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Electric Readiness in Residential Energy Code

Technical Brief

December 2024

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Richland, Washington 99354

Preamble

The U.S. Department of Energy (DOE) and Pacific Northwest National Laboratory (PNNL) developed a series of technical briefs supporting national, state, and local initiatives to update and advance building energy codes. These technical briefs represent specific technologies, measures, or practices that can be incorporated as module-based “plug-ins” via the national model energy codes, such as the International Energy Conservation Code (IECC) or ASHRAE Standard 90.1 or can be adopted directly by state and local governments pursuing advanced energy savings. . The collection of briefs is part of a larger effort to provide technical assistance supporting states and local governments working to update their building codes.

This technical brief provides requirements for electric readiness that could be incorporated into model residential energy codes. It provides background on the provisions, and model code language that can be plugged into the IECC or adapted into other energy codes.

Additional assistance may be available from DOE and PNNL to support states and local governments who are interested in adding electric readiness and other “stretch” provisions to their building codes. Forms of assistance include technical guidance, customized analysis of expected impacts (e.g., based on state-specific building stock, energy reduction goals, or utility prices), and further tailored code language to overlay state building codes or other standards. DOE provides this assistance in response to the Energy Conservation and Production Act, which directs the Secretary of Energy to provide technical assistance “to support implementation of state residential and commercial building energy efficiency codes” (42 USC 6833). PNNL supports this mission by evaluating concepts for future code updates, conducting technical reviews and analysis of potential code changes, and assisting states and local jurisdictions who strive to adopt, comply with, and enforce energy codes. This helps assure successful implementation of building energy codes, as well as a range of advanced technologies and construction practices, and encourages building standards that are proven to be practical, affordable, and efficient.

DOE Building Energy Codes Program

The U.S. Department of Energy provides technical assistance to states, municipalities and the design and construction industry supporting building energy codes. Modern building codes offer the latest technologies and cost-effective solutions, contributing to lower energy bills for homes and businesses and ensuring safe, efficient and affordable buildings. Learn more at energycodes.gov.

Executive Summary

States and jurisdictions interested in future-proofing their buildings for years into the future are starting to consider energy code provisions like electric readiness. Electric readiness supports consumers' ability to capture the value of demand response and demand flexibility as the market grows with increased variable renewable energy on the system. There are multiple opportunities for building owners to make their buildings electric ready. The scope of this technical brief includes five strategies for electric readiness in residential buildings: 1) Cooking appliances, 2) Household clothes dryers 3) Water heaters, 4) Combustion space heating and 5) Electric-ready circuits.

Demand on the energy grid continues to grow over time, which causes strain and congestion on the electrical system. In addition, the renewable energy resources and clean energy technologies are starting to shift what time of day energy is used on the grid. As buildings account for over 70% of U.S. electricity use (EIA 2023), effectively managing their loads can greatly benefit home and building owners, as well as improving stability and security of the grid system. Energy efficiency and demand flexibility play a key role in ensuring access to an affordable, reliable, and modern U.S. electric power system. Adoption of these strategies could provide $100-200 billion in U.S. electric power system cost savings over the next two decades.

Preparing a building for the future installation of technologies during construction is much more cost effective than retrofitting that building at a later point. A 2020 study compared the cost of installing heat pumps for space conditioning and water heating as original equipment to that incurred if installed as a retrofit (Group-14 Engineering 2020). The data indicated that retrofit electrical costs are over four times the cost of the original installation, increasing by $1,600, from $500 to $2,100. A separate study identifies residential electric panel capacity as a potential roadblock for installing electric and demand-flexible equipment. The results suggest that as many as 48 million households may require a panel upgrade to fully electrify. The incremental cost compared to the original cost is $1,000 to $5,000 per installation. Yet upgrading the panel capacity at the time of install costs only a few hundred dollars (Pecan Street 2021).

Electric-ready provisions ensure that a homeowner in a house built with fossil fuel burning appliances can have the option to select either fossil fuel or electric appliances at the time of replacement. Such provisions protect homeowners from high future retrofit costs, and provides security that the homeowner can make the best choice for them, considering the variable nature of electricity and fossil fuel prices and availability.

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1.0 Background

A transition of the U.S. power system is underway that is reshaping its operation and performance. Persistent growth in renewable energy resources—driven by declining costs, improved performance, and clean energy policies[1]—has noticeably impacted the electricity system (EPA 2024a). As buildings account for over 70% of U.S. electricity use (EIA 2023), reducing and effectively managing their loads can greatly benefit home and building owners, as well as improving stability and security of the grid system. Increased efficiency and demand flexibility are foundational to grid-interactive efficient buildings (GEBs). National adoption of GEBs could provide $100-200 billion in U.S. electric power system cost savings over the next two decades.

The incorporation of electric readiness in energy codes helps ensure homeowners have the ability to select either fossil fuel or electric appliances at the time of replacement. This, in turn, can support consumers' ability to capture the value of demand flexibility through the deployment of flexible load technologies such as smart, home energy management systems, energy storage, behind-the-meter generation, and electric vehicles (EVs). It makes it easier for homeowners to accommodate future electrical appliances and equipment, which protects against fluctuating costs for either electricity or fossil fuels.

[1] Thirty-seven states representing 80% of the U.S. population have enacted renewable portfolio standards or goals.

2.0 Technical Analysis

In 2022, residential and commercial building operations accounted for 31% of the U.S. annual carbon emissions (EPA 2024b). In their energy consumption survey, the U.S. Energy Information Administration (EIA) found that 31% of commercial buildings (EIA 2022) and 26% of residential buildings (EIA 2023) used electricity as their only source of energy. If the energy used for their materials and construction are also considered, it increases their contribution to 42%.[2] With the life expectancy of residential buildings exceeding 50 years and the energy using equipment within buildings lasting between 10 to 20 years,[3] addressing electric readiness today will support achieving near-term and future clean energy goals. Electric readiness considerations include providing sufficient electric panel space and capacity, necessary branch circuits, pre-wiring, sufficient space for heat pump water heating equipment, and electric vehicle (EV) charging. (For more information about code requirements supporting EV charging, see Salcido et al. 2025).

2.1 Costs

Electrical panel size is dependent on several factors, including the home's floor area, the electrical load of installed appliances, and the number of dedicated branch circuits. The difference in cost between installing a 100 Amp to a 200 Amp panel during construction is only a few hundred dollars. However, if a panel size is upgraded as a renovation, the upgrade costs can range from $1,000 to $5,000. Most all-electric homes require at least a 200 Amp service (Pecan Street 2021).

To avoid the added expense, the original panel should be sized sufficiently to accommodate all major electrical uses. Homes built with combustion equipment and appliances tend to have lower capacity electric panels that will likely need an upgrade if replacing with electric equipment. The results of one study suggest that as many as 48 million households may require a panel upgrade if the homeowners fully electrify all end uses. Assuming the incremental cost compared to the original cost is about $2,000 per installation, this implies that a $100 billion investment would be required to upgrade panel capacity to serve all-electric appliances and equipment in the United States (Pecan Street 2021).

A 2020 Colorado study compared the cost of installing a heat pump for space conditioning and a heat pump water heater at the point of construction to the costs incurred as a retrofit (Group-14 2020). Costs were also compared relative to natural gas systems. The results are summarized in Figure 1. The cost data indicate that the cost for electrical modification increases for the electric heat pump space and water heating equipment from $500 to $2,100, which implies an increased cost for the retrofit installation of $1,600 or about four times the original installation cost.

[2] https://architecture2030.org/why-the-building-sector/
[3] https://www.nachi.org/life-expectancy.htm

	End-of-Life Replacement		New Construction[1]	
Description	**Heat Pump**	**Natural Gas**	**Heat Pump**	**Natural Gas**
Central heating/cooling system (including install)	$15,000	$15,000	$13,000	$13,000
Tank type domestic hot water heater	$3,300	$2,600	$3,100	$2,400
Electrical modification	$2,100	----	$500	----
Natural gas connection and piping (new construction only)	----	----	----	$6,500
Total Cost	**$20,400**	**$17,600**	**$16,600**	**$ 21,900**
Delta in Cost for Heat Pump		***$2,800***		***$ (5,300)***

Figure 1. Single Family Home First Costs (Source: Group-14 Engineering 2020)

2.2 Benefits

By ensuring that a home built with natural gas or propane can easily accommodate future choice of electric or fossil fuel appliances, these provisions protect homeowners from future costs should either energy source become less affordable (or even unavailable) over the life of the building. For example, as the electric grid becomes cleaner, high-efficiency electric heat pump technology may increasingly offer utility bill and pollution reduction benefits over fossil fuel heating systems. Additionally, the ability to easily install electric appliances or equipment means that consumers have a greater ability to install systems with grid flexibility capabilities, which can help increase the security and stability of the electric grid.

3.0 Electric Readiness and Energy Codes

Building codes represent standard design practice in the construction industry and continually are updated based on technology advancements and construction practices. Historically, national model energy codes establish minimum efficiency requirements for new construction.[4] Expanding codes to further support electric readiness can help provide consumers with the ability to future proof their building, as well as supporting demand response (DR) communication standardization and advancing the deployment of flexible load technologies such as smart, home energy management systems, energy storage, behind-the-meter generation, and electric vehicles (EVs).

The incorporation of electric readiness into the model residential energy codes was considered for during both the 2021 and 2024 International Energy Conservation Code (IECC) code development cycles. However, the approved electric-readiness measures were removed from the 2021 IECC and relegated to an optional appendix in the 2024 IECC due to the results of appeals. This led to many sections, including sections on electric readiness, being moved to the appendix as a voluntary application.

This technical brief was developed to present the electric readiness measures that can be considered by states and local governments for direct incorporation into their codes, as well as for future IECC energy code development.

The scope of this technical brief includes five strategies for electric readiness in residential buildings:

- Cooking appliances
- Household clothes dryers
- Water heaters
- Combustion space heating
- Electric-ready circuits

3.1 Cooking Appliances

This electric-ready provision requires a sufficiently rated electrical receptacle be installed near permanently installed household ranges and cooking appliances. This assures that a home built with fossil fuel burning equipment and appliances can easily accommodate future electric replacements.

[4] While advanced codes can be considered model codes, in this document, the term “model energy code” refers to the current published version of the International Energy Conservation Code-Residential and ASHRAE Standard 90.1, as those documents are referenced by the Energy Conservation and Production Act, as modified by the Energy Policy Act of 1992, as the minimum requirements for states adopting energy codes. https://www.govinfo.gov/content/pkg/USCODE-2011-title42/pdf/USCODE-2011-title42-chap81-subchapII.pdf.

3.2 Household Clothes Dryers

This electric-ready provision requires a sufficiently rated electrical receptacle be installed near permanently installed household clothes dryers. This assures that a home built with fossil fuel burning clothes dryers can easily accommodate future electric replacements.

3.3 Water Heaters

This electric-ready provision requires a sufficiently rated electrical receptacle be installed near permanently installed household water heaters. This assures that a home built with fossil fuel burning water heaters can easily accommodate future electric replacements.

For electric water heater replacements, there are two standard options: electric resistance or heat pump water heaters (HPWH). To accommodate the installation of a HPWH, specific ventilation needs exist, such as space for a condensate drain. A HPWH also requires ventilation air in one of three ways: free air space around the unit, ducting to the outside, or vents providing access to additional indoor air. This electric-ready provision assures that sufficient indoor space is available near the installed water heater to accommodate a future installation of a heat pump water heater.

3.4 Combustion Space Heating

This electric-ready provision requires consideration for future installation of electric heating. Specifically, a space must be reserved in a designated exterior location that both has natural drainage (or proximate condensate drain) and a dedicated branch circuit in compliance with IRC Section E3702.11. Sufficiently rated electrical receptacles shall be sized to accommodate equipment complying with ACCA Manual S and J. Importantly, the space shall be labeled “For Future Heat Pump Space Heater.”

3.5 Electric-Ready Circuits

This electric-ready provision requires that electric equipment capacity needs must be considered as part of the panel sizing during construction. Specifically, space must be reserved in the electrical panel for the capacity of the required electric-ready appliance and equipment circuits. The circuits must be labeled as “spare.” Their loads must be included in the load calculations of the original panel box installation. Electric-ready circuits can be required for any number of electric loads including, but not limited to those presented here, space heating, electric vehicles, energy storage systems, and energy generation systems.

4.0 Sample Code Language

Jurisdictions seeking to adopt the language included in an appendix of the IECC need to consider the rules of the adopting jurisdiction to ensure adoption of the appendix and its code language is mandatory at the level intended. Jurisdictions can adopt appendices as mandatory for all new construction in one of two ways:

1. Add charging language to the mandatory requirements for buildings that compliance with the appendix (or appendices) is mandatory; or

2. Relocate language from the appendix into the body of the code in the appropriate location.

Both options for adoption are presented here. Each option has benefits and drawbacks. Additional charging language is a simpler amendment to the code but may be overlooked by design teams and authorities having jurisdiction (AHJs) enforcing the code. This can easily be overcome through specific training on the new requirements. This option is not recommended for jurisdictions adopting versions of the IECC that predate the 2024. Moving language from the appendix to the body will make the change clearer and more understood that enforcement is required, but it will make the code appear to be more heavily amended which many jurisdictions seek to avoid. For jurisdictions adopting versions of the IECC that predate the 2024, this option is preferred because the appendix will not be included in the book for the previous code versions. Both adoption strategies will make the electric-readiness provisions mandatory for new construction.

Appendix RK in the 2024 IECC contains model code language for any state or local government to overlay their existing adoption of the IECC with electric readiness requirements for residential buildings. A jurisdiction can elect to utilize Section 4.1 or Section 4.2 of this brief for the adoption of electric readiness provisions.

4.1 Residential Charging Language Option (2024 IECC Only)

The following text shall be added in Section R101.2 of the 2024 IECC:

R101.2 Scope. This code applies to the design and construction of detached one- and two-family dwellings and multiple single-family dwellings (townhouses) and Group R-2, R-3 and R-4 buildings three stories or less in height above *grade plane*.

> **R101.2.1 Appendices.** Provisions in ~~the appendices shall not apply unless specifically adopted~~ Appendix RK are adopted as mandatory.

The following text shall be added in Section R401.2:

R401.2 Application. Residential buildings shall comply with Section R401.2.1, R401.2.2, R401.2.3 or R401.2.4. All new residential buildings shall comply with provisions of Appendix RK.

4.2 Residential Relocation of Appendix Language Option

The following definitions shall be added to Section R202 of the current adopted version of the IECC Residential provisions.

COMBUSTION EQUIPMENT. Any equipment or appliance used for space heating, service water heating, cooking, clothes drying and/or lighting that uses fuel gas or fuel oil.

FUEL GAS. A natural gas, manufactured gas, liquified petroleum gas or a mixture of these.

LIQUID FUEL. A fuel oil or biodiesel blend.

The following text shall be added to Section R404 of the 2021 IECC or 2024 IECC residential energy provisions. If used with the 2021 IECC, the section numbering will begin with R404.4 instead of R404.5. If included in an adoption of an older version of the IECC, the section numbering should be reviewed and changed to be sequential with the current adoption.

R404.5 Electric readiness. Water heaters, space heating equipment, household clothes dryers, cooking appliances that use *fuel gas* or *liquid fuel* shall comply with the requirements of **Sections R404.5.1** through **R404.5.5**.

R404.5.1 Cooking appliances. A dedicated branch circuit outlet with a rating not less than 240 volts and not less than 40 amperes shall be installed and terminate within 3 feet (914 mm) of conventional cooking tops, conventional ovens or cooking appliances combining both.

R404.5.2 Household clothes dryers. A dedicated branch circuit with a rating not less than 240 volts and not less than 30 amperes shall be installed and terminate within 3 feet (914mm) of each household clothes dryer.

R404.5.3 Water heaters. A dedicated branch circuit with a rating not less than 240 volts and not less than 30 amperes, or not less than 120 volts and not less than 20 amperes, shall be installed and terminate within 3 feet (914mm) of each water heater.

R404.5.3.1 Water heater space. An indoor space that is at least three feet by three feet by seven feet high shall be available surrounding or within 3 feet of the installed water heater.

R404.5.3.2 Water heater ventilation. Ventilation to the water heater indoor space shall be provided by one of the following:

1. A space with a minimum volume of 700 cubic feet (20,000 L),
2. The equivalent of one 16-inch (406mm) by 24-inch (610mm) grill to a conditioned space and one 8-inch (203mm) duct of no more than 10 feet (3048mm) in length for exhaust air.
3. One 8-inch (203mm) duct of no more than 10 feet (3048mm) in length for supply air and one 8-inch (203mm) duct of no more than 10 feet (3048mm) in length for exhaust air.

R404.5.4 Combustion space heating. A designated exterior location(s) in accordance with the following:

1. Natural drainage for condensate from cooling equipment operation or a condensate drain located within 3 feet (914 mm), and
2. A dedicated branch circuit in compliance with **IRC Section E3702.11** based on heat pump space heating equipment sized in accordance with **Section R403.7** and terminating within 3 feet (914 mm) of the location with no obstructions. Both ends of the branch circuit shall be labeled "For Future Heat Pump Space Heater."

   Exception: Where an electrical circuit in compliance with **IRC Section E3702.11** exists for space cooling equipment.

R404.5.5 Electric-ready circuits. The unused conductors required by **Sections R404.5.1**through **R404.5.4** shall be labeled with the word "spare." Space shall be reserved in the electrical panel in which the branch circuit originates for the installation of an overcurrent device. Capacity for the circuits required by **Sections R404.5.1 through R404.5.4** shall be included in the load calculations of the original installation.

The following text shall be added to Section R405 of the 2021 IECC or 2024 IECC residential provisions, revising Table R405.2.[5,6]

TABLE R405.2 REQUIREMENTS FOR ENERGY RATING INDEX

SECTION	TITLE
Electrical Power and Lighting Systems	
R404.1	Lighting Equipment
R404.2	Interior Lighting Controls
R404.5	Electric Readiness

The following text shall be added to Section R406 of the 2021 IECC or 2024 IECC residential provisions, revising Table R406.2.[5,6]

TABLE R406.2 REQUIREMENTS FOR ENERGY RATING INDEX

SECTION	TITLE
Electrical Power and Lighting Systems	
R404.1	Lighting Equipment
R404.2	Interior Lighting Controls
R404.5	Electric Readiness

[5] Portions of the table not revised are omitted from this brief and are not intended to be deleted by adoption of this language.

[6] Previous editions of the IECC use a different method of notating mandatory measures. For adoption of language with previous editions, review how that edition indicates mandatory measures and incorporate that notation to ensure all EV measures are mandatory for all compliance paths.

Notes for jurisdictions adopting residential language:

The specific applications (water heaters, space heating equipment, household clothes dryers, cooking appliances) may be adjusted to be included or excluded based on the needs of each jurisdiction.

The addition of the electric readiness section to Table R405.2 and Table R406.2 make the requirements mandatory across all compliance paths (prescriptive, performance, and ERI). If only a select number of paths will require electric readiness infrastructure, those amendments can be adjusted to meet the needs of the jurisdiction.

5.0 References

42 USC 6833. Chapter 42, U.S. Code, Section 6833. Available at http://www.gpo.gov/fdsys/pkg/USCODE- 2011-title42/pdf/USCODE-2011-title42-chap81-subchapII.pdf.

EIA (Energy Information Agency). 2023. Accessed on May 31, 2024 at https://www.eia.gov/energyexplained/use-of-energy/ .

GridWise Architecture Council. 2015. GridWise Transactive Energy Framework Version 1.0. PNNL-22946. Pacific Northwest National Laboratory, Richland Washington. https://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf.

Group-14 Engineering. 2020. *Electrification of Commercial and Residential Buildings: An Evaluation of the System Options, Economics, and Strategies to Achieve Electrification of Buildings.* Prepared for Community Energy, Inc. https://www.communityenergyinc.com/wp-content/uploads/Building-Electrification-Study-Group14-2020-11.09.pdf

Pecan Street. 2021. *Addressing an Electrification Roadblock: Residential Electric Panel Capacity Analysis and Policy Recommendations on Electric Panel Sizing*. https://www.pecanstreet.org/panel-size-paper/

Salcido VR, M Tillou, and E Franconi. 2025. *Electric Vehicle Charging for Residential and Commercial Energy Codes*. PNNL-31576-1. Pacific Northwest National Laboratory, Richland, Washington.

U.S. Environmental Protection Agency (EPA). 2024a. *Power Sector Evolution*. https://www.epa.gov/power-sector/power-sector-evolution

U.S. Environmental Protection Agency (EPA). 2024b. *Sources of Greenhosue Gas Emissions.* https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

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