Benefit/Cost Assessment of Residential Natural Gas & Electricity Decarbonization Pathways

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William Liss

Vice President, Energy Delivery & Utilization

Situational Assessment

- Active policy discussion on greenhouse gas (GHG) reductions
- This includes electrification as a GHG reduction strategy
  - Transportation and **building sectors**
- For buildings, there are two market trends
  - **Lower carbon power generation**: coal replaced by natural gas, wind, and solar
  - **Electric heat pumps**: newer cold-climate electric heat pumps for space conditioning and electric heat pump water heaters
- Policy discussions often lack a full understanding or vetting of the various challenges & issues with building electrification

Residential Energy Use and Greenhouse Gas (GHG) Reduction Pathways

- Presentation draws on a series of GTI studies for Black Hills Energy
  - Uses independent information resources (e.g., DOE-EIA, EPA, others) along with algorithms which are grounded in actual equipment testing
- Objective was to conduct a series of **benefit/cost assessments for residential natural gas and electricity use** in various cities within their service territory
  - Lawrence, KS; Lincoln, NE; Dubuque & Decorah, IA; Fayetteville, AR
- Full reports available to public (link at bottom of page)

Energy Planning Analysis Tool

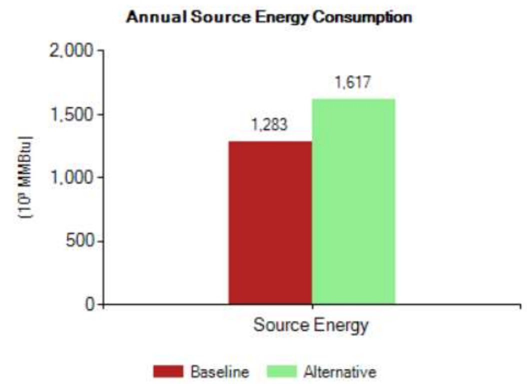
Home | Residential City Level Comparison | Residential State Level Comparison | Tool Description | Contact

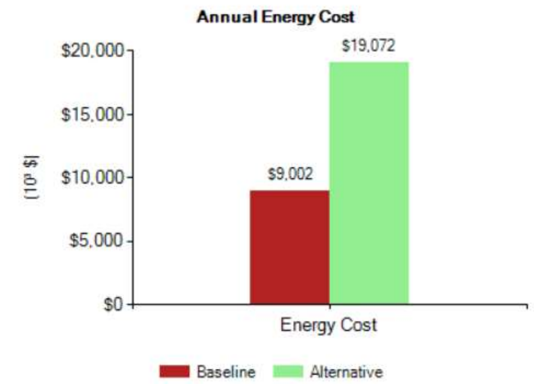
Welcome!

The Energy Planning Analysis Tool evaluates the potential implications of energy and technology choices in residential applications by analyzing the energy, environmental, and economic impacts of natural gas and propane end use technologies compared to electric alternatives. Through this evaluation, the tool provides evidence of the technical merits of direct fuel use as an affordable option for energy efficiency programs, building energy codes and standards, regulatory initiatives, or other areas of public policy.

The tool calculates and compares annual energy cost, source energy consumption, and greenhouse gas emissions, as well as criteria pollutant emissions, associated with site energy consumption by purchased energy form for alternative technologies providing the same energy services. Electric, natural gas, and propane applications are defined by user-selectable and default inputs for comparisons. The tool shows the potential energy, environmental, and cost benefits of replacing or buying more energy efficient equipment, comparing electric, natural gas, and propane alternatives, based on an annual snapshot or over a life cycle of up to 30 years.

- EPAT is an available no-cost online calculator developed and refined by GTI over past 7 years
- Uses independent authoritative data sources: DOE-EIA, NREL, EPA eGRID
- Captures full-cycle energy use and emissions (conventional and GHG)





Go to **epat.gastechnology.org** for more information on this free public access analytical tool

Residential Energy Use and Low GHG Pathways

- **Multiple natural gas and electric cases analyzed** based on good/better equipment scenarios and future low GHG options (e.g., RNG, advanced generation mixes)
  - 13 core cases (scenarios)
  - Each is compared to a baseline home using natural gas for space & water heating, cooking, and drying (baseline efficiency levels)
- **Objective benefit/cost comparison on key metrics, including**:
  - Consumer Energy Costs and Annualized Costs (Energy + Capital)
  - GHG Emissions
  - GHG Abatement Cost (e.g., $/metric ton GHG)

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Parametric Analysis Relative To An Existing Typical Natural Gas Baseline Home

Grid Supply Decarbonization

Residential Equipment

	Natural Gas	No RNG	50% RNG	
	Baseline (80% efficient furnace, 62% efficient water heater, standard cooking and dryer appliances)	Baseline	--	
Good	Existing High-Efficiency (98% efficient furnace, 95% efficient water heater, high-efficiency dryer)	1	2	
Better	Emerging High-Efficiency (140% efficient natural gas heat pump, 130% efficient gas heat pump water heater, high-efficiency dryer)	3	4	

4 cases

	Electricity	Current Power Mix	Scenario 1 Power Mix	Scenario 2 Power Mix
	Baseline Electric (all electric-resistance heating equipment)	5	6	7
Good	Typical High-Efficiency Electric (HSPF 9.0 electric heat pump, water heater/EF = 0.95, standard cooking/dryer)	8	9	10
Better	Emerging High-Efficiency Electric (HSPF 13.0 electric heat pump, electric heat pump water heater EF 2.0, induction cooking, high-efficiency dryer)	11	12	13

9 cases

Residential Natural Gas Low Greenhouse Gas Pathways

Near-Term (25-50+%)

Expanded use of high-efficiency gas equipment

Hybrid natural gas furnace/ boilers and electric heat pump systems

Building envelope improvement

Next-Gen (40-60+%)

Natural gas heat pumps for space & water heating

Micro CHP systems

Deep building retrofits

Renewables (Added 10-30%)

Renewable gas blends (bio-methane, hydrogen)

Solar thermal & geothermal /natural gas space & water heating

Lower Methane Emissions (5-10%)

Reducing full-cycle natural gas methane emissions

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* Numbers indicate nominal GHG reduction potential

Residential Electric Low Greenhouse Gas Pathways

- **Three different electric equipment scenarios**:
  - All-electric resistance equipment (which is most homes today that have electric space and water heating)
  - Electric heat pumps based on nominal Energy Star-rated equipment (e.g., HSPF 9 air-source heat pump)
  - Higher-efficiency "Cold-Climate" air-source heat pumps (HSPF 13), electric heat pump water heater, and induction cooktop
- **Three different electric grid scenarios** (specific to each region):
  - Today's grid mix
  - Future Mix 1
  - Future Mix 2

These are meant to reflect possible future grid mixes in the circa 2030-2040 timeframe

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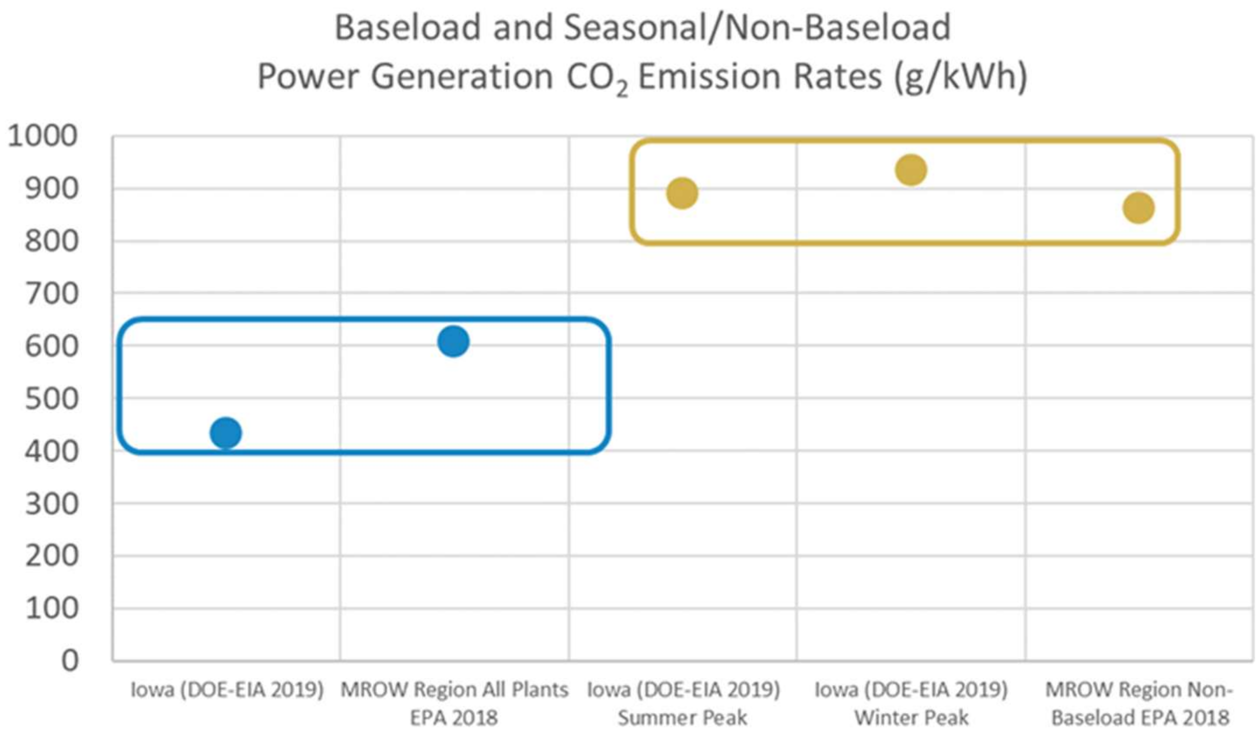
Understanding Building Electrification In Practice

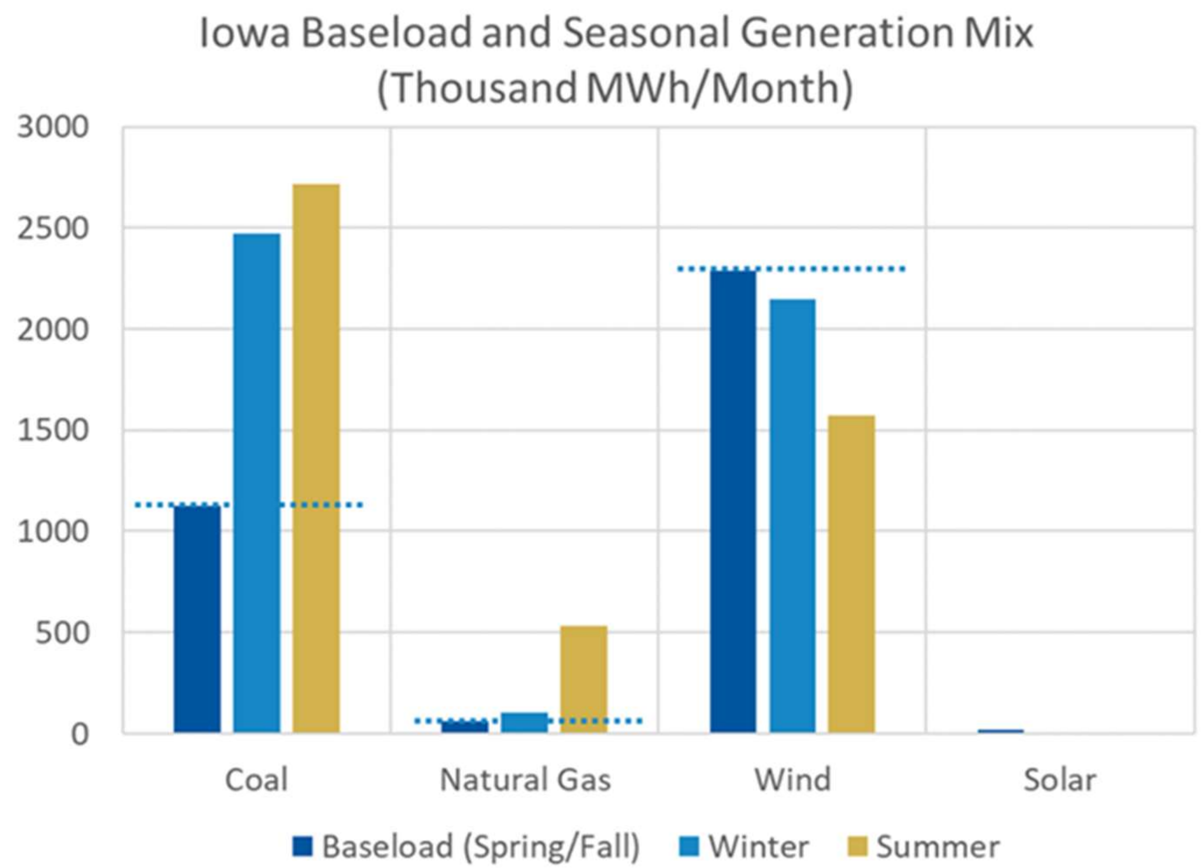
- Key concepts for assessing real-world building electrification benefits and costs (often not part of discussion):

1. **Power Generation Mix:** (1a) **seasonal power generation mix** and (1b) **impact of peak demand** above normal year-round baseload use
   - Building electrification scenarios often omit peak demand and seasonal uses; in most simplistic cases opt to assume 100% wind & solar and electric heat pumps at rated efficiency (47^{o}F)
2. **Impact of Cold Temperatures** on electric heat pumps
   - While newer cold-climate electric heat pumps are an improvement, there are significant cold weather impacts (2a)
   - At cold temperatures, this impacts (2b) utility peak day requirements for electricity and (2c) consumer space heating economics

- These topics reviewed in the GTI reports (along with energy storage)

Baseload and Seasonal Generation (1a)

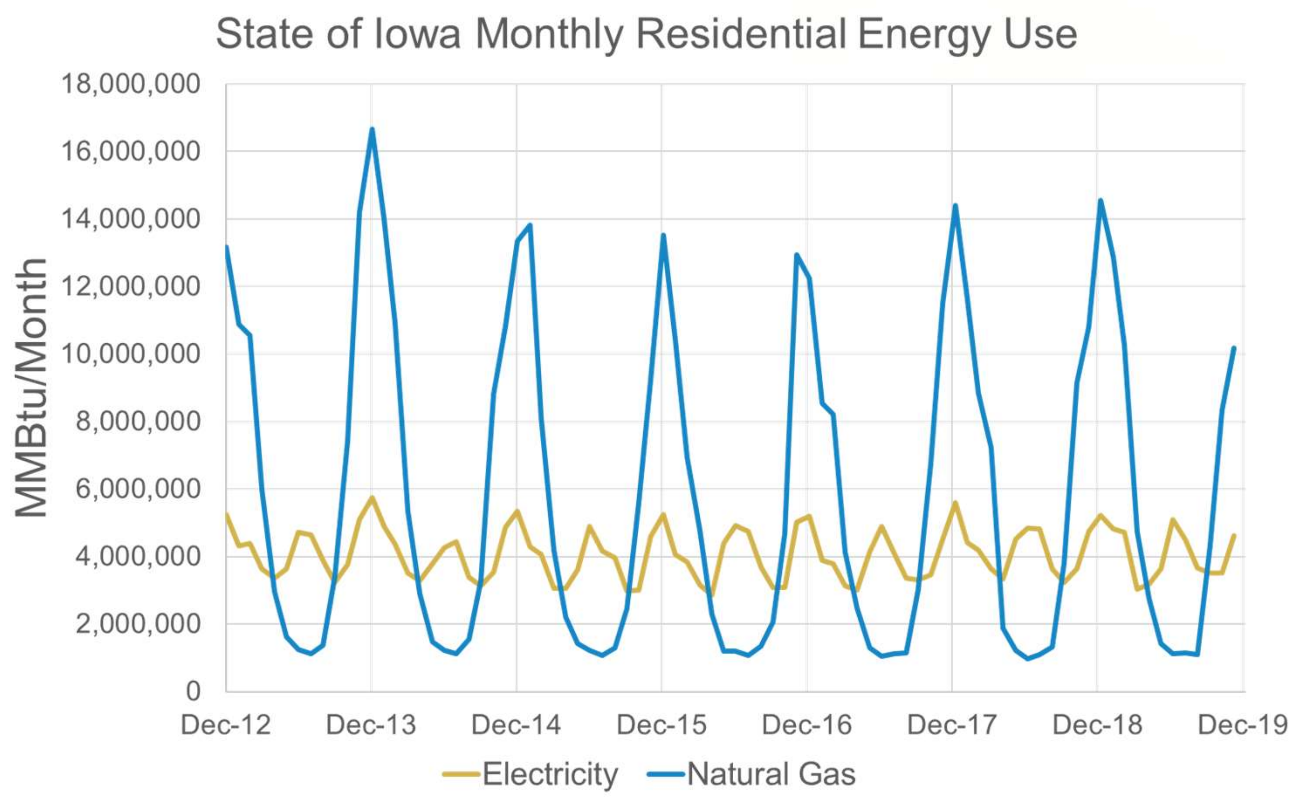


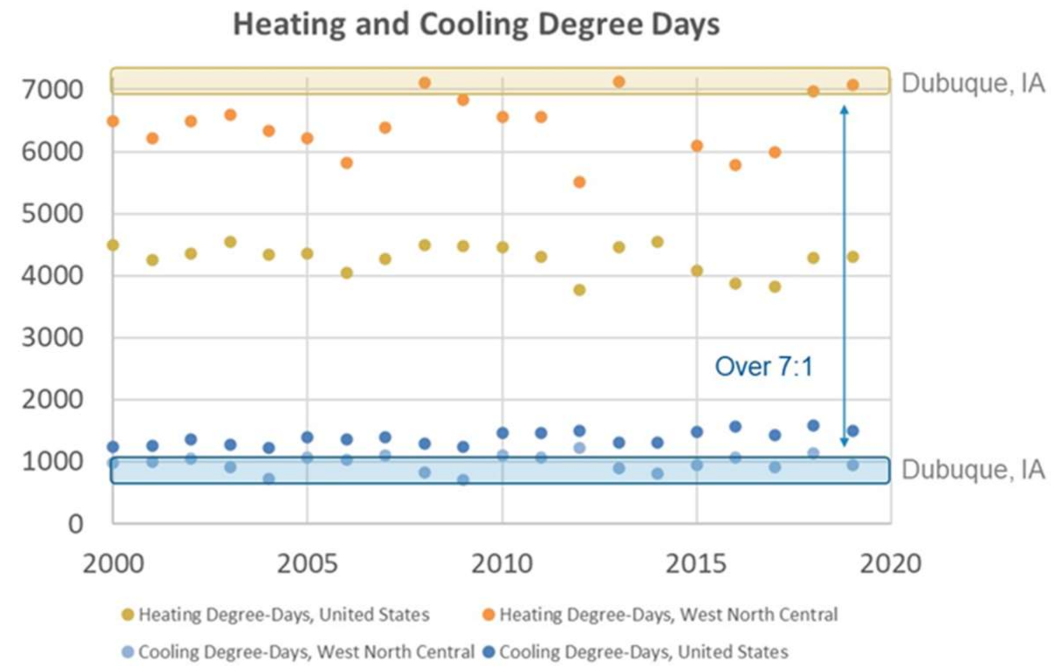


Source: DOE-EIA 2019 data, GTI analysis

Throughout the U.S., electric space conditioning seasonal loads (cooling & heating) use a power generation mix that has significantly higher GHG emissions than baseload generation. Without major changes in grid practices, **electric space heating will not achieve anticipated GHG reductions**.

Challenges: Seasonal Residential Energy Use for Space Conditioning (Heating >> Cooling; 1b)

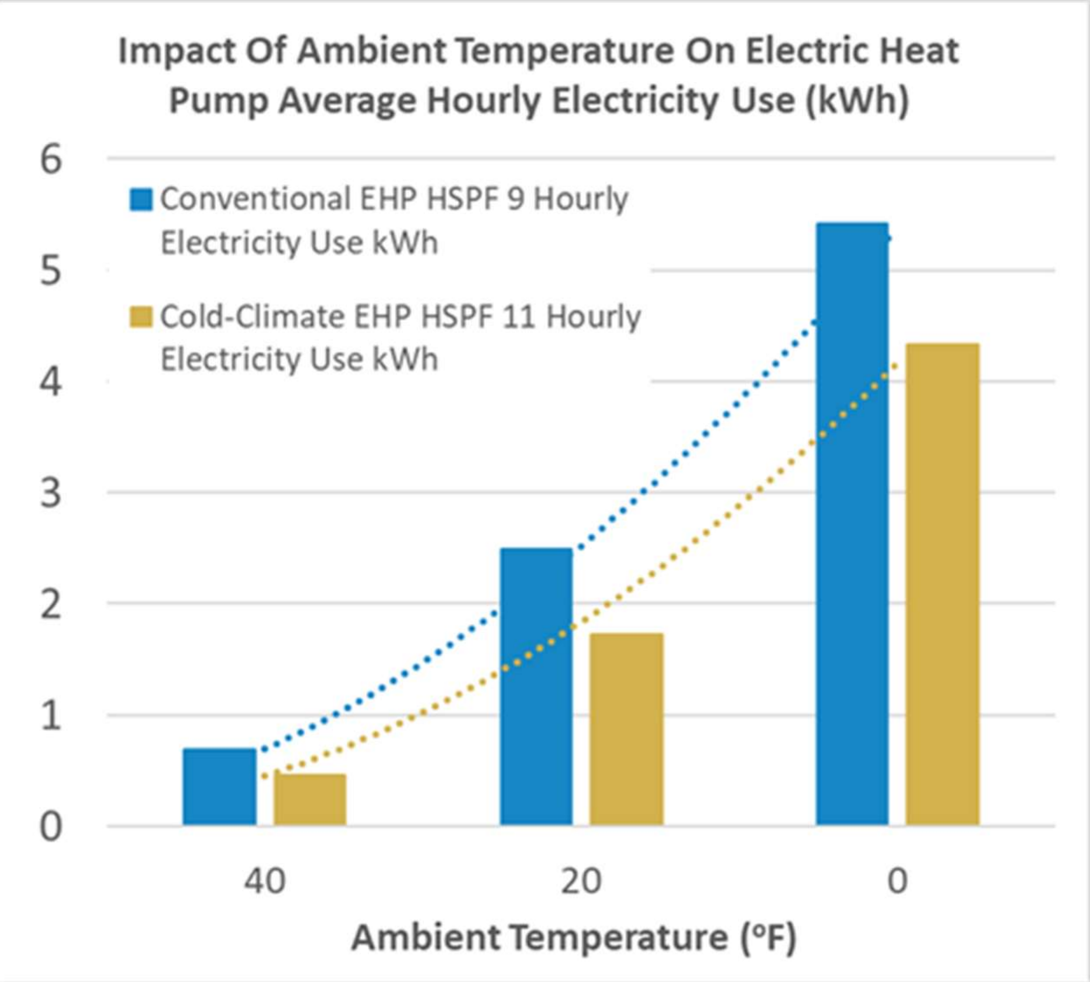


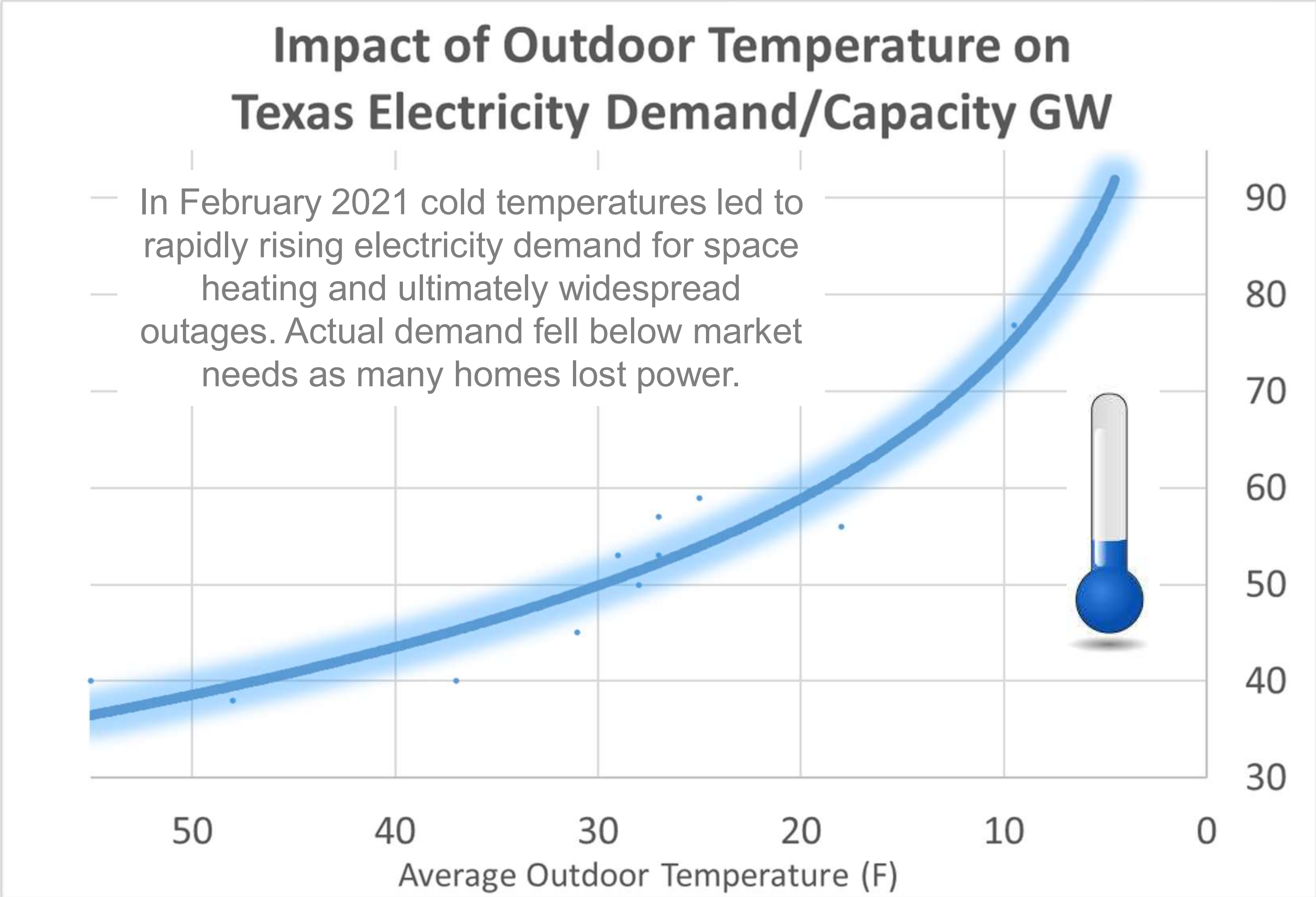


Winter Heating from 0°F to 70°F …is like… **Summer Cooling from 145°F to 75°F**

Heating loads in most U.S. regions substantially exceed cooling energy use. Electric space heating results in MUCH HIGHER peak & seasonal electricity use, particularly in colder climates (leading to greater levels of seasonal generation with higher GHG emission rates).

Compounding, Non-Linear Increase In Electric Heating Energy Use With Outdoor Temperature: Theory & Practice (2a, 2b)



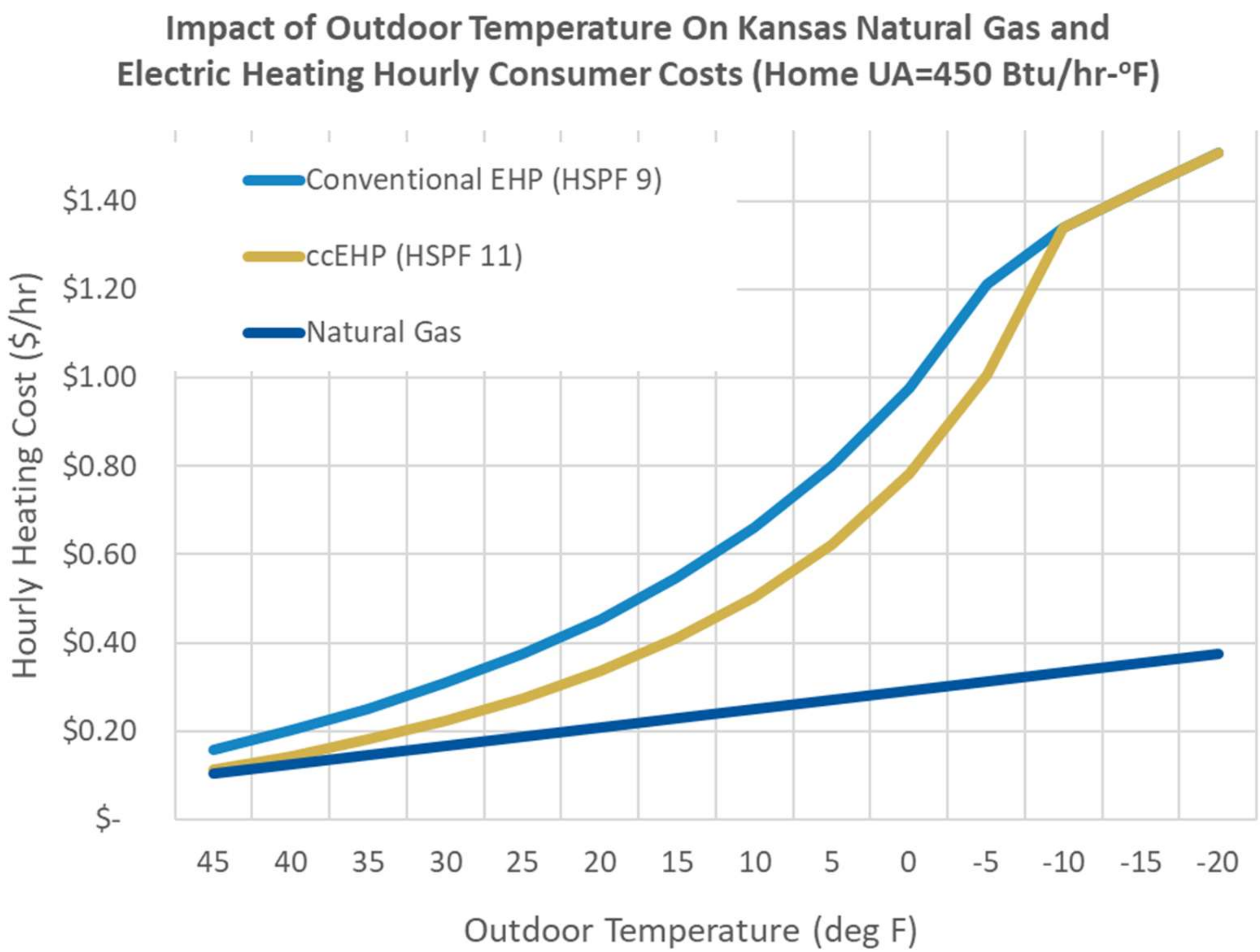


Compounded non-linear growth in electricity consumption at cold temperatures

DOE-EIA; temperatures are average temperature in Dallas, TX

Extreme winter weather is disrupting energy supply and demand, particularly in Texas - Today in Energy - U.S. Energy Information Administration (EIA)

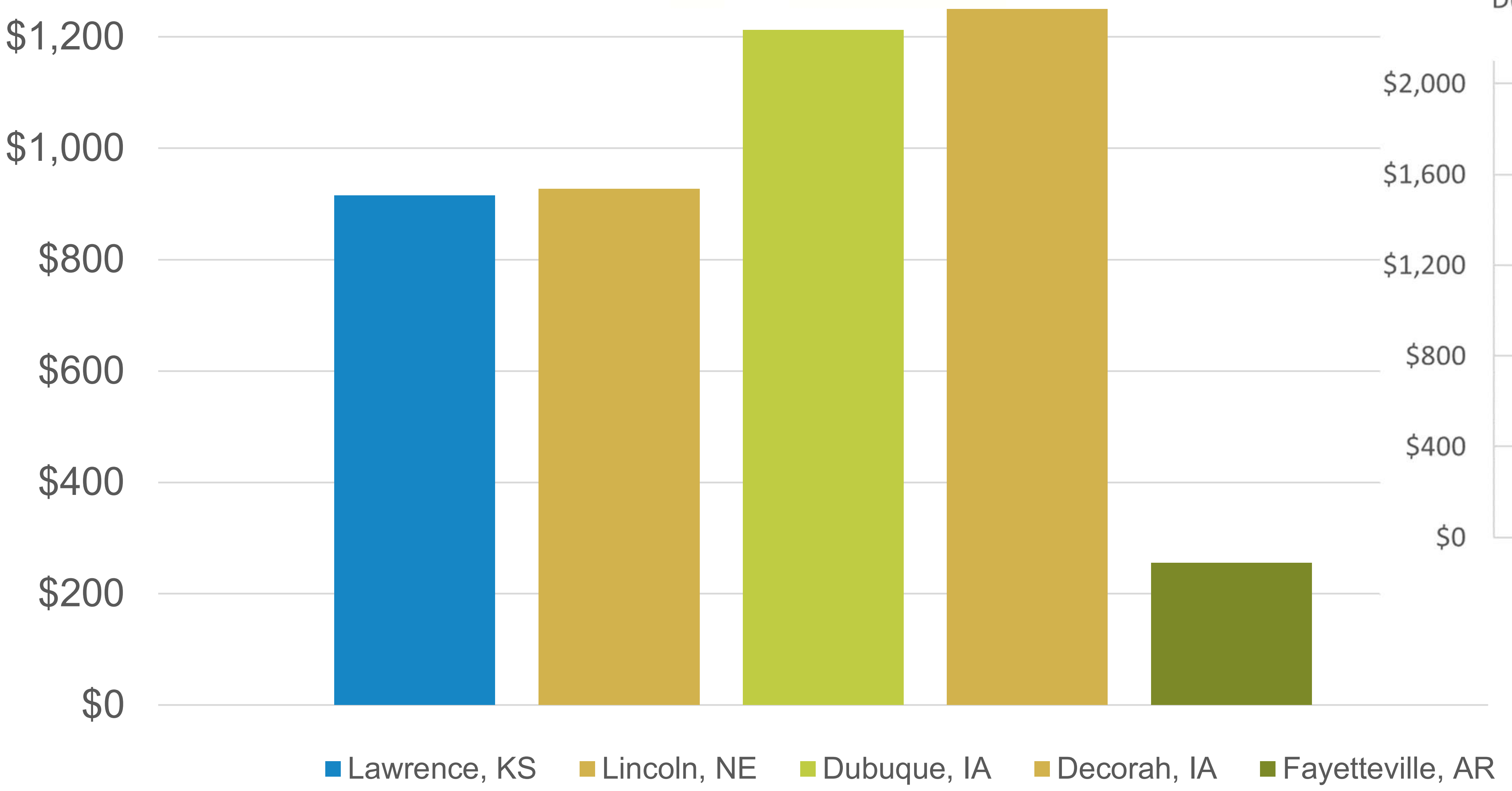
Cold Temperature Impact On Home Electric Space Heating Cost (2c)

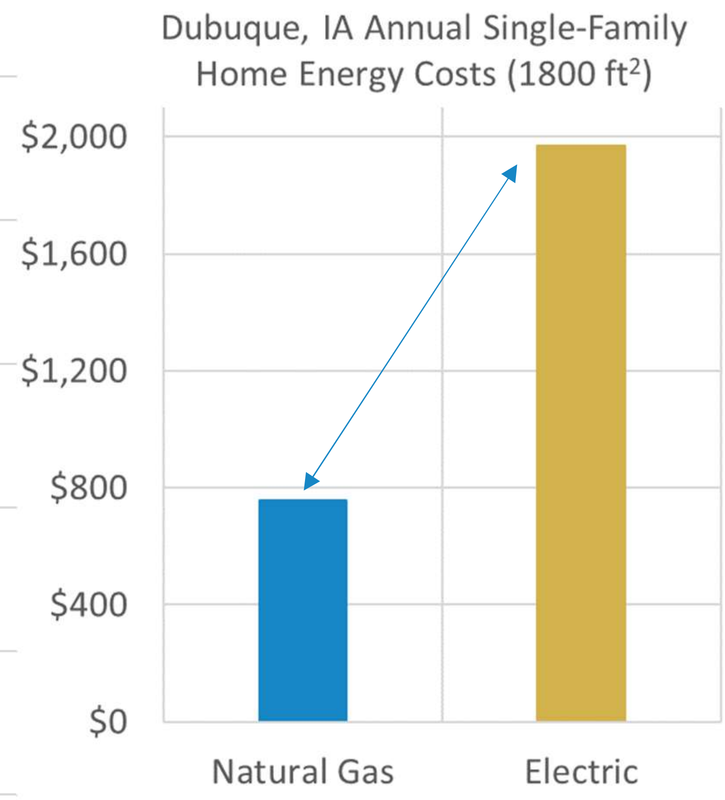


Hourly cost for electric space heating rises rapidly with colder temperatures.

At very cold temperatures, can be 3-4 times more expensive.

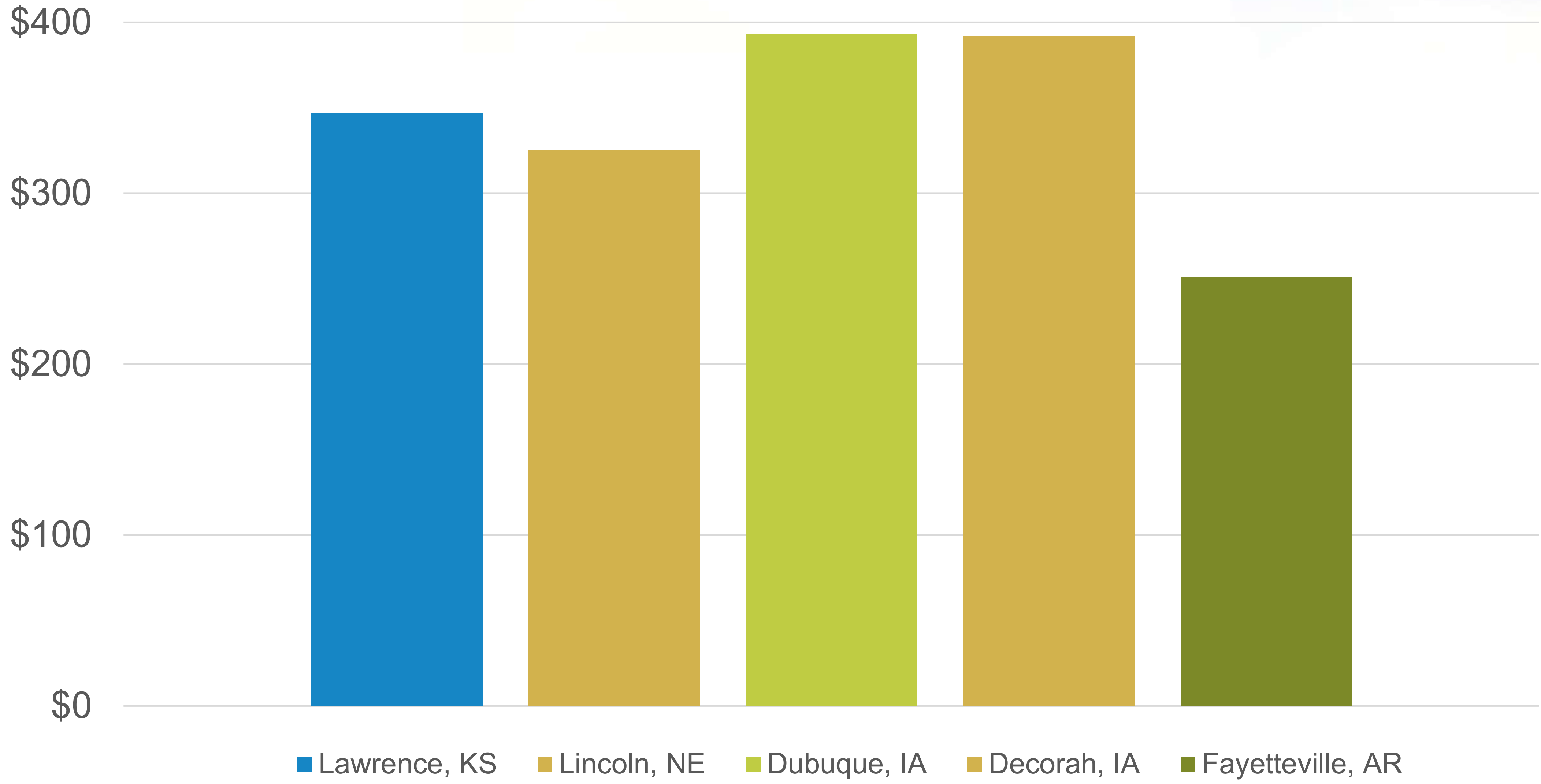
Annual Home Energy Cost Increase With All-Electric Conversion ($/Year)



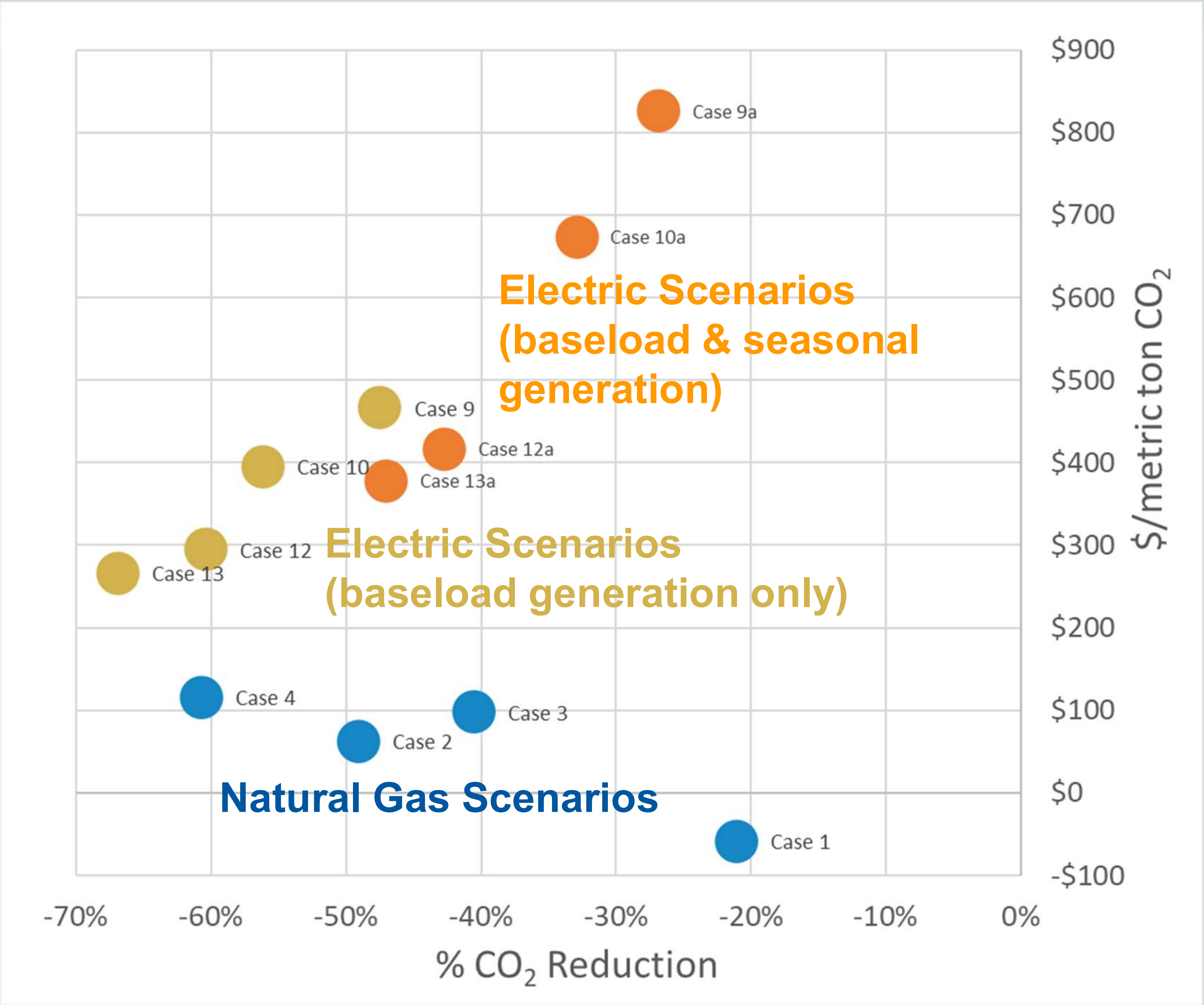


Based on Middle Case Electrification Scenarios; typical single-family home

GHG Abatement Cost With All-Electric Conversion ($/metric ton CO_2e)



Based on Middle Case Electrification Scenarios and Scenario 1 power generation mix (no seasonal generation factor)



Graph shows Benefit/Cost chart for Dubuque, IA scenarios.

Natural gas scenarios have considerably greater cost effectiveness.

Electric scenarios are more costly using an idealized baseload generation mix (gold circles) but even more costly and less impactful (lower % reduction) when accounting for higher seasonal GHG emission rates used for space heating loads (orange circles, using natural gas combined cycle generation).

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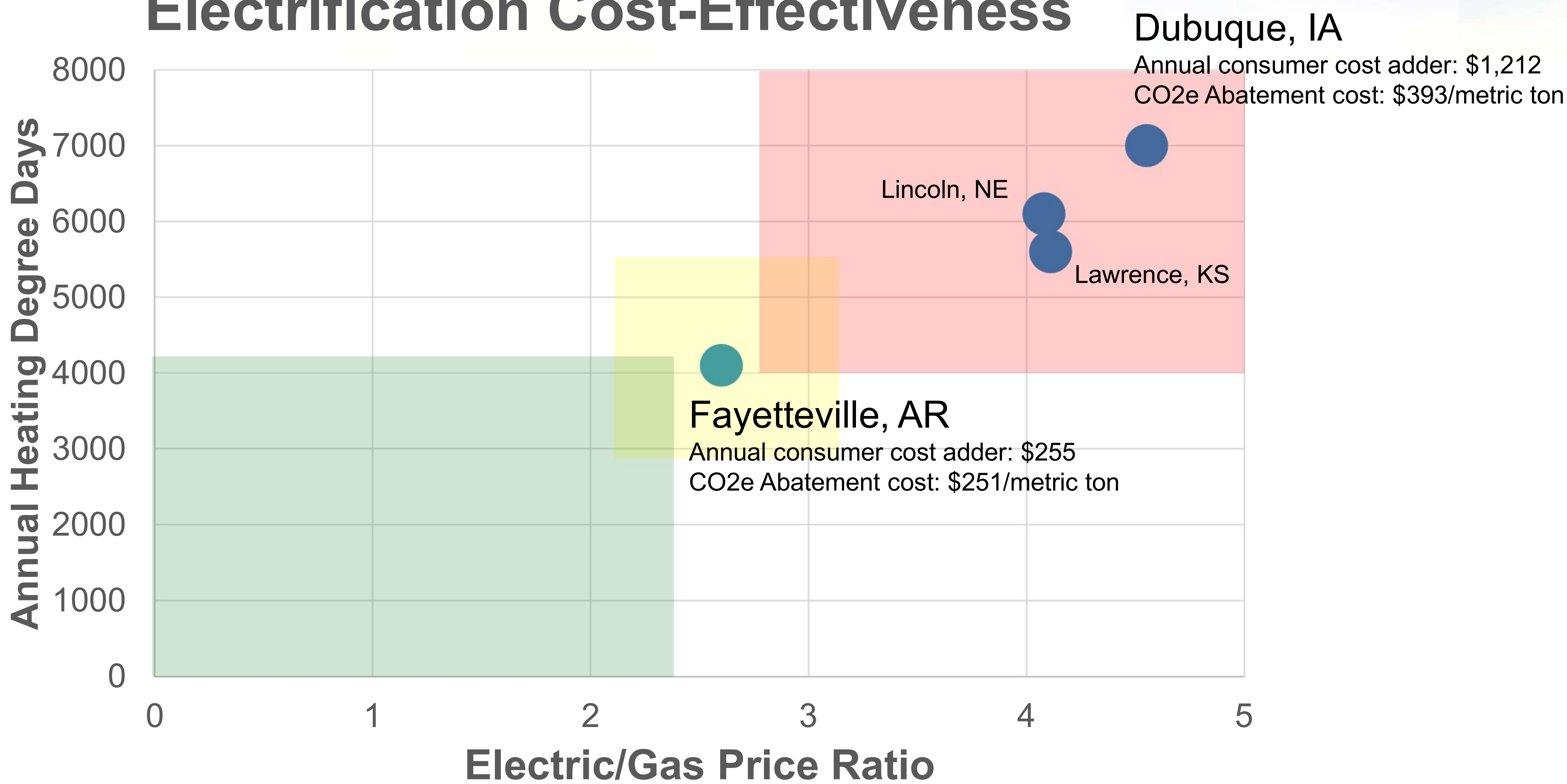
Key Factors Influencing Electrification Cost-Effectiveness



Summary

- Thank you for the opportunity to share the results from reports done by GTI for Black Hills Energy
- Puts together important puzzle pieces, helping inform the debate on GHG reduction options, pathways, costs, and considerations
- When assessing electrification, important to ensure key factors are being assessed:
    1. Consumer and societal cost impacts
    2. Electric utility grid capacity impacts
    3. Major influence of temperature on space heating loads as well as electric heat pump output and efficiency
    4. High GHG emission rates with seasonal generation (particularly in the winter)

William E. Liss
Vice President, Energy Delivery & Utilization
GTI
O: 847.768.0753
M: 847.312.5014
wliss@gti.energy
www.gti.energy