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Electric Readiness in Residential Energy Code

Technical Brief

October 2021

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U.S. DEPARTMENT OF ENERGY

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Preamble

The U.S. Department of Energy (DOE) and Pacific Northwest National Laboratory (PNNL) are developing 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 and greenhouse gas emissions reductions. The collection of briefs is part of a larger effort to provide technical assistance supporting states and local governments and to help them realize their policy goals.

This technical brief provides requirements for electric readiness that could be incorporated into model residential energy codes. It provides background on the basis and benefits of 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, climate considerations, 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

DOE supports the advancement of building energy codes. Modern building codes and standards offer cost-effective solutions, contributing to lower utility bills for homes and businesses and helping mitigate the impacts of climate change. Learn more at energycodes.gov.

Executive Summary

In support of decarbonization, the nation is moving towards the use of clean energy sources, including a renewable electric grid. As buildings account for over 70% of U.S. electricity use[1], effectively managing their loads can greatly facilitate the transition towards a clean, reliable grid. Strategic building electrification combined with energy efficiency and demand flexibility play a key role in ensuring access to an affordable, reliable, and modern U.S. electric power system. Their national adoption could provide $100-200 billion in U.S. electric power system cost savings over the next two decades. The associated reduction in CO_2 emissions is estimated at 6% per year by 2030.[2]

Many cities and states are enacting new laws, updating building codes and advancing regulatory action in efforts to phase out gas appliances and ensure homes are heated and powered with clean electricity.[3] In California, 50 jurisdictions have passed policies to phase out gas appliances in new construction and 37 of them specify all-electric requirements in new residential buildings.[4] Seattle's new energy code will eliminate the use of fossil fuel for space and water heating for large multifamily construction.[5] New Jersey plans to electrify 90% of its buildings by 2050.[6] Even cold climate states are targeting the adoption of electric heat pumps as a key step towards electrification and achieving emission reductions. Maine aims to install heat pumps in more than 50% of its total households by 2030.[7] In Colorado, the target for heat pump installations are 60% and over 95% of residential heating equipment sales by 2030 and 2040, respectively.[8]

A recent study compares the cost of installing heat pumps for space conditioning and water heating as original equipment to that incurred if installed as a retrofit.[9] The data indicate that retrofit electrical costs are over four times the cost of the original installation. They increase $1,600, from $500 to $2,100. A separate study identifies residential electric panel capacity as a potential roadblock for electrification. 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.[10]

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[1] EIA (Energy Information Agency). 2020. Accessed on October 15, 2021 at https://www.eia.gov/energyexplained/use-of-energy/ .
[2] DOE (U.S. Department of Energy). 2021. *A National Roadmap for Grid-Interactive Efficient Buildings*. Washington DC. https://gebroadmap.lbl.gov/
[3] https://www.greenbiz.com/article/2020-watt-year-building-electrification
[4] https://www.sierraclub.org/articles/2021/07/californias-cities-lead-way-gas-free-future
[5] https://durkan.seattle.gov/2020/12/mayor-durkan-announces-ban-on-fossil-fuels-for-heating-in-new-construction-to-further-electrify-buildings-using-clean-energy/
[6] https://www.nj.gov/emp/docs/pdf/2020_NJBPU_EMP.pdf
[7] https://climatecouncil.maine.gov/future/sites/maine.gov.future/files/inline-files/DraftMaineClimateActionPlan_11.8.20.pdf
[8] https://energyoffice.colorado.gov/climate-energy/ghg-pollution-reduction-roadmap
[9] Group-14 Engineering. 2020. *Electrification of Commercial and Residential Buildings: An Evaluation of the System Options, Economics, and Strategies to Achieve Electrification of Buildings*. https://www.communityenergyinc.com/wp-content/uploads/Building-Electrification-Study-Group14-2020-11.09.pdf
[10] 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/

Electric-ready provisions ensure that a home built with gas or propane can easily accommodate future electric appliances. Such provisions protect homeowners from future costs, should fossil fuels become less affordable or even unavailable over the life of the building. For example, a clean electric grid and high-efficiency electric heat pump technology can offer utility bill and pollution reduction benefits over gas. As this becomes the case, customers may want to transition from natural gas to electric equipment and appliances.

The scope of this technical brief includes four strategies for electric-readiness in residential buildings: 1) household ranges and cooking appliances, 2) household clothes dryers and water heaters, 3) electrification-ready circuits, and 4) water heater space.

Contents

1.0 Building Decarbonization

In support of decarbonization, the nation is moving towards the use of clean energy sources, including a renewable electric grid. 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 decarbonization policies[1]—is starting to noticeably impact the electricity system (GridWise Architecture Council 2015). As buildings account for over 70% of U.S. electricity use (EIA 2020), reducing and effectively managing their loads can greatly facilitate this transition towards a clean, reliable grid. Building electrification, in combination with increased efficiency and demand flexibility, is 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 associated reduction in CO_2 emissions is estimated at 6% per year by 2030 (DOE 2021).

Many cities and states are enacting new laws, updating building codes and advancing regulatory action in efforts to phase out gas appliances and ensure homes are heated and powered with clean electricity[2]. New Jersey plans to electrify 90% of its buildings by 2050.[3] The strategy outlined in its energy master plan is seen as being essential to meet the state's climate goals. Even cold climate states are targeting the adoption of electric heat pumps as a key step towards electrification and achieving emission reductions. Maine aims to install heat pumps in more than 50% of its total households by 2030.[4] In Colorado, the target for heat pump installations is 60% and over 95% of residential heating equipment sales by 2030 and 2040, respectively.[5]

To achieve these building decarbonization and greenhouse gas emission goals, cities and states are implementing building code advancements. In California, 50 jurisdictions have passed policies to phase out gas appliances in new construction and 37 of them specify all-electric in new residential buildings.[6] At the state level, the California 2019 Building Energy Efficiency Standards require 200 Amp electric panels in new homes and renovations and the 2022 code, currently under development, would require a 225 Amp panel and incentives for electrified end uses (Pecan Street 2021). Seattle's new energy code will eliminate the use of fossil fuel for space and water heating for large multifamily construction to cut building sector emissions.[7] Several municipalities in Massachusetts have passed measures asking the state legislature to allow them to require all-electric appliances in new construction and in some major renovations.[8] St. Louis established a building energy performance standard to address emissions from existing buildings to meet its 100% carbon reduction goal by 2050.[9]

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[1] Thirty-seven states representing 80% of the U.S. population have enacted renewable portfolio standards or goals.
[2] https://www.greenbiz.com/article/2020-watt-year-building-electrification
[3] https://www.nj.gov/emp/docs/pdf/2020_NJBPU_EMP.pdf
[4] https://climatecouncil.maine.gov/future/sites/maine.gov.future/files/inline-files/DraftMaineClimateActionPlan_11.8.20.pdf
[5] https://energyoffice.colorado.gov/climate-energy/ghg-pollution-reduction-roadmap
[6] https://www.sierraclub.org/articles/2021/07/californias-cities-lead-way-gas-free-future
[7] https://durkan.seattle.gov/2020/12/mayor-durkan-announces-ban-on-fossil-fuels-for-heating-in-new-construction-to-further-electrify-buildings-using-clean-energy/
[8] https://energynews.us/2021/07/15/massachusetts-cities-try-new-legal-path-toward-banning-new-fossil-fuel-hookups/
[9] https://www.greentechmedia.com/articles/read/st-louis-adopts-midwests-first-building-performance-standard

The incorporation of electric-readiness in energy codes will help improve the cost effectiveness of electrification in the future. Electric-readiness supports consumers' ability to capture the value of demand flexibility as the market grows with increased variable renewable energy on the system. It makes it easier for homeowners to accommodate future electrical appliances and equipment, which protects against carbon pricing or other future policy-imposed additional costs associated with fossil-fuel based energy sources.

2.0 Technical Analysis

The operation of buildings contributes to 28% of the U.S. annual carbon emissions. If the energy used for their materials and construction are also considered, it increases their contribution to nearly 40%.[1] With the life expectancy of residential buildings exceeding 50 years and the energy using equipment within buildings lasting between 10 to 20 years,[2] addressing electric-readiness today will support achieving near-term and future carbon emissions 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 (Salcido et al. 2021).

2.1 Costs

Inadequate electric panel capacity in homes can constrain electrification efforts. 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.[3] (Pecan Street 2021).

To avoid the added expense, the original panel should be sized sufficiently to accommodate full electrification. An indication of the need to address sufficient panel size at the time of home construction is indicated in Figure 1. The figure shows the prevalence of mixed-fuel homes in most U.S. geographic regions. Homes built with combustion equipment and appliances tend to have lower capacity electric panels that will likely need an upgrade for electrification. The study's results suggest that as many as 48 million households may require a panel upgrade to fully electrify. Assuming the incremental cost compared to the original cost is about $2,000 per installation, this implies that a $100 billion investment is required to address electric panel capacity for residential electrification in the United States (Pecan Street 2021).

[1] https://architecture2030.org/why-the-building-sector/

[2] https://www.nachi.org/life-expectancy.htm

[3] The Pecan Street study notes that it is possible to electrify a home with a 150 Amp electric panel but it is dependent on the EV charger size and required amount of heat pump auxiliary electric resistance heat requirement.

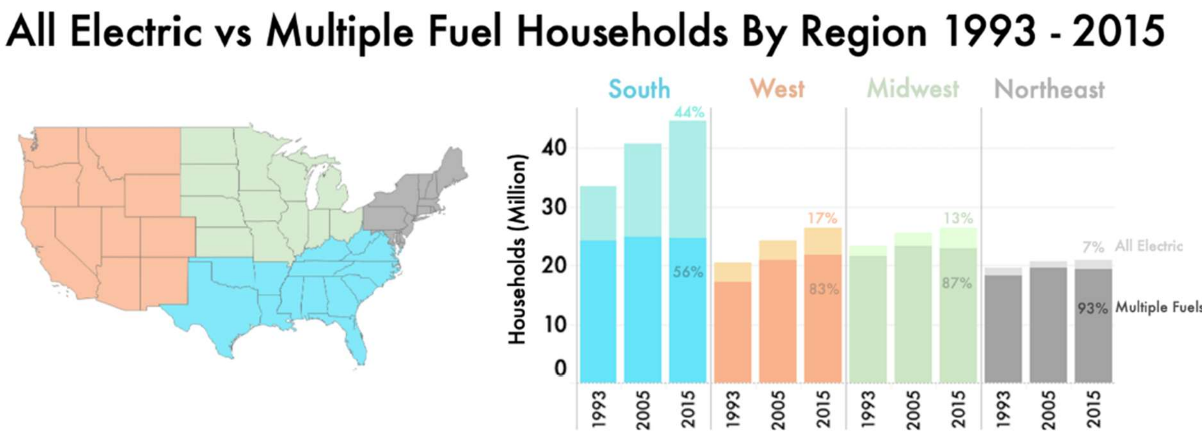

Figure 1. All-electric homes by *region* (Source: Pecan Street 2021)
All electric in light shading, multiple fuels in dark shading

A recent Colorado study compares the cost of installing a heat pump for space conditioning and a heat pump water heater as original equipment to the costs incurred as a retrofit (Group-14 2020). Costs are also compared relative to natural gas systems. The results are summarized in Figure 2. 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. It is worth noting that the data also indicate that when installed as the original system, the heat pump installation has a significantly lower first cost relative to the natural gas installation.

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

2.2 Benefits

By ensuring that a home built with gas or propane can easily accommodate future electric appliances, these provisions protect homeowners from future costs should fossil fuels 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 will increasingly offer utility bill and pollution reduction benefits over gas. Moving forward, customers may want to transition from natural gas to electric space and water heating.

Federal, state, and local environmental and public health policies may also encourage, or even require, the transition in some areas. For example, the California Air Resources Board (CARB) published a resolution in support of an all-electric new construction requirement in the Title-24 2022 code cycle due to the opportunity to improve indoor air quality by replacing fossil fuel use in buildings with zero carbon electricity.[1] In addition, the New York City Housing Authority (NYCHA) released a strategic plan to reduce carbon emissions associated with its properties. Its first course of action is to adopt electrification of heat and hot water. It will also replace gas stoves with electric induction stoves. While gas stoves consume a relatively small amount of fossil fuel, they are problematic for the NYCHA due to health and safety concerns regarding potential leaks, the use of stoves for supplemental heating, and the age of the gas line.[2]

[1] https://ww3.arb.ca.gov/board/res/2020/res20-32.pdf
[2] https://www1.nyc.gov/assets/nycha/downloads/pdf/NYCHA-LL97-Whitepaper.pdf

3.0 Electrification and Energy Codes

Building codes represent standard design practice in the construction industry and continually evolve to include advanced technologies and innovative practices. Historically, national model energy codes establish minimum efficiency requirements for new construction.[1] Expanding codes to further support decarbonization through strategic electrification is a pivotal step towards reducing regional and national carbon emissions. Strategic electrification involves moving energy end-uses to renewable electricity, 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 the 2021 International Energy Conservation Code (IECC) code development cycle. The approved electric-readiness measures were later removed in response to appeals.[2] DOE developed this technical brief to reinstate the electric-readiness concept such that it 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 four strategies for electric-readiness in residential buildings.

- Household ranges and cooking appliances
- Household clothes dryers and water heaters
- Electrification-ready circuits
- Water heater space

3.1 Household Ranges and 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 gas or propane can easily accommodate future electric cooking equipment and appliances.

3.2 Household Clothes Dryers and Water heaters

This electric-ready provision requires a sufficiently rated electrical receptacle be installed near permanently installed household clothes dryers and water heaters. This assures that a home built with gas or propane can easily accommodate future electric clothes dryers and water heaters.

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[1] 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.

[2] https://www.iccsafe.org/building-safety-journal/bsj-technical/code-development-a-process-of-evolution-and-improvement/

3.3 Electric-Ready Circuits

This electric-ready provision requires that electrification 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.

3.4 Water Heater Space

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 should one not be originally installed.

4.0 Sample Code Language

This section contains model code language for any state or local government to overlay the 2021 IECC or that can be adapted to other existing residential energy codes.

4.1 Electric-Readiness

The following new text shall be added to create Section R404.4 of the 2021 IECC residential energy code or analogous location of other existing code.

R404.4 (IRC N1104.4) Electric readiness (Mandatory).
Systems using gas or propane water heaters, dryers, or conventional cooking equipment to serve individual dwelling units shall comply with the requirements of Sections R404.4.1 through R404.4.3. All water heating systems shall comply with Section R404.4.4.

R404.4.1 Household Ranges and Cooking Appliances.
An individual branch circuit outlet with a minimum rating of 250-volts, 40-amperes shall be installed within three feet of each gas or propane range or permanently installed cooking appliance.

R404.4.2 Household Clothes Dryers and Water Heaters.
An individual branch circuit outlet with a minimum rating of 250-volts, 30-amperes shall be installed within three feet of each gas or propane household clothes dryer and water heater.

R404.4.3 Electrification-ready circuits.
The unused conductors required by Sections R404.4.1 or R404.4.2 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 R404.4.1 or R404.4.2 shall be included in the load calculations of the original installation.

R404.4.4 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.

> Exception: The water heater space requirement does not need to be met where a heat pump water heater or tankless water heater is installed.

5.0 References

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