Electric Resistance

Renewable Thermal Technology

RENEWABLE
THERMAL
COLLABORATIVE

Technology Overview

Description of technology

- Electric resistance (ohmic) thermal equipment uses an electric current to provide heating due to a material's electrical resistivity
- There are two types of electric resistance heating:
    - Indirect – The current runs through an electrical resistor, which heats up surrounding materials through convection, conduction, or radiation. This is the primary form of electric resistance heating currently applied in industry.
    - Direct – The current runs through the material to be heated via its own electrical resistivity

Types of equipment

- Electric resistance heating is capable of directly replacing most natural gas fired industrial heating equipment without major system modifications.

Electric ovens[4]

Electric furnaces[5]

Electric boilers[6]

Electric air heaters[7]

Note: Example equipment not exhaustive

Technical characteristics

- **Temperature range:** Up to 1,800 ºC
    - Meets all industrial heating temperature requirements aside from highest temperature applications (e.g., cement kiln, steelmaking, metal fabrication)
- **Heat flux:** High
    - Dependent on resistive element configuration and use of convective drivers (i.e., fans)
- **Heated materials:** Most materials are applicable
    - Electric resistive heating elements are usually in direct contact with the heated medium (e.g., water, process fluids, air)
    - Electrical heating eliminates potential contamination of heated materials with fuel particulates or combustion flue gases

- **Emissions:** Higher emissions relative to natural gas combustion in all but a handful of US states currently
    - Emissions intensity ranges from 10 kg CO_2/MMBtu (VT) to 358 kg CO_2/MMBtu (HI) depending on grid mix and system efficiency [1]

- **Technical maturity:** High maturity
    - The simplest and oldest form of electric heating

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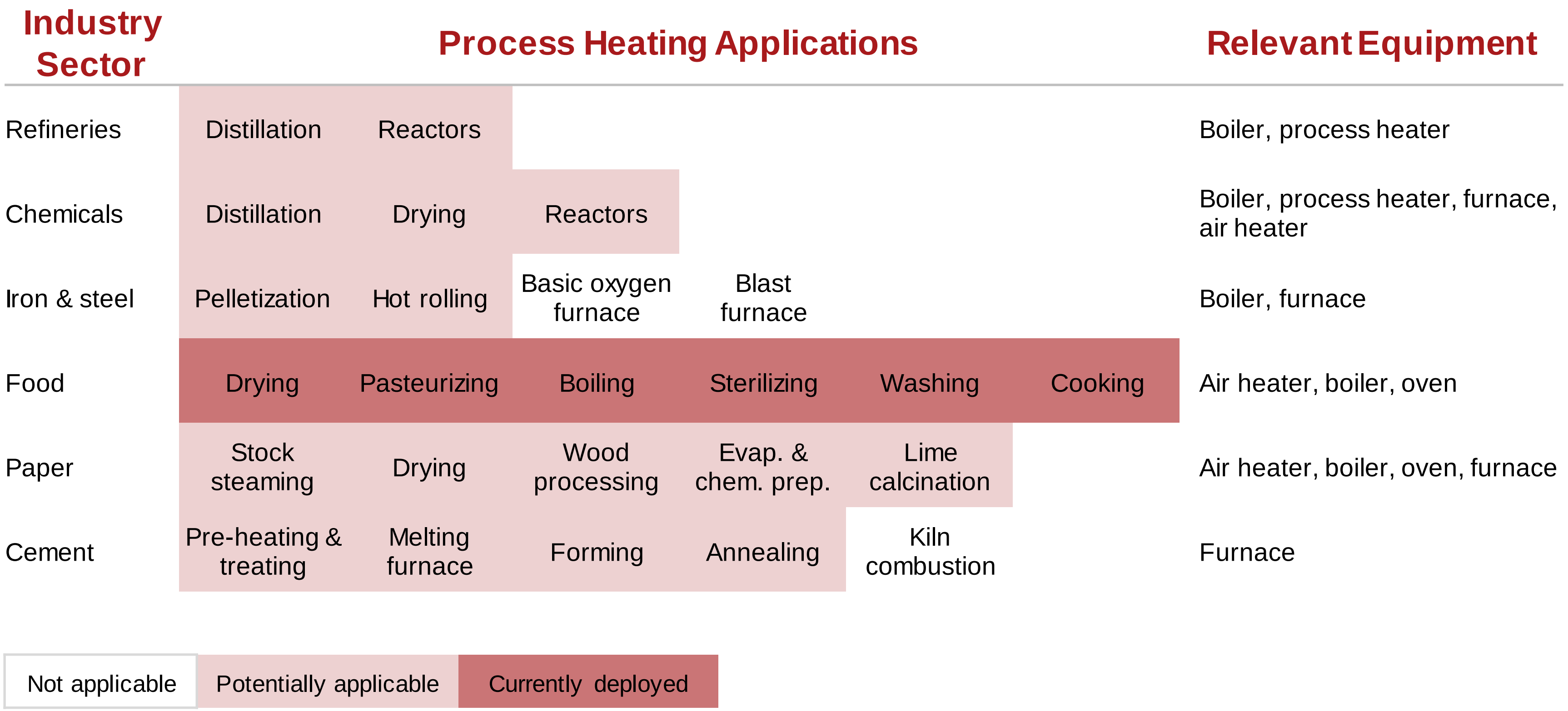
1. US EIA Electricity Data with BCG analysis (2022); 2. Renewable energy options for industrial process heat – Appendix (ARENA); 3. US EIA Electric Data – Average industrial electricity prices; 4. Industry Plaza – Industrial ovens; 5. Industry Plaza – Industrial Electric furnaces; 6. Industrial Boilers – Electric Boilers; 7. Industrial Fans Direct – Ruffneck Electric Air Heater

Electric resistance heating is applicable to all but the highest temperature industrial applications

Key properties of electric resistance include:

- 1,800 ºC max. temp.
- High heat flux
- Heats all materials

These properties align with requirements for several process heating applications.



Industry Sector	Process Heating Applications						Relevant Equipment
Refineries	Distillation	Reactors					Boiler, process heater
Chemicals	Distillation	Drying	Reactors				Boiler, process heater, furnace, air heater
Iron & steel	Pelletization	Hot rolling	Basic oxygen furnace	Blast furnace			Boiler, furnace
Food	Drying	Pasteurizing	Boiling	Sterilizing	Washing	Cooking	Air heater, boiler, oven
Paper	Stock steaming	Drying	Wood processing	Evap. & chem. prep.	Lime calcination		Air heater, boiler, oven, furnace
Cement	Pre-heating & treating	Melting furnace	Forming	Annealing	Kiln combustion		Furnace

Not applicable

Potentially applicable

Currently deployed

1. US EIA Electricity Data - Detailed EIA-923 emissions survey data (2020); 2. Renewable energy options for industrial process heat – Appendix (ARENA); 3. US EIA Electric Data – Average industrial electricity prices

Industrial electric resistance heating is currently only used in niche applications and specific regions

- Currently, electric resistance heating is generally not economically viable for industrial application in the US
- However, a combination of factors may make electric resistance heating attractive. These include:
  - **Specific heating application requirements**
    - Precise heating controls
    - Stringent health or safety standards
    - Minimal maintenance
  - **Regional characteristics**
    - Low electricity prices relative to natural gas prices
    - High quantities of electricity supply

Practically applicable sectors & locations

- Potentially viable and applicable deployment of electric resistance industrial heating include:
  - **Industry sectors**
    - Food & agriculture,
    - Paper products,
    - Pharmaceuticals, and
    - Small-batch specialty chemicals production
  - **Regions**
    - **Pacific Northwest** – high quantities of hydroelectric power
    - **Portions of southern Midwest** – increasing quantities of wind and solar power

Two case studies of industrial electric resistance heating show the range from mature to emerging application areas

Case study 1: Fulton electric heating equipment

- **Maturity:** Mature application area
- **Industry sector:** Food & beverage (brewery, distillery, meat processing, etc.)
- **Process heating application:** Various (pasteurizing, boiling, sterilizing, washing, etc.)
- **Location:** Various in US

Fulton manufacturers electric steam boilers and thermal fluid heaters, which are used extensively throughout the food & beverage industries. They offer a wide variety of heat transfer products and size ranges for a variety of process application requirement.

FBL electric steam boiler
Size range: 1.2-100 BHP

FBE electric steam boiler
Size range: 1.2-18 BHP

FT-N Vertical Electric Thermal Fluid Heater
Size range: 2.2-50 BHP

Case study 2: Norsk Hydro alumina refining

- **Maturity:** Emerging application area
- **Industry sector:** Metals (aluminum)
- **Process heating application:** Alumina refining
- **Location:** Brazil

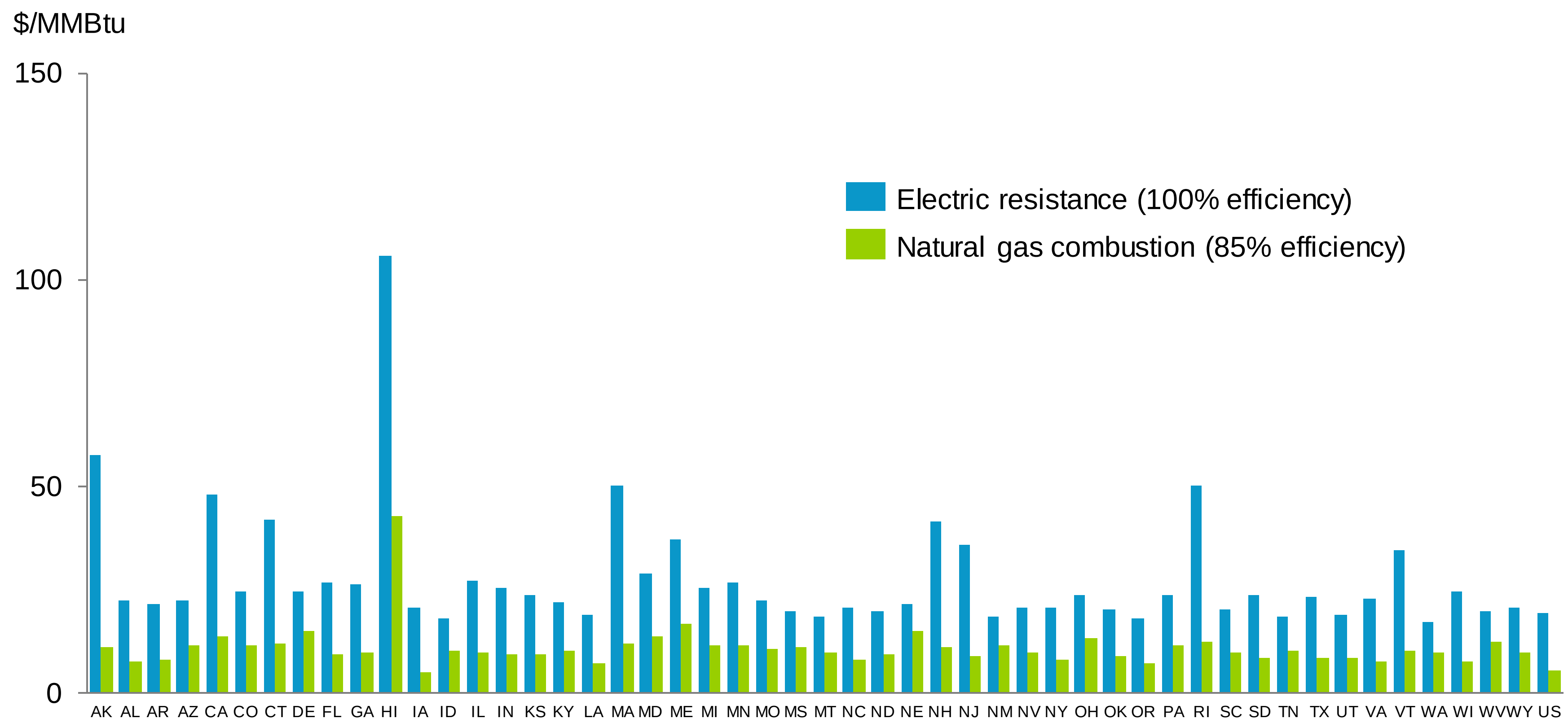
Norsk Hydro ASA's Alunorte alumina refinery began using an electric boiler in March 2022. The boiler is expected to cut the plant's carbon emissions by 100,000 tonnes per year.

The boiler cost $7.6 million USD and can produce up to 95 tonnes of steam per hour while consuming 60 MW. The alumina refinery is planned to commission two more electric boilers within the next two years.

Initially, the boilers will operate with electricity purchased from the local grid. Norsk Hydro is examining options to acquire green electricity to power the boilers.

Source: Fulton Industries Food & Beverage Processing; Norsk Hydro Commissions New Electric Steam Boiler At Alunorte Alumina Refinery (Aluminium Insider)

All US states show significantly higher fuel costs for electric resistance comparted to natural gas heating



Relative fuel costs between electric heat pump and natural gas combustion heating in May 2022

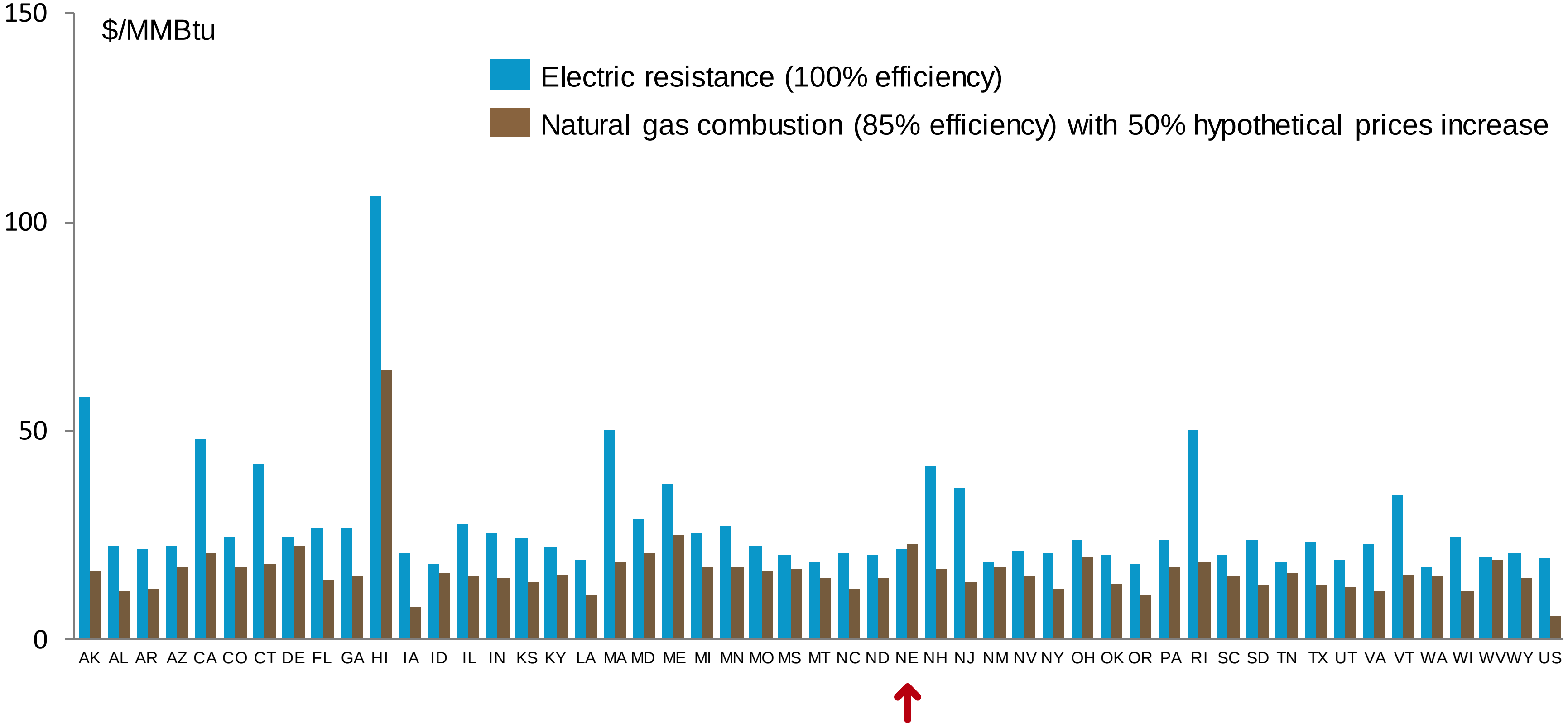
Source: US EIA Industrial Electricity Prices (May 2022), US EIA Industrial Natural Gas Prices (May 2022)

To make relative fuel costs economically viable,

- Significant incentives must be provided to users of electric heating or
- Natural gas prices or tariffs need to increase substantially

All US states show significantly higher fuel costs for electric resistance comparted to natural gas heating

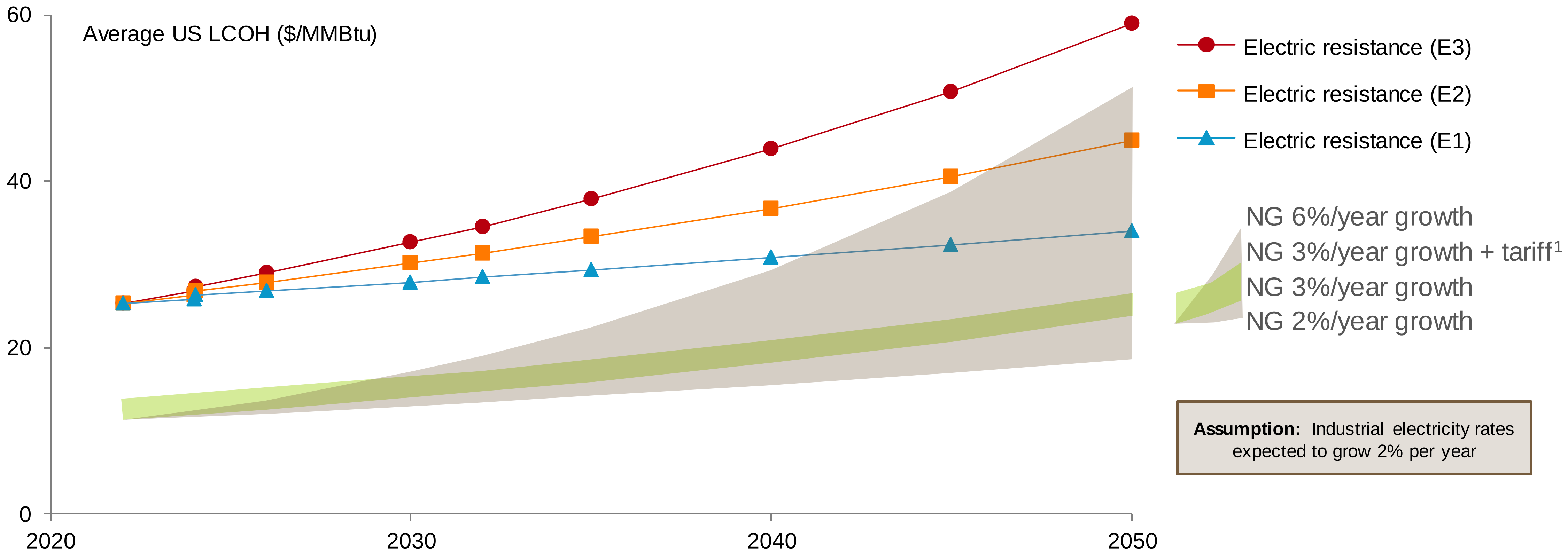
Relative fuel costs between electric heat pump and natural gas combustion heating with hypothetical 50% increase in natural gas prices



Source: US EIA Industrial Electricity Prices (May 2022), US EIA Industrial Natural Gas Prices (May 2022)

Electric resistance industrial heating using grid electricity is likely more expensive relative to natural gas

Electric resistance is not expected to be more cost effective relative to NG aside from extreme future scenarios, but better control may reduce overall heat needs



Assumption: Industrial electricity rates expected to grow 2% per year

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1. Based on $51/tonne CO2 social cost of carbon

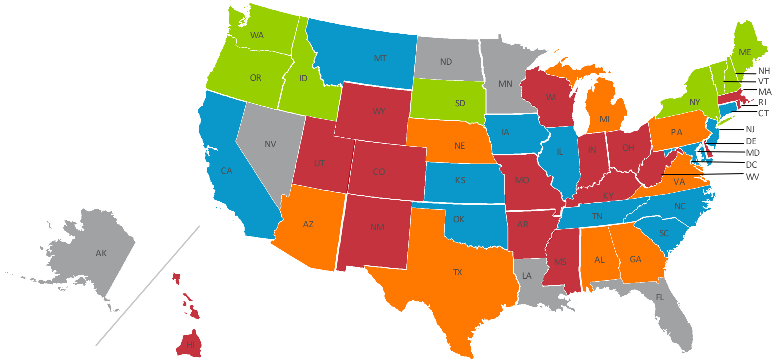
Note: Subsidized are shown in plots, subsidized and unsubsidized LCOHs are within 5%

In all scenarios by 2026, more than half of states may be able to reduce emissions by switching to electric resistance heating

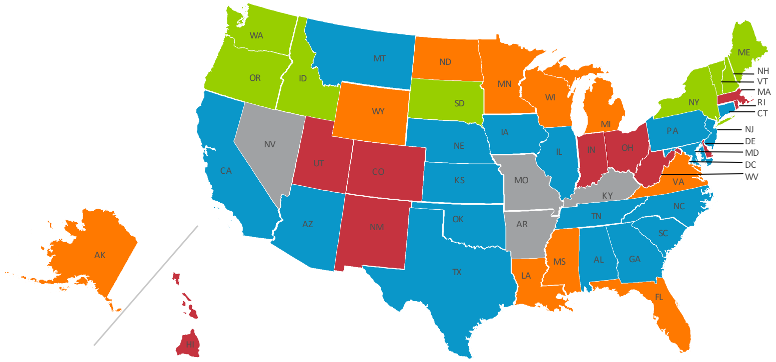
Likely reduction in emissions by switching from natural gas combustion[1] to electric resistance heating:

- ● Today
- ● By 2026
- ● By 2030
- ● By 2035
- ● Beyond 2035

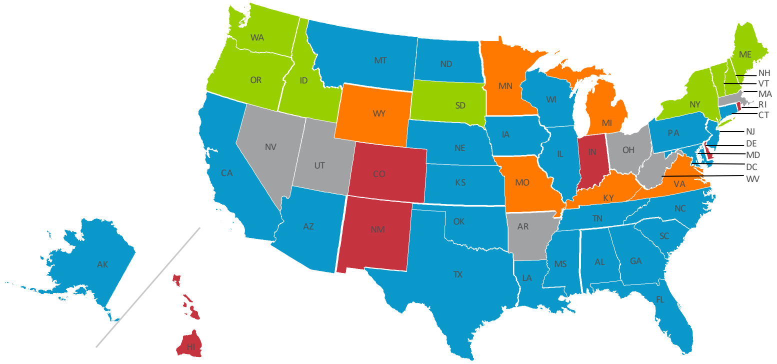
Scenario 1: 80% renewables by 2050



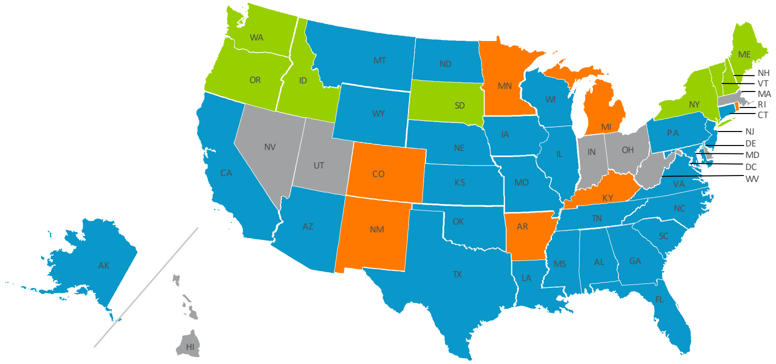
Scenario 2: 65% renewables by 2030



Scenario 3: 80% renewables by 2030



Scenario 4: Near 100% renewables by 2035



Sources: US EPA GHGRP (2019); US EIA; State Renewable Portfolio Standards; IEA ETSAP Industrial Combustion Boilers Fact Sheet; BCG analysis

[1] Calculated using 85% efficiency for natural gas boiler

Electric resistance industrial heating has many advantages, but faces several key barriers to adoption

Advantages

- Minor modifications from combustion system
- Capital costs equal to or below combustion
- Precise control of temp. and heat input
- Approaches 100% efficiency
- Low maintenance requirements
- Improved health & safety due to lack of combustion

Barriers

- Likely higher fuel costs compared to gas systems
- Limited emissions reduction potential using grid electricity in many states before 2026
- Extensive electrical infrastructure upgrades may be required

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