



Charleston's early architecture relied on windows and piazzas for natural ventilation and shade. (www.loc.gov)

R7

RESILIENCE GUIDANCE: BUILDING SYSTEMS

SYSTEMS IMPROVEMENT GOALS

Power and water supply systems are critical for health and safety and can become severely compromised during a natural hazard event. Installation of secondary and back-up systems will limit secondary dangers like mold and fire, and aid the recovery process. Reducing energy and water use saves money and improves resilience.

MAINTENANCE AND PERMITTING

A building permit may be required for any of these suggested work items. (Refer to Resilience Guidance: Permit Review, page R1.5.) Also, if the property is subject to review by the Board of Architectural Review or Design Review Board, additional reviews may be required. For any questions or concerns, contact the Permit Center. Additional resources and codes can be found on the last page of this topic section.

Building systems and equipment can be significantly impacted by environmental factors. If damaged, they are typically costly to repair or replace, and if rendered non-functional, they can impact recovery after an event such as a severe storm. Resilience upgrades for building systems and equipment can address preventive measures to reduce direct impacts from climate threats, as well as secondary goals, such as improving efficiency and reducing energy and water use. Limiting water use also reduces wastewater and its volume in the combined sewage and stormwater systems, reducing potential flood risk.

Vulnerable systems and equipment include mechanical, electrical, plumbing, and telecommunication elements that can be located on interior spaces, mounted on a building's roof or walls, or located elsewhere on the property.

- **Flooding or heavy rains** can damage systems and components that require electricity to operate and cause backups in plumbing systems
- **High winds** and impact from airborne debris can dislodge equipment, topple trees onto electrical lines, and rupture gas line connections, potentially causing a fire and interrupting utility services
- **Earthquake** shaking can topple roof-mounted equipment and hot water heaters, potentially rupturing gas lines and water supply lines
- **Extreme heat** burdens electrical systems through increased use of fans and air conditioners

The upgrades referenced in this section can be completed incrementally with modifications to existing systems. Others are best completed when a system, such as an air conditioning unit, is being replaced or as part of a building improvement project.





A significant remodeling project can provide an opportunity to elevate electrical and plumbing components to improve resilience.

BUILDING SYSTEM COMPONENTS

Building systems are made up of a number of parts that work together to service a space. These systems generally fall under the mechanical, electrical, and plumbing categories listed below, but can also include fire protection in larger residential and commercial buildings.

- **Mechanical systems** primarily provide the heating and cooling for a space, and they also ventilate through air movement and fresh air intake. Heating systems can be powered by gas, oil, or electricity; while the other components are usually powered by electricity.
- **Electrical systems** provide power within and outside a building and they power mechanical systems, kitchen and laundry appliances, internet service, and some hot water heaters. Power systems include electrical panels, conduits, junction boxes, outlets, and switches. Power can also be supplied through alternative means such as solar panels, wind turbines, and generators, which can be beneficial if there is a disruption in the city's electrical service. *(Refer to Solar Collectors, page R3.8.)*
- **Plumbing systems** include basic water service, plumbing fixtures, roof vents, roof drains, floor drains, hot water heaters, and irrigation systems.
- **Fire protection systems** tend to be limited to commercial buildings and larger-scale residential buildings, and typically include a sprinkler system and potentially a fire pump.

There are several basic system maintenance tasks that can be completed by property owners, while repairs and system inspections may require a specialized service person and a building permit. ***A trained technician should be contracted to perform manufacturer's recommended system service or any work that is unfamiliar or potentially dangerous.***

BUILDING SYSTEM COMPONENTS

The types of system components found in a building varies, but may include any of the items listed below.

- Mechanical equipment, air conditioner compressor units, heaters
- Electrical systems and fans
- Vents, including restaurant exhaust, plumbing, and laundry
- Satellite dishes and antennae
- Hot water heaters
- Generators
- Septic tanks
- Solar panels
- Wind turbines
- Building-mounted piping
- Irrigation systems

SPECIALTY PERMITTING

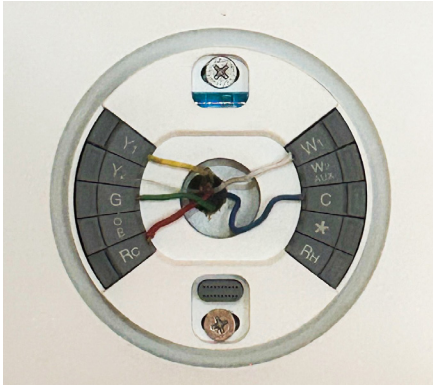
In addition to a building permit, specialty contractor permits may be required for mechanical, electrical, plumbing, and fire protection technicians. *(Refer to Resilience Guidance: Permit Review, page R1.5.)*

SYSTEM MAINTENANCE MANUAL

A maintenance manual can help keep track of conditions, problems, maintenance tasks, and contractors who perform the work. Information could include:

- Names and telephone numbers of repair technicians
- Information on the installed system components, maintenance manuals, warranties
- List of recommended maintenance requirements and frequency, such as how often to replace air filters in an HVAC unit
- Log describing maintenance and repair work performed, including date and who performed the tasks

(Refer to Maintenance Manual, page R1.3.)



Replacing an older thermostat with a compatible digital model can be a DIY project to help maximize efficiencies.



A combination of habits, like closing shades on southern exposures in the summer and reducing air conditioning, can save utility costs and prolong the system's lifespan.



Secure propane tanks to reduce movement during a flood or earthquake.

BASIC SYSTEMS MAINTENANCE TO IMPROVE RESILIENCE

For optimal performance and increased resilience, building systems need to be maintained, weaknesses or deficiencies identified, and repairs made on a regular basis. The list below includes relatively basic tasks that may be possible for a property owner to complete. All work performed, including regular maintenance, should be recorded in a Maintenance Manual. *(Refer to System Maintenance Manual, sidebar page R7.2, and Maintenance Manual, page R1.3.)*

KEY TIPS:

- Replace incandescent light bulbs with LEDs to reduce electrical use and heat generation from bulbs
- Limit use of heat-generating appliances, including clothes dryers, ovens, and dishwashers to the evening or early morning
- Set the thermostat temperature as high as tolerable in the summer and reduce use while sleeping or away
- Install a programmable thermostat and smart bulbs or and/or motion-activated lights to reduce energy use
- Clean or replace heating/air conditioning filters monthly to improve efficiency
- Clean registers and keep furniture, carpeting, or drapes from blocking air flow
- Locate main water shutoff and know how to turn it off in case of a leak
- Drain sediment from water tank or instant hot water heater every 6 months to improve efficiency
- Remove air from radiators to increase heat output
- Adjust window shades seasonally: keep them open in colder months on south-facing windows during the daytime and closed at night for better insulation; in warmer months keep shades closed to reduce heat impact from the sun
- Locate exterior sewer clean-out valve and maintain an accessible area around it
- Inspect septic tanks annually and pump out every 3-5 years at a minimum to prevent clogs
- Avoid driving or parking on drain fields to reduce possible piping damage
- Ensure any gaps around water pipes, electric wiring, internet cables, or other conduits are sealed *(refer to Weatherstripping and Caulk, page R6.8)*
- Monitor fasteners for building- or ground-mounted equipment for rust, and missing or broken pieces
- Clear clogged or slow-draining pipes as they are discovered to avoid potential backups and reduce flood risk
- Close fireplace flues when not in use to minimize drafts
- Secure outdoor grills, and pool or spa power supplies
- Ensure connections to propane tanks are securely fastened and install straps to prevent tank from floating or toppling during a flood or earthquake
- Test smoke and carbon monoxide detectors monthly and replace batteries every 6 months to reduce fire risk



Stands for elevating equipment can be purchased or made from lumber at home. Stainless steel or galvanized connectors will limit rusting.



Relocate ducts to attic, above potential floodwater. Installing new insulated ductwork will increase system efficiency. (www.energy.gov)



Package-style HVAC systems require more space and exterior ductwork at ground level, which can complicate system elevation. Ducts in flood-prone areas are vulnerable to damage.

HEATING AND AIR CONDITIONING

Damage to building systems and equipment can be a costly effect of flooding. Traditionally, heating, ventilation, and air conditioning (HVAC) systems and equipment are located in a crawl space, on the first floor, at exterior grade, or mounted on building roofs or walls. For equipment located in flood-vulnerable areas, even short-term exposure to floodwater will necessitate replacement and render them useless when they are needed most during the first critical days of recovery. In addition, relocating equipment to a higher elevation level may limit an environmental hazard by preventing gas, oil, and chemicals from mixing with floodwater, and avoid potential electrification. Equipment mounted to building walls or a roof can be dislodged in high winds or an earthquake if not securely fastened.

KEY TIPS:

- Elevate or relocate furnace/heat pumps, air conditioners, hot water heaters, and vulnerable kitchen and laundry appliances to limit flood vulnerability
- Secure roof-mounted and wall-mounted equipment to prevent dislodging in high winds or an earthquake
- Secure fuel supplies and connections to prevent potential ruptured lines
- Replace damaged or worn duct systems; relocate to attic or above floodwater level or install ducts certified for wet installations
- Insulate ducts to reduce cooling or heat loss
- Replace older HVAC equipment with right-sized, high energy-rated, variable-speed models that also help with dehumidification, and seek financial incentives

from local and national rebate programs (*refer to Right-Size Heating and Cooling Equipment, sidebar below, and Potential Rebate Offers, sidebar page R7.5*)

- Minimize the visibility of equipment to the public right-of-way and neighboring properties
- Locate equipment to meet all applicable codes and the manufacturers' recommended requirements for clearance, access, and ventilation
- Replace multiple window air conditioner units with a more efficient, ductless mini-split cooling system
- Use a dehumidifier, fan, or ceiling fan to improve comfort and reduce air conditioner use
- Install a whole-house fan in the attic if conditions allow

RIGHT-SIZE HEATING AND COOLING EQUIPMENT

Mechanical engineers and HVAC contractors can calculate heating and cooling requirements for a building to determine the size of equipment needed to meet occupant demands.

- When equipment is oversized, initial costs are higher, heating/cooling efficiency is reduced, more duct leakage occurs due to higher operating duct pressures, comfort may be compromised, and energy costs increase with larger fan use
- Similar to an automobile in stop-and-go traffic, the overall efficiency of an air conditioner, furnace, or heat pump is reduced by excessive cycling in oversized units
- As the overall efficiency of a building is improved by reducing air leakage or adding insulation, the recommended size of the HVAC system should drop (U.S. Dept. of Energy)

ELECTRICAL

Electricity is used to power many building systems, appliances, equipment, medical devices, and communication devices. A loss of power, even temporarily, can be highly disruptive, potentially hindering recovery from an event like a severe storm. Without electricity, food in refrigerators can spoil, fans and dehumidifiers cannot be used to minimize mold in flood events, internet service may be impacted, sump pumps are idle, and cell phones and power tools cannot be charged.

KEY TIPS:

- Trim tree limbs that may fall onto power lines (*refer to Trees, page R2.9*)
- Convert overhead utility lines to underground lines to reduce potential downed service, fire, and electrification
- Elevate associated secondary elements such as electrical outlets, junction boxes, switches, disconnects, panels, and meters above potential flood level
- Install and maintain a generator that can power equipment, including fans, a sump pump, dehumidifier, refrigerators, and essential needs
- Obtain portable photovoltaic panels with battery storage that can be mobilized and deployed temporarily
- Consider installation of solar panels (*refer to Solar Collectors, page R3.8*)
- Replace older appliances with Energy Star products and seek financial incentives from local and national rebate programs (*refer to Potential Rebate Offers, sidebar below*)



When charged, portable, solar powered backup batteries can be deployed in an emergency. (Example from Solar Stik)



Generators can be installed as a permanent system that is ready to use when there is a power outage.

ENERGY ASSESSMENTS

Reducing energy saves money and improves resilience. An energy check-up is one of the best ways to understand how a building uses energy and where improvements can be made. A professional home energy assessment can identify improvements that may include adding or replacing insulation or sealing openings to reduce heat loss or gain, and drafts. It can also identify appliances or systems that are inefficient, near the end of their life spans or are costly to operate, allowing replacement to be planned prior to failure.

KEY TIPS:

- Obtain a building energy check-up with a certified energy assessor (www.energy.gov)
- Install insulation in areas otherwise un-insulated or upgrade insulation, particularly in attics and crawl spaces (*refer to Attic, page R3.9, and Insulation Matrix, page R8.6*)
- Seal openings to prevent drafts (*refer to Weatherstripping and Caulk, page R6.8*)
- Select high-efficiency appliances and building system components when replacement is warranted
- Retrofit a traditional fireplace with a fireplace insert to increase heat output

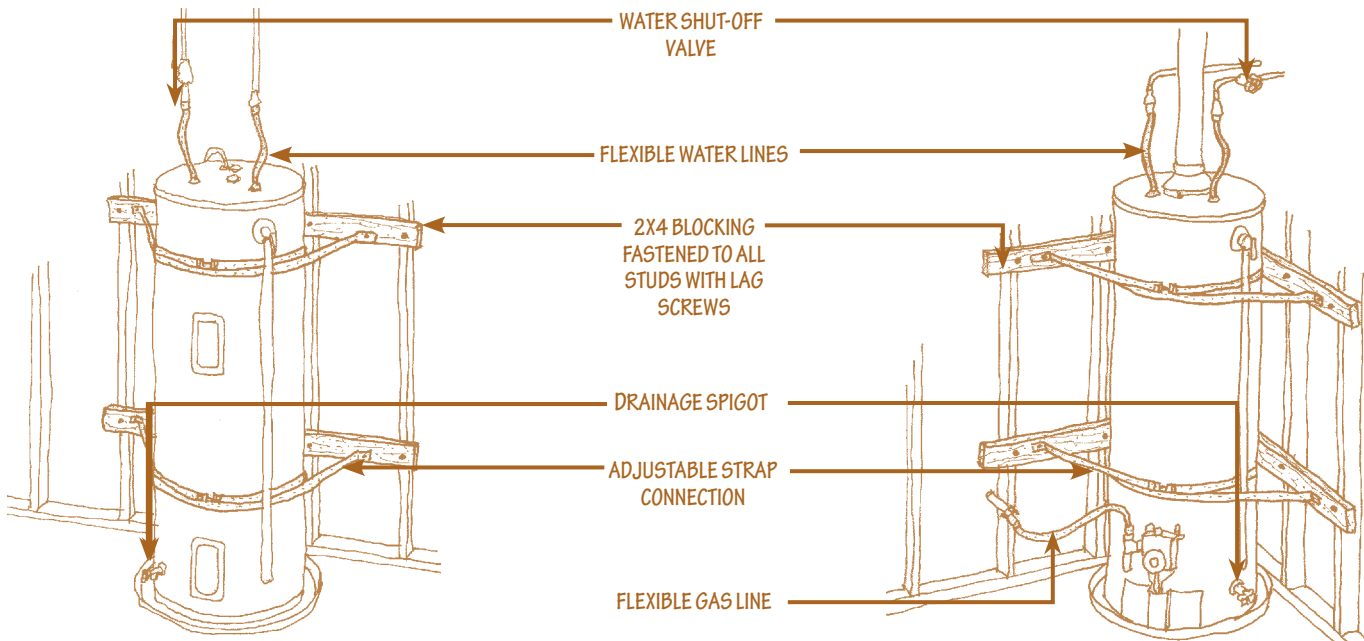
POTENTIAL REBATE OFFERS

Rebates and tax credits for energy efficiency retrofits for single- and multifamily-buildings may be available depending on program funding, the amount of energy savings achieved, and applicant's income. The federal Energy Star website has information about efficient products, rebates, and tax credits. (*Refer to www.energystar.gov.*) In addition, contact the South Carolina Energy Office for information if replacing appliances or performing improvements identified below. (*Refer to www.energy.sc.gov.*)

- Clothes dryers
- Space heating and cooling
- Water heaters
- Electric panel and wiring upgrades
- Stoves, cooktops, ranges, and ovens
- Air sealing
- Duct sealing
- Building insulation (*refer to Insulation Matrix, page R8.6*)
- Ventilation systems

The City of Charleston website includes links to energy companies and energy audit programs. (www.charleston-sc.gov/2020/You-Can-Help)





Straps and flexible fuel and water lines can improve the resilience of traditional hot water heaters. Fitted insulation can be added around tank to decrease standby heat loss. (Base diagrams obtained from www.fema.gov.)

PLUMBING

When there are intense rains or a flood event, plumbing systems can be vulnerable to backups as can septic systems and drainage fields. While most backups occur at landscape drains or floor drains, when the water is higher, backups can occur through toilets and sinks. Additionally, a leaking drain in an area with a high water table can contaminate local waterways. (Refer to *Drains*, page R2.8.)

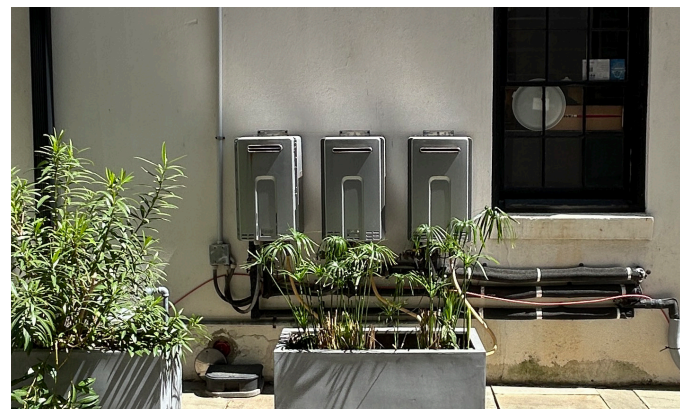
Hot water heaters can represent another resilience vulnerability. Traditional hot water tanks can float in floodwater and topple in earthquakes. This can cause a hazard by rupturing water and fuel lines and damaging electrical connections.

KEY TIPS:

- To minimize the potential for sewage backup through floor drains, toilets, and sinks, install a backflow preventer
- Install low-flow shower heads and efficient toilets to reduce water use
- Install straps to secure hot water tanks
- Install flexible fuel and water lines at hot water tanks
- Install fitted insulation at hot water heater tanks and metal piping to decrease standby heat loss
- Secure fuel supplies and connections
- Replace tank-style hot water heater with an on-demand or “instant” hot water system to reduce energy use



The backflow preventer, disguised by the green cover, keeps floodwater from backing up into drains and plumbing fixtures.



On-demand hot water heaters reduce energy use since it is not necessary to maintain a tank of water warm at all times.



The generator is highly obscured by fencing and surrounding plants.

BAR

Refer to the BAR Jurisdiction Chart and Map or speak with City staff to determine if a property has additional permit or review requirements.

BAR Policy Statements:

- Solar Collectors
- Storm Windows

HISTORIC PRESERVATION CONSIDERATIONS

Properties located in a historic district or design review district may require additional City review whether a permit is required or not. Contact the Permit Center, or the BAR or DRB staff, to speak with someone directly. Information is provided below for best practices toward maintaining the historic character of a property when changes are made to building systems and equipment.

BASIC MAINTENANCE

- Preserve existing fireplaces and chimneys, making any retrofits to the interior flue and fireplace
- When making any repairs to building-mounted equipment, limit damage to historic materials and repair with in-kind materials

EXISTING SYSTEMS AND EQUIPMENT

- Relocate all building systems and equipment out of flood-prone areas to an inconspicuous location, minimizing visibility from the public way and neighboring properties
- Screen ground-mounted systems and equipment with landscaping or fencing to minimize visibility

INSTALL SECONDARY POWER SOURCES

- Locate secondary power sources out of flood prone areas to an inconspicuous location
- Locate roof or wall-mounted secondary power sources, including solar panels, in a manner that minimizes visibility from the public right-of-way

BUILDING SYSTEMS IMPROVEMENT CHECKLIST

The Building Systems Improvement Checklist on the following pages identifies maintenance information, system upgrades, and other related potential resilience improvements. Information on the relative costs, expertise, and vulnerabilities addressed are keyed with icons described at right.

Level of Risk and Professional Help: The Checklist identifies work that can be completed by property owners or tenants who are able to safely and comfortably use hand tools or power equipment, as needed. Any lifting, bending, or exertion beyond a person’s abilities should be undertaken by professionals.

Vulnerabilities: The icons below are used throughout this guide. Completion of the proposed improvements can increase a building’s resilience from the following vulnerabilities:
















-  Flood
-  Wind
-  Earthquake
-  Heat
-  Good maintenance























Cost: The relative cost of the proposed improvement is denoted by symbols below. The cost will vary based on the conditions and extent of the impacted area.

- ¢ Minimal supplies under \$100
- \$ \$100-\$1,000
- \$\$ \$1,000-\$5,000
- \$\$\$ \$5,000 and above

“Off-the-Shelf” Solution Available: An item that is relatively available for purchase and easy to install by a property owner or contractor.

BUILDING SYSTEMS IMPROVEMENT CHECKLIST

ACTION / PROJECT <i>PERMITS: A building permit may be required for any of these suggested work items. Additionally, if the property is subject to review by the Board of Architectural Review or Design Review Board, additional reviews may be required. For any questions or concerns, contact the Permit Center.</i>	RESILIENCE BENEFIT	COST	DO-IT-YOURSELF	CONTRACTOR MAY BE REQUIRED	ARCHITECT OR ENGINEER MAY BE REQUIRED	“OFF-THE-SHELF” SOLUTION AVAILABLE
BASIC SYSTEM MAINTENANCE TO IMPROVE RESILIENCE Page R7.3						
<input type="checkbox"/> Replace incandescent light bulbs with LEDs		¢	●			●
<input type="checkbox"/> Limit use of heat-generating appliances to evening and early morning		¢	●			
<input type="checkbox"/> Install a programmable thermostat and set as high as tolerable in the summer and reduce further while sleeping or away from home		¢	●			●
<input type="checkbox"/> Clean or replace heating/air conditioning filters and clean registers		¢	●			●
<input type="checkbox"/> Drain sediment from water tank every 6 months and bleed air from radiators		¢-\$	●	●		
<input type="checkbox"/> Use window shades seasonally		¢	●			
<input type="checkbox"/> Locate exterior sewer clean-out valve and keep a clear space around it		¢	●			
<input type="checkbox"/> Ensure any gaps around water pipes, electric wiring, internet cables, or other conduits are sealed		¢	●			●
<input type="checkbox"/> Pump out septic tanks every 3-5 years at a minimum to prevent clogs		\$		●		
<input type="checkbox"/> Avoid driving or parking on septic drain fields		¢	●			
<input type="checkbox"/> Monitor building- or ground-mounted equipment fasteners for rust, and missing or broken pieces		\$	●	●		
<input type="checkbox"/> Clear clogged or slow-draining pipes as they are discovered		¢-\$\$	●	●		
<input type="checkbox"/> Close fireplace flues when not in use		¢	●			
<input type="checkbox"/> Ensure outdoor barbecue grills, propane tanks, and pool or spa power supplies are secured when not in use		¢	●			●
<input type="checkbox"/> Locate, test, and service smoke and carbon monoxide detectors, replacing batteries every 6 months		¢	●			●

ACTION / PROJECT <i>PERMITS: A building permit may be required for any of these suggested work items. Additionally, if the property is subject to review by the Board of Architectural Review or Design Review Board, additional reviews may be required. For any questions or concerns, contact the Permit Center.</i>	RESILIENCE BENEFIT	COST	DO-IT-YOURSELF	CONTRACTOR MAY BE REQUIRED	ARCHITECT OR ENGINEER MAY BE REQUIRED	"OFF-THE-SHELF" SOLUTION AVAILABLE
HEATING AND AIR CONDITIONING Page R7.4						
<input type="checkbox"/> Elevate or relocate furnace/heat pumps, air conditioners, and vulnerable appliances		\$\$-\$	●	●		●
<input type="checkbox"/> Secure roof-mounted and wall-mounted equipment to prevent toppling		C-\$	●	●		
<input type="checkbox"/> Secure fuel supplies and connections		C-\$	●	●		
<input type="checkbox"/> Replace damaged or worn ducts, relocate above flood level, install wet-certified products		\$\$\$\$		●		
<input type="checkbox"/> Insulate ducts to reduce heat/cooling loss		\$\$-\$	●	●		
<input type="checkbox"/> Replace older HVAC equipment and locate with minimal visibility that meets code		\$\$\$\$		●		
<input type="checkbox"/> Replace multiple window air conditioner units with an efficient ductless mini-split		\$\$\$\$		●		●
<input type="checkbox"/> Use a dehumidifier, fan, or ceiling fan		\$	●			●
<input type="checkbox"/> Install a whole-house fan in the attic		\$\$		●		●
ELECTRICAL Page R7.5						
<input type="checkbox"/> Trim tree limbs that may fall on power lines		C-\$	●	●		
<input type="checkbox"/> Bury overhead utility lines		\$\$\$		●		
<input type="checkbox"/> Elevate electrical system elements like outlets, junction boxes, and switches		\$\$-\$		●		
<input type="checkbox"/> Install and maintain a generator		\$\$\$	●			●
<input type="checkbox"/> Obtain portable photovoltaic panels with battery storage		\$\$	●			●
<input type="checkbox"/> Install permanent solar panels		\$\$\$		●	●	
<input type="checkbox"/> Replace old appliances with Energy Star products		\$\$-\$	●			●
PLUMBING Page R7.6						
<input type="checkbox"/> Install a backflow preventer		\$\$-\$		●		●
<input type="checkbox"/> Install efficient shower heads and toilets		C-\$	●	●		
<input type="checkbox"/> Install straps to secure water tanks and use flexible fuel and water lines		C	●			●
<input type="checkbox"/> Secure fuel supplies and connections		C	●			
<input type="checkbox"/> Insulate hot water tank and metal piping		C-\$	●	●		●
<input type="checkbox"/> Replace tank-style hot water heater with an on-demand or "instant" hot water system		\$\$-\$		●		●

BUILDING SYSTEMS RESOURCES

Charleston Water System

Overview of Backflow Prevention

charlestonwater.com

City of Charleston

Guidelines and Requirements for HVAC System Ducts

Sustainability: You Can Help

charleston-sc.gov

Dominion Energy

Ductwork Improvement Rebate

Virtual Home Energy Check-up

dominionenergy.com

Federal Emergency Management Administration

Earthquake Safety at Home P-530

Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems: New and Substantially Improved Buildings, 3.1

Protecting Building Utility Systems from Flood Damage, P-348

fema.gov

Mississippi State Extension Office

Energy Efficient Homes: Air Conditioning

extension.msstate.edu

State of South Carolina

Energy Saver Tool and Energy Audit

energysaver.sc.gov

U.S. Department of Energy

Energy Star Products

Fact Sheet 31318 Right-Size Heating and Cooling Equipment

Finding and Selecting an Energy Assessor

Minimizing Energy Losses in Ducts

energy.gov



REGULATIONS TO REVIEW

- International Existing Building Code
- South Carolina Residential Code
- South Carolina Mechanical; Fuel, Fire, Plumbing
- City of Charleston Code of Ordinances
- City of Charleston Flood Hazard Prevention and Control Ordinance

This is not a comprehensive list and is intended only to provide additional resources to consider when planning a project. Contact the Permit Center for detailed information.

City of Charleston Permit Center

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Charleston, SC 29401
843.577.5550
permits@charleston-sc.gov