors such the escalation rate of energy prices, the inflation rate of the value of money, and maintenance costs are not included in a simple payback calculation. It also does not take into account the nonmonetary value you receive from the more efficient technology. For certain technologies, however, this method is easy to calculate and can provide a relevant measure for economic analysis.

| Advantages | Disadvantages |
|---|---|
| Easy to calculate | Limited in its application |
| Can incorporate range of complexity depending on economic elements included, such as maintenance costs, changes in energy prices, inflation, or discount rate | Not well suited to complex measures in which costs and savings vary in magnitude and timing |
| Snapshot of cost effectiveness of technology | Very limited as a means for evaluating the total value or as a measure or technology |

### Savings-to-Investment Ratio

The Savings-to-Investment Ratio (SIR) is the inverse of simple payback; for example, it is equal to the cost of the measure(s)/the anticipated $ savings (over its useful life). In this method, the higher the number is, the more attractive the technology is. A SIR of 1.0 is the breakeven point at which the investment pays for itself through the realized savings. An SIR score of more than 1.0 will result in a positive return on your investment over time.

#### Cashflow Calculators

Many user-friendly online tools will help you perform a cashflow analysis. ENERGY STAR provides a Cashflow Opportunity Calculator that helps guide financial decisions regarding energy-efficiency projects and that addresses the "we don't have the money" objections that many organizations face. The calculator quantifies the costs associated with the project (initial investment, expected savings, interest and utility rates, and so on) and helps translate energy savings into monetary savings. In addition to providing financial information for the current project, the calculator also evaluates the potential for making additional energy-efficient improvements based on the anticipated savings.

### Monthly Cashflow

Cashflow is often preferred over simple payback for energy-efficiency investments because payback is irrelevant for projects that must be financed over time. Using monthly cashflow can better determine the value of an investment for several reasons. Oftentimes cashflows are irregular, especially in regard to energy-efficiency investments because savings can vary from month to month.

Using a monthly cashflow analysis provides a more relevant evaluation of the financial status of the building over time. Furthermore, the payback analysis does not account for cashflow beyond the investment payoff. Again, using a monthly cashflow analysis gives a more accurate picture of projected expenses and savings. A cashflow method also enables you to adjust for fluctuating interest and utility rates and include estimated maintenance costs. What can appear as a large initial investment often looks more manageable and attractive when you consider it from the more realistic perspective of actual cashflow. In its most basic form, calculating monthly cashflow involves identifying and summing all the savings and expenses associated with a particular technology or a set of technologies over a certain period of time. Consider the following real-life example of a group home in Washington, D.C.

Design Phase

## Case Study: Washington, D.C. Youth Group Home

A group home for at-risk youths, in Washington, D.C., received funding from several public and private sources to upgrade the building's aging equipment and appliances and to make other energy-efficiency improvements as the budget permitted. The 4,400 ft2 home, constructed in 1900, had six bedrooms, five bathrooms, three offices, three recreational areas, and one kitchen. The home had eight residents and as many as five staff people, some of whom prepared meals three times per day. Annual utility costs (paid by the building owner) for the all-electric home were more than $11,000.

An energy consultant modeled the building, estimating the magnitude of expected savings from the equipment and appliance replacement and prioritizing other improvements with the remaining funds. In addition to replacing two air-source heat pumps, two water heaters, and all the appliances, the modeling identified a number of other measures (air sealing, windows, lighting, and low-flow plumbing appliances) that were the most cost effective. The incremental cost for these upgrades was $22,700. (Where applicable, the incremental cost is the cost difference between minimum-efficiency equipment and ENERGY STAR or higher performing equipment.) The first year of utility bills revealed enormous energy and dollar savings—more than 36,000 kWh amounting to approximately $4,700 at $0.13/kWh. The payback period was very good, at slightly less than five years; from a monthly cashflow standpoint, however, it looked even more attractive.

If the building owner had not had funding and had needed to borrow the money to do this work, he would also have had to calculated interest costs. At an interest rate of 4.5 percent over 10 years, monthly payments would have been $235, including principal and interest. With average monthly energy savings amounting to $392, the monthly payment on the loan would have been 40 percent less than the monthly savings on the utility bill. From another perspective, before the upgrade the average monthly utility payments were $916. After completing the upgrade, the average monthly utility costs plus monthly loan and interest payments would have equaled $759 or a 17 percent reduction in the first month. Keep in mind that utility bills, and therefore, realized savings will vary from month to month, primarily depending on need for space heating or cooling. The analysis showed this decision to be the right one.

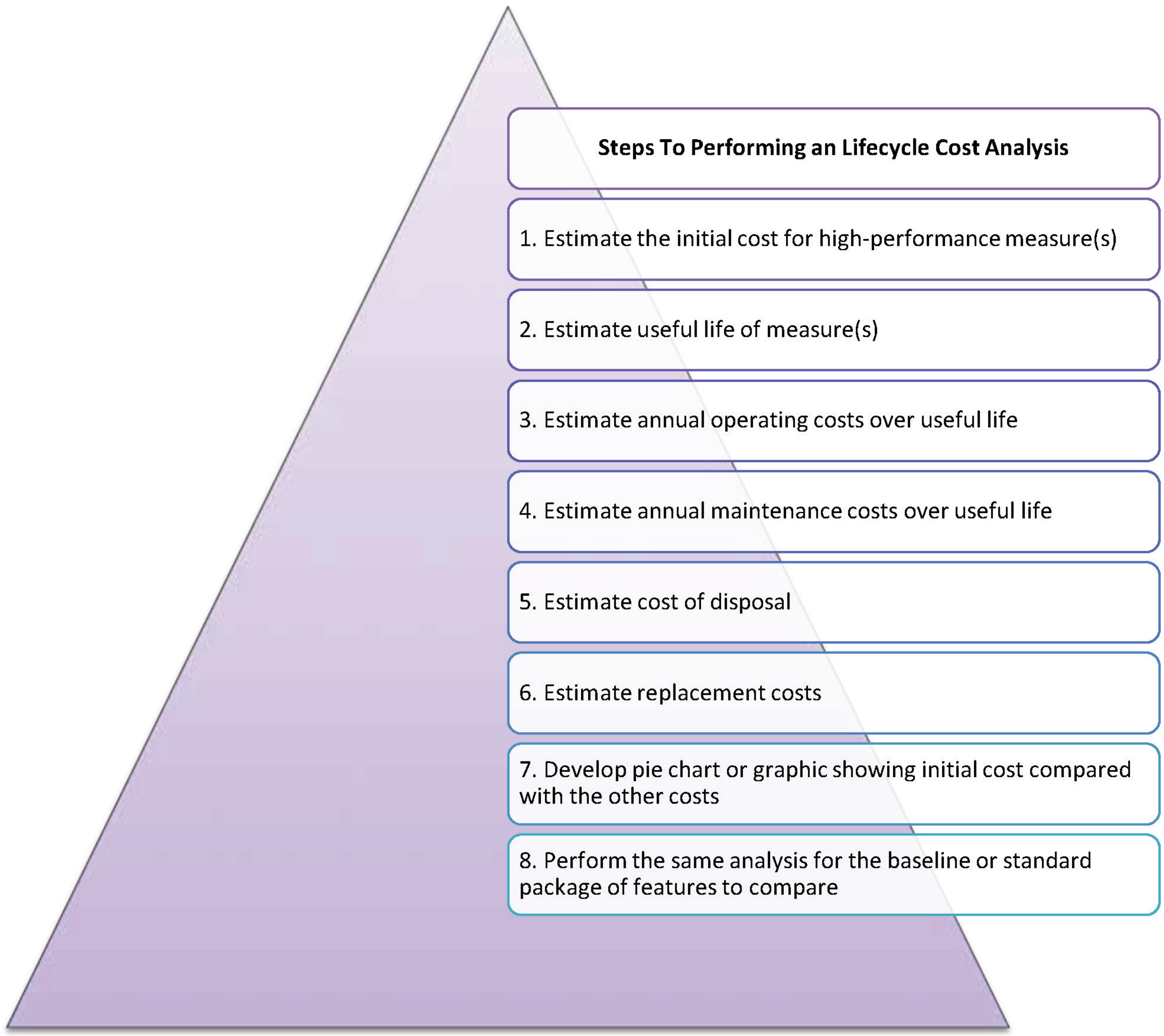
### Life-Cycle Cost Analysis

Life-cycle cost analysis (LCCA) is a more complex analysis method that incorporates a variety of economic factors. LCCA looks at the costs of a building or building system over its entire life and can be used as a tool to compare multiple options. It incorporates all the costs of owning, operating, maintaining, and disposing of the building or system in question. LCCA can be used when making small decisions, such as choosing one type of air-conditioning unit over another, or large decisions, such as determining which building design will result in higher performance and greater energy efficiency. Building or system costs generally fall into the following categories:

| | |
|---|---|
| Initial costs | • Purchase, acquisition, and construction |
| Financing costs | • Fees, interest, and insurance |
| Operating costs | • Fuel, service charges, and distribution charges |
| Maintenance costs | • Repairs—routine and breakdown |
| Replacement costs | • Parts or whole products, and installation labor |
| Residual value | • Resale value, salvage value, or disposal cost |
| Nonmonetary benefits or costs | • Environmental health |

LCCA can get very complex and require significant research, especially if you start delving into intangibles such as carbon emissions or depletion of natural resources. It is a valuable method of economic evaluation for building technologies, however, because it helps the building owner look beyond initial cost. Even if the dollar amounts attached to certain elements such as disposal costs are estimates, a basic LCCA enables you to view each type of cost as a percentage of the whole. Very often, the initial cost of a technology or whole building is a relatively small percentage of the total cost when compared with operation and maintenance costs. Products with greater durability will have a lower replacement frequency. In many cases, differences in replacement costs can outweigh differences in first cost when using LCCA.

Estimating costs associated with each phase can be helpful to gain a perspective of the total cost. Such an exercise can also be helpful in making the general decision of whether to take action. Costs associated with doing nothing may also be an option.




### Value Engineering and Optimization

In addition to the cost/benefit analysis methods discussed previously, that works well in construction for both controlling costs and optimizing performance is value engineering. VE is a systematic and structured approach designed to optimize value (initial value and long-term investment) and improve projects, products, and processes. VE can be used with any economic analysis method listed previously; it has been used in the construction industry for many years and has proven to be an effective method for evaluating and improving economic costs and building performance. The VE approach analyzes the requirements of a project to achieve the desired function at the lowest total cost over the lifetime of the project. Identifying several approaches and analyzing them based on identified criteria relevant to the project often achieves tremendous savings, in initial and life-cycle costs.

The value of a particular technology or measure may be either quantitative or qualitative, or a combination of both. For instance, energy-efficiency measures will have a quantifiable value in terms of operating cost savings, but will also have qualitative value in terms of greater comfort, reduced potential for damage because of moisture or condensation issues (which also carries quantitative effects in terms of repair), and improved indoor air quality. For energy efficiency, quantitative value can be either direct and immediate (cost savings), or indirect and long term. Examples of the latter are the resale value of the building, including its desirability to potential future buyers and the hedge it provides against rising utility rates. Both of these qualitative values are hard to predict and make it difficult to define the precise economic value. When considering innovative technologies, however, be sure to think beyond the time you expect to own the building; value can be realized even if you do not realize it personally.

Some measures may provide solely qualitative benefits that you deem important to provide improved livability and amenities for your anticipated residents. For instance, it may be very important to you to provide both indoor and outdoor gathering spaces so that residents can socialize. Whole building or apartment mechanical ventilation may hold particular value for occupants that may be more prone to smoking in their dwelling units.

VE should not be thought of as merely a cost-cutting endeavor. The goal of performing VE analyses is to ensure that the decision you make is the most efficient and that alternative ways of attaining your desired goals or functionality at a lower cost are not always viable. Using VE, you may be able to include additional technologies or amenities through the savings you achieve in another area.

Economic considerations will change, depending on the context of your project. For example, think about the ways in which you place value on measures that improve energy efficiency, improve the security of your building and occupants, or reduce vulnerability to natural disasters. Each measure will have quantitative and qualitative elements. The importance of an investment in security measures, such as lighting, locks, and cameras, may far outweigh savings related to energy efficiency. Regarding security and natural disasters, the risk of loss of financial property or human life is likely to hold greater weight compared with the initial monetary investment in the measure.

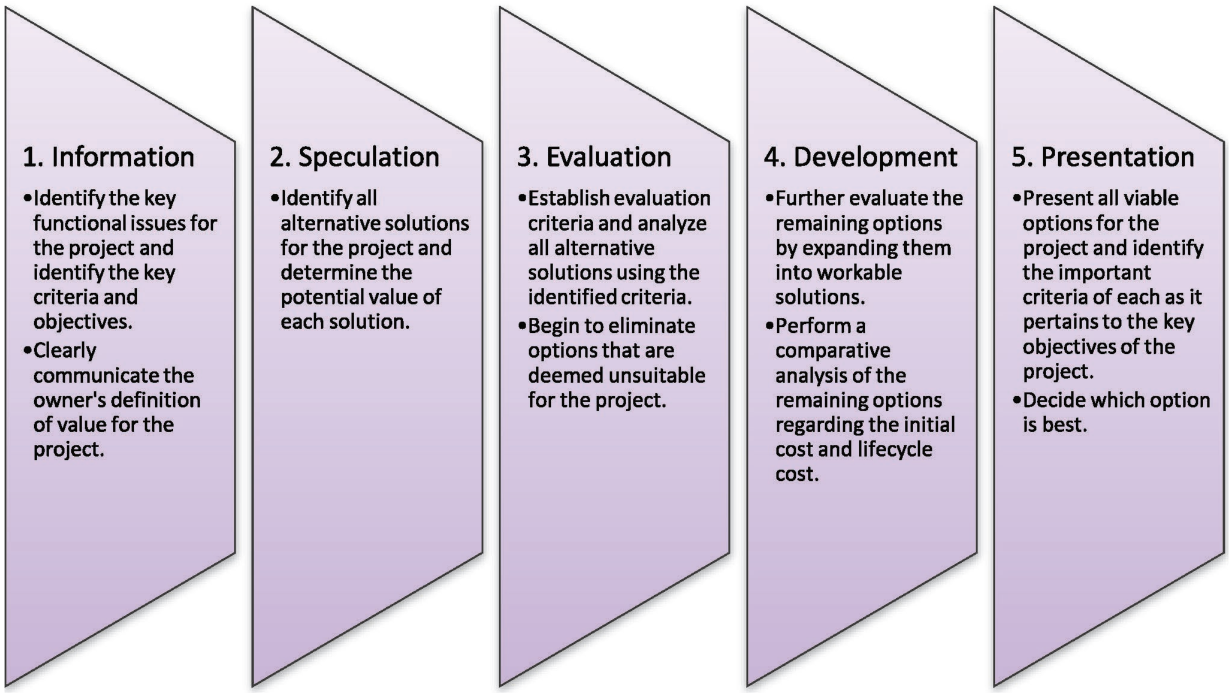
Including VE analysis during the initial conceptual phase may be beneficial. The building owner or manager is in the best position to identify the needs or required functionality for your project. If you are renovating or adding on to an existing building, this process may start by identifying what is not working.

***Some initial questions to ask about the requirements of your project include—***

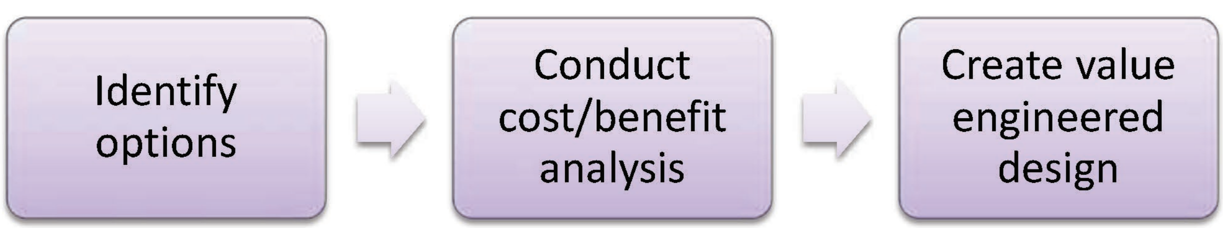
1. What are the inadequacies of your current building (or of other buildings previously owned)?
2. What systems do you want to improve/upgrade?
3. What types of functionality do you need, given the nature of the residents? (For example, space that is compliant with the Americans with Disabilities Act, or ADA; indoor community space; outdoor community space; and central food-preparation and dining areas.)
4. Which do you prefer—central or distributed utilities? Is one more feasible than the other

Incorporating a VE approach at the design or conceptual phase of a project generally involves the use of a VE workshop. The workshop provides an opportunity to bring the design team and the building owner together to establish the scope of the project. This workshop can help identify the owner's definition of value relating to the project, all potential design solutions, cost estimating, scheduling, and approach.

**A formal VE approach has five key steps:**




Although your design team may certainly perform VE as part of the design process, it can be beneficial to have an additional VE effort beyond only your architect and engineer. Professional VE consultants are often hired for very large and complex construction projects, in most cases, they are not likely to be needed or realistic for public housing projects. Assemble the varied expertise on your team to review the design and specifications as they are developed. This workshop is not intended to be a criticism of the design, but rather an effort for those with experience in a particular area to offer informed suggestions for improvement in function or reduction in cost. Keep in mind that VE is not simply cost cutting, but rather an effort to obtain equal or greater value for equivalent or reduced dollars spent.



## Implementation Phase—Operational and Maintenance Costs

After installing a building innovation or constructing a building using innovative technologies, other economic considerations appear as these innovations are used. In the implementation phase of an innovation, economic issues can have a major impact on whether adopting the innovation was a good choice. The major economic considerations during the implementation phase are—


- Financing and interest costs.
- Operating costs.
- Maintenance costs.
- Replacement costs.

For the economic analysis during the design phase, you may have chosen to simply analyze the first costs for your decisionmaking process. If so, you should still be aware of the costs you will encounter during the implementation phase. If the design phase included any payback or lifecycle cost analyses, it is likely you have already considered at least some of these costs.

### Financing and Interest Costs

For any money that you plan to borrow, you must include the associated financing costs. In addition to interest rates, the cost may include application fees, credit check fees, and points paid. Interest is the largest piece because it adds up to a significant amount over 30 years. For instance, a 30-year loan for $400,000 at a 4.5-percent interest rate will accrue total interest payments of nearly $330,000, approaching the amount you borrowed.

Depending on the amount of money you need to borrow and what you need it for, multiple different types of loan packages may be available. Exactly as you are likely to obtain multiple bids or proposals from several general contractors, it is wise to talk with several banks or mortgage institutions to learn about the different types of loan packages they can offer. They will be glad to calculate the costs associated with each over the life of the loan. Be sure to investigate any penalties you might incur, such as fees for late payments or early loan payoff.

Online mortgage calculators are readily available, designed to be easy to use and comprehend. Analysis on financing and interest costs is taken into account for any lifecycle cost analysis.

### Operating Costs

Commonly considered operating costs are the utility costs associated with operating your building or perhaps the actual technology. For instance, the insulation, windows, and HVAC equipment will all affect the heating and cooling costs for your building. These costs are not at all insignificant as many of these systems will be around for a long time. For example, if the building is still functional the insulation and windows may be functional; and the HVAC equipment is likely to have a 15- to 20-year lifespan. So, as you consider annual operating cost, be sure to multiply it by the expected life of the technology you are considering.

For all public and assisted housing, especially multifamily buildings, safety and security are concerns that can impact operating costs. For instance, both indoor and outdoor lighting must be designed to ensure the safety of the residents and deter unwanted intruders. To avoid high electrical costs associated with lighting in common areas, corridors, and stairways it may be a wise economic decision to not only invest in more efficient lighting technologies, such as LEDs (light emitting diodes), but also advanced innovative control systems. Such controls can range from motion sensors and astronomical time clocks to Wi-Fi automation that enables you to program and control all the lighting for your building from a central location or remotely. Such an investment may mean greater savings in operating your building over many years, thereby offsetting the higher initial cost. The safety and security of the residents and the actual building are enhanced as well.

Nonenergy operating should also be considered. An example of this approach would be a security system that requires remote monitoring. The actual system has an initial cost, but it also includes a monthly expense to keep the technology effective.

As you consider operating costs, be sure to investigate different metering strategies and time-of-use plans offered by your utility. Such plans may offer economic advantages and warrant consideration of slightly different types or sizes of equipment to find the best-fit solution for your project.

### Maintenance/Repair Costs

Maintenance costs required for the technology may be a little bit difficult to accurately predict, but these costs is certainly closely connected to your *performance considerations*. Talking with others who have used the technology is a good way to gauge the amount and type of maintenance it may require and understand how reliable it is. This assessment is also a good time to obtain input from your maintenance staff. Although they may not have experience with the exact technology, they may be familiar with its internal components, motors, or other similar technologies.

***Case Study***

## Can You Fix It?

A builder constructing a new building decided on an innovative, energy-efficient water heater for his project. Economic analysis showed the energy savings from the water heater would pay for the increased cost of the heater over a more conventional, inefficient unit.

Several years later, the unit needed a repair, but the building owner could not find any local contractors who would work on this particular unit. The cost of having a nonlocal company complete the repair was prohibitive.

The availability of a workforce and the ability to maintain technology often factors into the overall economic impact of an innovation. Although the initial assessment of energy savings as an economic decision point was a good approach, the builder failed to account for higher future costs resulting from the lack of local qualified repair contractors.

***Lesson Learned***

## Consider All Costs

Often an energy-saving innovation is cost effective when considered over the life of the technology, but other factors, such as maintenance, should not be overlooked.

### Replacement Costs

Again, closely tied to performance, the expected life of a technology is an important economic consideration. This indicator will estimate how often you will have to replace it. Light bulbs are a good example. An incandescent bulb has a life expectancy of about 1,200 hours; a CFL bulb, on average has a life expectancy of approximately 10,000 hours, although an LED is expected to have a useful life of about 50,000 hours. So, for any technology, you should also consider how often it will need to be replaced. Be sure to include the labor to replace it in addition to the cost of the product.

The durability of a product or technology will impact future costs for both replacement and maintenance. Therefore, as you select technologies to include in your project, always consider how well they will hold up under the expected wear and tear they will get. For example, more durable flooring materials will not only last longer than cheaper alternatives, but they also may not require as much maintenance, such as waxing or refinishing. The countertop is another product for which you may want to consider higher quality materials that will last longer than the least cost option. More durable materials and equipment may reduce the amount you need to set aside in your reserve fund each year.

### Resale Value

Resale value is another economic consideration that you may want to take into account even in a building that you plan to own for many years. Although it may not be a deciding factor in your selection of technologies or products, it would be important to keep this value in mind should you sell the building sooner than initially anticipated. If this property is a rental, many of the same attributes that make a building or a site more attractive to a potential buyer also make it more desirable to a renter.

### Indirect Costs or Savings

Indirect costs and savings are those that are not immediately attributed to the actual technology but are, in fact, related in some manner. One example of indirect savings may be reduced fire hazard insurance rates when monitored security systems are added. An example of an indirect cost might be the need to install carbon monoxide alarms when switching from an electric to a gas heating system. Another example of indirect savings might be made in reduced tenant turnover because of tenants' higher levels of satisfaction with a dwelling unit, whether because of better comfort, a more secure facility, more durable fixtures, or any other benefit resulting from an innovation.

# Chapter 3—Feasibility Considerations

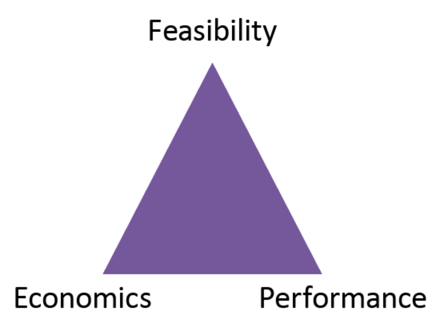
## Feasibility Top 5

1. Does the innovation meet the occupant's needs?
2. What are you allowed to do?
3. Have you talked to the building official
4. Is the innovation right for your location?
5. Can the innovation be maintained?

## Introduction

Feasibility considerations regarding viable building systems, assemblies, or equipment for your project often may be automatic considerations that you take into account nearly without realizing it. For instance, if you have secured a grant to upgrade space-conditioning equipment in your multifamily building and have no other source of funding, it may not be feasible for you to think about a more substantial retrofit of the building envelope. Likewise, a gut rehab may not be viable if tenants are to remain in their apartments during construction. So, in many ways, the feasibility of certain improvements or technologies may be "givens" that are largely unconscious decisions.

So, why do we raise feasibility to a higher, intentional level of consideration in this guide? Although we discuss these reasons in more detail in a subsequent section, several reasons come to mind right away.




- A technology that ranks high in the performance and cost areas is not likely to be a good choice if it falls down with respect to one or more of the feasibility considerations. If a technology is simply impractical, it is not worth spending a lot of time researching pros and cons. You might think of *economics, performance, and feasibility* as the three legs of a stool. Without three solid legs, the stool will not stand.
- A second (and somewhat opposite) reason is so you do not overlook opportunities that might add value to your project. For instance, although you may not be able to open up walls in individual apartments as part of an energy retrofit, you might be able to blow insulation into wall cavities from the exterior. Or, perhaps, add insulation in the attic. Within the context of replacing heating and cooling equipment, it may be advantageous to consider a different type of equipment altogether rather than simply replace in kind. For example, a dual-fuel heat pump may make sense from a performance and economic standpoint rather than a stand-alone furnace and air-conditioner. As you can see, similar to performance and economic considerations, feasibility considerations are also closely linked with the other sections.

**Conceptual Phase**
Occupant and Program Needs

- What innovations do occupants need?
- Does your organization or program have specific limits or requirements?

**Scoping Phase**
Local Zoning and Building Codes

- Explore zoning and code issues up front to flag obstacles.
- Be aware of local regulations that may limit innovations.

**Design Phase**
Compliance

- Explore product certification and compliance reports.
- Confirm overall project code compliance.

**Implementation Phase**
Construction Trades and Schedules

- Consider how scheduling and sequencing affect adoption of innovation.
- Explore the availability of skilled maintanence staff for innovation.



## Conceptual Phase—Occupant and Program Needs


From a feasibility perspective, the conceptual phase is the step in which the project is focused based on occupants' needs and the goals of the individual or organization that owns or operates the property. A number of catalysts may drive a project or the consideration of an innovation. Clearly understanding and identifying these drivers will help in addressing feasibility in the conceptual phase of the project. A few situations that may create the need for a project include—

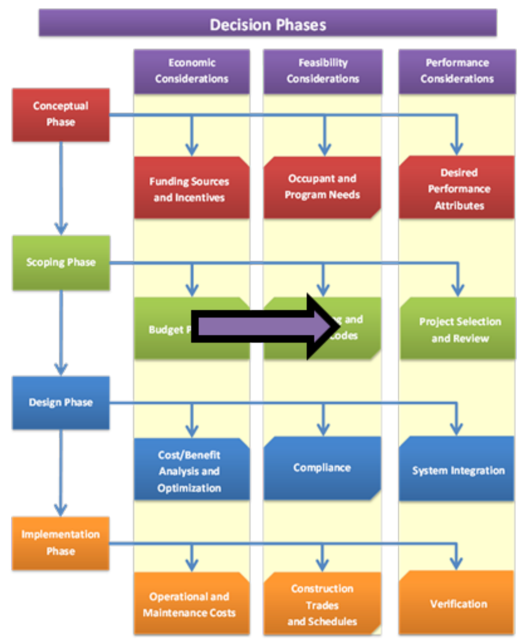
- Recognized need.
- New requirements.
- Failure or substandard performance.
- Funding opportunity.
- Site opportunity.
- Combination of all on this list.

In addition, a federally funded grant, for example), may have specific requirements tied to the work that has to be done with that funding. Knowing these program requirements will help direct the project.

A recognized need might be the need for more space because of a tenant waiting list. This need might drive a project that includes adding space to a building. A housing authority may decide that all their buildings must provide security systems, driving the implementation of new security innovations. A federal grant might be offered for converting bathroom fixtures to water efficient units. All these different drivers will affect what needs to be considered in a project.

During the conceptual phase, it is necessary to clearly lay out the needs and goals for the community or project and for the developer and funding agency. This discussion will help make decisions regarding site selection (if one has not already been identified), new construction, renovation of an existing building, or alteration of your own facility. At this phase, ask the following questions :

- What is the expected occupancy or use of the community/building? (For example, housing for seniors, affordable housing for families, and short-term housing for at-risk individuals.)
- What are the needs of the expected occupancy or use? (For example, proximity to public transportation, health care, schools, food shopping, security, and recreation.)
- Is a funding source in place? If yes, what are the associated requirements for the project location, site, or general building type?
- Does the project consist of multiple single-family buildings or one or more multifamily buildings?
- Does the project require an expanded environmental review (State Environmental Quality Review, or SEQR)?
- Are any variances or special permits required?
- Are the required utilities available?






## Scoping Phase—Local Zoning and Building Codes

Any building project needs to consider a variety of regulations, and interacting with these requirements early in the process will help avoid any feasibility obstacles. The following example depicts situations in which a project may need to consider different regulations, depending on the scope of your project.

| Zoning and Planning Regulations | Building Code | Program Requirements |
| --- | --- | --- |
| New construction ✓ | New construction ✓ | New construction ✓ |
| Rennovation or equipment change *Unlikely* | Rennovation or equipment change *Likely* | Rennovation or equipment change ✓ |
| Repurposing/change in occupancy ✓ | Repurposing/change in occupancy ✓ | Repurposing/change in occupancy ✓ |

During the conceptual phase, if you have a site in mind or in hand, it is not too early to discuss your project with the local officials or to ensure that it meets Local zoning ordinances and comprehensive plans, if any are in place. Make it a point to meet with the following boards or officials.

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### *Planning Board*

Most towns, cities, and even villages will have local planning boards. The primary function of the planning board is to recommend and oversee land use ordinances and zoning. Although it is the role of the legislative body, for instance a town council, to actually adopt zoning laws, the planning board makes recommendations, participates in developing comprehensive plans, reviews subdivisions and large development projects for compliance with existing ordinances, and oversees the SEQR process or environmental impact assessment.

### *Zoning Ordinances and Zoning Board of Appeals*

Zoning ordinances are developed at the local level (city, town, or village) and consist of written regulations and laws that define how property in specific geographic areas can be used. Zoning ordinances specify whether zones can be used for residential, commercial, industrial, or agricultural purposes, and they may also regulate lot size, building setback, density, and the height of structures. Local zoning ordinances also often cover issues such as required off-street parking, signage, grounds maintenance, trash removal, historic districts, and more. As individual or neighborhood-based renewable energy systems are becoming more prevalent, many jurisdictions are adding ordinances regarding size and placement of these systems. Some land use regulations may, either intentionally or unintentionally, place restrictions on wind-power generation, the use and storage of propane, onsite power generation for combined heat and power or solar electric systems that sell electricity back to the utility company, and the use of electric heat. In addition, the local zoning ordinance will lay out required procedures for handling infractions, granting variances, and hearing appeals.

> Because so many varied local ordinances might impact your project, it is important to check with zoning and building officials early in the conceptual phase.

### *Zoning Official*

If a jurisdiction has a zoning ordinance in place, the city, town, or village board will appoint a zoning official to handle enforcement. In many cases, the building code official also fills the role of zoning official. For smaller and straightforward construction projects, such as a single-family home or even a single multifamily building, the zoning official will determine whether the proposed project complies with local ordinances, such as occupancy, use, setbacks, and so on. For subdivisions and other large projects, the project must be presented to the planning board. Such projects often trigger a SEQR or environmental impact assessment. Assuming no significant environmental issues exist, the SEQR is usually not lengthy but does require the applicant to file an environmental assessment form and often a draft environmental impact statement. After the public notice is made about the project, a 30-day (usually) public comment period ensues. If objections are raised, the planning board is likely to hold a public hearing before making its final decision regarding approval of the project. You can obtain a copy of the local zoning ordinance on your municipality's website or through your local building department.

Scoping Phase

### *Potential Impacts of Zoning Ordinances on Your Project*

Just as you want to make sure that all aspects of your project are compliant with the relevant building code, you also want to be sure you are in compliance with local zoning ordinances. Your design professional will usually take primary responsibility for this step, but depending on the characteristics of your project and the design development process, you, or your representative, may want to discuss your plans with the local zoning official or building code official and your own legal counsel early in the conceptual phase. It will nearly always be necessary to obtain formal site plan approval and it is wise to do this step before the details of the building/project design get too far along. For instance, a few examples of how a local zoning ordinance might affect your building design or even your entire project concept include—

- Setbacks from the lot lines affect the size or shape of the building.
- Space for offstreet parking must be adequate for proposed number of units/occupants.
- Proposed occupancy or use may require a variance.
- Project may be in a wetlands or 100-year flood zone.
- Building footprint and required green space.

### *What if your project does not comply with all local ordinances?*

A process for appeal is used if a project is not in compliance with a particular local ordinance. It is likely that a jurisdiction will have appointed a zoning board of appeals to hear such cases and grant variances. The criteria for granting a variance are established by state law and typically revolve around the following attributes:

- Undue hardship as a result of the unique characteristics of the property; for example, the narrowness of the lot size and the hardship has not been caused by the appellant.
- Physical conditions of the property prevent reasonable use of the property.

***Case Study***

## I Have Never Seen That Before!

A housing authority's staff members were managing construction of a new multifamily housing unit. Because of a cost issue, the standard piping materials used in the authorities' plumbing specifications would not work for the project. A local supplier proposed using an innovative new piping material to save on cost and improve connection durability.

Staff approached the local building department to ask about code compliance, but the product was not currently permitted by code. The housing authority submitted an application to the state plumbing review board for acceptance of this material.

After gaining approval, the housing authority was able to use the new piping material, realize cost savings, and improve the durability of the project, reducing future maintenance costs.

***Lesson Learned***

## Know the Process

By understanding how to gain approval for new materials through the code process, the Housing Authority was able to use a material that met their performance and economic needs.

Scoping Phase

- Variance will not affect the essential character of the neighborhood and will not pose a danger to the public welfare.
- Variance is the minimum that can be done to afford relief and represents the least modification of the local law.
- Check with your zoning official regarding the timeline prescribed for taking a project through the appeals process.

After taking high-level feasibility considerations into account and identifying general needs and goals for the project, you can begin to take the next step in defining your project. With no major roadblocks affecting the overall feasibility of the project, you can lay out more specific characteristics of the project. During the scoping phase, you will identify any constraints or prerequisites that may dictate aspects of the design of the building(s). Examples of constraints may be the size and shape of the lot, the anticipated occupancy, the need for accessibility features or elevators, or required architectural features if these constraints have been put in place at the local level. Some scoping considerations that apply to nearly every project are discussed in the following section.

### *Is the project new construction or renovation of an existing building?*

Example: Existing building:

- Is the project a significant renovation, an addition, a repair, or a replacement?
    - *Importance: Will trigger applicable code provisions.*
- Will the project entail a change of use or occupancy?
    - *Importance: Will trigger applicable code provisions; may require a variance.*
- Will the building be occupied during construction or is swing space available to house current residents?
    - *Importance: Will influence the type of work that may be feasible.*

***Case Study***

## You Do Not Want to Open That.

A multifamily building was undergoing a deep energy retrofit to try to save the building owner and tenants money on energy costs. Multiple energy-savings measures were considered for the project including updating HVAC equipment, adding insulation, upgrading windows and sealing air leaks.

During the planning process, it was discovered that the building had aluminum wiring. A discussion with the local building department determined that uncovering a significant amount of this wiring would require a complete rewiring of the building—well beyond the budget of the project. Because of the desire to leave the existing wiring in place, wall insulation was eliminated as a possible energy-saving measure. The budget was focused on other items, and the building was still able to achieve more than 40 percent reduction in energy use, despite limited options.

***Lesson Learned***

## Talk to the Building Department

Early communication with the local building department identified code issues that would have added prohibitive cost to the project depending on retrofit choices. It is vital to identify code issues early for successful planning of any project.

- Are related improvements required that may enhance the planned scope or simply make sense to make at the same time?
    - *Examples: air sealing, duct sealing, replacing windows, upgrading interior and exterior lighting and controls, or replacing existing thermostats with programmable thermostats.*

***What is the approximate project budget?***

For obvious reasons, the size of the budget that is available will influence the scope of the scope of the improvements to be included in a renovation project or the size of an addition or new construction project. It may define the types of technologies that are reasonable for you to consider. For more discussion of budgetary considerations in the scoping phase, see the economic considerations chapter.

***Do any site conditions constrain the project?***

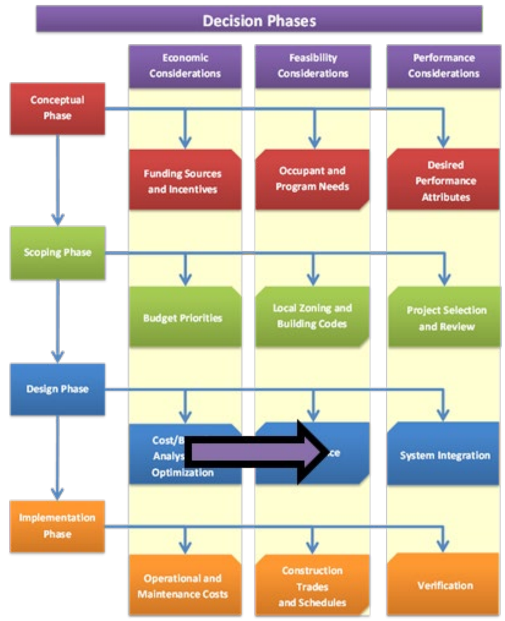
Consideration of site conditions will always come into play as you are planning and scoping your project. Such conditions may pertain to the lot, such as lot size or soil type, or they may pertain to the location of the site, such as geographic region or, more specifically, the surrounding neighborhood. The geographic region may warrant mitigation of risk, such as hurricane or earthquake resistance. The characteristics of the neighborhood may also influence project scope and design—for instance, if the building is in a historic district where certain features must be maintained or in an urban area that requires increased soundproofing or security.

**During the scoping phase, visit the local building department and speak with the building code official regarding building codes that are in place for the jurisdiction where your project is located—especially if you are aware of some constraints cited here.**

***Does the site have any issues with hazardous materials; for example, with brownfield contaminants, lead, or asbestos?***

Environmental concerns such as these will have a significant influence on the measures that must be included in your project and on your project budget. Regulations regarding remediation, removal, or disposal are developed at the federal level and typically enforced at the state level by an agency such as a department of environmental conservation. In some cases, local governments come into play by specific land use laws included in their zoning ordinances.

## Design Phase—Compliance




During this phase, the building design and technologies to be included are developed and specified. Depending on the size of the project, one or more design professionals are likely to be on board and take the lead in this phase.

As the building design takes shape and technologies are being identified and selected, in this phase you are likely to be considering performance, economics, and feasibility issues concurrently. Assuming that you have ensured or are in the process of ensuring that your project complies with all local zoning ordinances, the design phase is the time during which the most considerations related to elements of feasibility will come into play. As you review different technologies for inclusion in your project, evaluate them in light of the following questions:

**Code Compliance**

- Is the product allowed by code?
- Does my design incorporate the product as code requires?
- Does the overall project comply with code?
- Is there testing or an evaluation report?

**Climate Appropriateness**

- Is the product's effectiveness affected by climate?
- Do temperature or weather concerns affect the product?
- Do moisture concerns affect the product?

**Regional Appropriateness**

- Is the product's effectiveness impacted by disaster mitigation needs?
- Is the product's effectiveness impacted by other natural factors (e.g., pest risk factors)?
- Is use of the product regionally acceptable?

### Code Compliance

#### *Background on Building Codes*

Although the United States has no official national building code, the building codes developed and maintained by the International Code Council (ICC) are widely adopted by states and municipalities across the country. The ICC, a member organization of building code officials and other local government representatives, develops, publishes, and maintains building codes for residential buildings, commercial buildings, and energy efficiency. Two other national organizations—the International Association of Plumbing and Mechanical Officials and the National Fire Protection Association—develop the Plumbing Code, Mechanical Code, and National Electric Code. Collectively, these codes are often referred to as "the I-Codes." As they adopt one or more of the I-Codes, many state and local jurisdictions include amendments to better fit their locale or region.

Design Phase

Depending on the innovation, multiple codes may apply when determining compliance. A few codes, however, are likely to be more relevant as a resource than others. A locally adopted building code provides a way for builders, contractors, and building owners to evaluate whether a product or technology is permitted according to building regulations.

In addition, the code may provide information about applications in which certain product classes are required rather than others. For example, a certain piping material may be permitted for above-grade plumbing supply lines, but it is not permitted for underground use. This type of guidance will help in determining a product's feasibility if a jurisdiction has adopted one or more of the ICC codes.

If a building code is in place in your jurisdiction, keep in mind that all new construction projects must meet this code at a minimum. Additions to existing buildings must also meet the local code, although the existing portion of the entire building is not required to be brought up to these standards as long as it was legal when it was constructed. Likewise, renovations to existing buildings do not always need to meet the current code. If the occupancy or use of an existing building will change, however, the building must meet code as if it were new construction. *Check with your local code official about these specifics related to compliance.*

**Although your architect or contractor may know whether a particular product or technology is code compliant, it is still important to verify with the local building official regarding who has the final word.**

***Example:*** **In a single-family home, if you open the exterior walls, the International Energy Conservation Code requires that you fill the cavity with insulation, although not necessarily to the level required by code for new buildings. When replacing mechanical equipment or water heating equipment, however, you must meet minimum code requirements for that new equipment.**

Design Phase

*Primary I-Codes of Likely Interest*

**International Existing Building Code (IEBC)**

Applicability

- Changes to all existing buildings except one- and two-family dwellings and townhomes with three stories or less

Scope

- Repairs, alterations, changes of occupancy, additions, and relocation

What is covered?

- Level 1 Alteration: Replacement or recovering exsisting materials, equipment, or fixtures with those that serve the same purpose
- Level 2 Alteration: Reconfiguration/extension of space or system, addition or elimination of door or window, installation of additional equipment
- Level 3 Alteration: Work area exceeds 50% of total area of the building

**International Residential Code (IRC)**

Applicability

- Single-family homes ≤ three stories
- Two-family homes ≤ 3 stories
- Townhomes ≤ 3 stories

Scope

- New construction, alterations, relocation, replacement, repair, equipment, use and occupancy, and demolition

What is covered?

- Structural, fire safety, interior/exterior finishes, mechanical, water heating, electrical, plumbing, energy, solar systems, and swimming pools

**International Building Code (IBC)**

Applicability

- Residential buildings > three stories
- Commercial buildings (multiple types)

Scope

- New construction, alterations, relocation, replacement, repairs, equipment, use and occupancy, location, maintenance, and demolition

What is covered?

- Structural, fire safety, interior/exterior finishes, mechanical, water heating, electrical, plumbing, energy, accessibility, elevators, solar systems, and swimming pools

**International Energy Conservation Code (IECC)**

Applicability

- Residential buildings
- Commercial buildings

Scope

- New construction, additions, alterations, renovations, and repairs
- Exempt: historic buildings listed on national register designated as historic buildings at the state or local level

What is covered?

- Insulation requirements, windows, HVAC and water heating equipment, envelope and duct leakage, electrical power and lighting systems, and swimming pools

View the electronic versions of the I-codes made available by the ICC.

**Building Code Examples**

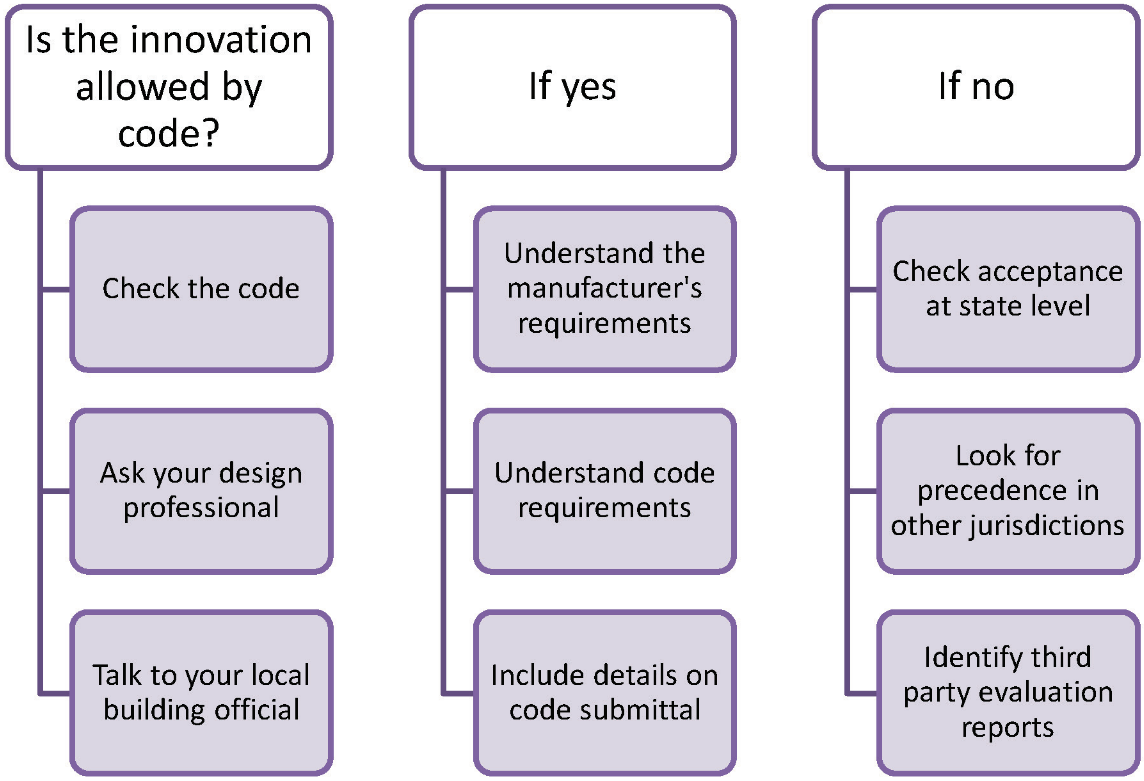
- A new three-story apartment building must comply with the IBC for structural, fire safety, mechanical, plumbing, and electrical requirements.
- The same three-story apartment building must comply with the residential requirements of the IECC.
- A new four-story apartment building must comply with the IBC and the commercial requirements of the IECC.
- A new single-family home must comply with the IRC and the residential requirements of the IECC

**To find out what codes are applicable to your project:**

- Contact the local building department where your project is located.
- Check with your design professional or contractor.
- Check the website of the city, town, village where your project is located.

Although you do not need to have the same depth and breadth of understanding of the applicable building codes as your design professional, some familiarity with basic code requirements or those that are most relevant can benefit your project. Code requirements, whether pertaining to structural elements, energy efficiency, fire safety, or local risks are the minimum that can be done. In many cases, you may decide to go beyond the minimum to enhance the performance of your building. For instance, in a hurricane prone region, you may want to increase the strength of structural connections or raise the building higher off the ground, or use more durable and weather resistant materials than those required by code. In nearly any region of the country, you may decide to increase insulation levels or use higher performing windows or more efficient HVAC equipment to lower operating costs and increase comfort over the time you own the building.

***Are the technologies/products/materials under consideration code compliant?***




It may not always be clear if an innovative product you want to use is permitted by code. You may have a good grasp of the code or be able to find the answer through diligent research. You may also need to consult a design professional, however. Either way, it is important to touch base with your local building official to see how the jurisdiction views the product, or if they have even heard of it. If the product is already permitted by code, your job is not yet done. To achieve smooth integration of the product, make sure you understand requirements in the code and the manufacturer's installation instructions. If the product is not currently permitted by code, you are not out of options. You may be able to point your local building official to a precedent at either the state level or in another jurisdiction. In addition, you may need to follow a process to gain acceptance for the product, such as submitting a code evaluation report on the product from an independent third party.

### *Code Evaluation Services*

A number of independent third party companies evaluate products and materials for compliance with the major building codes. Developers and manufacturers of innovative products and materials will often have their products evaluated to achieve ready-acceptance by local building officials. This step can be significant in getting their products into the marketplace and increasing their use.

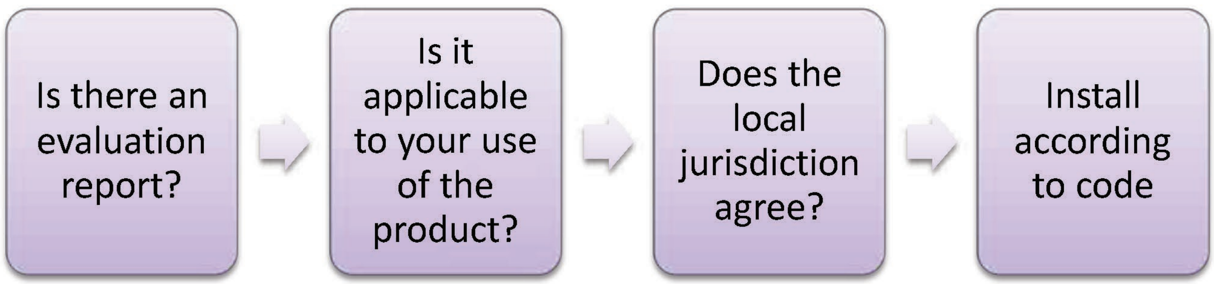
Evaluations for code compliance will undoubtedly entail requirements for testing according to relevant test standards. Usually the evaluation certificate will indicate the particular standards to which the product was tested.

Keep in mind that a successful evaluation for compliance with a particular building code paves the way only for its being allowed according to that code. Full code compliance will also entail proper application and installation. A product may have a code evaluation report demonstrating compliance with certain provisions, but the product may not be appropriate for the specific application you are considering.

How to determine if a product has had such an evaluation:

- Check the product literature and the manufacturer's website.
- Check the websites of the code evaluation services listed in the appendix. An area of the website may list all the products they have evaluated.

Also keep in mind that compliance with one or more of the I-Codes does not mean that the product complies with your local code or that your code official will adopt it without question.




Some available independent code evaluation services are listed in the appendix.

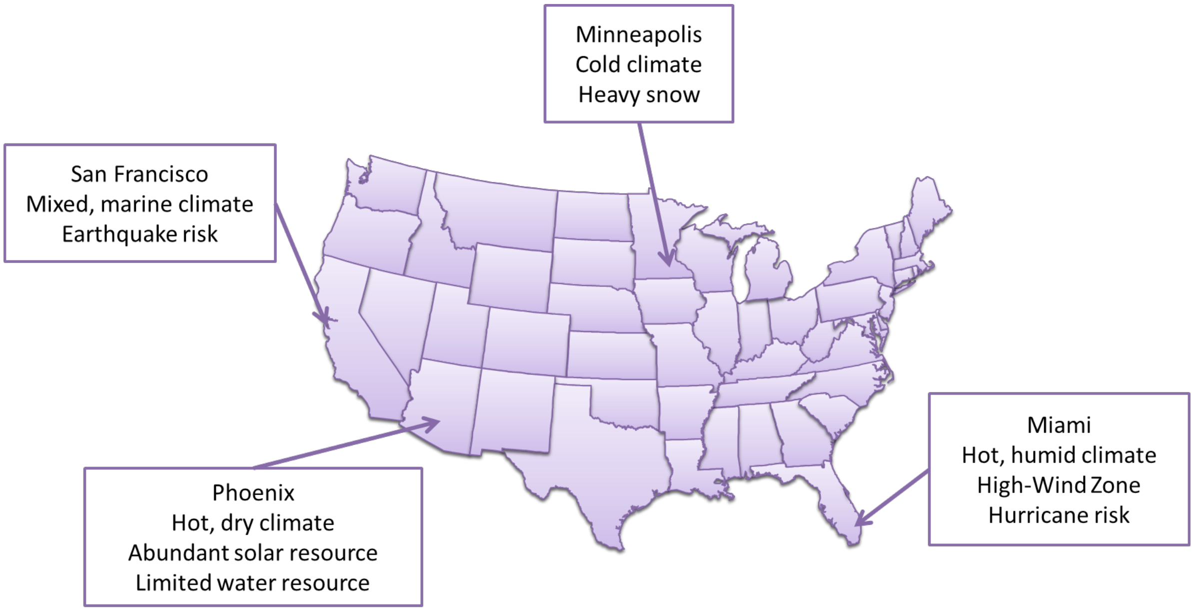
### Climate Appropriateness

Considerations regarding climate-appropriate technologies are areas in which feasibility, performance, and economics often intersect. By selecting technologies that are practical for your climate, you will be optimizing the performance of your building, which, in turn, will result in cost-effective operation and maintenance.

#### *Identify Your Climate Zone*

DOE climate zones serve as the basis of IECC requirements for insulation levels, window performance characteristics, and HVAC and water heating equipment sizing and efficiency.

As your climate becomes more severe (either hot or cold, or humid or dry), you will want to consider higher levels of insulation, better performing windows, and more efficient space-heating/cooling equipment.




Although not prohibited by code, certain types of space-heating equipment may not be as suitable for certain climates. For instance, a standard air-source heat pump will not perform cost effectively or produce desired levels of comfort in climates with very cold temperatures (for example, significant periods below 40 °F). Some manufacturers have developed air-source heat pumps that do perform well at these lower temperatures, however, so it is worth looking at what is frequently referred to as a "cold climate heat pump."

In a hot, dry climate like Phoenix, Arizona, the emphasis will be on cooling, and selecting the most efficient air-conditioning equipment the budget permits may be advisable. Standard space-heating equipment for a short, moderate heating season may be all that is really warranted, given the amount of time it will operate.

The choice in selecting the most effective innovations may be driven by both temperature and humidity. For example, in colder climates, a heating recovery ventilator may be appropriate. In humid climates, dehumidification strategies may be needed.

For new projects or additions, your climate zone will affect the orientation and design of your building. When feasible, maximize southern exposure in all climates that have a heating season; maximize exposure to prevailing winds in cooling dominated climates; avoid significant north-facing glazing in cold climates and west-facing glazing in warm/hot climates. These examples are only a few of the ways that climate considerations may affect your design. The humidity or dryness of your climate affects the method of application of vapor barriers, strategies in HVAC duct location, and appropriate ventilation design.

## Regional Appropriateness

Feasibility considerations will also pertain to the geographic region where your project is located. Characteristics of the region, such as susceptibility to natural disasters, environmental specificities, or typical construction practices, will affect the feasibility of certain building technologies. For instance, if the building is in an area that is prone to flooding, a pier foundation rather than a basement foundation is likely to be a more practical, durable, and resilient choice.

### *High Hazard Areas*

In areas where risks are very high, the building code will specify more stringent construction requirements for new construction, whether it is a new building or an addition. For replacements or renovations, the more stringent requirements may apply if the component or assembly in question is addressed by a particular code provision. For instance, replacement of roof underlayment or shingles in high wind areas will require additional fasteners and closer spacing of fasteners, whether directly specified by the code or specified in manufacturer installation instructions. Be sure to check with your design professional or code official regarding any special provisions or severe risks that apply in your region.

Even if your project is not in one of the high-hazard areas designated by the building code, you may want to consider the specified materials or construction practices that are recommended when a moderate risk is present. As an example, the International wildland-urban interface (WUI) code has mapped regions of the country where the risk of wildfire is high; the code requires fire-resistant materials and provides construction details for new construction in these locations. Yet, in recent years, a number of large and very serious wildfires have occurred in areas not specifically identified on the map. Given the property losses that have occurred, it may be wise to incorporate more fire-resistant construction practices if your project is located in an area where you believe the risk may be high.

### *Market Acceptance*

In some cases the appearance of a product, or the perception of that product may be positive in a certain region and negative in a different region. For example, the exterior cladding used on a home or building (stucco, vinyl siding, fiber cement, cedar, and stone veneer) often varies greatly from region to region. In some cases, this variation is because of performance issues. In other cases, the reason is more because of aesthetics and market perception. Keep in mind that a product may perform well, but would not be consistent with the vernacular of the local community. If a certain type of exterior cladding is not accepted in your region, it may affect your ability to attract tenants or sell a home.

Implementation Phase

## Implementation Phase—Construction Trades and Schedules

The availability of experienced labor, in addition to scheduling of construction trades and careful staging of construction can have a large effect on the feasibility of an innovation. If the integration of an innovation is not carefully planned for, the most efficient point in construction for the installation of that innovation may be missed. Likewise, if construction trade personnel are not available who understand the installation of the innovation, it may not be feasible to use.


### Schedule and Construction Staging

To ensure that the installation of the product is feasible ask a number of important questions

| New Construction | Existing Building |
| --- | --- |
| When in the process does the innovation need to be installed? | What preparations need to happen to be able to add the innovation? |
| When are your construction trades available? | How will the schedule affect occupants? |

Example: A building owner constructing a new apartment building decided to use innovative air-sealing products to eliminate building air leaks and offer higher levels of comfort, moisture control, and sound control to tenants. If the insulation and drywall are installed and finished before air sealing is complete, the process will be much more difficult and expensive. Ensuring that the air-sealing contractor arrives at the right point in the schedule will make use of this innovation feasible.

Implementation Phase

### Availability of Experienced Labor

Typical construction practice may also vary according to geographic region. Often, it may be because of climate, but sometimes it is simply because of contractors being slower to pick up a new technology. For instance, although Pex piping is fairly widely used now, it did not have uniform regional acceptance across the country until recently. Tile roofs and stucco exterior wall finishes are much more common in the Southwest than they are in the Northeast.

It is important that all trades involved in the installation of a new technology review the specifications well ahead of procurement and installation.

Although innovative construction technologies may, by definition, not be "typical practice," the availability of experienced installers should be taken into account when considering both initial installation and maintenance in the future. If the closest installer of a technology you are considering is 100 miles away, it may be more expensive to procure and install and harder to obtain regular servicing and maintenance.

If your facility has a maintenance staff, their skill set is a related consideration. Consider the learning curve that will be required to ensure that your staff understands the day-to-day operation of the equipment or systems in the building and has sufficient knowledge to troubleshoot small issues and identify larger issues that may require the skills of an expert technician.

# Chapter 4—Performance Considerations

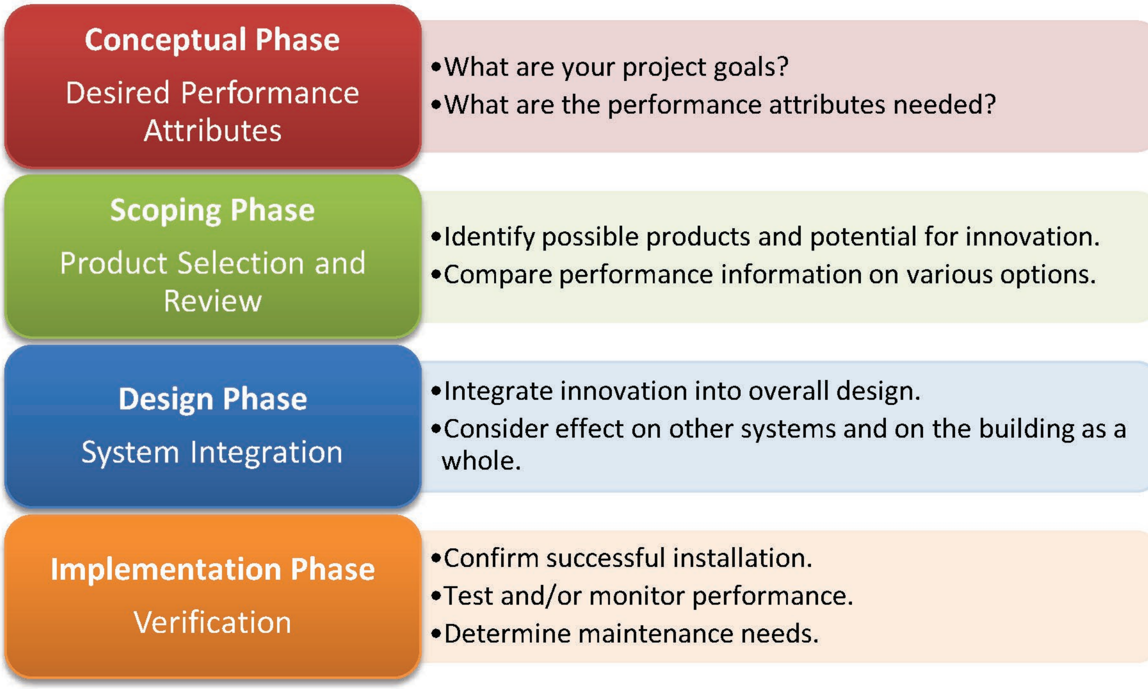
## Performance Top 5

1. How do you want your innovation, home, or building to perform?
2. What innovations address that performance issue?
3. Has the innovation been tested or certified?
4. How does the innovation affect other systems or the whole building?
5. Make sure the innovation performs as designed.

## Introduction


Evaluating a technology for performance considerations is a critical part of specifying what products and systems will be used in your project. How the technology performs will ultimately determine whether you have met the objectives of the project. For example, if you want to replace your appliances and want to achieve some energy savings in the process, you might be able to find a cheap clothes washer somewhere that will certainly wash your clothes, but the chances of your actually experiencing any energy savings as a result of that newly purchased equipment are slim to none. If you invest in an ENERGY STAR-certified clothes washer (which also happens to be eligible for some rebates), however, you would have assurance (through testing) that the washer would not only clean your clothes but would also increase your energy efficiency. Likewise, if you are looking for quality and durability as performance characteristics in an innovation, you may find the lowest cost option does not necessarily meet your performance expectations.

Performance is a broad category that may vary widely depending on the technology under consideration and the context in which it will be installed. Specific attributes you look for will depend on a variety of factors, such as the local climate, the type of occupants or needs of residents, new construction versus existing, desired life expectancy, and, of course, any requirements associated with a funding source. In short, evaluating a technology for performance also requires you to consider both the economic and feasibility considerations of the project as well. As we have mentioned throughout this guide, all three of these considerations are critical to the success of a project.




Conceptual Phase

## Conceptual Phase—Desired Performance Attributes

As you construct a new building, plan a renovation, or simply purchase an innovative product, your performance objectives will significantly affect how you choose innovations. For example, if your goal is to reduce water use, you may focus on low-flow plumbing fixtures or perhaps an efficient plumbing layout to minimize waste. If your goal is to replace worn-out flooring in a high-traffic area, you may choose a material that is highly durable or perhaps that is easy to clean. If you are building a new home in an area with high tornado risk, you will probably consider innovations that provide structural durability and resilience. Considering how you want your building or product to perform and the level of performance you want to achieve will help focus scope and design.

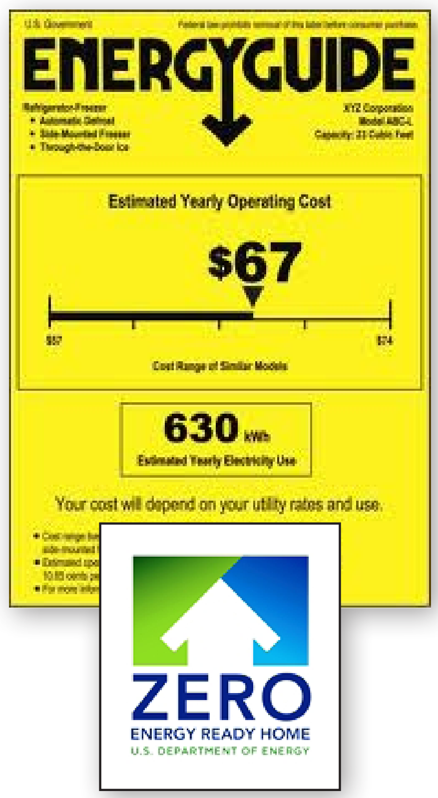

**Energy Efficiency**

Energy efficiency is often a top performance attribute desired in innovative building technologies. An energy-efficient building or system offers both the qualitative benefit of comfort and the quantitative benefit of dollar savings. With unpredictable and fluctuating energy prices—usually in the "UP" direction—an efficient building envelope and efficient equipment will help insulate (literally) you and the building residents from rising utility bills. Top energy-efficiency considerations include—

Product efficiency → System efficiency → Whole house/building efficiency

*How energy efficient should your building be?*

The short answer is, "As efficient as your budget permits." The ENERGY STAR label for new homes and the Home Performance with ENERGY STAR for existing homes can provide guidance about measures you can incorporate into your project. A new ENERGY STAR home is about 15 to 20 percent more efficient than the same home built to code minimum standards.




Under the DOE Zero Energy Ready Home Program, builders have routinely constructed homes to achieve performance 30 percent, 40 percent, and greater above code. Net Zero homes that produce as much energy as they consume over the course of a year are certainly not unheard of, although they do require some type of renewable energy on site, such as solar or wind power.

Both the ENERGY STAR and Zero Energy Ready home programs offer certification to lowrise (three stories or lower) and some midrise (four or five stories) multifamily buildings. ENERGY STAR also has a certification for highrise buildings. Although certification under these programs is not necessary to achieve an energy-efficient home or building, certifications do provide a level of assurance that the designed efficiency has had some verification, and, in the programs described previously, the efficiency level is set by a federal agency, adding credibility to any claims of energy efficiency.

Although a whole building label may not be a realistic option if you are making improvements to an existing building or replacing a piece of equipment or an appliance, remember that many products carry energy-efficiency labels. For example, look for the yellow Energy Guide label that you will find on many types of equipment and appliances. This label will show you the energy performance of the particular model compared with the highest and lowest performing similar products on the market. These products may or may not be ENERGY STAR-labeled, but the label does provide a snapshot of the energy ranking of the product you are considering. ENERGY STAR also provides labels for many classes of products that will indicate a high level of performance.

The U.S. Environmental Protection Agency's (EPA's) ENERGY STAR Products Program was developed as a way to make it easier for consumers to identify and purchase more energy-efficient products to save energy and in the process, save money. In addition to being available for many electronic products, the ENERGY STAR label is available for much of the equipment and appliances in buildings, including—

- Furnaces, boilers, and air-conditioners.
- Refrigerators and freezers.
- Dishwashers.
- Clothes washers.
- Water heaters.
- Windows, doors, and skylights.
- Light fixtures and bulbs.

Many HUD-funded programs, projects, and grants require that ENERGY STAR-labeled products be used whenever they are available and cost effective.

Also, keep in mind that the Energy Code adopted in your jurisdiction is the lowest level of efficiency permitted by law. Unless your city or town has adopted above-code energy requirements, consider ways to incorporate above-code measures in your project.

### What does the ENERGY STAR label mean?

The EPA uses the following criteria to determine whether a particular product is eligible for the label.

- Product categories must contribute significant energy savings nationwide.
- Qualified products must deliver the features and performance demanded by consumers, in addition to increased energy efficiency.
- If the qualified product costs more than a conventional, less-efficient counterpart, purchasers will recover their investment in increased energy efficiency through utility bill savings, within a reasonable period of time.
- Energy efficiency can be achieved through broadly available, nonproprietary technologies offered by more than one manufacturer.
- Product energy consumption and performance can be measured and verified with testing.
- Labeling will effectively differentiate products and be visible for purchasers.

Conceptual Phase

## The Economics of Energy-Efficiency Decisionmaking

Energy-efficiency considerations are one of the areas where you will constantly be moving back and forth between the performance benefits of increased efficiency and the associated economic costs and savings. Energy cost savings are an important performance metric to keep in mind while analyzing any energy-efficient innovation. Although some considerations, such as comparing several product options, may be fairly straightforward, other evaluations can be quite complex and involve building modeling, pricing projections, inflation, and depreciation.

Consider the energy and economics expertise you have access to and whether you might be well served to hire an outside expert in the field, such as the Building Performance Institute (BPI), Inc., which trains and certifies energy auditors who can prioritize energy improvements for your building, while ensuring that the indoor environment is safe and combustion appliances operate properly. An energy audit can help identify those measures that offer the greatest savings for the investment. See the economic considerations chapter for more discussion on economic analysis.

### Sustainability/Green

"Green" is also a term that has become widely used in relation to building technologies and generally, can refer to the environmental impact of a particular product, system, or whole building. Green labeling takes into account the entire life cycle of the building or product including sourcing materials, manufacturing, use/operation, and disposal. A building lot or site can also be considered "green," for instance an infill lot or brownfield site or a site within walking distance to shopping, schools, and public transportation.

Several national green building programs, such as LEED, LEED for Homes, and the National Green Building Standard, have been developed.

In addition, many local green building programs, such as those in Austin, Texas, Denver, Colorado, New Mexico, and several locales in Washington State, have been created. Nearly all consist of sections related to site development, resource efficiency, energy efficiency, water efficiency, and healthy indoor air quality. A set of mandatory requirements and a series of elective guidelines are typically associated with a point system. Each program usually offers the user the option of several "tiers of green." All these programs involve some type of third party verification that includes plan review and site inspection. Even if you are not able to have or are not interested in having your

**CAUTION**

Because many local jurisdictions have local green building programs, you should check to see if any are in your area. Be cautious, however, because "green" has become the ubiquitous endorsement of everything from building products to children's toys, and manufacturers have rushed to find ways to market their products as environmentally preferable. Labels often can be misleading and claims vague, giving consumers a less-than-accurate understanding of what the green label means. The EPA and Federal Trade Commission are stepping in to provide more robust rules about "ecolabeling" and environmental marketing claims. So, it is recommended that you carefully "check the source" when selecting a product based on claims of being "green-certified." Was it certified by a third party or recognized by a federal agency such as the EPA? Is the third party nationally recognized and certified as a qualified green-certification agency? What is the basis of the manufacturer's claim that the product is green?

Conceptual Phase

project designated by one of these programs, it can be useful to review their guidelines to get ideas for sustainable measures that may be realistic to include in your project.

### Durability/Resiliency

Durability and resilience are closely related but have slightly different implications. Durability refers to a product or system that is long lived, having characteristics that allow for it to withstand the anticipated conditions to which it will be exposed, while continuing to maintain its function or purpose. For instance, a siding material will be exposed to weather, including wind, sun, rain, and hail. On occasion, it may be exposed to the occasional baseball or lawn mower. We look for siding materials that maintain their shape and color, resist bulk water penetration, and do not crack easily.

Durability is also linked to maintenance in the sense that a product may last 100 years, with the condition that it is regularly painted, waterproofed, and so on. Quite often, you will be evaluating the durability of a product on a relative scale. How does one product compare with another option to fulfill the same function?

Resilience is quickly coming to be the focal point of good building design. Whether because of the numerous natural disasters in recent history around the country and around the world, the growing concerns about climate change, or the increasing interconnectedness and complexity of systems, building science professionals are looking to materials and detailing that will allow for a building to "bounce back" after a severe event. A number of elements can improve the resilience of a building:

- Redundancy.
- Flexibility.
- Adaptability.
- Self-sufficiency.
- Durability.

***Case Study***

## The Up (or Down) Side of Carpet

A non-profit housing organization installed wall-to-wall carpet in a building that served as temporary housing for mentally disabled adults. The intent was to increase the occupant's comfort.

The nature of the use of the housing, the population being served, and the near-constant turnover of tenants required routine heavy cleaning of the carpeting.

The constant damage sustained and cleaning needed quickly destroyed the carpet. The organization decided to replace the carpet with a flooring type that was easier to clean.

***Lesson Learned***

## Know Your Tenant Population

Despite desirable performance attributes that drove the flooring choice, the feasibility of using carpet with this specific population and building use made a cheaper, easier to clean, flooring choice a better option.

### Low Maintenance

As a public housing owner or manager, building products and finishes that do not require frequent painting, cleaning, or tinkering will save money in operating costs throughout the life of the building. If the building is in a climate with frequent severe weather, select durable materials for the exterior that will stand up to heavy rains, hail, snow, or whatever your weather conditions may be. Exterior building materials that require painting generally may not be the best choice if low maintenance is an attribute on your list. It is also important to keep maintenance considerations in mind when planning the lawn area and landscaping around the building. Frequent watering, pruning, and general care will require hired labor and use of utility-metered resources. On the interior, look for materials that are easy to clean and hold up well to the anticipated traffic or use different areas will get.

Low maintenance also includes the frequency of replacement that entails recurring costs over the life of your building. Consider purchasing materials that are expected to be long lasting and durable, even if they cost a little more up front. Again, consider the economic implications over the life of the building—not just the initial purchase price.

### Disaster Resistance

The extent to which disaster resistant is high on your list of attributes is likely to depend on the characteristics of the geographic region your building is located. To a certain degree, the building codes identify and address high-risk areas. Evidence of significant property damage certainly exists in areas that are not necessarily formally associated with high risk, such as the severe flooding in many Upstate New York towns as a result of Hurricane Irene. Although not natural disasters, widespread power outages or blackouts can also create significant issues for residential and commercial establishments alike. Depending on the nature of your facility and the demographic of the occupants, consider whether some measures to mitigate effects of a disaster might be warranted. Measures can range from the very basic, such as elevating equipment above floor level, to the more costly, such as installing backup generator capability.

The FORTIFIED Home™ Program developed by the Insurance Institute for Business and Home Safety (IBHS) is designed to strengthen new and existing homes against hazards that they may experience. The program identifies a set of mandatory measures, based on the location of your property, that must be implemented to receive the designation. A trained and certified FORTIFIED™ evaluator provides third party verification that your project has been designed and constructed to meet the hazard-mitigation standards appropriate for your area. The program goes a step further than the building codes via a more conservative mapping of regions that are prone to high winds, severe winter weather, thunderstorms, and hail.

Resilience STAR™ is a pilot program developed by the U.S. Department of Homeland Security to build and retrofit single-family homes to make them more hurricane resistant. This program employs guidelines of the IBHS and targets buildings under severe threat in the coastal regions of the South and Southeast.

**NAHB/Bank of American Home Equity: Study of Life Expectancy of Housing Components**

The life expectancy of housing components depends on a number of variables, including installation, maintenance, environmental conditions, use, technology, and consumer preferences. The average life expectancy for certain components has increased over time but has decreased for other components. In 2006, the National Association of Home Builders (NAHB) conducted a comprehensive telephone survey of manufacturers, trade associations, and researchers to analyze information regarding the longevity and life expectancy of housing components.

Many participants indicated that the quality of maintenance and changing consumer preferences have significant effects on the life expectancy of housing components. Components such as HVAC equipment require regular maintenance and can substantially affect the product's longevity. Cabinets, appliances, and technology are vastly affected by consumer preferences, trends, and styles. The study covers a wide variety of housing components, ranging from electrical lighting to footings and foundations. For each component analyzed, the survey findings are summarized in a brief description of characteristics regarding presumed life expectancy. For example, for decks the study states, "Because they are subject to a wide range of conditions in different climates, the life expectancy of wooden decks can vary significantly. Under ideal conditions, they have a life expectancy of about 20 years." Findings are also summarized in a table outlining the different components and their presumed life expectancies.

### Water Efficiency

The degree to which water efficiency is an important attribute for you is also likely to depend on your geographic region. Areas such as the Southwest, central California, and agricultural areas of the Midwest are regions where states and municipalities engage in significant efforts to encourage water conservation. In many of these places, water is rationed at least during certain times of the year and the price you pay for water is likely to be connected to the volume of consumption.

EPA WaterSense℠

The WaterSense Program is another EPA-sponsored initiative that enables consumers to identify products that will use at least 20 percent less water than standard products without sacrificing performance. Products eligible to earn the label include bathroom faucets, showerheads, toilets and urinals, and weather-based irrigation controllers. In addition, new homes can earn the label whereby a third party rater verifies that the home will be water efficient both indoors and out. *For a product to earn the WaterSense label, it must—*

- Perform as well or better than its less efficient counterparts.
- Be 20 percent more water efficient than average products in that category.
- Realize water savings on a national level.
- Provide measurable water savings results.

- Achieve water efficiency through several technology options.
- Be effectively differentiated by the WaterSense label.
- Obtain independent, third party certification.

Even in regions of the country where water scarcity is not as large a concern, water quality may be. Rural and urban areas alike have sources of water contamination, including pesticide/chemical runoff, sediment and runoff near large cities and busy roadways, dumps and landfills, some types of energy production, and a host of other consequences of human activities. Often water use rights are also a political issue and demands, such as drinking water versus agricultural uses versus energy production, each compete for the limited resource. Numerous examples show that water is piped long distances from the source to areas with greater population or demand. So, regardless of where your building is located, it is important to give consideration to water-conserving plumbing fixtures, faucets, and outdoor use.

### Health/Indoor Air Quality

Because Americans spend most of their time indoors—90 percent according to a 1989 EPA study[2]—indoor air quality has become an increasing health concern. Some attribute increasing severity of asthma symptoms in children to higher levels of indoor particulate matter.[3] As building envelopes become tighter and more efficient, fresh air needs to be introduced in a controlled manner. The International Code Council recognized the need for fresh air in tight buildings and has incorporated related requirements into the code. The EPA Indoor airPlus program offers guidance and certification for homes built with comprehensive indoor air quality measures.

As a building owner or manager of a public housing facility, whether it is a single-family home or multifamily unit, your building may pose special conditions regarding indoor air quality. The building and mechanical systems may be old, giving rise to specific air-quality concerns; dirt and particulate matter may have accumulated over the years; and some locations may have more residents who are likely to smoke. As you plan new construction or renovation projects, give consideration to the ways you might address or avoid indoor air-quality concerns. Examples include—

1. Are the finishes such as paints, carpets, and wall coverings low- or no-VOCs and free from other potentially harmful contaminants such as formaldehyde?
   Have you checked the radon levels in the soil around your building?
2. Can local exhaust fans in bathrooms and kitchens be upgraded?
3. Can new or existing duct runs be shortened or hard ducted to move air more effectively?
4. Can some type of whole building mechanical ventilation be included?
5. Are windows easily operable to provide natural ventilation?

[2] U.S. Environmental Protection Agency. 1989. Report to Congress on indoor air quality: Volume 2. EPA/400/1-89/001C. Washington, DC.
[3] Johns Hopkins University, 1989. Indoor Air Pollution Increases Asthma Symptoms. Baltimore, MD.

Like some building certification programs that focus on energy, sustainability, and security, some voluntary programs recognize healthy homes. Again, regardless of whether you decide to pursue formal certification, the program guidelines can provide useful educational tools as you plan your project and select technologies.

## Scoping Phase—Product Selection and Review

- ✓ **Identify and Prioritize Project Goals and Objectives**
- ✓ Perform initial research
- ✓ Review manufacturer’s specifications and professional perspectives
- ✓ Consult with your team
- ✓ Check product labeling, certification, and testing
- ✓ Evaluate the contractor/installer


### Identify and Prioritize Project Goals and Objectives

What is the driving force behind the project? Is it a failed piece of equipment? Are you taking advantage of a recently advertised incentive program? What are the desired performance attributes you hope to obtain from the technology?

To know what technology is going to be the best fit for your project, you must first identify what your project is and why you are doing it. For example, maybe you have not replaced any windows in the building because it was built 50 years ago. You just found out that another window has cracked, leaving you with more broken windows in the building than working ones. You ultimately decide that now, because of failing equipment, it is finally time to replace all the old windows.

Now you need to decide what kind of windows you want. Have you been losing a lot of heating and cooling through your windows? Maybe you have a new HVAC system but have not been able to see the energy savings because most of the energy was being lost through the old broken windows. In that case, you might want to go with windows with ENERGY STAR-rated windows that will better accompany your efficient HVAC system. Whatever the case may be, you need to start identifying the different needs and desired attributes you want from a technology. You can start to categorize these attributes into two groups: (1) those you NEED and (2) those that would be NICE TO HAVE.

### Perform Initial Research

Now that you know what your project is and have determined what performance attributes you desire, you can begin performing some initial research on the different technologies that will apply. Internet searches, web reviews, and consumer publications are all good places to start your research. Check out what other people are saying about these technologies to get a feel for how they might operate. Although information from manufacturers will certainly be important, these channels are a great way to get an idea of real user interaction with the technologies.

If you have not already started searching for any relevant rebate or incentive programs for that type of technology, you should start now. In many cases, rebate and incentive programs will permit a wide range of products under a specific technology category. Some may limit it to ENERGY STAR-certified products for example, but generally you will have a number of different options to choose from. Specifying the exact product you will use will not come into play until you are a little farther down the road, but you need to identify any financial support programs you might be eligible for a given technology.

Performing this initial third party research will begin to narrow the scope of the technologies that will achieve your desired results and are within budget.

### Review Manufacturer Specifications and Professional Perspectives

After you have performed some initial research and have identified a couple of different options for your project, your next move is to further investigate these technologies to see how they stack up against each other. The initial research you performed weeded out some options right off the bat, enabling you to focus on those that best fit your project. Get a closer look at these identified technologies to help you weigh the pros and cons of each when it comes time for a final decision. You can use a number of sources to further examine the applicability of these technologies.

#### *Manufacturer's Literature*

A good place to start your review is with the product specifications, brochures, and other materials available directly from the manufacturer. Reviewing the manufacturer literature can help you determine if the technology is going to be a fit for your project. You need to make sure that the technology you are researching will be compatible with the other components in your building. Remember, think of your building as a whole rather than the sum of its parts. The various components interact with each other on a daily basis and can significantly affect how each performs. Simply because a technology provides your desired attributes does not mean it will work for your building.

At this point, you can also review what third party certifications a particular technology has earned. A number of agencies and companies test and certify various products for performance measures for every type of technology. Products that earn certification marks or labels from third parties provide a level of assurance that a product is going to meet a certain set of criteria or standards of performance.

#### *Professional Perspectives*

As a building owner or manager, one of your best sources of information is the professional who has first-hand experience with the technology. Reaching out to contractors, labor specialists, other building owners, and tenants will enable you obtain a better perspective on how the technology has worked in other applications that might be similar to your project. You should identify local projects that are using these technologies and talk with both the tenants and owners/managers to gain their perspectives. These opinions may differ. Maybe the building owner likes his new HVAC system because it saves him money on energy bills; however, the tenants may complain that the temperature of their units is uncomfortable. A building owner may be considering an innovative faucet, but a professional review of that specific product or model may reveal the unit is difficult to maintain.

You should also look to see what skilled labor is locally available to you. It may be that nobody in your area has ever used this technology making installation of technology expensive or run the risk of it being done improperly. These professionals are also a great source of information. The people who handle these technologies on a regular basis are likely the ones who have the strongest opinions on which ones perform the best, are the most reliable, and will last the longest.

Another important contact to make is with your local code official. He/she will know whether a technology will be compliant with the local building code. In addition, they are likely to see the technology through a different lens and might be able to give you an alternative point of view. Learning how these different professionals view a certain technology will help make you feel more comfortable when you ultimately make your choice.

### Consult With Your Team

After performing a more indepth review of various technologies, talk with your team and weigh your options. Your team will include those who are directly involved in designing, developing, and implementing your project. It is critical to include each team member in your decisionmaking process, because they are the ones who will execute the plan. They will be able to determine what is needed and what will work best for the project.

Your team also includes all those who will be affected by the project, such as the building maintenance, security, and residential staffs. It is likely that all these people will have different viewpoints, desires, and opinions related to the project. A member of the maintenance staff, for example, is likely to heavily emphasize reliability and durability, while a residential staff employee might push for technologies with better indoor air quality for a healthier environment.

All the information you have gathered to this point for each technology should be organized and evaluated by you and your team. Develop a list of the pros and cons of each option and determine how they compare with the goals, objectives, and desired performance attributes you previously identified. Be sure to consider the economic and feasibility aspects of the technology as well. Although performance is important, combining evaluations of these three considerations will enable you to make the best decision for your project.

### Check Product Labeling, Certification, and Testing

#### *What does product certification or labeling mean?*

A product certification or label indicates third party testing or review regarding a particular attribute or performance metric in addition to ongoing oversight and inspection of the manufacturing process to ensure consistency and quality are maintained. A certification provides assurance that a product or material will meet certain standards of performance related to attributes such as fire or life safety, energy efficiency, water efficiency, and environmental sustainability. In some cases, a product may hold a certification regarding overall quality, such as the Quality and Performance Mark by Intertek. In many cases, some of the same companies that perform product testing also offer product certifications. The federal government also offers product certifications or labels such as the EPA's ENERGY STAR or Water Sense labels. The following labels frequently appear on building products, equipment, or appliances.

| Agency/Company | Logo | Type of Certification |
|---|---|---|
| AAMA[4] | | Windows and doors |
| AHRI[5] | | Heating and Refrigeration equipment |
| ASTM[6] International | | Varied standards of performance |
| ENERGY STAR | | Energy performance |
| Factory Mutual | | Industrial and commercial product testing to prevent against loss-insurance industry associated |
| Home Innovation Research Lab | | Accessibility, insulation, plumbing products, green |
| Intertek | | Product safety, performance, and quality |
| NFRC[7] | | Thermal performance, visible transmittance of windows and doors |
| UL[8] | | Life safety |
| List may not be exhaustive of all certifications available for building products. | | |

[4] American Architectural Manufacturer Association
[5] Air-conditioning, Heating, and Refrigeration Institute
[6] American Society for Testing and Materials
[7] National Fenestration Rating Council
[8] Underwriters Laboratories

### *Are product certification and product testing the same?*

No. Product testing is more a snapshot in time that demonstrates a product performed to a particular standard when it was tested. Certification, on the other hand, involves ongoing oversight of the manufacturing process and product sampling to ensure that a uniform level of performance and quality is maintained over time. Certification is likely to cover a broader range of performance attributes than testing to a single standard. When evaluating a certification, make sure that the certification agency is ISO accredited by an agency approved by the International Laboratory Accreditation Agency. Do the same for product testing laboratories that you may encounter when reviewing manufacturers' literature. A comparison from the website of NTA Testing, Inc. (www.ntainc.com) provides a good comparison of the differences between testing and certification.

Scoping Phase

| | Building Product Certification | Building Product Testing |
|---|---|---|
| Generates data using nationally recognized standards (test report) | X | X |
| Provides performance data for a product. | X | X |
| Includes continual assessment of a product over time. | X | |
| Requires an in-house quality system inspected by a third party agency. | X | |
| Provides evaluation beyond a test standard (evaluation or listing report). | X | |

**Table 1: Source:** http://blog.ntainc.com/topics/building-products

Although in-house testing may certainly be reliable, it does not carry the weight or offer the assurance of testing by an outside third party. Third party testing and certification provide a level of confidence that a product will perform according to the manufacturer claims. As a building owner, the verification provided by an independent third party gives you confidence that the manufacturer's claims regarding performance relative to a specific attribute are warranted. Keep a few things in mind, however—

1. Products are most often tested in a laboratory situation—not as they are typically installed in the field.
2. Products are typically tested in isolation—not as they behave in a building assembly alongside of other materials.
3. Products are tested with respect to their behavior under a very specific set of conditions. Thus, test standards do not warrant the overall quality of a product or material; they warrant only its ability to withstand certain effects, exposure, and so on.
4. Neither product testing nor product certification automatically implies that the product meets the international building code or is accepted by your local code official.

### Evaluate the Contractor/Installer

Confidence regarding the performance of a particular product or technology is only part of the equation. If a great product is installed poorly or improperly, you will end up with a poor result that does not meet your expectations. Your contractor(s) needs to be qualified and skilled in the product or technology area for which he is performing work. You can gain confidence in several ways.

***References.*** Local references are probably one of the best ways to verify a contractor's experience and his ability to complete work on time and within budget. Be sure to check with multiple sources and make sure the scope and type of work were similar to those he will be performing for you. Although he may give you only the names of satisfied customers, it is usually fairly evident if they have reservations.

***Licenses.*** Requirements for general and trade contractors' licenses vary by state and by jurisdiction and by the particular trade. Although some states require builders and general contractors to hold a license, in other cases, particular municipalities require a license. Trade contractor licensing is most often found for the electrical or plumbing trades. The National Association of States Licensing Agencies tracks contractor-licensing requirements and has an interactive map in which you can search requirements by state. The National Association of Home Builders maintains similar information about all licensing required in a given state.

http://www.nascla.org/

http://www.nahb.org/directory.aspx?directoryID=1836

Keep in mind that licensing requirements may simply be a registration requirement to track building professionals within the state. Or, it may carry education requirements and, thus, mean that the builder or contractor has completed a certain amount of training—sometimes more business oriented than skill oriented. Regardless, it is important to find out if a license is required and, if it is, what the license means in terms of qualifications and also to find out if the contractor or builder you are considering is in good standing in the eyes of the state board.

***Association Membership.*** Although not a guarantee of quality workmanship, membership in a professional association, such as the National Association of Home Builders or one of the remodeling councils, is an indication of commitment to the building profession. Check your local chapter of these associations to find out who are members in your area. These associations usually offer training, education, and certifications in the following subjects:

- Certified Graduate Builder.
- Certified Graduate Remodeler.
- Certified Green Professional.
- Graduate Master Builder.

To find out more about these designations, go to http://www.nahb.org/page.aspx/category/sectionID=119.

### *Other Certifications*

***Home Energy Rating System (HERS) Rater.*** A HERS rater is typically associated with the ENERGY STAR Homes Program as one who inspects and tests the energy-efficiency features of your building to verify compliance with program standards. The rater will model the building using approved software to determine the HERS score, verify that the specified equipment and materials were installed properly, and complete the necessary paperwork for your project to be formally recognized at the state or national level. To become a HERS rater, one must complete training under a HERS provider approved by the Residential Energy Services Network (RESNET) and must complete multiple supervised onsite ratings.

RESNET is a not-for-profit membership corporation that is a recognized national standards-making body for building energy-efficiency rating and certification systems in the United States This RESNET link will direct you to further explanations regarding the advantages of working with a HERS professional and to information that will help you identify raters in your area http://www.resnet.us/certified-auditor-rater.

***Building Performance Contractor.*** The Building Performance Institute administers several designations for residential contractors having particular training and expertise in building performance—specifically energy efficiency, combustion safety, air sealing, and HVAC system performance. BPI certifications include the following designations, among others:

- Building Analyst
- Envelope Professional

- Heating
- Air Conditioning and Heat Pump
- Manufactured Housing
- Multifamily

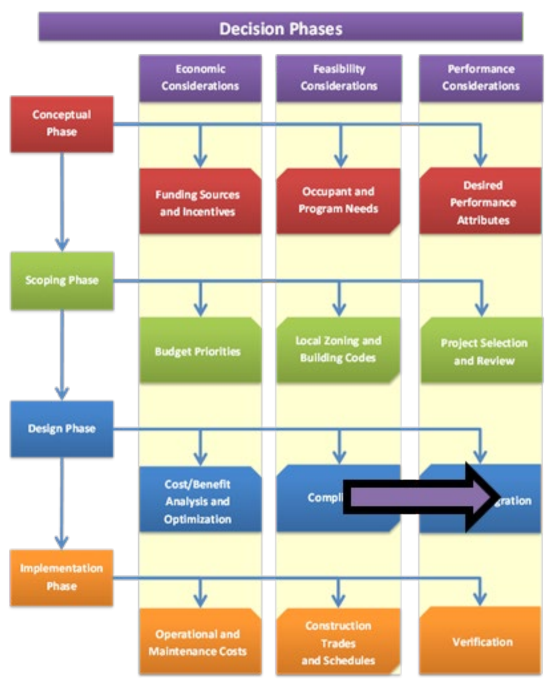
All certified contractors must initially attain the building analyst designation and then may move on to one of the more specialized areas. BPI has also developed more advanced certifications for auditor, installer, crew leader, and quality control. Visit the BPI website to learn more about the designations and how this expertise can enhance the performance of your project at [www.bpi.org/professionals.](www.bpi.org/professionals)

In general, BPI certifications are primarily geared to existing buildings and retrofit work, while ENERGY STAR raters are trained for inspection and verification of new homes. Yet, each carries an emphasis on ensuring that certified professionals have a solid understanding of building science and how different systems in a building interact.

Keep in mind that a formal, third party certification is only one indicator or path to expertise and high quality. Many builders, remodelers, and trade contractors have developed skills through trade journals, Internet research, conferences, and simply longstanding experience.

## Design Phase—System Integration

During the design phase, performance considerations are studied in context of how an innovation interacts with the other systems around it and with the building as a whole. Innovations can be optimally designed into a system that maximizes the performance of that innovation. When you are considering use of an innovation, three basic levels of rigor can be applied during the design phase.




At the high-level review, you would use software to analyze how the entire building would function from a building science perspective and how that function would change with the addition of an innovation. If the desired attribute of the innovation is energy efficiency, a whole building energy simulation would show the energy saved by that innovation in context with the rest of the building. If hurricane resistance was the desired attribute, a performance calculation of wind load resistance of the entire system including the innovation would show if the product helped reach the desired level of performance. These procedures are complex and would likely require specialized staff or outside professionals to complete. These procedures should definitely be used when building new construction.

Many projects will probably fall into the medium-level review. This review includes a step-by-step analysis considering how to optimally use the innovation, but without a whole building modeling. A standardized set of questions at this level will help ensure that all

High:

Full building modeling or simulation

Medium:

Comprehensive process for examining the effects of technology on other parts of the building

Low:

Installation of the innovation focused on optimal performance without consideration of other systems

important issues are considered. An example of this assessment might be considering changing from a wood to a steel framed wall to increase structural integrity, but in considering other effects, you discover the need to add insulation to reduce heat loss across the more conductive framing material.

A low-level review would simply be considering the technology as a stand-alone system and optimally using that innovation without consideration for other systems. An example in which this level of review might be appropriate would be changing appliances (such as a dishwasher or refrigerator) and considering the performance characteristics (such as efficiency and durability) in selecting the item, but not taking the analysis any further. In this example, the low-level analysis is probably appropriate, given the limited effect these systems would have on other systems in the home or building.

### *Project Example:* New Construction

You are planning to develop a new site, the first phase of which will be 12 two-family townhomes. The architect suggests that you consider a particular type of sprayfoam insulation for the exterior walls and that you also use the sprayfoam in the rafters to create an unvented attic. What considerations should you take into account and where should you go to find reliable information regarding performance?

| Must Have | Would Like To Have |
|---|---|
| **R-3.0 or more per inch** | R-value more than R-3.0 per inch |
| **Resistant to air flow or compatible with air-sealing system** | Sound deadening |
| **Able to meet or exceed code requirements regarding total insulating value and fire resistance** | Easy to install/forgiving |
| **Not susceptible to mold growth** | Resistant to moisture |
| **Not susceptible to damage from rodents/pests** | |
| **Fire resistance characteristics and ratings** | |
| **Cost effective/within project budget** | |

1. Identify the characteristics you are looking for in an insulation product. Lay out the attributes that you must have and those that you would like to have, but might be willing to compromise on. For example:
2. Review manufacturer's literature and claims.
3. Perform Internet search for product applications and for unvented attics.
4. Has the product undergone any testing by recognized outside third parties?
5. Has the product been locally installed? Are there local examples of unvented attics?
6. Who are the local installers of the product? What are their qualifications?
    - *Length of time in business.*
    - *References.*
    - *Certifications, training in product installation.*
7. Is the product recognized/acceptable to the local code official?
8. What are the cost implications of using this product versus the lowest cost option?
9. Does using the sprayfoam obtain additional benefits versus a conventional, lower cost option?

*Examples*:

Offers added structural integrity to wall and roof system.
Air sealing function is integral to insulating function.

**Manufacturer's Literature**

- Read the fine print.
- Be wary of unrealistic claims.
- Read warranty language and conditions.
- Look for third party testing or endorsement.
- Look for case studies.

### Project Example: Renovation of Existing Building

When considering an innovative technology for an existing building, many elements that go into the decisionmaking process will be the same as for new construction regarding performance issues. Of course, you will want to—

- Review manufacturers' literature regarding performance, reliability, and longevity; compare with other product options.
- Identify third party testing that has been performed and product designations, if any.
- Perform an Internet search to gain perspective on broader experience nationwide.
- Identify examples of local installations.
- Identify local installers and their qualifications.

In addition, however, an existing building will warrant additional considerations simply because of the need for the technology to "fit in with" the systems and materials that are already in place and not planned as part of the renovation. It is also important to ask the following questions regarding your maintenance staff and the current residents of the building.

Design Phase

- Does the maintenance staff have the skills to perform routine maintenance and troubleshooting?
- Do the residents have the skills and knowledge to operate the system properly, or can they develop the knowledge?
- What are the consequences if either of these groups fails to maintain or operate the system properly? Would such a failure result in complete breakdown or simply less than optimum performance?

**Project Example: Space-Heating/Cooling Equipment Replacement**

You are planning to replace 30-year old gas furnaces and wall-mounted air-conditioners in your multifamily apartment building in Maryland. One of the requirements of funding is that the equipment must be ENERGY STAR labeled. You are trying to decide between a 95-percent efficient furnace and an ENERGY STAR window-mounted air-conditioner or a dual-fuel heat pump that provides central cooling in the summer and heats via a heat pump in winter until outdoor temperatures fall below about 40 °F when it then cycles into gas mode. If you replace the thermostat, the code official will likely require a programmable thermostat.

Because the furnace/air-conditioner combination maintains the same basic type of equipment, you feel comfortable that it will perform well with greater efficiency than what currently exists, that it will be reasonably familiar to your maintenance staff and residents because it does not deviate significantly from the operational elements they are accustomed to, and that it is likely to be at least as reliable and long lived as the existing equipment was.

From what you have read, however, the dual-fuel equipment has some compelling advantages, such as reduced operating costs because of partial winter heating in heat pump mode plus greater comfort in the summer because of central cooling. In addition, the maintenance staff will not have to remove and replace window air-conditioners each spring and fall. Yet, given the senior occupants, you are concerned that they may not “feel” warm enough under winter heat pump operation and they may not use the new programmable thermostats correctly. This scenario could significantly affect the anticipated energy and operating cost savings. How to decide—

***Case Study***

## How do I work this thing again?

A nonprofit organization renovated a group home to cut operation costs from energy use. They installed new windows, improved air sealing, and changed the HVAC system to a new highly efficient unit. So why were their energy costs still so high?

After talking with staff at the group home, it was discovered that maintenance personnel were adjusting the set point on the thermostat whenever any room became uncomfortable. The thermostat was set to 80 oF in the winter, eliminating the possibility of any energy savings from the new efficient unit.

***Lesson Learned***

## Training With Technology

When implementing any new technology, make sure the user understands how it works. Without some training, the benefits from innovations can be lost.

- Look for examples of dual-fuel heat pumps in your area and installations where seniors live.
- Talk with your HVAC contractor about his experience with the equipment and whether he has encountered any issues.
- Consult with your maintenance personnel asking them to review literature and specs and provide their input.
- Consult with your code official about his experience with the equipment.
- Can you implement other efficiency measures to ensure comfort, such as—
    - *Air sealing?*
    - *Seal ductwork?*
    - *Replacement windows?*
    - *Increase insulation levels?*
- What type of training can you provide to bring residents up to speed on use of new thermostats and tips on achieving both comfort and energy efficiency?
- What type of routine checks or inspections can you put in place to ensure proper operation?
- Implement a pilot whereby the equipment and programmable thermostats are installed in a subset of apartments to help gauge appropriateness.
- Perform an economic analysis to compare the two alternatives.



## Implementation Phase—Verification

For any innovation used in a new or existing building, verification of performance is important. Integrating new technologies without increased performance will merely add cost to a project, with no benefit. Several options need to be considered during any project with a performance goal. Depending on the level of performance needed, and the extent of the project, one or more of these options may be appropriate.


At a minimum, a quality installation checklist should be used to ensure proper installation of the innovation. This checklist should include—

- Construction details designed for optimal performance.
- The manufacturers' installation instructions, which will often be linked to warranty requirements.
- Any code requirements identified during the feasibility review.

For a more rigorous level of verification, some technologies can be tested to ensure that they are working properly. For example, if air-sealing innovations are used in a building, a contractor can conduct a blower door test to ensure that the desired target for air tightness has been reached. For lighting innovations, a foot-candle test can be conducted to measure the achieved brightness of the lighting. When specific testing is not possible, inspections of the installers work can help add more assurance that the innovation was properly installed. These inspections could be conducted by a third party inspector, or they could simply be conducted by an internal inspector as part of a quality program.

| Installation | Testing and Inspection | Feedback |
|---|---|---|
| • Quality installation checklist<br>• Manufacturers' installation instructions and warranty requirements | • Diagnostics to ensure the system is working properly<br>• Inspections reviewing the work of installers | • Occupant's or user's feedback on performance of the system<br>• Monitoring of system for actual performance as used by occupant |

Finally, verifying the actual performance as the innovation is used by the occupants can help determine if the innovation is working as advertised or as designed. For example, a building owner who pays tenant utilities may be interested to see the actual energy reduction resulting from a new, efficient lighting system. Monitoring equipment could be installed to measure the actual energy use by that lighting equipment. For a new dehumidification system, occupant surveys could be conducted before and after installation to determine the effect on comfort. For a homeowner using a new innovation, simply taking notes on the noted performance of the innovation will help keep a record of how well it worked.

## Appendix: Evaluation Tools and Resources

# What Are You Looking For?

| Consideration | | |
|---|---|---|
| Economics | Simple payback<br>Cashflow<br>LCCA | Value engineering<br>Operating costs |
| Feasibility | Code compliance<br>Climate-based resources | **Geographic resources**<br>• High winds/hurricanes<br>• Flooding<br>• Earthquakes<br>• Termites<br>• Wildfire |
| Performance | **Desired attributes**<br>• Disaster resistance<br>• Durability<br>• Health/indoor air Quality<br>• Sustainability/green<br>• Maintenance<br>• Water efficiency | **Building components**<br>• Ceiling/roof<br>• Foundation<br>• Electrical/lighting<br>• Exterior wall<br>• HVAC<br>• SMART® technologies/ controls<br>• Water heating/ plumbing/piping<br>• Windows/doors |

## Economic Tools and Resources

| Simple Payback | | |
|---|---|---|
| **Economic Tool and Resource** | **Description** | **Link** |
| **U.S. Department of the Interior: Calculating Payback** | This resource offers guidance on standard methods for calculating payback. | Calculating payback |
| **U.S. Department of Energy's (DOE's) Federal Energy Management Program (FEMP) Energy Cost Calculator for Compact Fluorescent Lamps (CFLs)** | This user-friendly tool calculates energy savings related to CFLs and will calculate the energy savings potential of lighting upgrades. | CFL calculator |
| **U.S. Environmental Protection Agency's (EPA's) ENERGY STAR Calculators** | This tool calculates the potential energy savings of a proposed project compared with the average available non-ENERGY STAR new products. | Efficiency calculators |

| Cashflow | | |
|---|---|---|
| **Economic Tool and Resource** | **Description** | **Link** |
| **Good Mortgage Investment Property Calculator** | This tool provides a guide to possible financial outcomes of the purchase and rental of an investment property. | Investment property calculator |
| **Rental Cash Flow Analysis Worksheet** | This step-by-step template for and guide to conducting cashflow analysis for a rental property includes separate worksheets for income, expenses, loans, and debt, and it gives the user an overall cashflow analysis of the rental property. | Cashflow spreadsheet template |
| **Investment Property Analysis** | This resource serves as a primer on how to look at investment property. It provides only a general example, and any property will have more factors to look at, but this analysis provides the basics on how to begin an analysis of investment property. | Property analysis |

# LCCA

| Economic Tool and Resource | Description | Link |
|---|---|---|
| **U.S. General Services Administration: Life-Cycle Cost Analysis (LCCA)** | This resource introduces LCCA and discusses the methodology, procedures, and approach behind conducting this type of analysis. | LCCA |
| **LCCAid: Life-Cycle Cost Analysis (LCCA) for Integrative Design** | This LCCA tool provides an easy-to-use method to conduct LCCA for building design professionals (architects, engineers, and energy modelers) who have little or no previous experience with financial analysis. | LCCAid |
| **L-Cycle: The Lifecycle Cost Modeling Tool** | This tool estimates whether a property's replacement reserve balance will effectively be able to cover the cost of repairs, replacements, and renovations over time. | L-cycle |
| **National Institute of Standards and Technology (NIST) Building Life-Cycle Cost Program** | This tool evaluates water and energy cost savings and renewable energy projects. | BLCC |
| **Whole Building Design Guide: Life-Cycle Cost Analysis** | This resource provides an introduction to performing an LCCA and best practices for when to use this type of economic evaluation. | LCCA |

## Value Engineering

| Economic Tool and Resource | Description | Link |
|---|---|---|
| **Whole Building Design Guide: Value Engineering (VE)** | This resource provides an introduction to VE and best practices for how to effectively use VE for building projects. | Value engineering |
| **SAVE International: What is VE?** | This resource provides guidance and example methodologies for conducting VE analysis. | SAVE |
| **Green Building Advisor: Advanced Framing** | This blog discusses the pros and cons of using advanced framing techniques, a common VE application in the construction industry. | Advanced framing pros and cons |

## Operating Costs

| Economic Tool and Resource | Description | Link |
|---|---|---|
| **U.S. Environmental Protection Agency's (EPA's) ENERGY STAR Portfolio Manager** | This tool provides possible improvements for reducing consumption and monthly operating costs. | Portfolio manager |
| **Bright Power EnergyScoreCards™** | This online tool helps track building energy and water use, benchmarking one building against other similar building types in the same climate and recommending upgrades that will reduce consumption. | EnergyScoreCards™ |
| **WegoWise Energy Benchmarking** | This software tool benchmarks the energy consumption of a building and tracks and analyzes the usage of that building. | WegoWise |

## Feasibility Tools and Resources

| Code Compliance | | |
|---|---|---|
| **Feasibility Tool and Resource** | **Description** | **Link** |
| **Architectural Testing: Code Compliance Research Report (CRR)** | This report provides code and building officials with evidence, technical information, and professional evaluations to determine if products, components, and systems meet code requirements. | ATI |
| **ICC Evaluation Service** | The ICC Evaluation Service is one of the better known code evaluation services. This resource provides manufacturers with code-compliance evaluations and testing for products. The service publishes reports about compliance evaluations for public use. | ICC-ES |
| **Intertek Code Evaluation Services** | Intertek provides manufacturers with code compliance evaluations and testing for products. This service publishes reports about compliance evaluations for public use. | Code Evaluations |
| **Structural Building Components Research Institute (SBCRI)** | This resource performs product and assembly testing and provides code-compliance services. | SBCRI |
| **Underwriters Laboratories (UL) Evaluation Service Reports** | These resources help manufacturers get their product to market faster and with more confidence. The evaluation reports reveal findings from UL's testing and analysis of the products to ICC-ES Acceptance Criteria and evaluate them for code compliance. | UL evaluation |

# Geography-Based Resources

## *Hurricanes/High Winds*

| Feasibility Tool and Resource | Description | Link |
|---|---|---|
| **Building Science Digests: Flood and Hurricane Resistant Buildings** | This resource discusses lessons learned from flood and hurricane disasters and provides guidance for building better, more resilient homes in these high-risk areas. | Flood- and hurricane-resistant buildings |

## *Hurricanes/High Winds*

| Feasibility Tool and Resource | Description | Link |
|---|---|---|
| **Against the Wind: Protecting Your Home from Hurricane Wind Damage** | This document discusses protecting the home from hurricane and wind damage. | Against the Wind |
| **Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas** | This manual provides guidance for designing and constructing residential buildings in coastal areas that will be more resistant to the damaging impacts of natural hazards. | Coastal Construction Manual |

## *Flooding*

| Feasibility Tool and Resource | Description | Link |
|---|---|---|
| **Design and Construction in Coastal A Zones** | This document recommends design and construction practices in coastal areas where wave and flood conditions during the base flood will be less severe than in V Zones but where such conditions can still cause significant damage to typical light-frame construction. | Coastal A Zones |
| **Whole Building Design Guide (WBDG) Flood Resistance of the Building Envelope** | This resource provides design and construction best practices for flood resistance. | WBDG flood resistance |

# Geography-Based Resources

## *Flooding* *Continued*

| Feasibility Tool and Resource | Description | Link |
|---|---|---|
| **American Society of Civil Engineers (ASCE) 24: Flood Resistant Design and Construction** | This resource highlights the requirements of ASCE 24 referenced in the International Building Code regarding minimum requirements and expected performance for the design and construction of buildings and structures in flood hazard areas. | Flood-resistant design and construction |

## *Earthquakes*

| Feasibility Tool and Resource | Description | Link |
|---|---|---|
| **FEMA 232: A Homebuilders' Guide to Earthquake-Resistant Construction** | This publication presents seismic design and construction guidance for one- and two-family houses in a manner that home builders, knowledgeable homeowners, and other nonengineers can use. | Earthquake-resistant construction |
| **Faultine: Damage Control** | This resource provides guidelines for building and retrofitting to mitigate damage caused by earthquakes. | Damage control |

## *Termites*

| Feasibility Tool and Resource | Description | Link |
|---|---|---|
| **Termite Prevention: Approaches for New Construction** | This resource addresses approaches and steps to take during renovations and new construction to help reduce the likelihood of termite problems. | Steps to reducing termite damage |
| **Termite Resistant Construction and Building Materials** | This resource addresses current developments and trends contributing to the construction of termite-resistant buildings, particularly regarding control of the Formosan subterranean termite. | Termite-resistant construction |
| **Preventing Termite Infestations** | This resource presents best practices in design, construction, and building materials to prevent or reduce termite infestation. | Termite prevention |

# Geography-Based Resources

## *Wildfire*

| Feasibility Tool and Resource | Description | Link |
|---|---|---|
| **Fine Homebuilding: Fire-Resistant Details** | This report presents studies of homes that survived the 1993 Laguna Beach firestorms to yield lessons in building to withstand heat. | Fire-resistant details |
| **Designing Your Home To Survive Wildfires** | This report provides basic architectural design decisions to greatly improve chances of a home's survival during a wildfire. | Surviving wildfires |
| **California Wildland-Urban Interface (WUI) Code** | This resource highlights the requirements and standards set in California's WUI code. | Wildland-urban interface code |
| **2012 International Wildland-Urban Interface (WUI) Code** | This resource highlights the requirements of the 2012 international WUI code. | International wildland-urban interface code |

# Climate-Based Resources

| Feasibility Tool and Resource | Description | Link |
|---|---|---|
| **Building America Climate-Specific Guidance** | This resource demonstrates real-world solutions for improving the energy performance and quality of new and existing homes in five major climate regions. | Climate-specific guidance |
| **10 Steps to Climate-Responsive Building Design** | This site provides basic steps for designing a building that will optimize the potential of a specific site and reduce energy consumption based on different climates. | Climate-responsive design |

## Performance Tools and Resources

| Desired Attributes | | |
|---|---|---|
| *Disaster Resistance* | | |
| **Performance Tool and Resource** | **Description** | **Link** |
| **Insurance Institute for Business and Home Safety: Fortified Homes** | This resource provides design guidance and criteria for building or renovating homes for disaster resistance. | Fortified Homes |
| **Federal Emergency Management Agency (FEMA) Best Practice Portfolio: Mitigation** | This resource provides mitigation stories that describe measures individuals and communities have taken to reduce the loss of life and property from disasters. | FEMA Best Practices |
| **FEMA: Protect Your Property** | This resource instructs property owners and contractors about construction techniques to protect their property, home, or business from disaster with short, easy-to-understand pamphlets. | Protect Your Property |
| **Whole Building Design Guide (WBDG): Secure/ Safe** | This resource explains the interrelationship of disaster resistance and security with other WBDG design objectives early in the design process to help overcome the obstacles commonly encountered in achieving a secure and safe building. | Natural hazards and security |
| *Durability* | | |
| **Performance Tool and Resource** | **Description** | **Link** |
| **Resilient Design Institute** | This resource provides guidance and design solutions related to disaster resistance and resilience related to buildings, communities, and infrastructure. | Resilient Design Institute |

# Desired Attributes

## *Durability* *Continued*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **ResilientCity.org: Building Design Principles** | This resource provides guidance and design solutions related to disaster resistance and resilience related to buildings, communities, and infrastructure. | Building Design Principles |
| **Durability by Design: A Guide for Residential Builders and Designers** | This manual addresses building durability as a design consideration in housing. | Durability by Design |

## *Health/Indoor Air Quality*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **U.S. Environmental Protection Agency (EPA) Indoor airPLUS Program** | Building on the foundation of EPA's ENERGY STAR requirements for new homes, this resource provides additional construction specifications to provide comprehensive indoor air-quality protections in new homes. | Indoor Air Plus |
| **The Inside Story: A Guide to Indoor Air Quality** | These publications and resources provide information about indoor air quality, how it affects a homeowner, and best practices for improving air quality in a building. | Guide to Indoor Air Quality |
| **American Lung Association: Healthy Air** | This resource offers important indoor air quality factors to consider when constructing or retrofitting a home. | New construction and remodeling tips |

## *Sustainability/Green*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **U.S. Environmental Protection Agency (EPA): Green Building** | This online site provides information about green building practices. Topics include components of green building, building types, and funding opportunities. | EPA Green Building |

# Desired Attributes

## *Sustainability/Green* *Continued*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **BuildingGreen, Inc.** | This resource combines information with insight, convening conversations and generating knowledge to help building industry professionals and policymakers improve environmental performance and reduce the adverse effects of buildings. | BuildingGreen |
| **GreenBuildingAdvisor.com]** | This online resource provides information about designing, building, and remodeling energy-efficient, sustainable, and healthy homes. | Green basics |
| **GreenSpec Building Products** | This resource lists more than 2,600 green building products. The editorial team selects all products based on their independent research that assesses manufacturers' claims. | GreenSpec |
| **American Institute of Architects (AIA) Affordable Green Guidelines** | This resource offers design guidance to architects related to green building. | Green criteria |
| **Enterprise Green Communities** | This resource helps developers, investors, builders, and policymakers make the transition to a green future for affordable housing. | Green resources for housing |

## *Maintenance*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **STRUCTURE magazine** | This resource disseminates useful tips, tools, and techniques that will help structural engineers increase the quality, productivity, and profitability of their work, and it introduces new and innovative concepts in structural engineering. | Structure resources |
| American Financial Resources official blog | This resource provides tips for a low-maintenance home interior and exterior | Low-maintenance home tips |

# Desired Attributes

## *Water Efficiency*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **U.S. Environmental Protection Agency (EPA) WaterSense: Product Certification and Labeling** | This tool makes it easy for consumers to recognize products and programs that save water without sacrificing performance or quality. | EPA WaterSense |

## *Energy Efficiency*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Building America Solution Center (BASC)** | This resource allows the user to search for building science or energy-efficiency research and design guidance by climate, building component, or publication title. It is a compilation of research performed by the Building America Program | BASC |

# Building Components

## *Ceiling/Roof*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Building Science Corporation (BSC): High R-Value Roof Assemblies** | This resource identifies and evaluates residential assemblies that cost-effectively provide an improvement in thermal resistance over current building code minimums. | Roof Design |
| **U.S. Environmental Protection Agency's (EPA's) ENERGY STAR: Roof Products** | This resource provides information about ENERGY STAR-qualified roof products. | ENERGY STAR Roof Products |

# Building Components

## *Electrical/Lighting*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Energy.Gov: Solid-State Lighting (SSL)** | This resource provides research and information on new technologies related to SSL. | Solid-State Lighting |
| **U.S. Environmental Protection Agency's (EPA's) ENERGY STAR Lighting** | This resource provides information on ENERGY STAR-qualified lighting products. | ENERGY STAR Lighting |

## *Exterior Wall*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Building Science Corporation (BSC): High R-Value Wall Assemblies** | This resource identifies and evaluates residential assemblies that cost-effectively provide a 50-percent improvement in thermal resistance over current building code minimums. | High R-Value Wall Assemblies |

## *Foundation*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Building Science Corporation (BSC): High R-Value Foundations** | This resource identifies and evaluates residential assemblies that cost-effectively provide a 50-percent improvement in thermal resistance over current building code minimums. | High R-Value Foundations |

## *HVAC*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Energy.Gov: Space-Heating/Cooling Research** | This resource provides research, best practices, and other information on efficient heating and cooling technology and strategies. | Space Heating and Cooling |

# Building Components

## *HVAC* *Continued*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **U.S. Environmental Protection Agency's (EPA's) ENERGY STAR Air-Conditioning** | This resource provides information about ENERGY STAR-qualified air-conditioners. | ENERGY STAR Air-Conditioning |
| **EPA's ENERGY STAR Boilers** | This resource provides information about ENERGY STAR-qualified boilers. | ENERGY STAR Boilers |
| **EPA's ENERGY STAR Ductless Heating and Cooling** | This resource provides information about ENERGY STAR-qualified ductless heating and cooling. | ENERGY STAR Ductless Heating and Cooling |
| **EPA's ENERGY STAR Furnaces** | This resource provides information about ENERGY STAR-qualified furnaces. | ENERGY STAR Furnaces |
| **EPA's ENERGY STAR Air-Source Heat Pumps** | This resource provides information about ENERGY STAR-qualifies air-source heat pumps. | ENERGY STAR Air-Source Heat Pumps |
| **EPA's ENERGY STAR Geothermal Heat Pumps** | This resource provides information about ENERGY STAR-qualified geothermal heat pumps. | ENERGY STAR Geothermal Heat Pumps |
| **EPA's ENERGY STAR Ventilation Fans** | This resource provides information about ENERGY STAR-qualified ventilation fans. | ENERGY STAR Ventilation |

## *SMART® Technologies/Controls*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Energy.Gov: Sensors and Controls** | This resource provides research, best practices, and other information on sensor and control technology and strategies. | Sensors and controls |

## *Water Heating/Plumbing/Piping*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Energy.Gov: Water Heating Research** | This resource provides research, best practices, and other information regarding efficient water heating technologies and strategies. | Water heating |

# Building Components

## *Water Heating/Plumbing/Piping*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **U.S. Environmental Protection Agency's (EPA's) ENERGY STAR Water Heaters** | This resource provides information about ENERGY STAR-qualified water heaters. | ENERGY STAR water heaters |

## *Windows/Doors*

| Performance Tool and Resource | Description | Link |
|---|---|---|
| **Energy.Gov: Windows and Building Envelope** | This resource provides activities in windows and building envelope that focus on technologies such as highly insulating materials and systems; methodologies and analysis tools for measurement and validation of building envelope performance; and market-enabling efforts such as the creation of an organization responsible for rating, certifying, and labeling fenestration attachment products to better inform consumers. | Windows and Building Envelope |
| **U.S. Environmental Protection Agency's (EPA's) ENERGY STAR: Residential Windows, Doors, and Skylights** | This resource provides information about ENERGY STAR-qualified windows, doors, and skylights. | ENERGY STAR Windows, Door, Skylights |

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