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Benefits and Challenges in Deployment of Low GWP A3 (Flammable) Refrigerants in Residential Air Conditioning Equipment

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DIRECT GHG SAVINGS from Propane (R-290):

99.9% over R-410A (reference HFC high-GWP refrigerant)

99.7% over R-32 (alternative lower GWP refrigerant to R-410A)

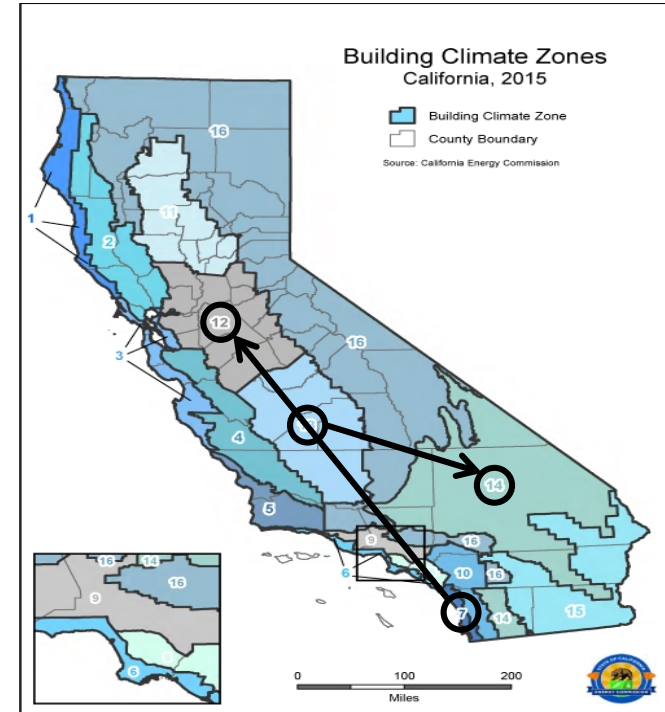
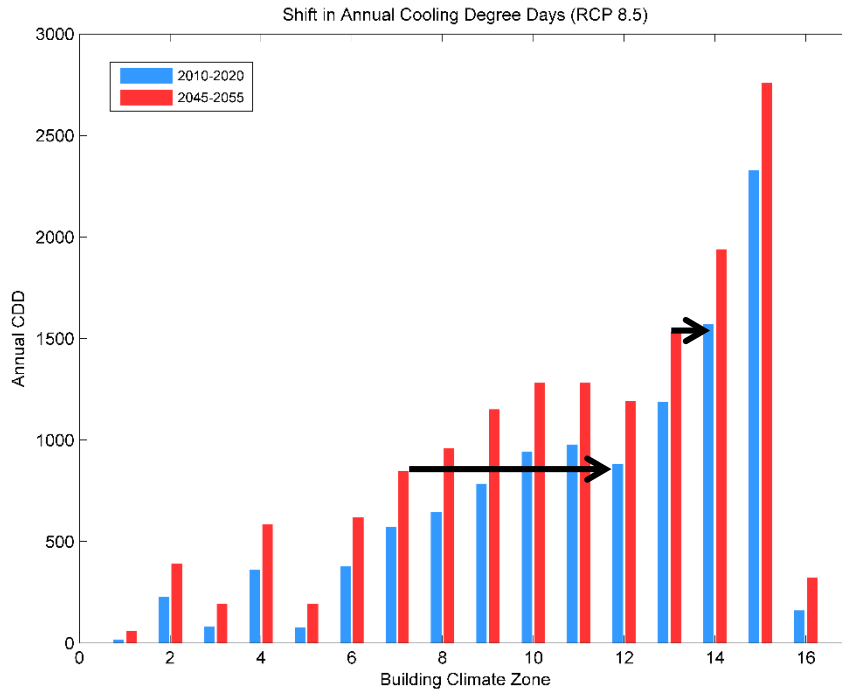
R-410A = 2088 (non-flammable, A1)

R-32 = 675 (mildly flammable, A2L)

R-290 GWP ~ 3.3 (flammable, A3)



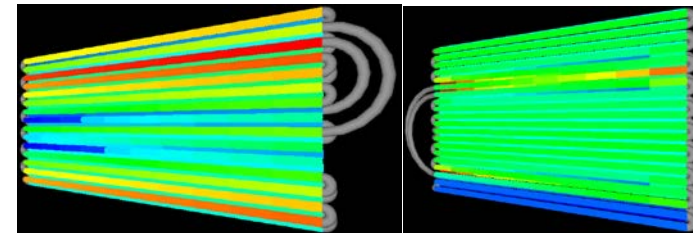
Refrigerant emissions may grow further from climate change-induced hotter weather and increased AC adoption



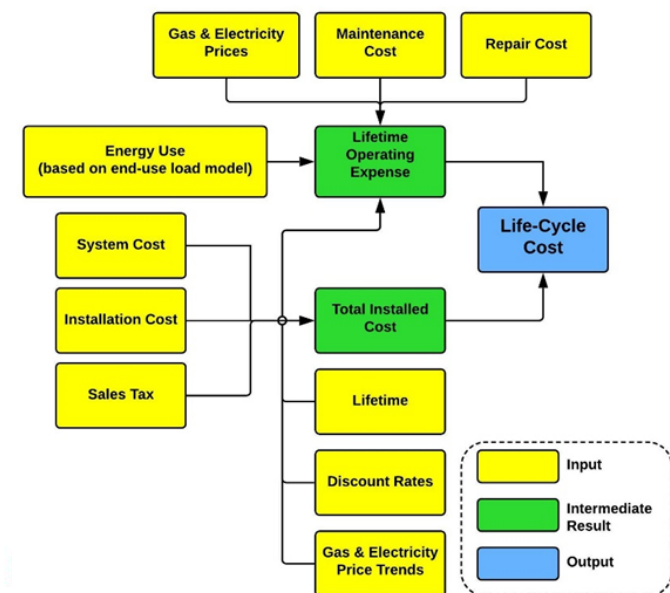
*Shifts in CDD by climate zone from 2015 to 2050:
More demand in existing ACs and more AC adoption*

Project Approach for Small AC with R-290 Propane

1. **Model window AC and mini-split AC for optimized performance** using industry-standard simulation tools
2. **Test 6 units of small AC for R-290 “drop-in” energy efficiency and capacity** vs reference R-22 refrigerant
 - Window AC (2 units)
 - Packaged terminal AC (2 units)
 - Mini-split AC (2 units)
3. **Estimate equipment cost impact** for shifting from reference refrigerants (R-410A, R-32) to R-290
4. **Model life-cycle cost impact and 30-year net impact analysis (LCC, NIA)**



Out of scope: risk assessment of R-290 in small AC; refrigerators/small CRE



AC types modeled and tested

Mini-split AC



*Not self-contained
(has outdoor unit)
Nominal 1.5 ton*

Packaged terminal AC (PTAC) Packaged terminal Heat Pump (PTHP)



*Self-contained
Nominal 0.75 ton*

Window AC

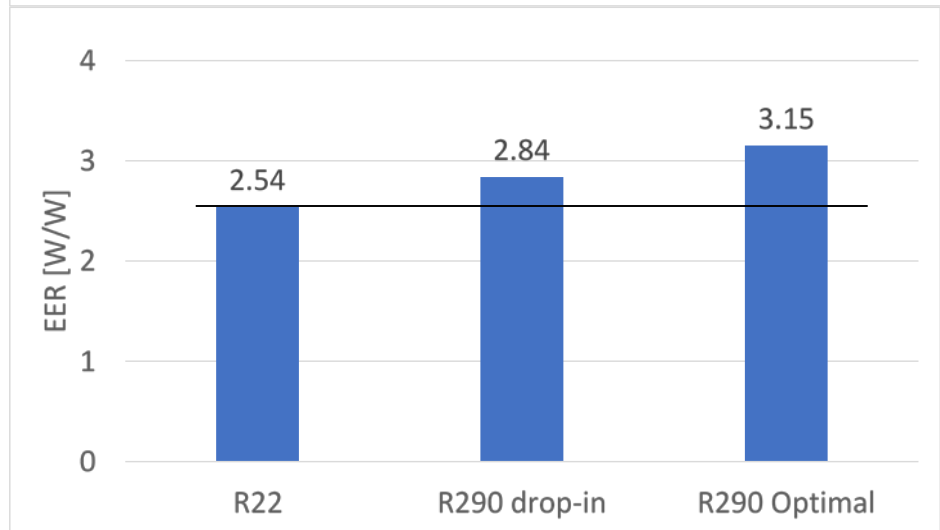
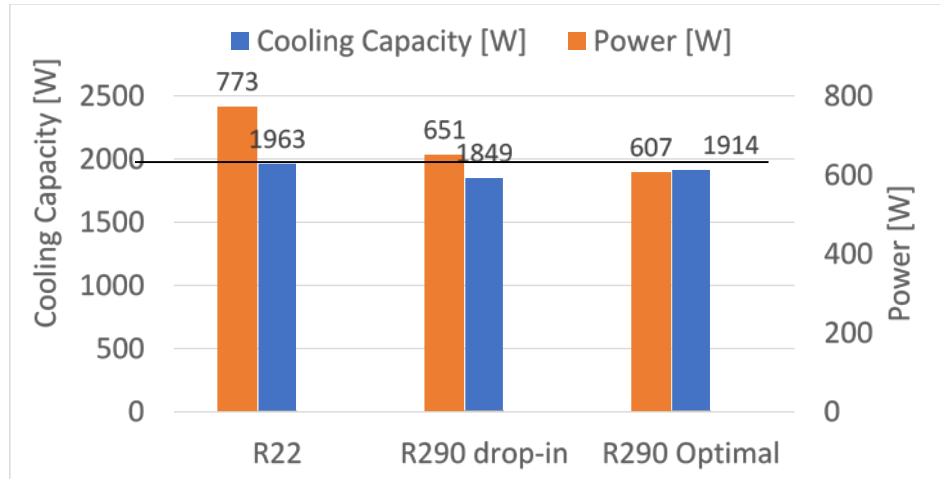


*Self-contained
Nominal 0.67 ton*

1. Modeling Results



- Optimal design for window AC:
 - +24% EER over reference R-22*
 - 2.5% lower capacity



	Baseline R22 (Subcooling=6.34K, Superheat=3.47K)	R290 drop-in (Subcooling=6.34K, Superheat=3.47K)	R290 Opt (Subcooling=5.42K, Superheat=3.0K)
Indoor Unit			
Tube length[m/in]	0.267/10.5	0.267/10.5	0.32/12.6
FPI	19	19	22
Fan Power [W]	73	73	58
Vertical spacing [m/in]	0.035/1.389	0.035/1.389	0.028/1.10
Horizontal spacing [m/in]	0.019/0.75	0.019/0.75	0.015/0.60
Outdoor Unit			
Tube length[m/in]	0.502/19.75	0.502/19.75	0.55/21.65
FPI	19	19	21.5
Fan Power [W]	109.5	109.5	87
Vertical spacing [m/in]	0.028/1.1125	0.028/1.1125	0.024/0.94
Horizontal spacing [m/in]	0.013/0.5	0.013/0.5	0.014/0.55
Net Air-side Capacity [W]	1962.878	1848.766 (-5.8%)↓	1913.657 (-2.5%)↓
Power [W]	772.652	651.344 (-15.7%)↓	607.074 (-21.4%)↓
System: COP	2.54	2.84 (11.8%)↑	3.152 (24.1%)↑

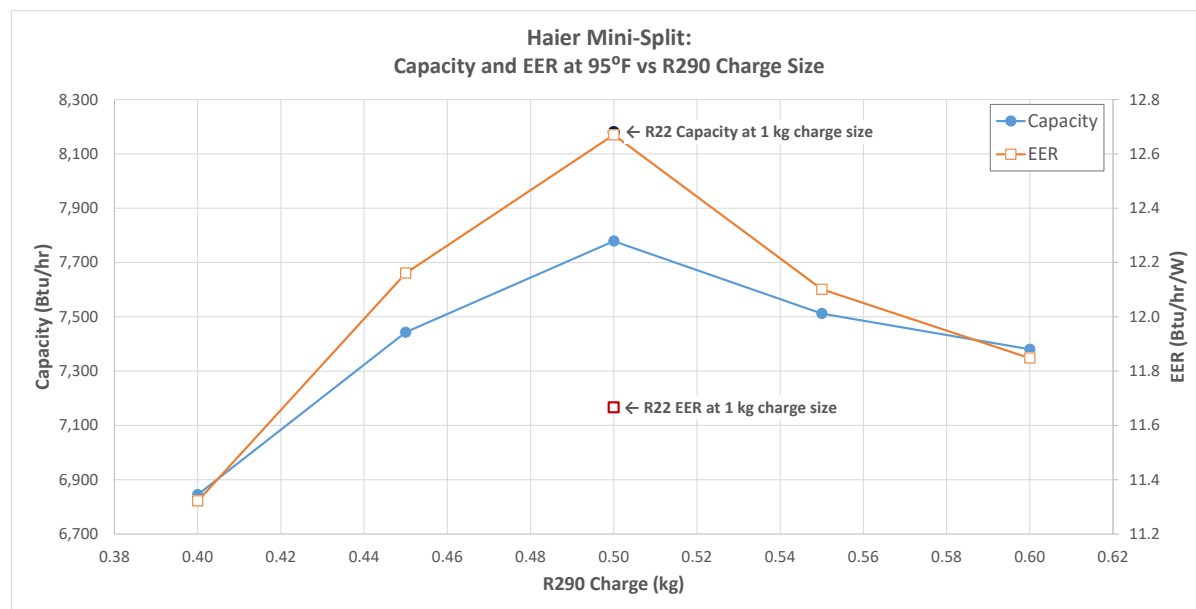
* Older HCFC-22 (R-22) used for testing because R-22 compressor compatible with R-290

2. Testing results

- Relative to R-22, optimal R-290 charge yields a small decrease in cooling capacity (3-6%) but a larger increase in efficiency (8-14%) [mini-split example below]
- Average optimal R-290 charge in window air conditioners is meeting EPA allowable maximums



LBNL Psychrometric Test Chamber

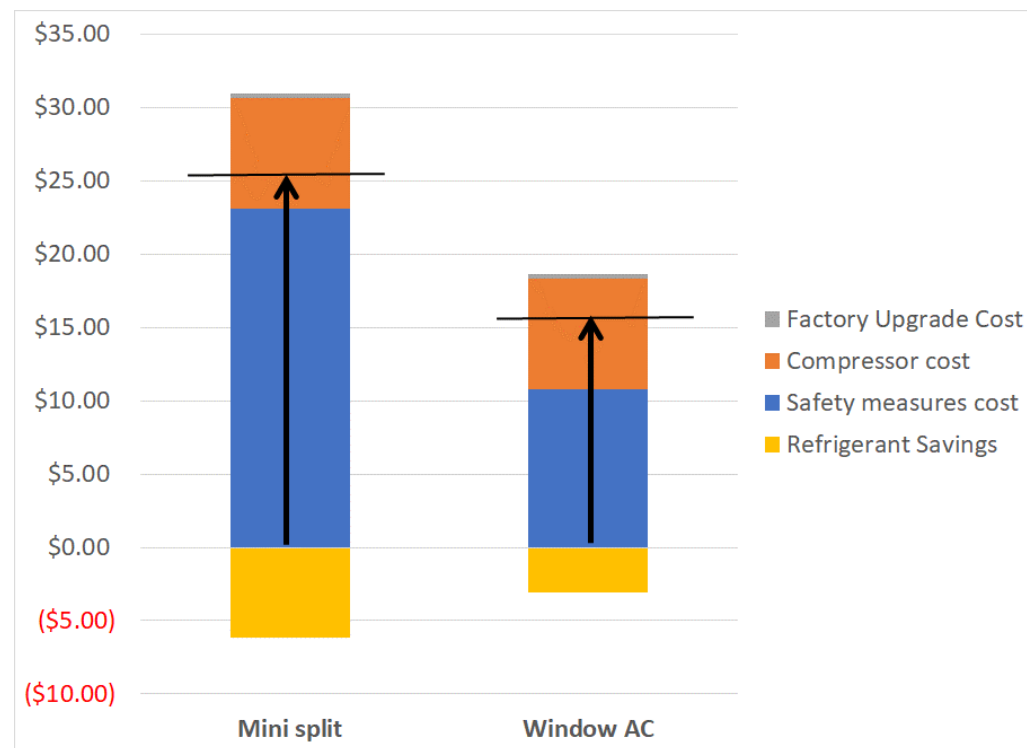


- Optimized R-290 charge yields a 5% drop in cooling capacity but an 8% increase in efficiency
- At DOE “B” test condition (82°F outdoor), cooling capacity is 4% greater with an efficiency increase of 19%

3. Incremental equipment cost for R-410A to R-290



- R-410A to R-290: Mini-split & window AC are +2.5%, +7% incremental cost, respectively (right)
- Accounting for:
 - factory upgrade
 - compressor change
 - safety measures
 - refrigerant change
- R-32 to R-290: about 1.5%, 3% increase for mini-split, window AC



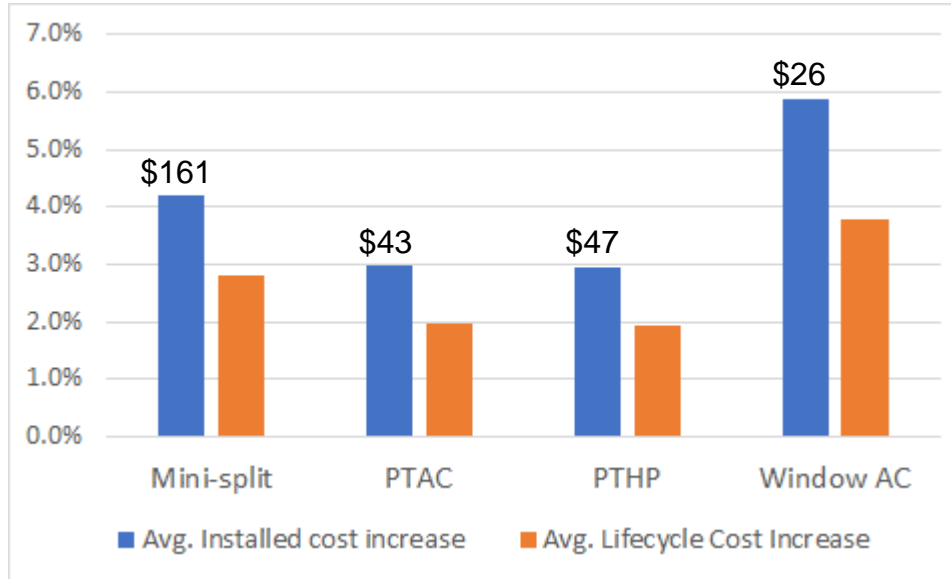
Mini-split AC unit
\$25/ \$1000
+2.5% unit cost

Window AC unit
\$16/ \$209
+7% unit cost

4. Life cycle cost and net impact analysis



Average installed cost and life-cycle cost increase, R-410A to R-290



- Window AC rebate ~\$26 for installed equipment cost parity
- Lifecycle cost increase < 4% for all products

Cumulative GHG savings, 2023-2052, all four product types:

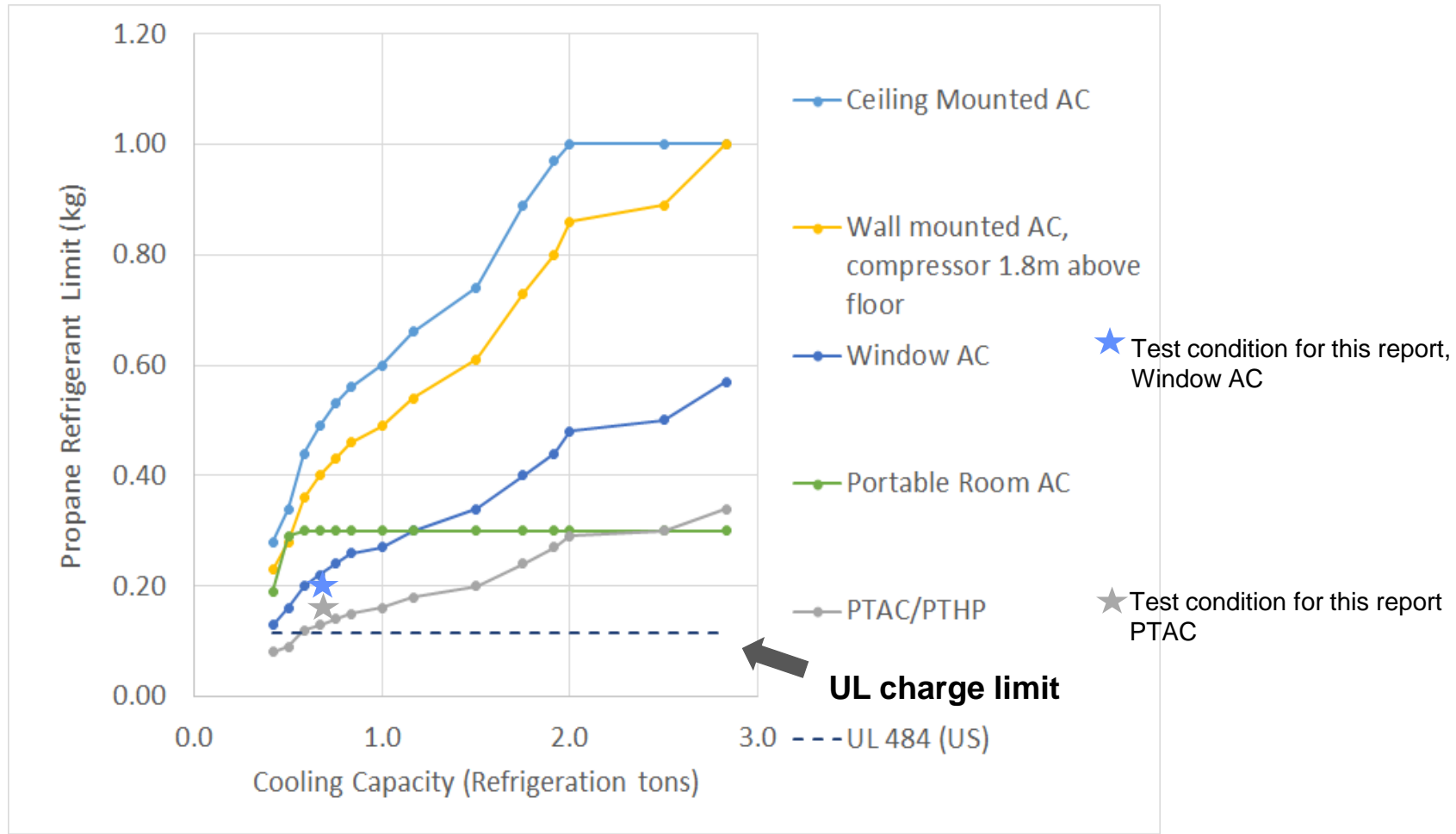
Baseline refrigerant	Avoided refrigerant GHG (Mtons CO2eq)
R-32	12,318,572
R-410a	38,232,137

- Cumulative GHG savings 12, 38 MMt-CO2eq for R-290 relative to R-32, R-410A

Regulatory Barrier: UL charge limit



EPA 2015 and UL 484 (2017) charge limits on air conditioning units



The IEC has already approved higher max charge limits than these EPA limits, subject to room size and configuration requirements.

Conclusions



- R-290 has >99% reductions in direct GHG emissions
- R-290 incremental costs are in low- to mid-single digit percent increase over R-32, R-410A reference refrigerants
- R-290 equipment modeling shows room for potential energy efficiency improvements over reference refrigerants
- R-290 testing shows that window AC can meet EPA 2015 charge limit for small AC <~ 1-ton
- Current UL limit is 114g R-290 for AC units, but IEC has moved forward with larger charge limits for R-290 in AC than the EPA 2015 limits

Thank you

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