the Energy to Lead

# A Technical Perspective on Zero Energy Buildings

RESNET Conference

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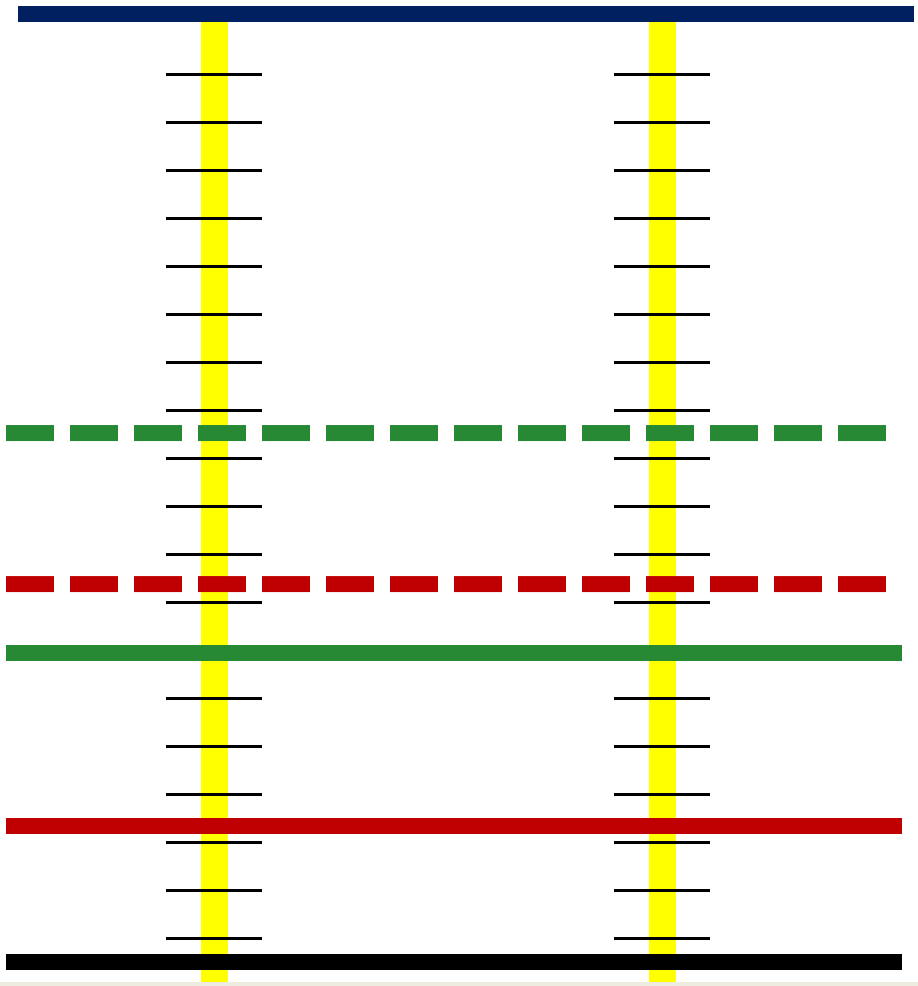
# Evolution of Building Energy Codes Toward Net Zero



Net Zero Building

New “Beyond Code”

New Minimum Code

Original “Beyond Code”

Original Minimum Code

Average Building



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# Owner Investments Impact Natural Resources and the Environment

- Owners impact natural resources and the environment every time they make a technology investment (economic) choice
  - If owners don't use the energy, it will not be supplied
  - Owners have control over their investment decisions
- Standards that drive owners to make poor building energy investment choices cause negative impact on natural resources and the environment
  - Increased consumption of higher impact energy
  - Decreased consumption of lower impact energy
  - Net increase in negative impacts



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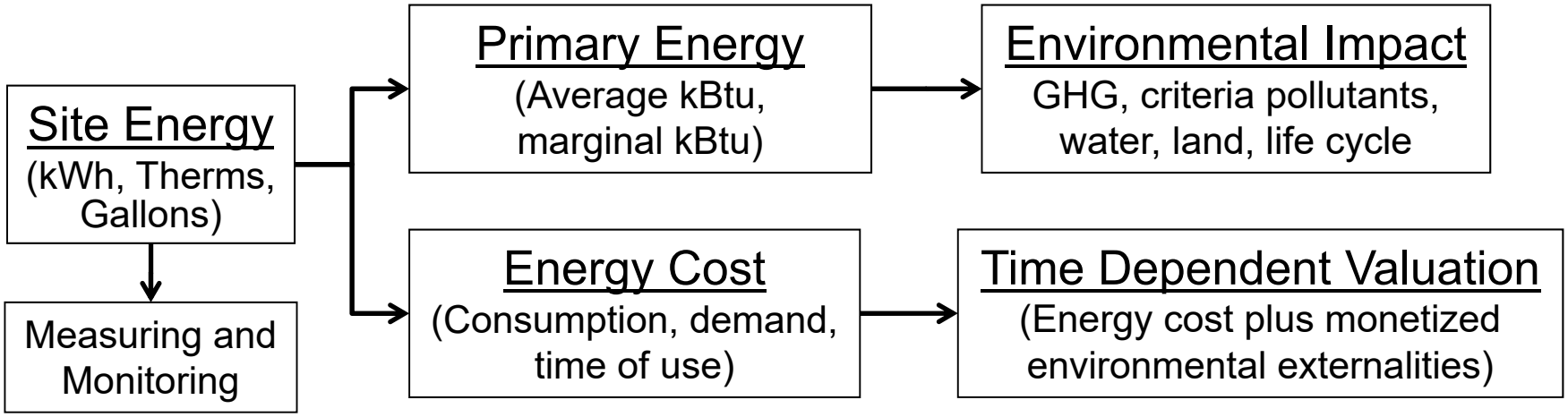
# Different Metrics and Methods Needed Depending on Primary Intent




- Site energy is needed when the primary intent focuses on measuring and monitoring, and is the essential starting point for converting to energy costs, primary energy, and greenhouse gas emissions attributable to design options or building operation.
- Energy cost is needed when the primary intent focuses on economic objectives.
- Primary energy is needed when the primary intent focuses on natural resources, the environment, or other societal impacts of energy use.
- Environmental impacts need supplemental metrics using factors that convert site energy to primary energy and associated greenhouse gas emissions or other impacts.

# Net Zero Energy (NZE) Buildings Issues

- Policy movement promoting NZE
- Net zero site energy definition favors all-electric
  - Easier for all-electric buildings to achieve net zero site energy
  - Direct gas use discouraged strongly based on site efficiency
- Potential role for direct gas use with source energy, cost, TDV*, or emissions definition
  - High efficiency components, structure first priority
  - Natural gas direct use can reduce PV array size and cost compared to all-electric building with these metrics

* TDV = time-dependent valuation; used in CA building codes



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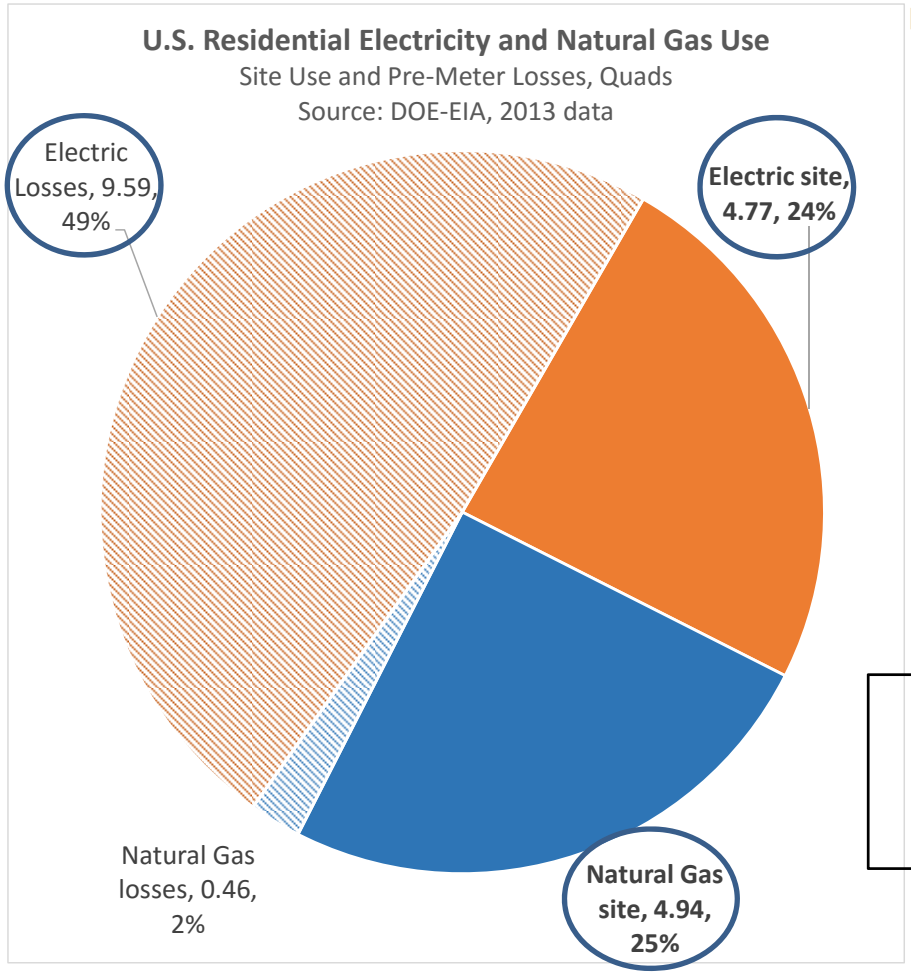
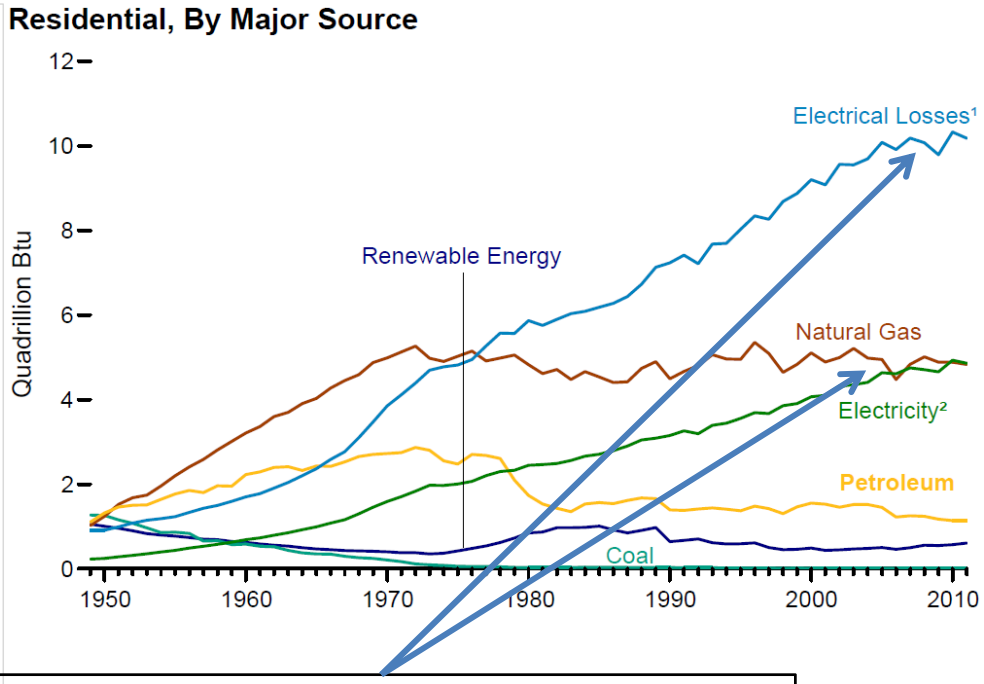
# Site Energy Is Insufficient for Use in Defining Zero Energy Buildings




Upstream Electrical Losses Equal Combined Gas and Electric Site Consumption in U.S. Buildings

# Primary Energy Use Reduction by Increased Natural Gas End Use

- Efficient direct use of natural gas can significantly reduce primary energy consumption compared to electric resistance technologies
- Natural gas direct use societal benefits
  - Low life-cycle costs to consumers
  - High primary energy efficiency
  - Low greenhouse gas emissions
  - Energy security
  - Domestic employment
  - Compatible with renewable methane



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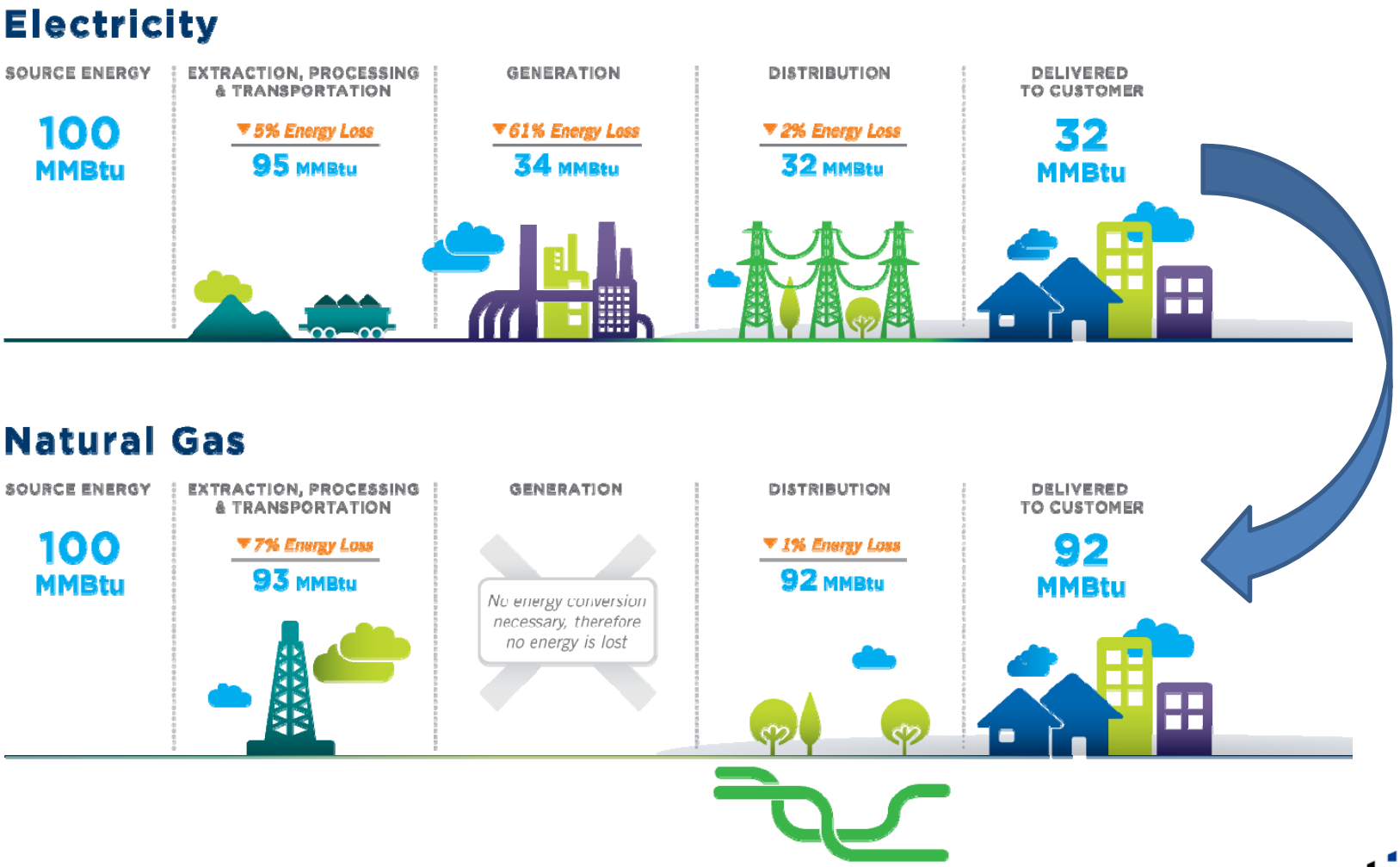
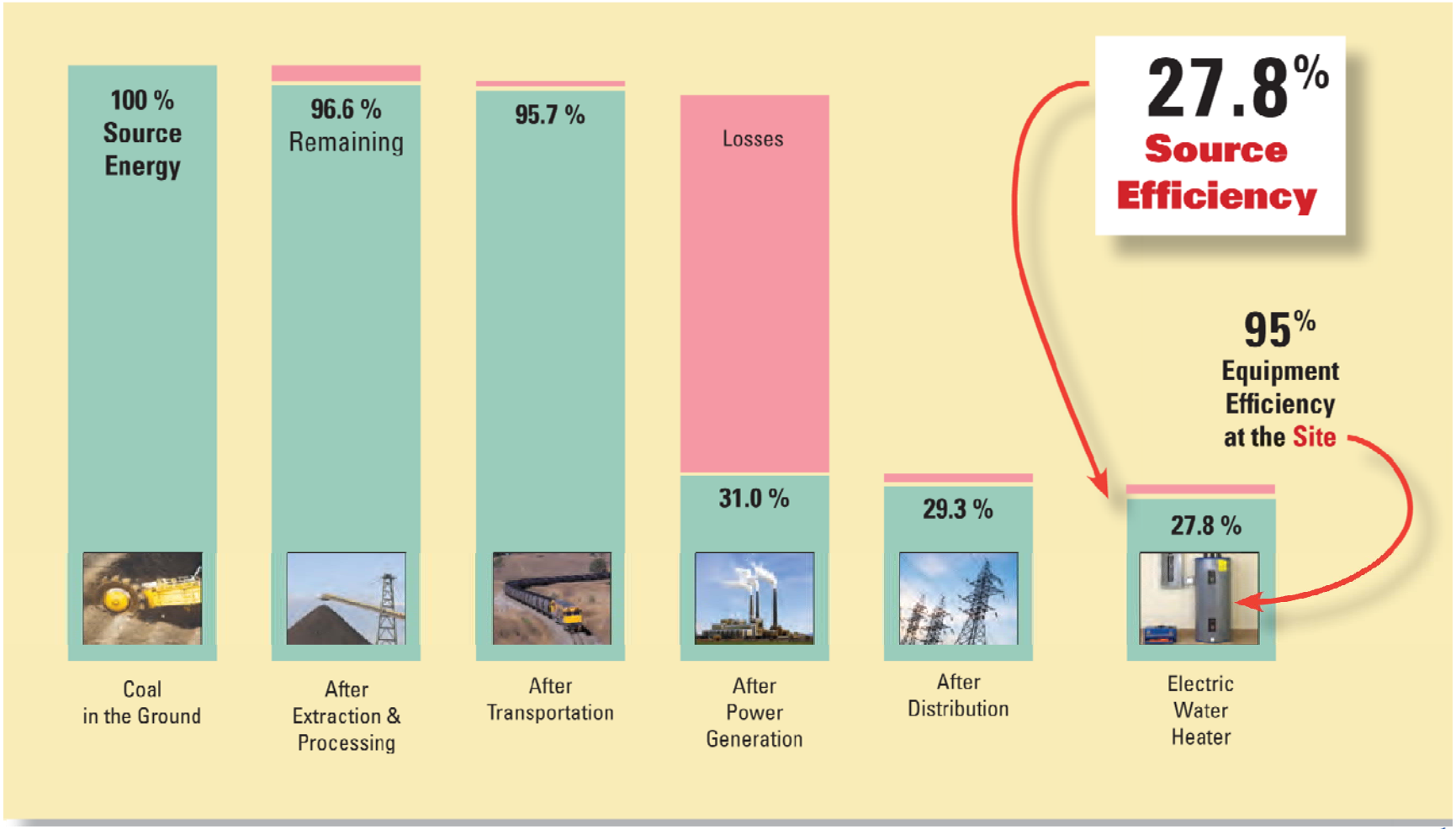
# Comparison of Source Efficiencies Delivered to Customers (%)

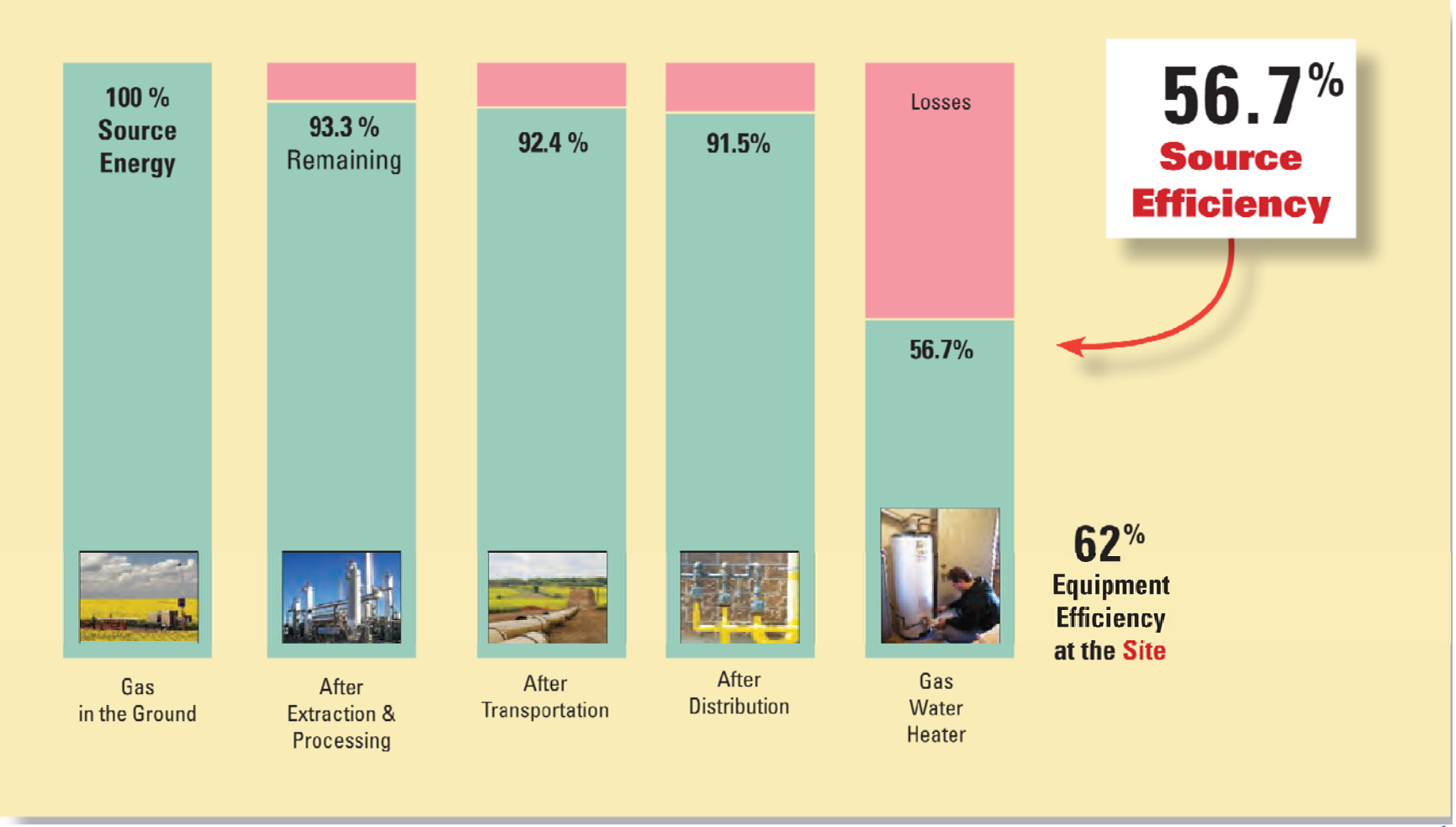



Source: AGA Policy Handbook

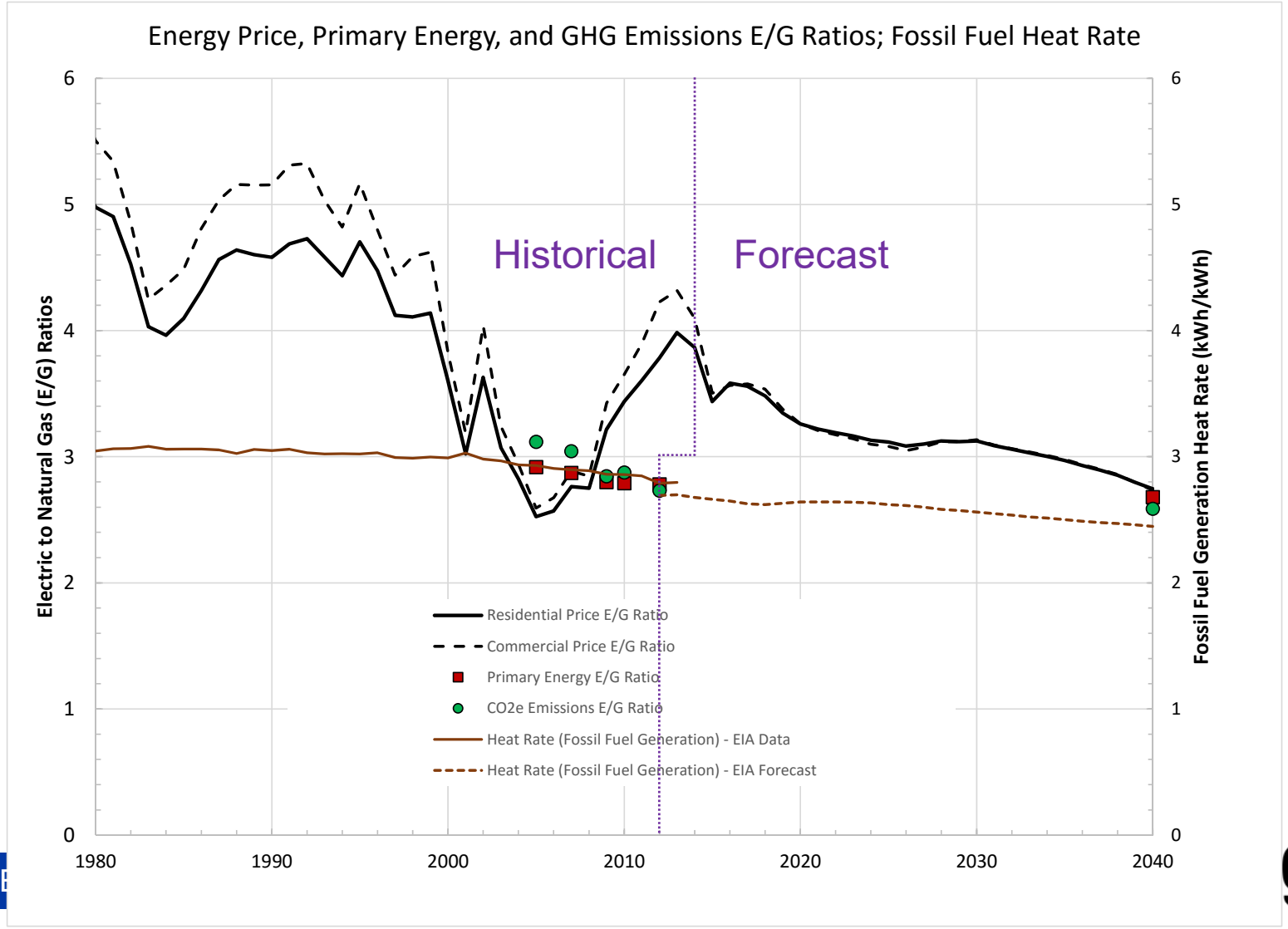
# Full-Fuel-Cycle Efficiency of Electric Resistance Storage Water Heater



# Full-Fuel-Cycle Efficiency of Natural Gas Storage Water Heater

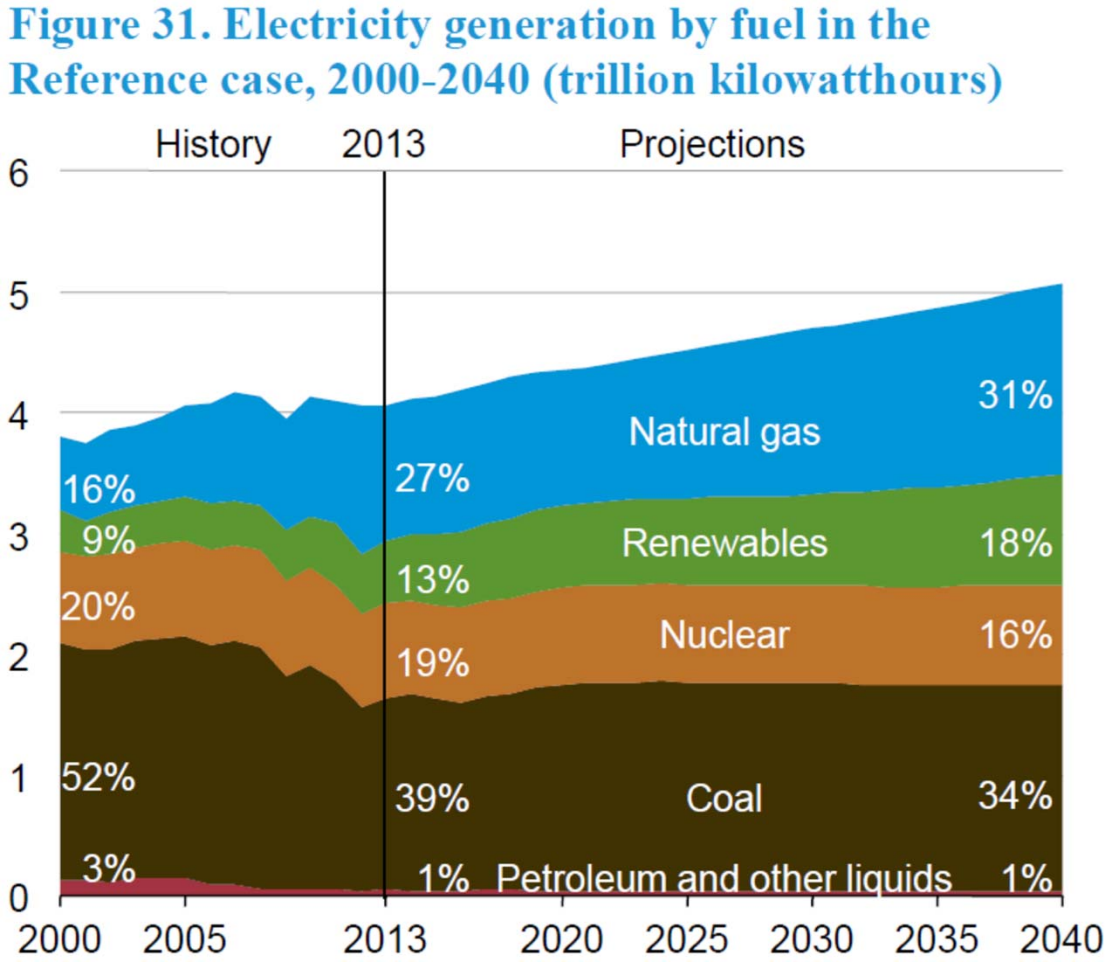


# Electric to Natural Gas Price Ratios (Historic and Projected)




Source: E

# US Electricity Generation Mix through 2040 – EIA 2015 Forecast




Coal, gas, and nuclear dominate U.S. power generation mix through 2040

Source: EIA Annual Energy Outlook 2015



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# RESNET HERS Index


- Integer value based on "linear" scale
  - 1 point = 1% change in site energy use relative to reference home, with adjustments
    - Normalized, modified load method for natural gas
  - Reference home Index value = 100
  - Home with no net purchased energy Index value = 0

Source: http://www.resnet.us/understanding-the-hers-index



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# IgCC Zero Energy Performance Index (zEPI) Based on Primary Energy

- zEPI = 52 * (Proposed building performance/ Baseline building performance)
  - Proposed building performance = the source energy use for the proposed design
  - Baseline building performance = the source energy use for the baseline design
- 52 = a fixed value representing the source energy performance of an ASHRAE Standard 90.1-2013 Appendix G baseline building

# DOE Zero Energy Building Definition Based on Primary (Source) Energy

An energy-efficient ***building,*** where on a ***source energy*** basis, the actual ***annual delivered energy*** is less than or equal to the on-site renewable ***exported energy***.



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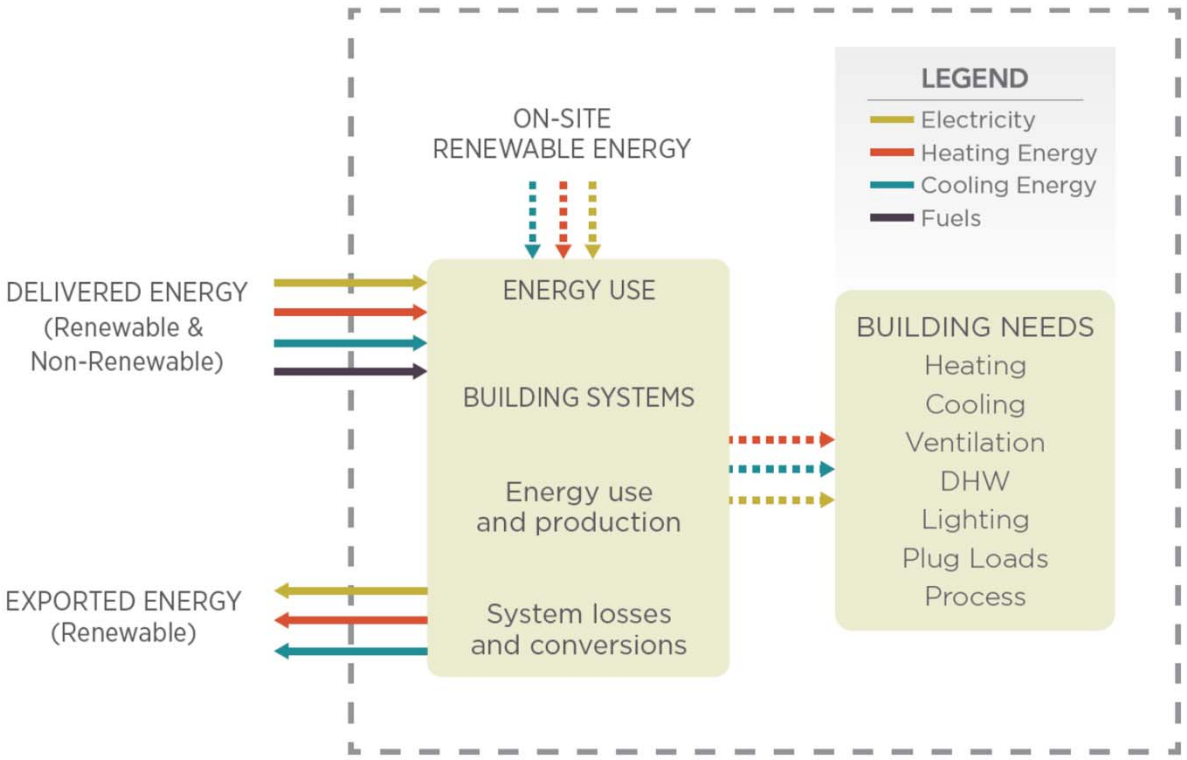
# Site Boundary of Energy Transfer

Figure 1 – Site Boundary of Energy Transfer for Zero Energy Accounting

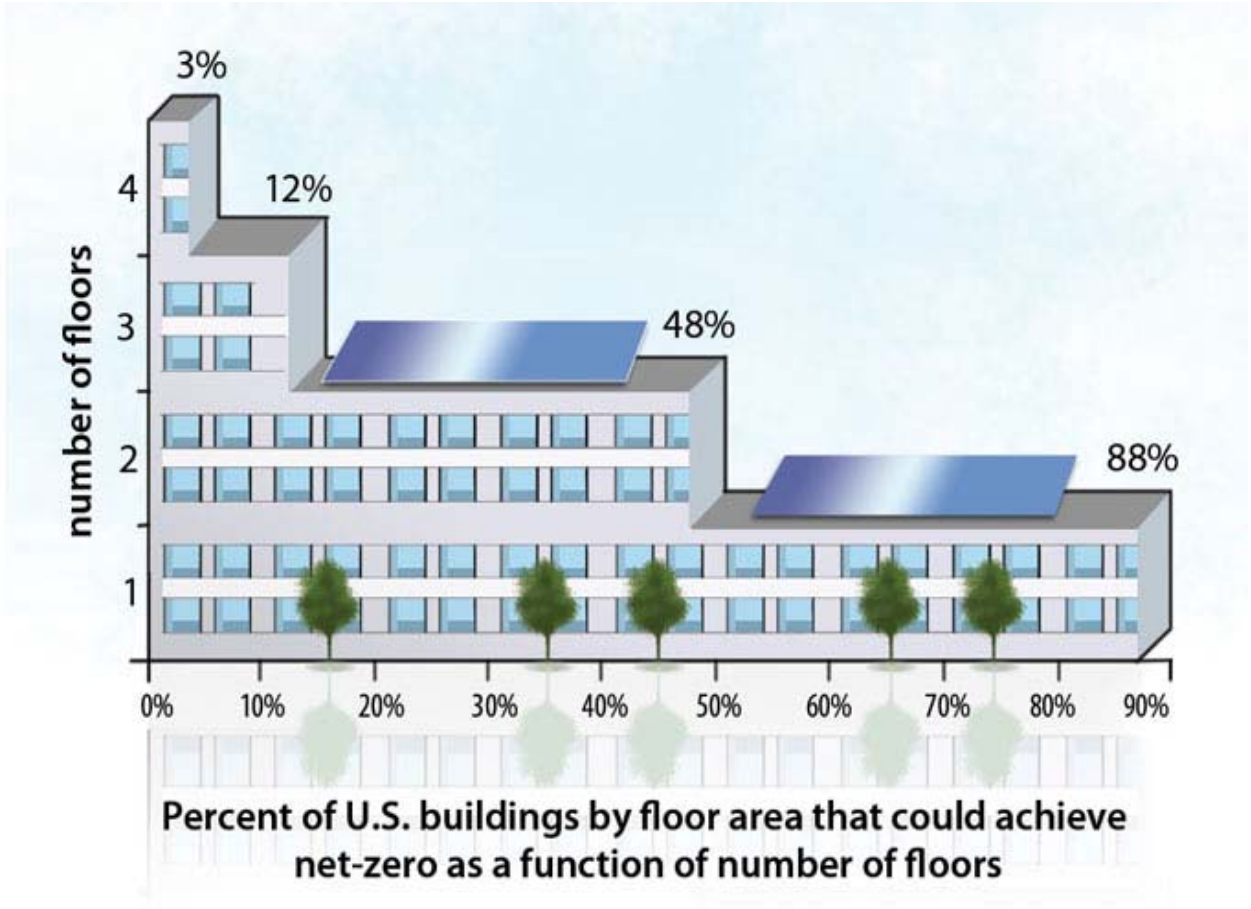



Notes

1. The dashed lines represent energy transfer within the boundary
2. The solid lines represent energy transfer entering/leaving the boundary used for zero energy accounting

Source: DOE Report: A Common Definition for Zero Energy Buildings (September 2015)

# Commercial Building Possibility for Net Zero Energy Performance




Source: http://www.buildinggreen.com/auth/article.cfm/2010/7/30/The-Problem-with-Net-Zero-Buildings-and-the-Case-for-Net-Zero-Neighborhoods/

# ASHRAE Conference Paper LV-11-C041, Published January 2011

- Gas Usage Roadmap to Zero Energy Homes
  - Authors:  Ryan Kerr, Doug Kosar
  - Describes how current design and operation approaches could limit the actual performance of buildings
  - Explains process needed to address plug and process loads in any low energy building
  - Provides natural gas usage scenarios in net-zero energy homes

# Objective

- Provide a Roadmap for Natural Gas Use in Zero Energy Homes (ZEHs)
  - ZEHs are homes with net-zero annual energy consumption

# Homes Evaluation: Chicago- Cold

| Chicago Homes | Source Energy Use (MBtu/yr) | Source Energy Savings | Total Therms | Therm Savings | Carbon Emissions (lbs/yr) | Carbon Savings | Incremental Cost | Cash Flow ($/yr) |
|---|---|---|---|---|---|---|---|---|
| **Chicago Benchmark** | 368 | NA | 1943 | 0% | 47,892 | 0% | $0.00 | $0.00 |
| **Chicago 30% Home** | 242 | 29.7% | 1261 | 35% | 33,771 | 29% | $5,216.55 | $537.53 |
| **Chicago 70% Home** | 121 | 67.1% | 517 | 73% | 16,999 | 65% | $32,969.59 | -$369.17 |
| **Chicago 70% Home- All Electric** | 148 | 59.8% | 0 | 100% | 21,494 | 55% | $32,859.59 | -$612.89 |

Electric Features:

- 18 SEER/9.2 HSPF Heat Pump
- 98 EF Tankless + Solar Water Heating
- Induction Cooktop, Electric Dryer (AT)

# Homes Evaluation: Chicago Summary

- Homes approaching 50% savings are technically possible and cost-effective
- Thermal loads greatly reduced, plug loads remain
  - Electric Savings ~ 50%
  - Natural Gas Savings ~ 75%
  - Gas still most cost-effective, carbon and energy efficient fuel for thermal loads in high performance homes (Dryer, cooking, space and water heating)

Source: ASHRAE Conference Paper AT-15-C0002



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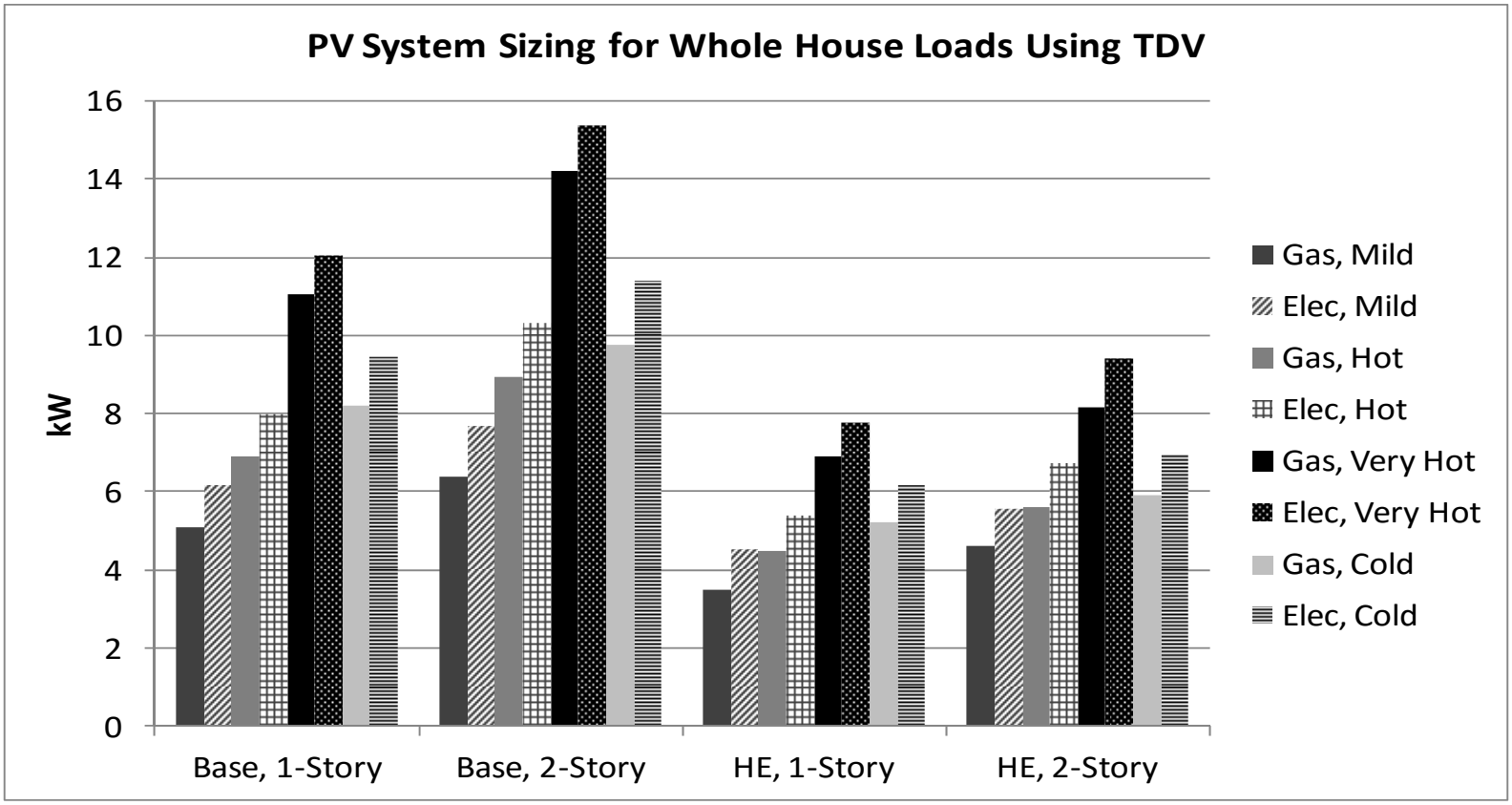
# ASHRAE Conference Paper AT-15-C0002, Published June 2015

- The Path to Achieving Zero Net Energy Homes – Energy Choices, Consumer Costs, and the Environment
  - Authors:  Larry Brand, Martha Brook, Neil Leslie
  - Describes how to minimize energy cost for net-zero and positive energy buildings
  - Describes how solar photovoltaic (PV) systems can be sized for all-electric and mixed fuel zero net energy (ZNE) houses
  - Shows that using site energy or time dependent valuation can produce significantly different solar PV size for ZNE houses

# How Much PV with TDV?




> ZNE PV should follow efficiency improvements

Source: ASHRAE Conference Paper AT-15-C0002



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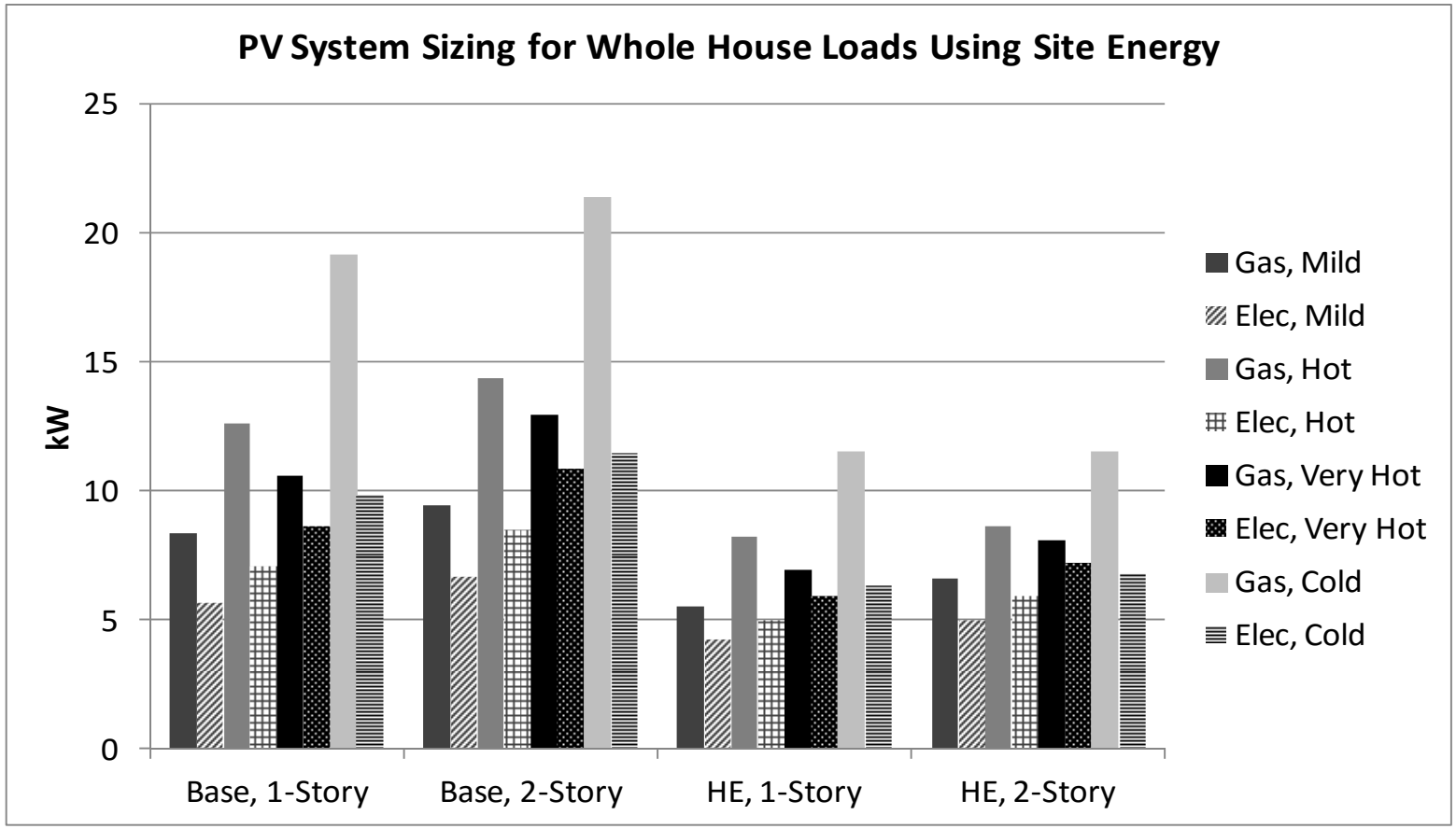
# How Much PV with Site Energy?




> PV system 9% larger with site energy

Source: ASHRAE Conference Paper AT-15-C0002



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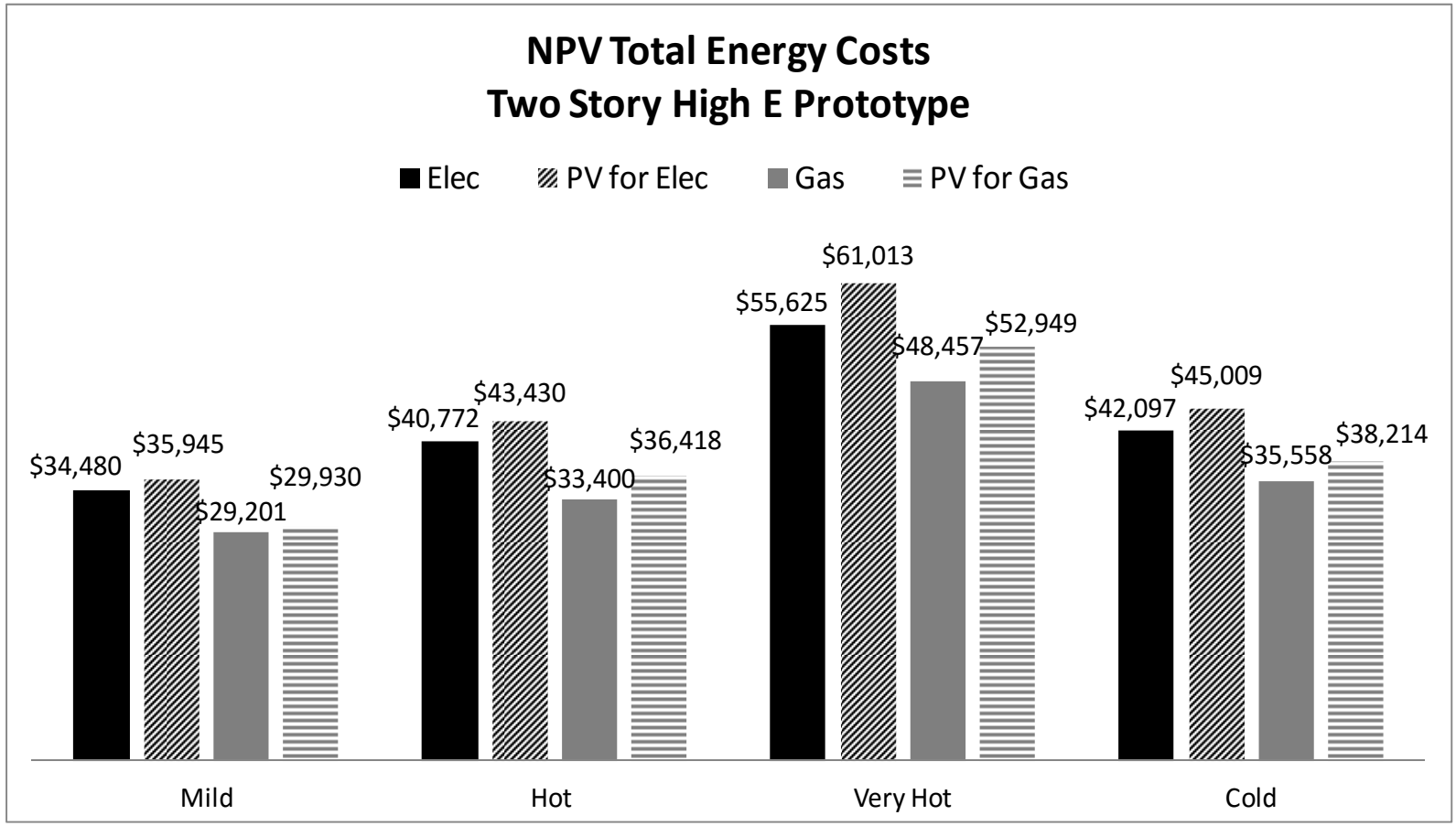
# Consumer Costs




> PV Costs are 2-9% more than the cost of energy over 30 yrs.

Source: ASHRAE Conference Paper AT-15-C0002

# ASHRAE Conference Paper Conclusions

- Applying solar PV systems to all electric or mixed fuel houses is straightforward
- All electric houses require a larger PV system than mixed fuel to achieve ZNE when using the TDV methodology
- Using site energy instead of TDV adds 1.1 kW to the PV size on average
- NPV of the utility costs over 30 years is 6% less than the PV system (cost of High E upgrades not considered) – PV system costs need to drop significantly for ZNE to be cost-effective
- Policy issues need to be addressed to size PV systems for the whole house load

Source: ASHRAE Conference Paper AT-15-C0002



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# Summary

- Efficient direct use of fossil fuels can significantly reduce full-fuel-cycle energy consumption compared to electric resistance technologies
- Several definitions for net zero energy
  - High bias toward all-electric buildings to achieve net zero site energy
  - Role for natural gas with a source energy-based definition (primary energy, GHG emissions, TDV)
- It will be impractical to achieve net zero energy in a large number of buildings and locations