Modeling the Greenhouse Gas Emissions Impacts of Refrigeration Systems

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ATMOsphere AMERICA business case natural refrigerants

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SFSU School of Engineering

- San Francisco State University (SFSU) Industrial Assessment Center (IAC):

  provides energy-efficiency audits for small- to medium-sized manufacturing facilities
- Education in HVAC engineering, building energy simulation
- Life cycle assessment (LCA) experience with bio-derived transportation fuels

California ARB Research Project

"Low-GWP Commercial Refrigeration Feasibility and Cost-Benefit Engineering Evaluation"

- Objective: determine the feasibility, cost, and greenhouse gas (GHG) reduction benefits of using low-global warming potential (GWP) refrigeration systems in supermarkets and grocery stores
- Subcontractors:

VaCom Technologies   Life Cycle Associates

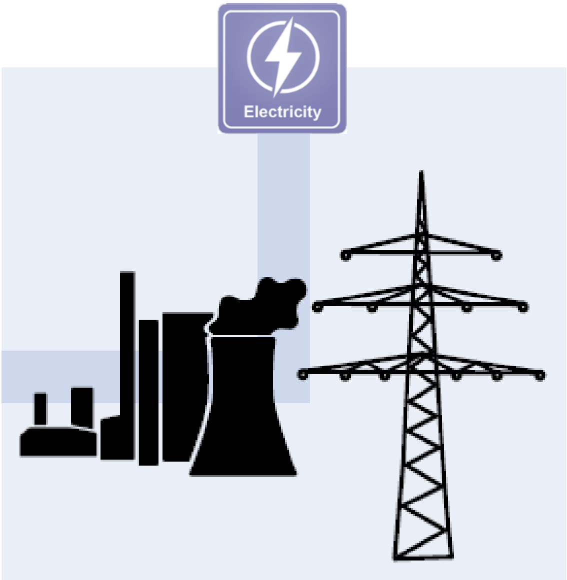
- Project scheduled to begin in August 2014

Greenhouse Gas (GHG) Emissions from Refrigeration Systems

- Direct release of refrigerants into the atmosphere

Source: Fluke Corporation

- Indirect emissions associated with energy consumption



TEVI vs. LCCP

Total Equivalent Warming Impact

Considers direct and indirect GHG emissions that occur:

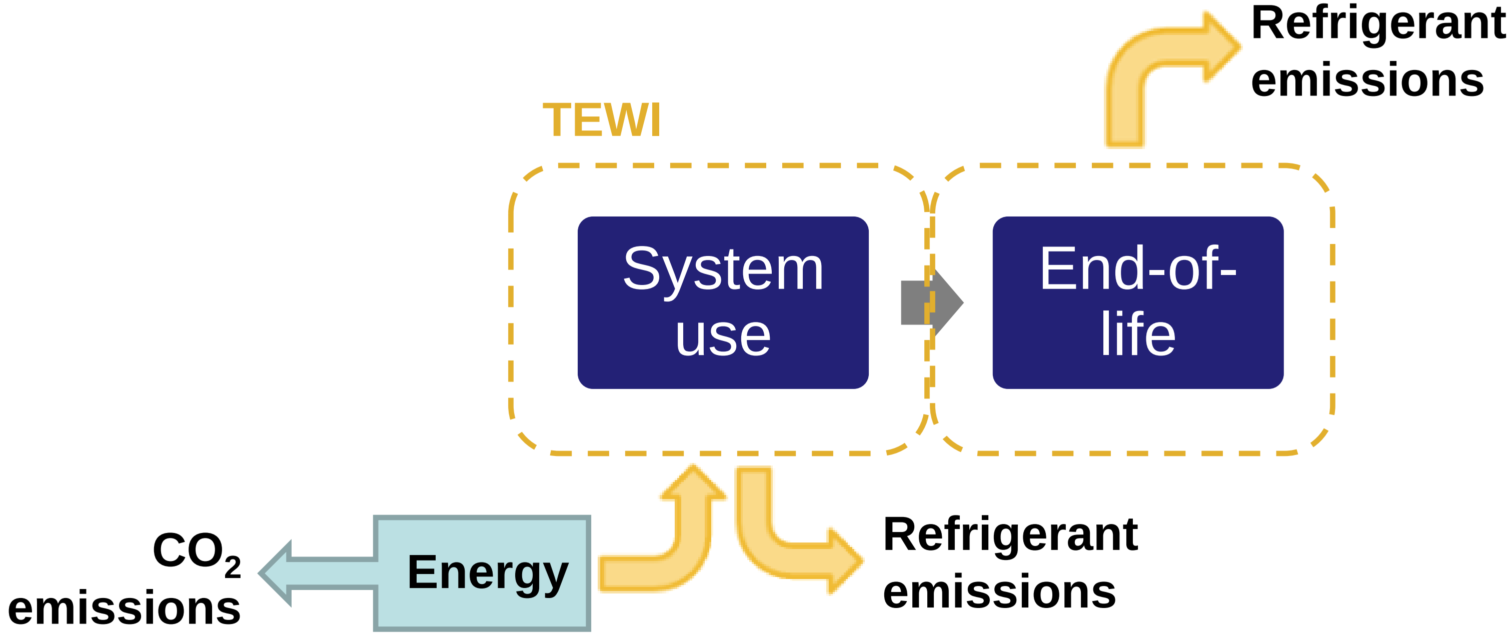
- while refrigeration system is in use
- during recovery/recycling of refrigerant (at system end-of-life)

Life Cycle Climate Performance

TEWI, *plus* direct and indirect GHG emissions from:

- Refrigerant production and distribution
- Component/system manufacturing, distribution, and recovery/recycling

Total Equivalent Warming Impact



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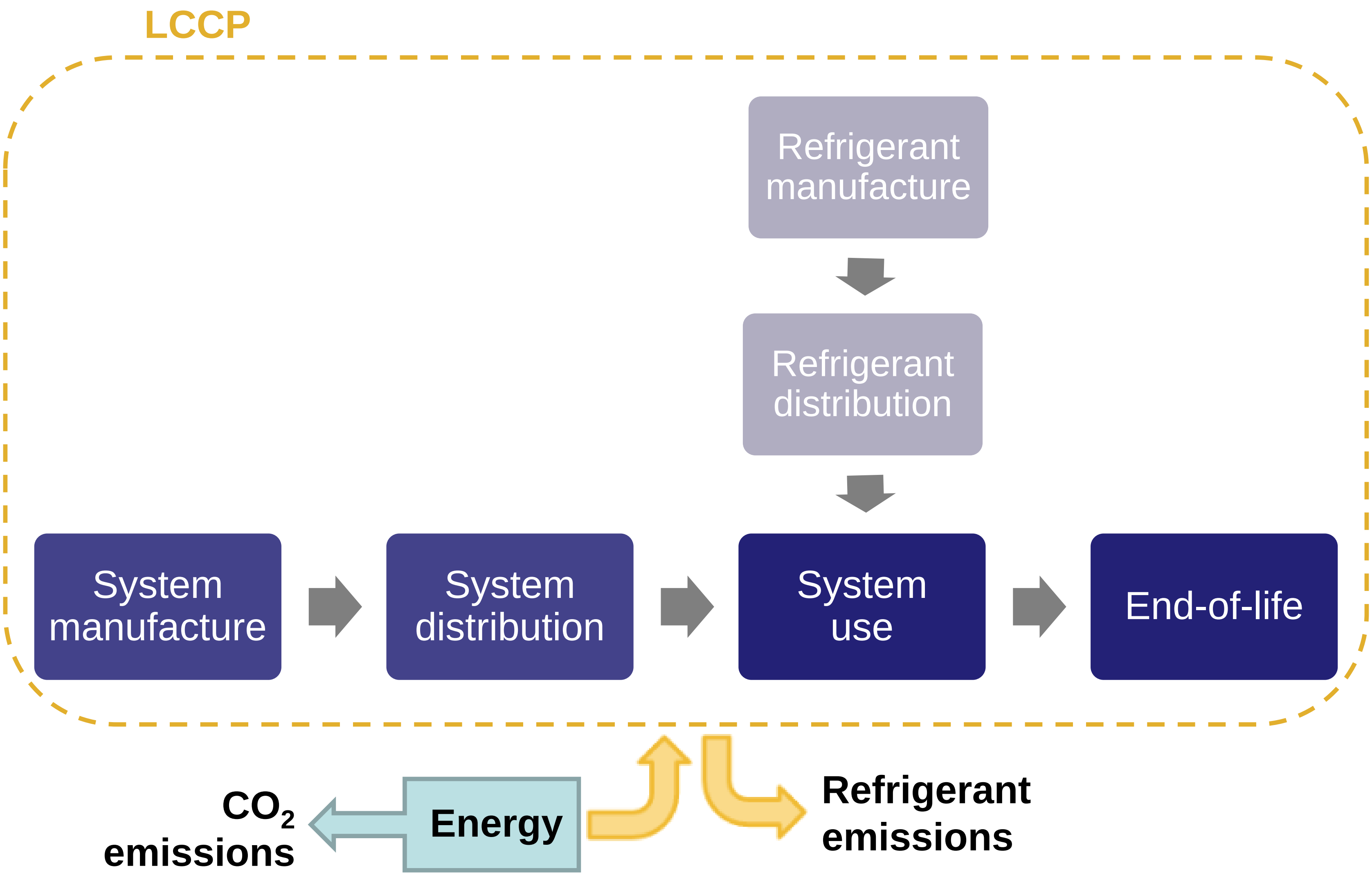
Life Cycle Climate Performance



Modeling Challenges

- Must be predictive – i.e., cannot rely on in-use data for electricity consumption, leak repair, refrigerant recharge, etc.
- Should be capable of modeling advanced-technology systems and alternative refrigerants
- Must address impacts of varying (local) climates on refrigeration system operation
- Requires accurate input data or calculation methodology for refrigerant leak rates

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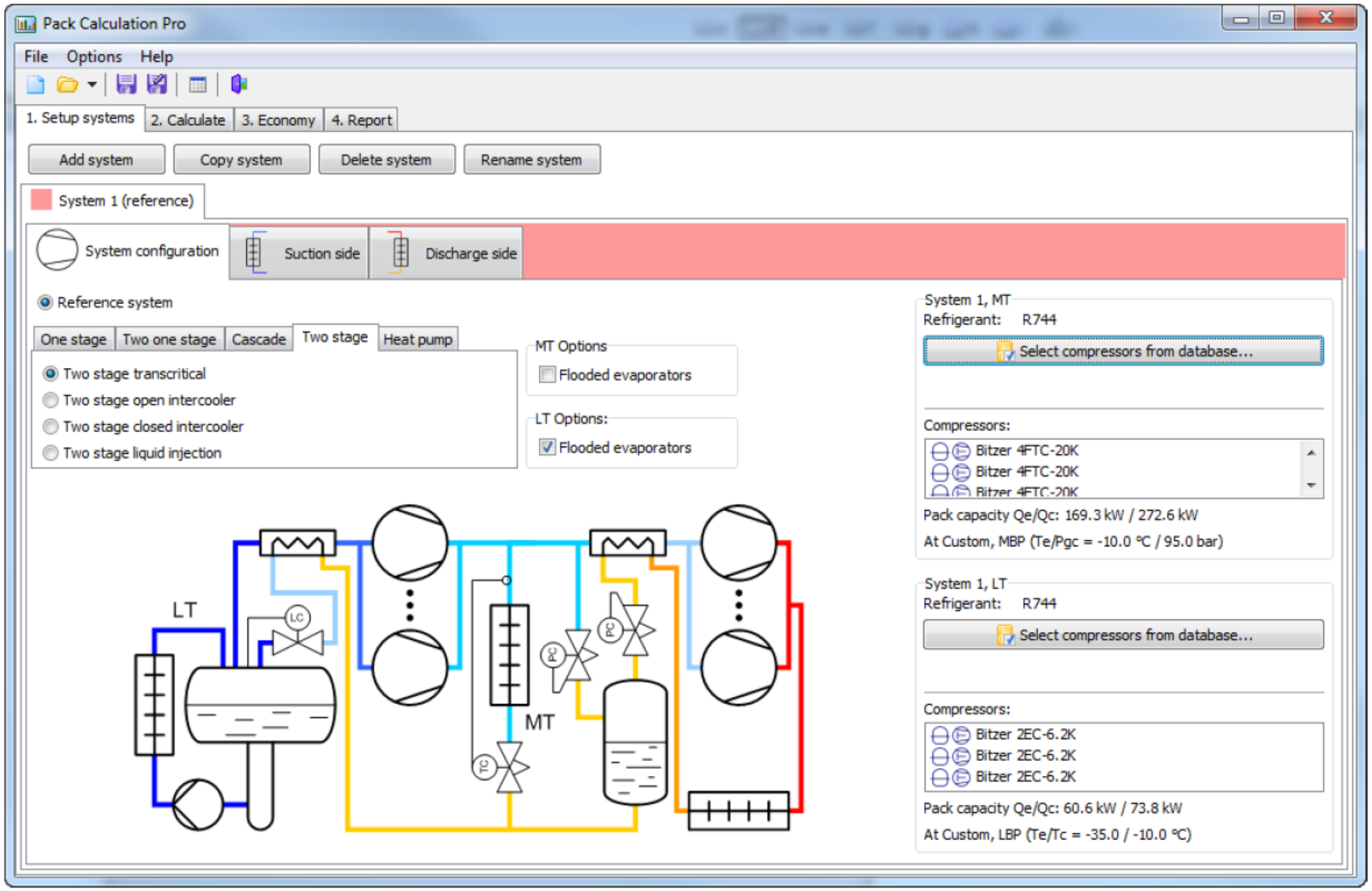
Existing Modeling Tools: IPU Pack Calculation Pro

TEWI only; evaluates *costs* as well



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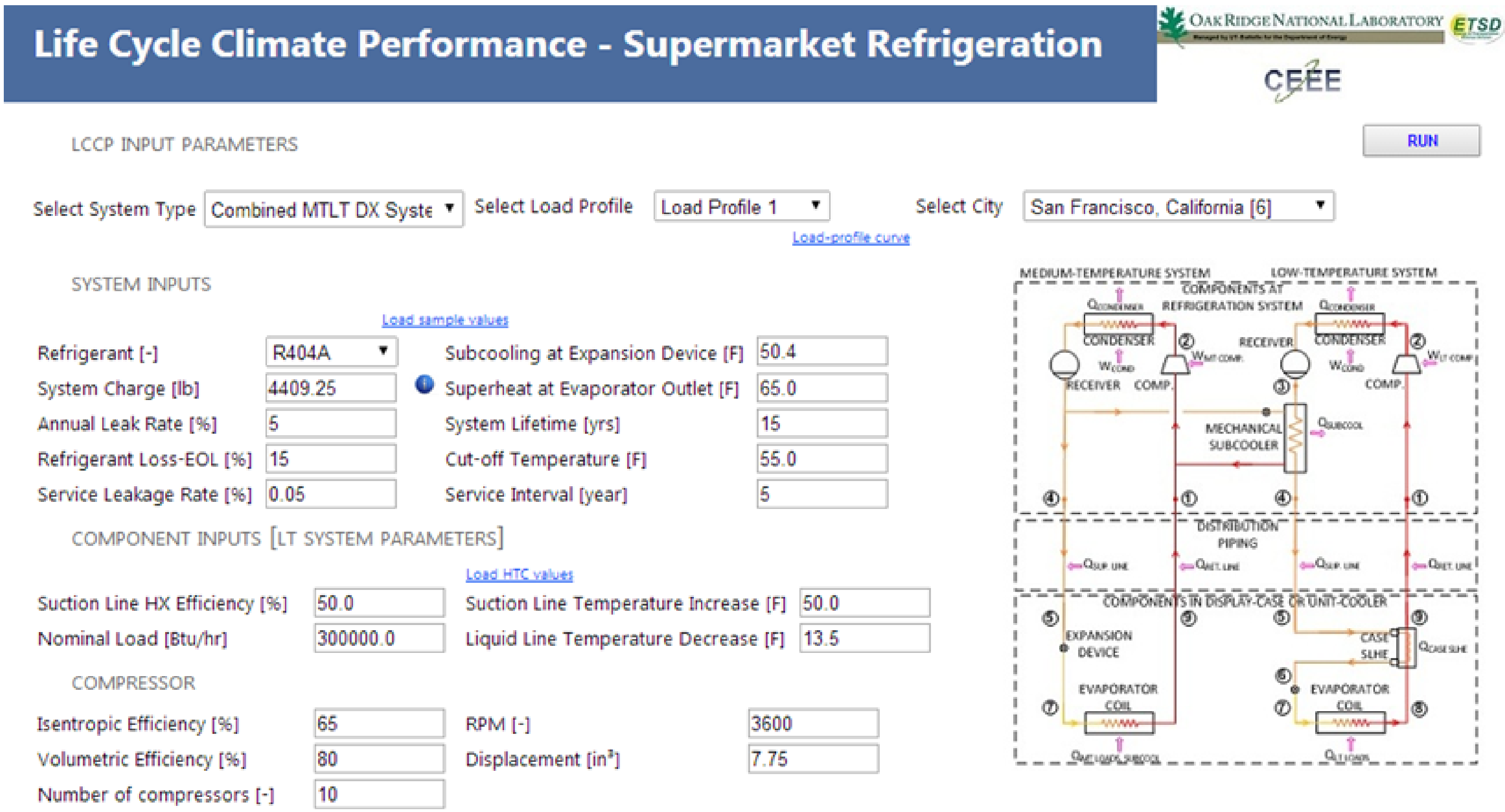
Existing Modeling Tools: AHRTI'S LCCP Model

Spreadsheet based, LCCP; developed for residential heat-pump systems

	A	B	C
1		**Calculation Settings**	
2			
3	**TMY3 Data Folder Path**	C:\AHRTI LCCP HP\tmy3data	
4			
5			
6	**Input Parameters**		
7	**Case Number**	1	
8	**Case Name**	System A	
9	**Location**	SAN FRANCISCO, CA	
10	**Refrigerant**	R410A	
11	**HP Data Worksheet**	HPData-SS-FF-EN	
12	**Results Output Sheet**	Results	
13			
14			
15			
16			
17			
18	**Summary Results**		
19	Status	Success	
20	**Total Lifetime Emission [kg CO2-Eq.]**	51849	
21	**Total Direct Emission [kg CO2-Eq.]**	8524	
22	Emission - Ref. Leakage [kg CO2-Eq.]	7103	
23	Emission - Ref. Loss at EOL [kg CO2-Eq.]	1421	
24	Emission - Decomposition [kg CO2-Eq.]	0	
25	**Total Indirect Emissions [kg CO2-Eq.]**	43325	
26	Emissions - Energy Consumption [kg CO2-Eq.]	42785	
27	Emissions - Equipment Mfg[kg CO2-Eq.]	517	
28	Emissions - Equipment EOL [kg CO2-Eq.]	23	
29	TMY3 Location	SAN FRANCISCO INTL AP	

Existing Modeling Tools: LCCP (ORNL/UMCP)

For supermarket refrigeration and residential heat pumps; web-based tool available



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Existing Modeling Tools: GREEN-MAC-LCCP

Spreadsheet-based tool for *mobile* air conditioning systems; well established and peer reviewed

	A	B	C	D
1				
2	Baseline-R-134a	United States	United States	United States
3	REFRIGERANT LEAKAGES & SERVICE	Phoenix	Houston	Boston
4	*(function of climate)*			
5	Avg. Annual Temp (6AM-24PM)	24.3	21.1	11.0
6	Lifetime [yrs]	9	9	9
7	Refrigerant Charge [g]	550	550	550
8	Estimated loss before Service is required	200	200	200
9				
10	REGULAR and IRREGULAR			
11	Regular Leakage [g/y]	13.4	11.0	5.7
12	Irregular (Accidental) Leakage [g/y]	17	17	17
13	SERVICE			
14	Calculated Number of Services	1.4	1.3	1.0
15	Year of Recharge	6.6	7.2	8.8
16	Actual Number of Services	1	1	1
17	*Leaks from Professional Service*			
18	Loss in each service [g]	35	35	35
19	Loss from Can Heels per service [g]	5	5	5
20	Service loss[g/lifetime]*	40	40	40
21	*Leaks from DIYers Service*			
22	Loss in each service [g]	52	52	52
23	Loss from Can Heels per service [g]	108	108	108
24	Service loss[g/lifetime]*	160	160	160
25	% DIYes	25%	25%	25%
26	*Weighted Leaks due to Service*	70	70	70
27	END-OF-LIFE			
28	EOL with refrigerant capture[g/lifetime]	48	50	55
29	EOL without refrigerant capture[g/lifetime]	476	498	545
30	Vehicles in Collision			
31	*Weighted EOL Leaks*	305	319	349
32	Assembly Plants (fixed loss) [g/lifetime]	3.5	3.5	3.5
33	TOTAL LEAKAGE LOSS			
34	Total Refrigerant Loss	652	644	627
35	Lifetime Refrigerant Charge	1202	1194	1177
36	Lifetime NEW Refrigerant	754	754	754

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Modeling Tool Comparison and Development

	TEWI	LCCP	Stand-alone program	Spreadsheet-based	Comments
IPU Pack Calculation Pro	✓		✓		Includes cost analysis
AHRTI LCCP		✓		✓	Developed for residential heat-pump systems
ORNL/UMCP LCCP		✓	✓		Web-based tool available
GREEN-MAC-LCCP		✓		✓	For *mobile* air-conditioning systems

International Institute of Refrigeration (IIR) Working Party on LCCP Evaluation has been established to assess different methods and to develop and promote a recommended methodology

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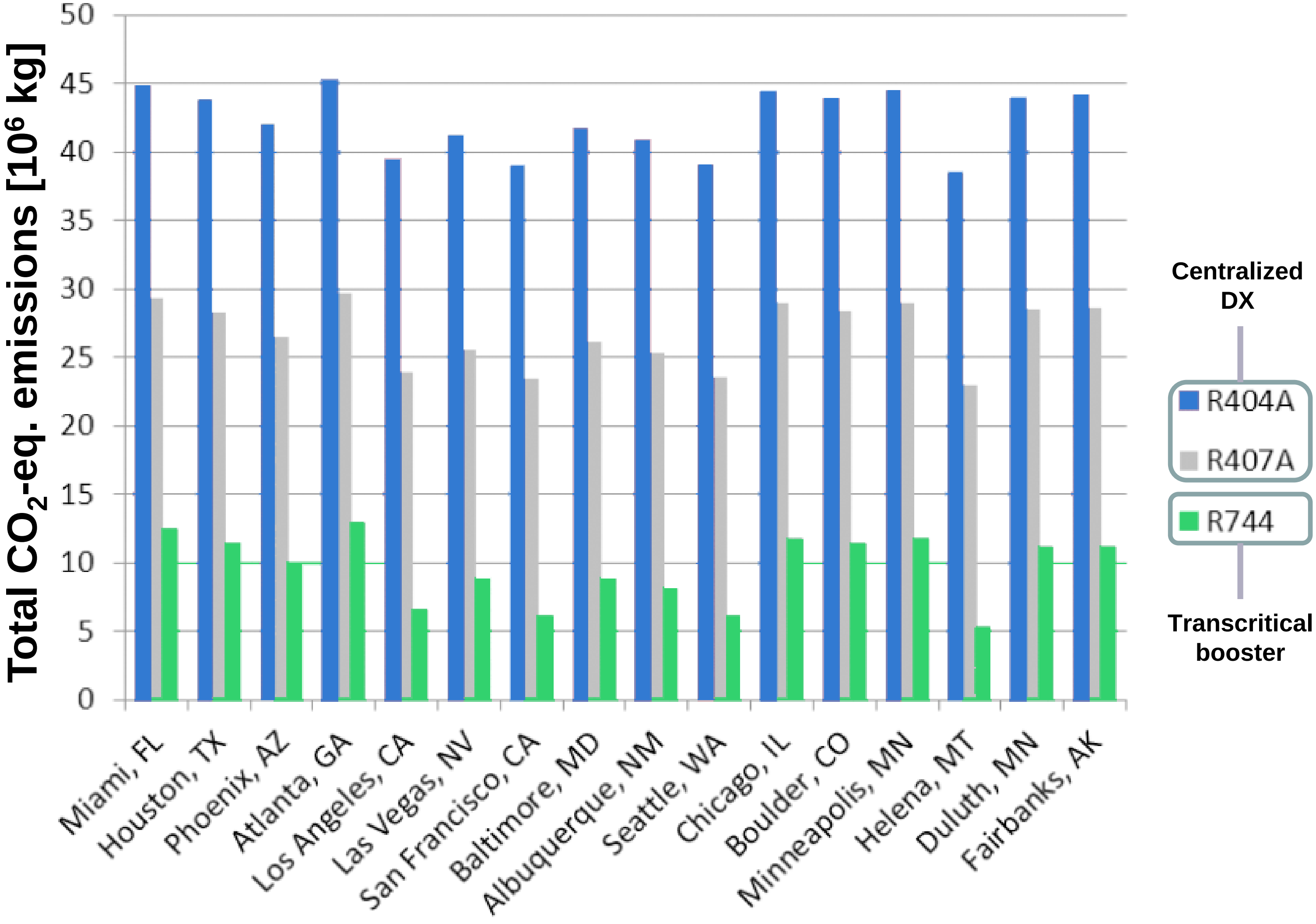
Representative Model Results: LCCP (ORNL/UMCP)



Source: Abdelaziz et al. 2012.

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Thank you!

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