There's a New Tool in Town: Carbon Rating Index

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NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Energy Rating Index

Energy Rating Index (ERI) scores are used extensively for residential new construction

- Over 350,000 homes received ERI scores in 2023
  - Approximately one third of all new homes
- At least 4.2 million homes since inception

ERI scores are used for:

- RESNET HERS®
- IECC ERI pathway (2015 or newer)
- Above-code labeling programs (EPA's ENERGY STAR® New Homes and DOE's Zero Energy Ready Homes)
  - 45L tax credits (up to $5000 per home)

ZERO ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

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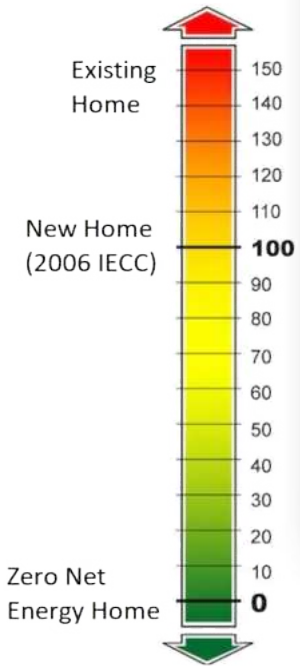
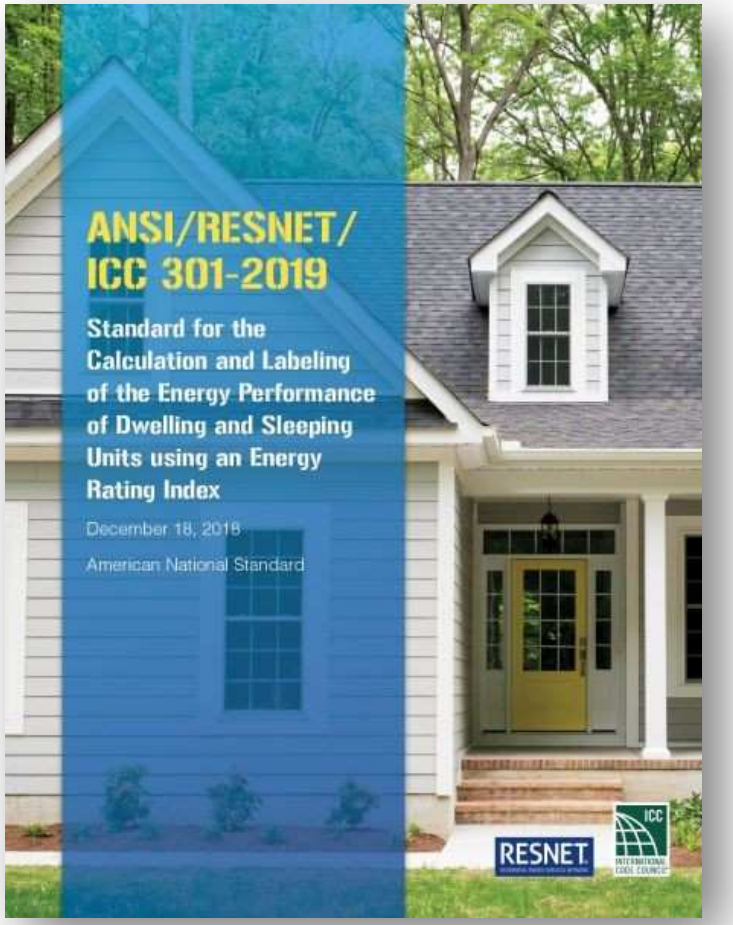
Energy Rating Index

- Defined by ANSI/RESNET/ICC 301
  - *Standard for the Calculation and Labeling of the Energy Performance of Dwelling and Sleeping Units using an Energy Rating Index©*
- Calculated (approximately) as:

$$\frac{\text{Annual end uses of rated home, modeled}}{\text{Annual end uses of reference home, modeled}}$$

- Developed around 2000





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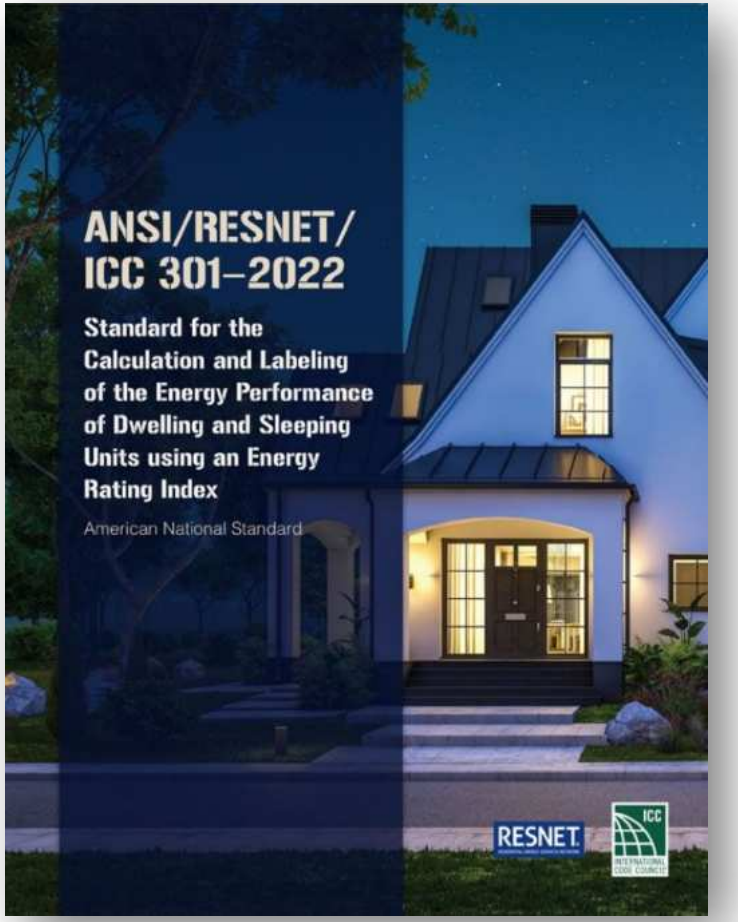
Carbon Rating Index: A New Metric

- New metric in 301-2022 version
  - For the first time, a standardized metric to measure home performance using operational carbon emissions
  - Developed by RESNET Load Flexibility Task Group
- Calculated as:

$$\frac{\text{Annual } CO_2e \text{ emissions of rated home, modeled}}{\text{Annual } CO_2e \text{ emissions of reference home, modeled}}$$

- Alternative to ERI, not a replacement



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ERI vs CRI: How Different Are They?

ERI (Cadillac Eldorado, 1963)

CRI (Ford Mustang Mach-E, 2021)

CRI was an opportunity to develop a new metric that:

- Credits new and emerging building technologies (e.g., cold-climate heat pumps)
- Better reflects the environmental impact of homes
- Incorporates the latest science, data, and future trends

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ERI vs CRI

Difference #1: Rating Method

ERI

- **Units**: Normalized Modified End Use Loads (nMUELs)
  - Adjustments to energy use that forces equal scores for gas furnace vs electric HP
- **Reference Home**: Variable baseline (Same fuel as Rated Home)
- **Result**: ERI scores for two homes of same size and in the same region may poorly reflect relative environmental impact, particularly for mixed-fuel vs all-electric homes

CRI

- **Units**: CO_2e emissions, with emissions factors from:
  - **Electricity**: NREL's Cambium; **Fossil fuels**: EPA's eGRID (plus, e.g., methane leakage)
- **Reference Home**: Fixed baseline (All-electric Home)
- **Result**: CRI scores for two homes of same size and in the same region appropriately reflect relative environmental impact

ERI vs CRI

Difference #1: Rating Method

First nation-wide set of hourly electricity emission factors for future modeled projections of the power sector

- Uses ReEDS capacity planning model for the bulk power system to evaluate ~70 future scenarios
- Similar methodology used in California's Title 24 Energy Code
- Long sought resource by buildings industry

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ERI vs CRI

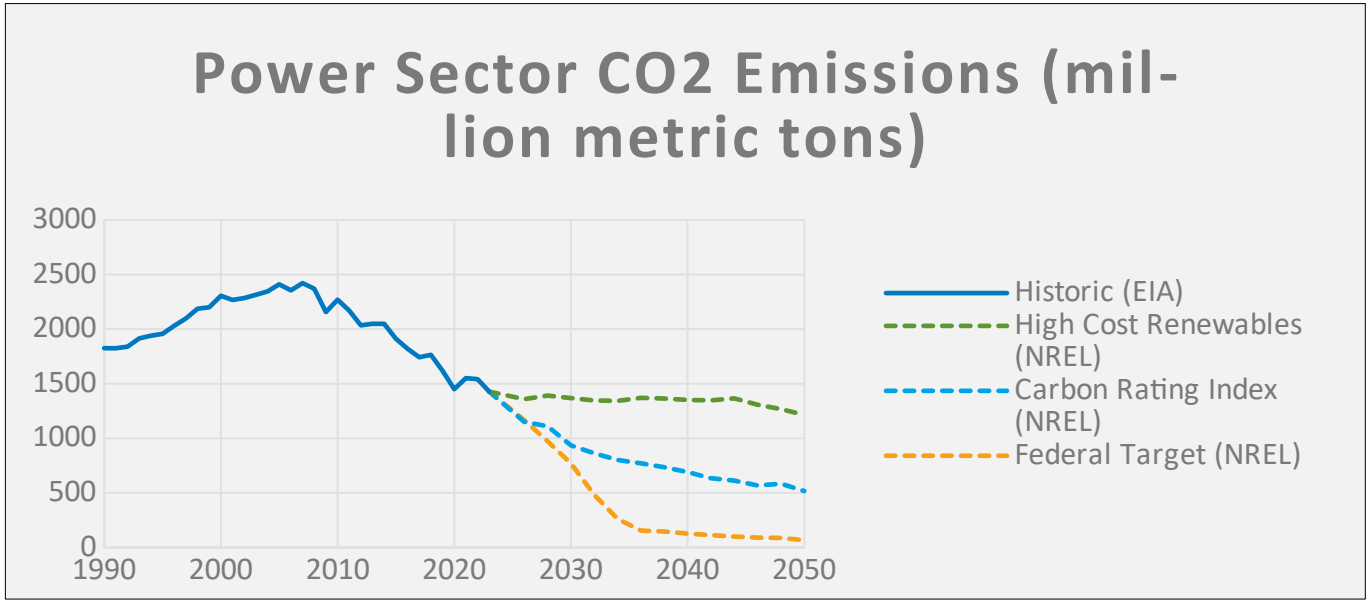
Difference #2: Future Projection

ERI

- Insensitive to power sector changes over time

CRI

- Includes 2025-2050 NREL projection for electric power sector
  - Power sector emissions have dropped rapidly since 2010 (~40% reduction)
  - Power sector emissions will continue to drop



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ERI vs CRI Diversity

Difference #3: Geographic

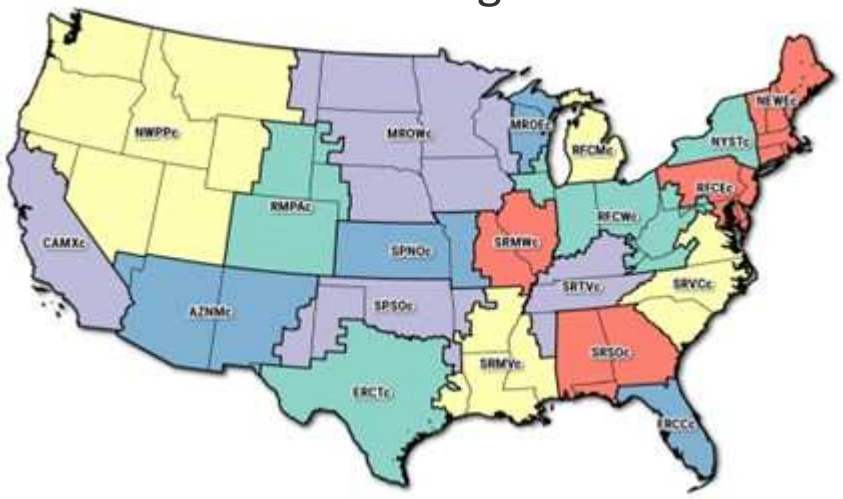
ERI

- Electricity valuation insensitive to geographic region

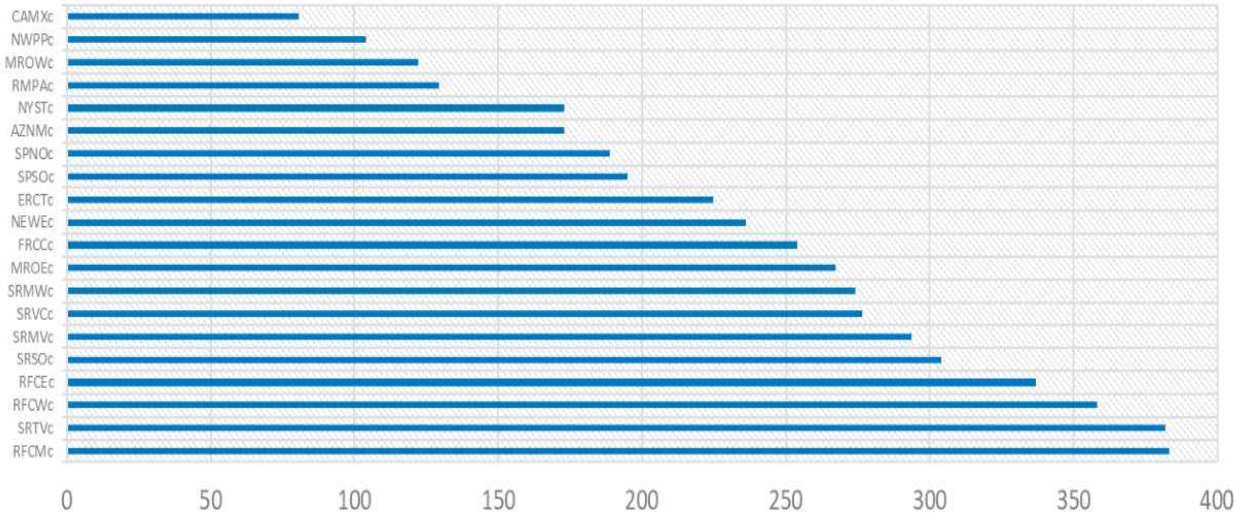
CRI

- Electricity emissions factors based on 20 regions
  - Grouped using transmission, distribution, and utility service territories of power plants (similar to EPA's eGRID regions)
- Highest carbon region (MI) is 4x lowest carbon region (CA)

Cambium Regions



CO_2e Emission Rates by Region (kg/MWh)



ERI vs CRI Resolution

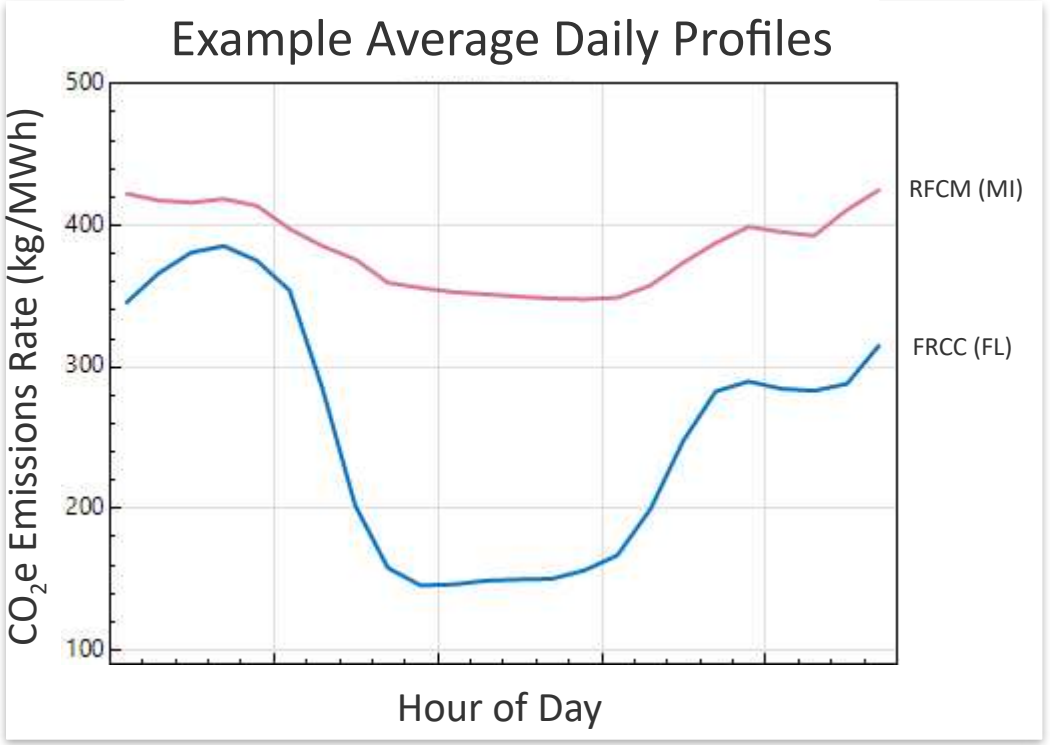
Difference #4: Temporal

ERI

- Based on **annual** energy use
- **Penalizes or ignores** load flexibility technologies
  - E.g., batteries produce a higher ERI score due to a net increase in energy use from round-trip inefficiencies

CRI

- Based on **hourly** emissions factors
- **Credits** load flexibility technologies that shift when electricity is used to align with lower emissions
  - Can induce more renewables to be built
  - Today: Batteries
  - Future: Connected devices or thermal energy storage



ERI vs CRI

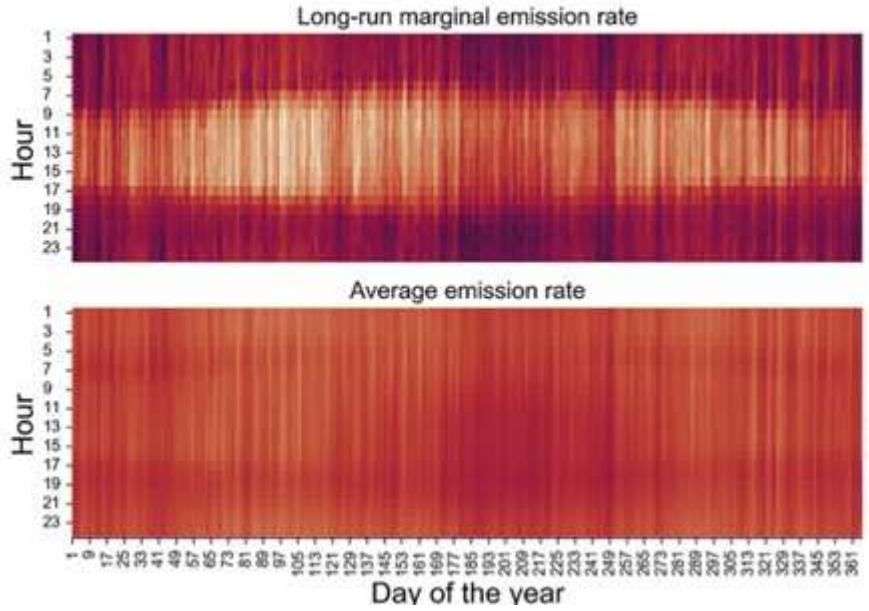
Difference #5: Attribution

ERI

- Insensitive to which grid assets serve the building

CRI

- Electricity emissions factors are:
  - **Marginal** (not average), reflecting the *change* in emissions specifically associated with meeting new electricity demand
  - **Long-run** (not short-run)**,** reflecting the possible build out of new generation (which is often very different than the current makeup of the grid) to meet the new electricity demand
- Scientists and grid experts agree that long-run marginal emissions best reflect real-world impacts



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ERI vs CRI: Summary

		ERI	CRI
Rating Method	**Units**	Normalized Modified End Use Loads (nMEULs)	CO_2e Emissions Factors
	Reference Home	Based on 2006 IECC Same Fuel Type as Rated Home	Based on 2006 IECC All-Electric
Electricity Valuation[1]	**Future Projection**	None	2025-2050
	Geographic Diversity	National	20 Regions
	Temporal Resolution	Annual	Hourly
	Attribution	N/A	Long-Run, Marginal Factors

[1] Hourly energy simulations in a particular climate zone are used for both metrics.

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ERI vs CRI: High-Level Impacts on Scores

All-electric homes

- CRI and ERI scores are **very similar**

Mixed-fuel homes

- CRI scores vary from **somewhat higher** to **substantially higher**

All homes

- CRI can **credit** batteries (today)
- CRI can **credit** connected devices or thermal energy storage (future)

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CRI in Software

The Carbon Rating Index is available today.

No new inputs required.

Software tools that produce ERI also now produce CRI:

- RESNET
  - APEX
  - Ekotrope RATER
  - EnergyGauge® USA
  - REM/Rate
- Building Science Institute (BSI)
  - HouseRater

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Deep Dive on Score Impacts

(Simulation Study)

What We're Exploring

NREL performed simulation-based analysis to answer a variety of questions, including:

- How do CRI scores compare to ERI scores?
- How difficult is it for a mixed-fuel home to compete with an all-electric home in different climate zones/regions?
- Which building technologies have the greatest potential to reduce CRI?

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Our Strategy

- For various climate zones/regions, run:
  - All-electric, Zero Energy Ready Home (ZERH) v2
  - Mixed-fuel, Zero Energy Ready Home v2
  - Mixed-fuel, Production Builder Max Spec
  - Mixed-fuel, Max Tech Spec (max equipment efficiencies, passive house level enclosure)

- Also run mixed-fuel homes with additional building technologies (PV, batteries, dual-fuel heat pump, heat pump water heater, etc.)

DOE EnergyPlus / OpenStudio ERI

NREL Cambium

EPA eGrid

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Building Characteristics: General

Parameter	Specification
Housing Type	Single-Family Detached
House Size	2,400 ft^2 (plus 1,200 ft^2 of conditioned basement, where applicable), 2 stories
Foundation Types	Location dependent based on prevalence: • Slab • Crawlspace • Unconditioned basement • Conditioned basement
Locations	Three climate zones/regions: • Detroit, MI (zone 5A, high-carbon region) • Houston, TX (zone 2A, mid-carbon region) • Salt Lake City, UT (zone 5B, low-carbon region)

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Building Characteristics: Enclosure (Zone 5A)

Specification	All-Electric, ZERH v2	Mixed-Fuel, ZERH v2	Mixed-Fuel, Production Builder Max	Mixed-Fuel, Max Tech
Thermal Enclosure				
Ceiling U-Factor	0.024		0.017	0.014
Wall U-Factor	0.045		0.045	0.03
Door U-Factor	0.17		0.17	0.17
Frame Floor U-Factor	0.033		0.031	0.031
Slab Insulation & Depth	R-10, 4’		R-10, 4’	R-20, entire-slab
Window U-Factor	0.27		0.22	0.16
Window SHGC	0.3		0.4	0.4
Infiltration and Mechanical Ventilation				
Infiltration	2 ACH @ 50Pa		1 ACH @ 50Pa	0.3 ACH @ 50 Pa
Mechanical Ventilation	HRV, 65%		HRV, 65%	HRV, 79%

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Building Characteristics: Equipment (Zone 5A)

Specification	All-Electric, ZERH v2	Mixed-Fuel, ZERH v2	Mixed-Fuel, Production Builder Max	Mixed-Fuel, Max Tech
HVAC				
Heating System	9.5 HSPF Heat Pump	0.95 AFUE Furnace	0.98 AFUE Furnace	0.98 AFUE Furnace
Cooling System	16 SEER Heat Pump	16 SEER AC	22 SEER AC	26 SEER AC
HVAC Fan Power	0.45 W/CFM		0.45 W/CFM	0.3 W/CFM
Thermostat Type	Programmable		Programmable	Programmable
Duct Location	100% conditioned space		100% conditioned space	100% conditioned space
DHW				
Water Heater	2.57 UEF Heat Pump Water Heater	0.95 UEF Gas Tankless	0.95 UEF Gas Tankless	0.95 UEF Gas Tankless
Lighting & Appliances				
Interior Lighting	100% LED		100% LED	100% LED
Refrigerator	450 kWh/yr		450 kWh/yr	450 kWh/yr
Dishwasher	270 kWh/yr		270 kWh/yr	240 kWh/yr
Clothes Washer	284 kWh/yr		116 kWh/yr	105 kWh/yr
Clothes Dryer	3.01 CEF		3.93 CEF	4.3 CEF

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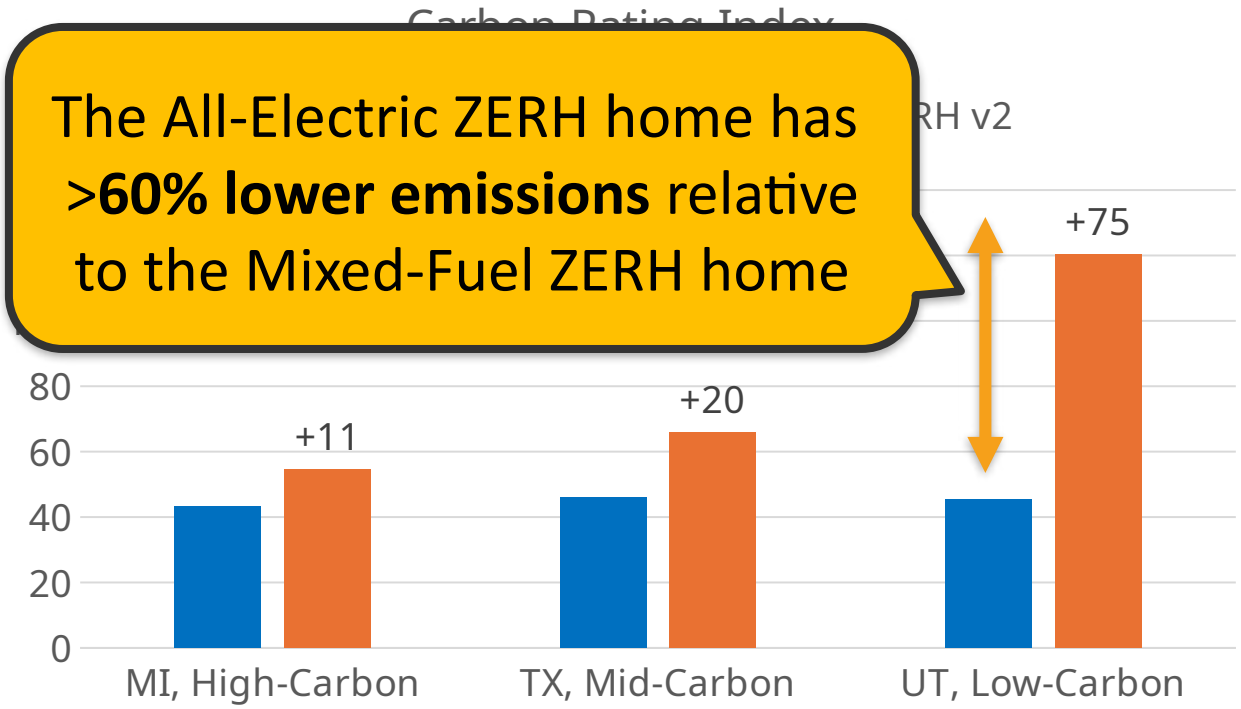
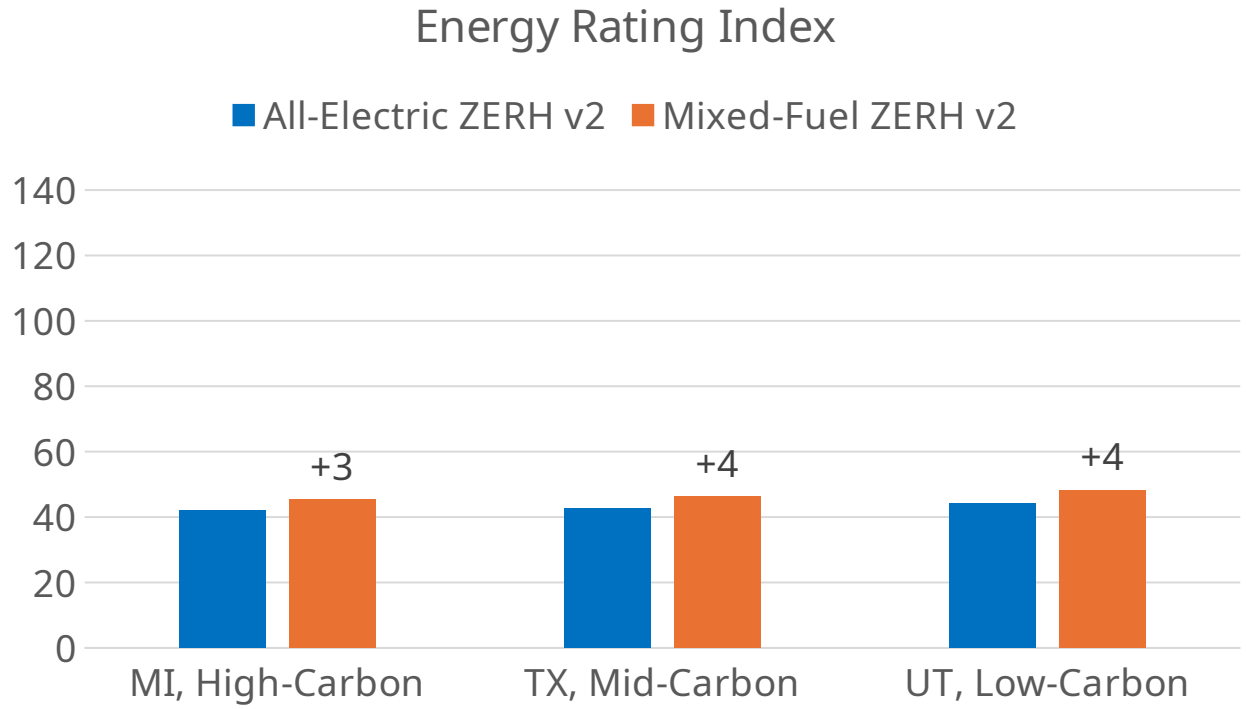
Mixed-Fuel vs All-Electric Homes

- The type of energy source (electric vs. mixed-fuel) has a significant impact on CRI, even if ERI is nearly the same.
- CRI shows a substantial gap between electric and mixed-fuel homes, especially in low-carbon regions and colder climates.

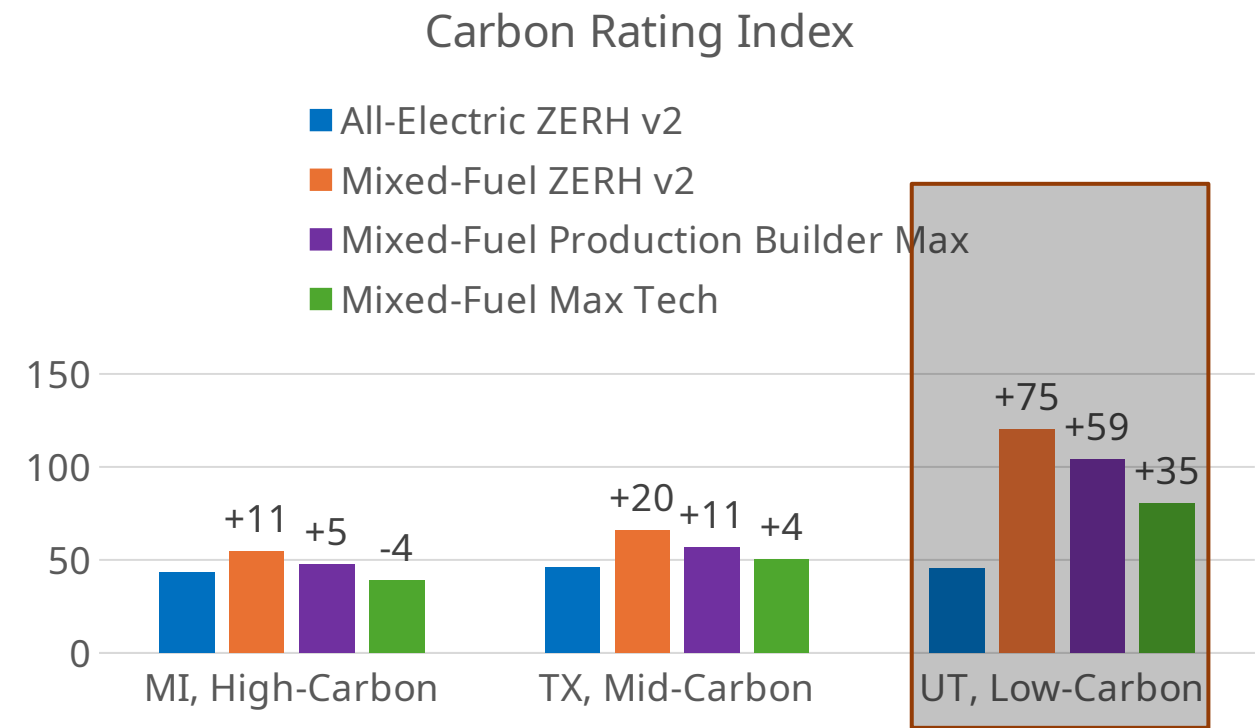
The All-Electric ZERH home has **>60% lower emissions** relative to the Mixed-Fuel ZERH home

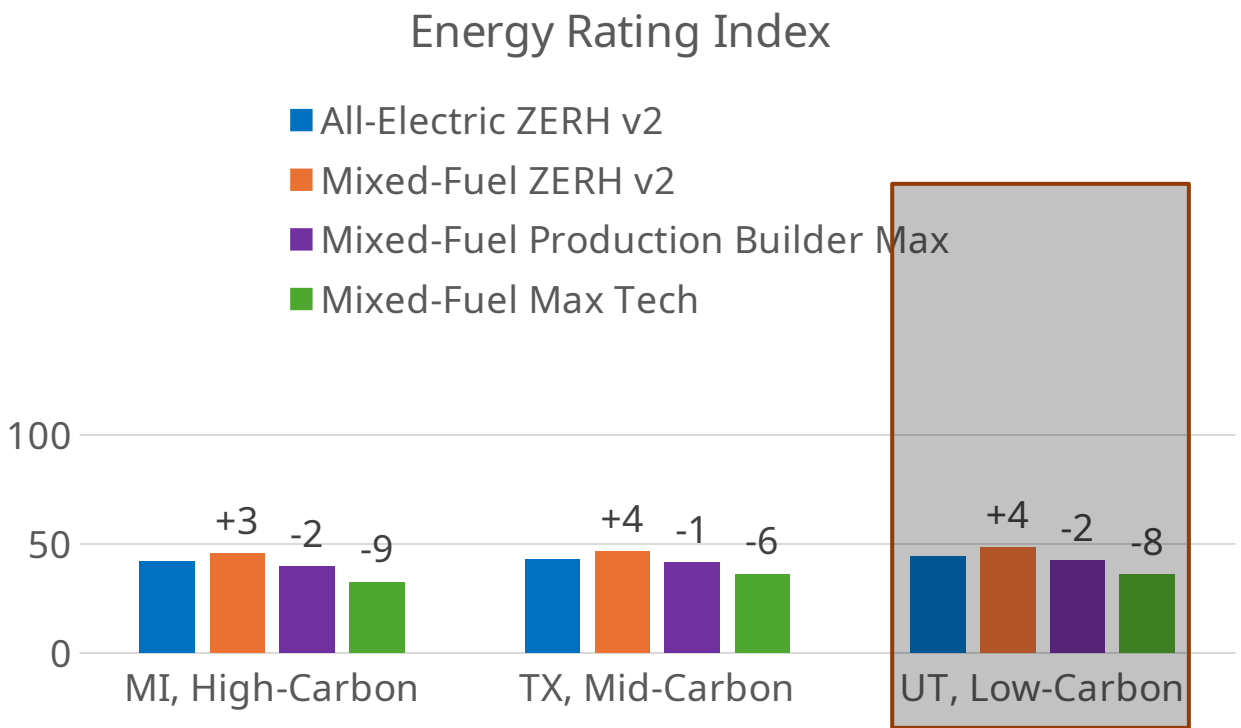




Mixed-Fuel vs All-Electric Homes

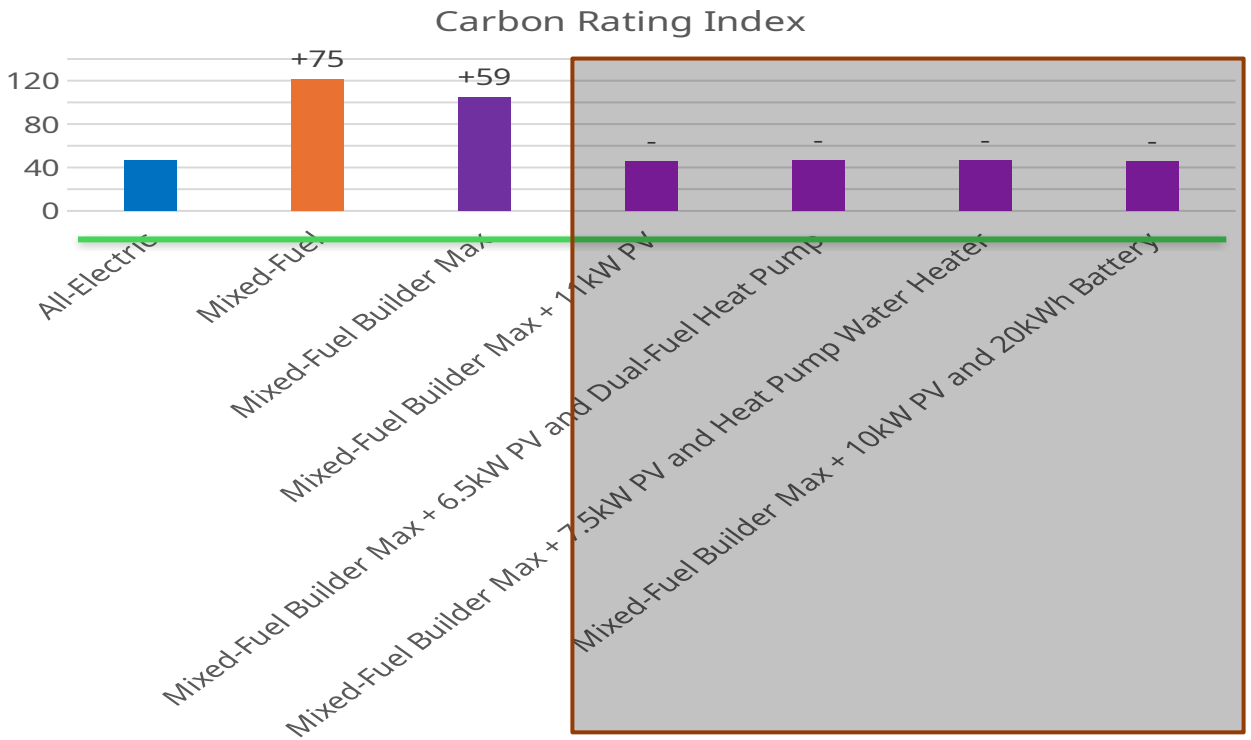
- In high-carbon regions, mixed-fuel home with Production Builder Max spec can achieve the same CRI score as electric home
- In low-carbon regions, it's hard for high-efficient mixed-fuel homes to achieve CRI scores as low as electric home

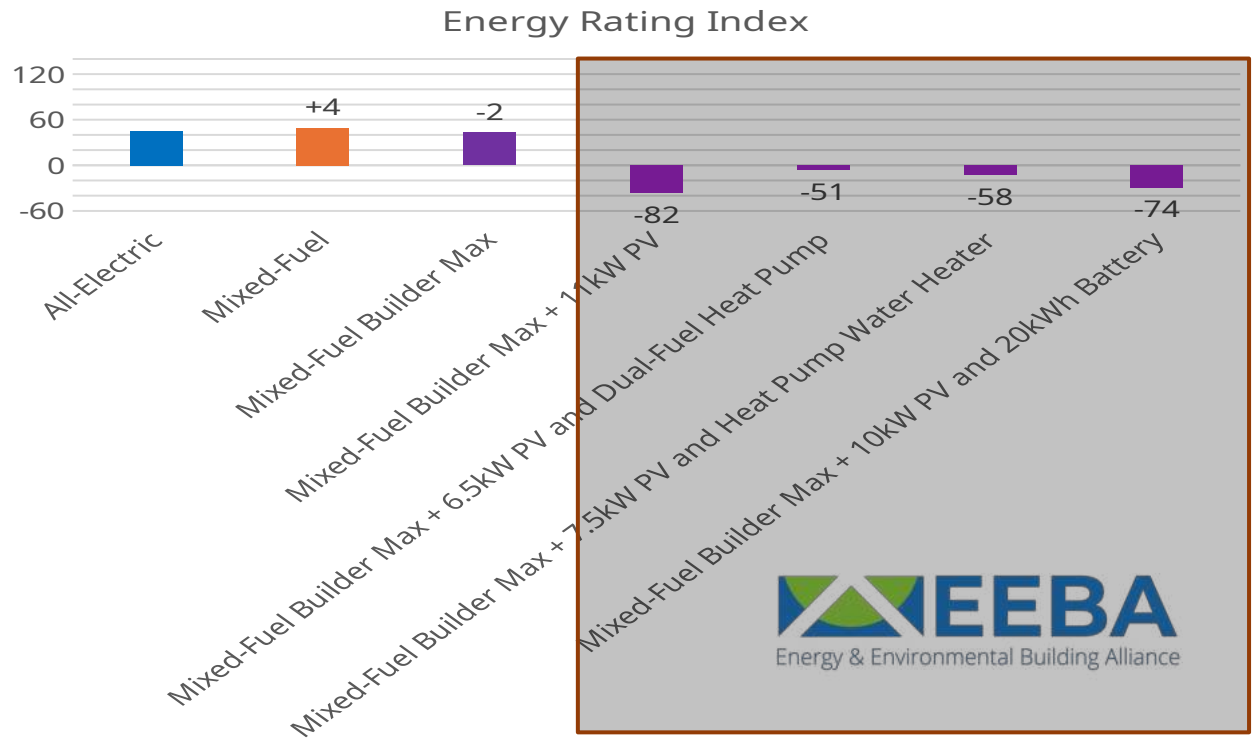




Mixed-Fuel vs All-Electric Homes: Bridging the Gap (Salt Lake City, UT)

- Even with Production Builder Max specifications, more is required to narrow the CRI gap with an electric home
- A large PV system is required to achieve an equivalent CRI
  - PV is credited less with CRI (-60 points) than ERI (-80 points)





Mixed Fuel Homes: CRI vs ERI

- For mixed-fuel ZERH homes, CRI scores compared to ERI scores are:
  - Somewhat higher in warmer, high-carbon regions
  - Substantially higher in colder, low-carbon regions

	Difference between CRI score and ERI score																		
	Cambium GEA Regions (From Lowest to Highest emission rates)																		
IECC Climate Zone	CAMXc	NWPPc	MROWc	RMPAc	NYSTc	AZNMc	SPNOc	SPSOc	ERCTc	NEWEc	FRCCc	MROEc	SRVCc	SRMWc	SRMVc	SRSOc	RFCEc	RFCWc	SRTVc	RFCMc
1											14									
2						17			19		16				15	17				
3	92					27		36	20				17		17	15				
4					47	40	36						17	18			11	9	8	
4C		81																		
5		72	58	59	42	49				25							9	7		9
6		80	61	65						24		16								
7			67																	

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Impact of Individual Measures: Heat Pump

- Larger CRI reductions are observed in low-carbon regions.
- The impact is highly dependent on the regional carbon emission rates.

	Individual Measure CRI Reductions Relative to Mixed-Fuel Homes																		
	Cambium GEA Regions (From Lowest to Highest emission rates)																		
IECC Climate Zone	CAMXc	NWPPc	MROWc	RMPAc	NYSTc	AZNMc	SPNOc	SPSOc	ERCTc	NEWEc	FRCCc	MROEc	SRVCc	SRMWc	SRMVc	SRSOc	RFCEc	RFCWc	SRTVc	RFCMc
	Heat Pump (24 SEER / 11 HSPF)																		
1											3								
2						3			6		3				6	8			
3	16					8		19	7				7		9	6			
4		35			21	10	16						6	9			6	6	5
4C		35																	
5		34	34	27	25	24				15							7	7	8
6		45	39	35						17		13							
7			45																

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Impact of Individual Measures: Dual Fuel Heat Pump

- Larger CRI reductions are observed in low-carbon regions, especially in mild climates.
- In colder climates, dual-fuel systems are outperformed by all-electric systems in terms of emission savings.

	Individual Measure CRI Reductions Relative to Mixed-Fuel Homes																			
	Cambium Regions (From Lowest to Highest emission rates)																			
IECC Climate Zone	CAMXc	NWPPc	MROWc	RMPAc	NYSTc	AZNMc	SPNOc	SPSOc	ERCTc	NEWEc	FRCCc	MROEc	SRVCc	SRMWc	SRMVc	SRSOc	RFCEc	RFCWc	SRTVc	RFCMc
	Dual Fuel Heat Pump (24 SEER / 11 HSPF)																			
1											3									
2						3			6		3				6	8				
3	16					8		14	6				6		7	6				
4		34			17	8	11						5	6			5	5	4	
4C		34																		
5		26	16	16	13	13				10							5	4		5
6		28	14	17						8		7								
7			13																	

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Impact of Individual Measures: Heat Pump Water Heater

- Notable CRI reductions in low-carbon regions, but generally performs lower compared to the dual-fuel heat pump.
- Limited CRI reductions in high-carbon regions.

	Individual Measure CRI Reductions Relative to Mixed-Fuel Homes																			
	Cambium Regions (From Lowest to Highest emission rates)																			
IECC Climate Zone	CAMXc	NWPPc	MROWc	RMPAc	NYSTc	AZNMc	SPNOc	SPSOc	ERCTc	NEWEc	FRCCc	MROEc	SRVCc	SRMWc	SRMVc	SRSOc	RFCEc	RFCWc	SRTVc	RFCMc
	Heat Pump Water Heater (4 UEF)																			
1											6									
2						7			7		7				6	5				
3	41					8		7	7				6		4	5				
4		22			8	12	7						6	4			3	3	3	
4C		22																		
5		17	10	13	8	11				5							3	3		2
6		15	9	12						4		3								
7			8																	

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Impact of Individual Measures: PV

- Significant CRI reductions compared to the dual-fuel heat pump and heat pump water heater, particularly in regions with greater solar resource availability.

	Individual Measure CRI Reductions Relative to Mixed-Fuel Homes																			
IECC Climate Zone	Cambium Regions (From Lowest to Highest emission rates)																			
	CAMXc	NWPPc	MROWc	RMPAc	NYSTc	AZNMc	SPNOc	SPSOc	ERCTc	NEWEc	FRCCc	MROEc	SRVCc	SRMWc	SRMVc	SRSOc	RFCEc	RFCWc	SRTVc	RFCMc
	4kW PV																			
1											19									
2						24			22		21				21	15				
3	26					27		18	27				17		16	16				
4		18			15	31	16						16	14			13	13	16	
4C		18																		
5		19	13	23	13	28				15							12	12		16
6		17	11	20						11		11								
7			9																	

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Impact of Individual Measures: PV and Battery

- The most significant CRI reductions, showing the enhanced energy storage to optimize solar energy use, especially in regions with greater solar resource availability.

	Individual Measure CRI Reductions Relative to Mixed-Fuel Homes																			
	Cambium Regions (From Lowest to Highest emission rates)																			
IECC Climate Zone	CAMXc	NWPPc	MROWc	RMPAc	NYSTc	AZNMc	SPNOc	SPSOc	ERCTc	NEWEc	FRCCc	MROEc	SRVCc	SRMWc	SRMVc	SRSOc	RFCEc	RFCWc	SRTVc	RFCMc
	4kW PV & 10kWh Battery																			
1											24									
2						26			24		27				24	20				
3	36					29		20	29				22		19	22				
4		21			19	34	18						21	17			17	16	20	
4C		21																		
5		23	15	26	15	31				18							16	15		17
6		19	13	22						13		13								
7			11																	

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Results Summary

- In low-carbon regions, an all-electric ZERH home can achieve over 60% lower emissions compared to a mixed-fuel ZERH home.
- In low-carbon regions, even with Production Builder Max specifications, additional measures – such as 11kW PV or 6.5kW PV paired with a dual-fuel heat pump – are needed to match the CRI of an all-electric home.
- Heat pump, dual-fuel heat pump, and heat pump water heater can reduce CRI by up to 41 points in low-carbon regions.
- A 4kW PV and 10kWh battery measure achieves the greatest CRI reduction - up to 36 points - in regions with greater solar resource.

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Conclusions

Conclusions

The power sector is rapidly decarbonizing

- When buildings use energy can be as important as how much energy is used

The Carbon Rating Index (CRI) is a new metric that:

- Provides an alternative to ERI
- Better reflects the real environmental impact of a home, including future projected emissions
- Credits load flexibility technologies like batteries that align electricity use with lower emissions
- Is available in multiple software tools today

Mixed-fuel homes in colder, low-carbon regions can have substantially higher CRI scores and emissions.

- Enclosure improvements, heat pumps, PV, batteries, etc., are needed to bridge the gap

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Questions?