Sustainable
Refrigeration Summit

Connecting the Pieces for
Supermarket Refrigeration Solutions

NORTH AMERICAN
Sustainable
Refrigeration
Council

nasrc.org

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Summit Program

Day 1: Monday, October 24

9AM-10AM PST
Keynote: Industry & Regulatory Trends

11AM-2PM PST
Technology Focus: Driving CO2 Performance

1PM-2PM PST
CO2 Systems: What Retailers Need to Know

Day 2: Tuesday, October 25

9AM-10AM PST
Distributed and Self-contained Systems

11AM-12PM PST
Technology Focus: Total Cost of Ownership

1PM-2PM PST
Measuring Performance of Natural Technologies

Day 3: Wednesday, October 26

9AM-10AM PST
Integrating Naturals into Existing Stores

11AM-12PM PST
Technology Focus: Modular Tech. for Existing Stores

1PM-2PM PST
Funding for Naturals

Day 4: Thursday, October 27

9AM-10AM PST
Solving the Technician Shortage

11AM-12PM PST
Technology Focus: Natural Innovations

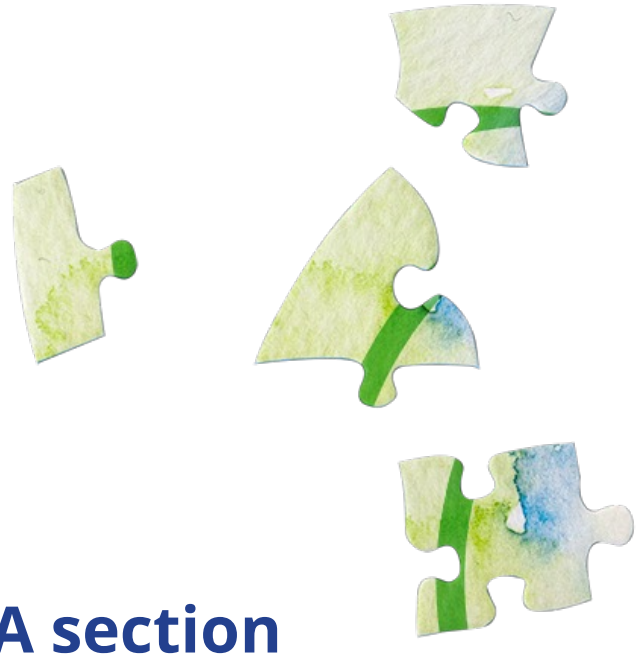
1PM-2PM PST
Reducing Refrigerant Emissions

Day 5: Friday, October 28

9AM-10:30AM PST
State & Federal HFC Regulations

11AM-12:30AM PST
Workshop: Utility Incentives for Refrigerant GWP

Housekeeping & Logistics



Question and Answer Session

- Participants are muted
- Questions will be moderated at the end
- To ask a question, enter your comment into the **Q&A section**

Need Help? Click the Support button on sustainablerefrigeration.com

Missed a Session? Session recordings and slides will be available on the platform

NORTH AMERICAN Sustainable Refrigeration Council

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Measuring Performance of Natural Technologies

Case studies to highlight results and methodology to measure and validate the energy performance of various natural installations.

Frank Davis
Senior Director of Refrigeration and Sustainability
Grocery Outlet

Safdar Chaudhry
Senior Engineer Manager
ADM Associates

Kathleen Ave
Sr. Climate & Ecosystem Strategist, Customer & Grid Strategy
SMUD

Measuring Performance of Natural Technologies

Case Studies from SMUD's Natural Refrigerant Incentive Program

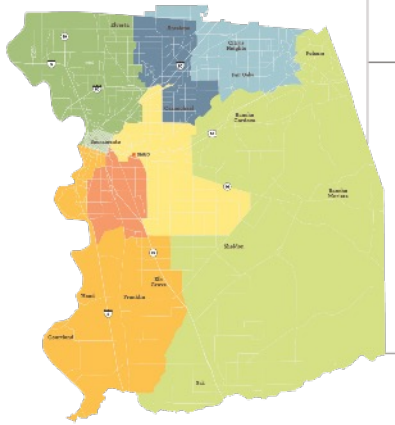
Kathleen Ave & Ryan Hammond, SMUD

October 25, 2022

About SMUD

SMUD is your community-owned, not-for-profit electric service.

6th largest community-owned **in the U.S.**



70+ Years
Est. 1946

Power mix that's more than **50%** **carbon-free**

100% Zero carbon by **2030**

The most ambitious goal of any large utility in the United States

~645,000 Customers

~2,200 Employees

7 member Elected Board of Directors

Rates among the lowest in CA. On average **35%** lower than PG&E

SMUD®

Pathway to zero carbon by 2030

Natural gas generation repurposing

Retire 2 power plants by 2025 and retool remaining 3 to minimize emissions

Proven clean technology

Expand SMUD's renewable and battery storage resources by 3.5x

>3,000 MW of new renewable energy & storage – equivalent to energy needs of more than 600,000 homes

Support customer resources

Growing rooftop solar and batteries

90% reduction of greenhouse gas emissions

~$2 billion investment

New technology & business models

Pilot & scale new projects and programs

- 2x savings from energy efficiency & building electrification
- Education & demand flexibility
- Virtual power plants & vehicle-to-grid technology
- New grid-scale technologies

Financial

- Pursue grants & partnerships
- Limit rate impacts to rate of inflation

~$2.5 billion investment

Maximize community benefits

- Keep affordable rates & reliable power
- Improve local air quality & overall community health
- Reduce regional impacts of carbon – drought, wildfires & extreme weather
- Create regional clean tech jobs
- Strengthen all communities
- Support under-resourced communities
- Involve our customers & community in this transition

Goal:

Eliminate CO_2 from SMUD's power supply

CO_2

100%

Zero carbon by 2030

Thousands of new regional clean tech jobs

SMUD

CALIFORNIA CLIMATE STRATEGY

An Integrated Plan for Addressing Climate Change

VISION

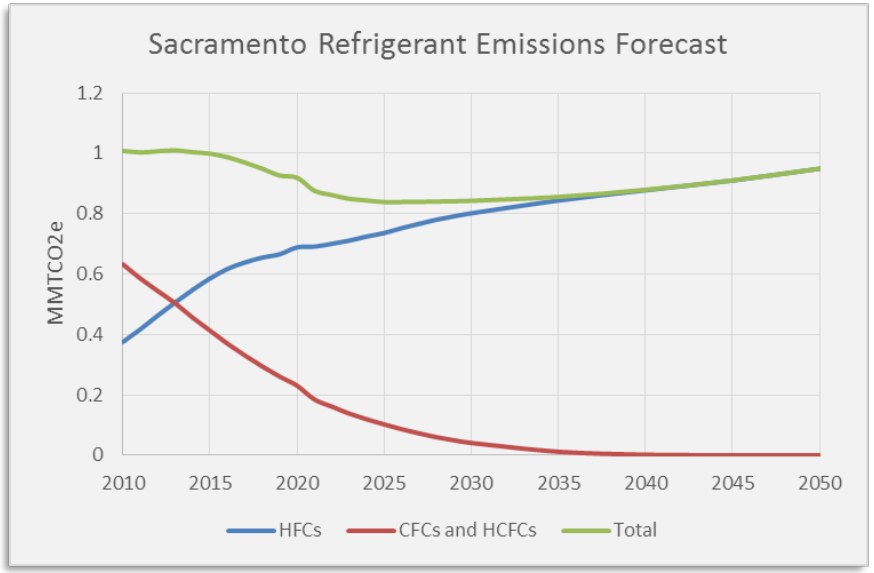
Reducing Greenhouse Gas Emissions to 40% Below 1990 Levels by 2030

GOALS

- 50% renewable electricity
- 50% reduction in petroleum use in vehicles
- Double energy efficiency savings at existing buildings
- Carbon sequestration in the land base
- Reduce short-lived climate pollutants
- Safeguard California

SMUD's Pilot Natural Refrigerant Incentive Program

- Launched in March 2017 at NASRC Workshop hosted at SMUD
- Built on SMUD's existing Custom Incentive and Savings By Design programs
  - Maintains incentive for energy (kWh) and demand (kW)
- **Additional incentive for direct GHG emission reductions from new or retrofitted low-GWP systems**
  - SMUD pays for energy performance metering and data collection to understand performance of low-GWP systems



High-GWP refrigerants are projected to result in annual GHG emissions of over 1 million $MtCO_2e$ in Sacramento alone by 2050

Program created with technical assistance from

WSP | PARSONS BRINCKERHOFF

SMUD
Sacramento Municipal Utility District

SMUD Program Objectives

- Spur market transformation to support SMUD's Environmental Leadership Directive (SD-7)
- Help establish a cost-effective pathway for Natural Refrigerants
- Create a model incentive for others to reference
- Build a network of manufacturers, engineers, technicians, and customers
- Position SMUD to leverage potential state funding on our customer's behalf
- Support transition to a carbon metric for program evaluation

"SMUD will provide leadership in the reduction of the region's total emissions of greenhouse gases through proactive programs in all SMUD activities and development and support of national, State, and regional climate change policies and initiatives." SMUD Strategic Directive 7

Customer Benefits

- **End the expensive cycle** of refrigeration system upgrades and retrofits due to refrigerant phase outs and replacements with a permanent long-term solution
- **Assist with the initial cost** of new equipment installation
- **Support emerging technologies** that enable customers to improve energy efficiency and reduce direct GHG reductions
- **Lower customer energy bills and refrigerant costs**
- **Eliminate liability** associated with leak inspections, fines, and enforcements
- **Provide Access** to network of equipment manufacturers, engineers, technicians, and successful project implementations

Incentive Eligibility and Structure

Program Parameters	Existing Program Requirements	Refrigerant Incentive Requirements
Retrofit	Meet the existing requirements of the Custom Incentive Program	System uses natural refrigerant (CO2, ammonia, hydrocarbon)
New system	Meet the existing requirements of the Savings By Design Program	System uses natural refrigerant (CO2, ammonia, hydrocarbon)
Required system monitoring	None	Three years, SMUD pays installation/integration
Permanent Change	Permanent physical system change required so operation doesn't revert to the baseline technology	Physical system component or change must be made that prevents reverting to high-GWP refrigerant

Custom Program Incentive	Direct GHG Emissions Reductions Incentive
Incentives are based on decreasing your energy use: • $0.10/kWh Energy Reduction Incentive and • $200/kW Demand Reduction Incentive • Total incentive limited to 30% of project cost or $150,000, whichever is less	Incentives are based on decreasing direct emissions from refrigerants over the system lifetime: • $25/Mt$CO_2$e emissions reduction from refrigerants • Total incentive limited to 30% of project cost or $150,000, whichever is less All projects located in disadvantaged communities (with preference for those in the top 10%) and implemented by small-to-medium sized business owners will receive a 25% incentive bonus
Combined incentive limited to 50% of project cost or $250,000, whichever is less	

Developing an Appropriate Direct Incentive

- Direct incentive rate was evaluated in two ways, both supported a valuation of approximately \$25/$MtCO_2e$

1. Based on SMUD current energy incentives (Custom Incentive and Saving By Design)
   - \$0.10/kWh converted to \$/$MtCO_2e$ using marginal emission factor for 15 year life

2. Based on California GHG Allowance Price Floor
   - Average of price floor for 15 years based on annual escalation of 5% plus inflation

Important note: Not a “Low GWP” Program

- Actual composition and impact of HFO’s in broad use not well studied or understood
- Significant concerns emerging about toxic by-product trifluoroacetic acid (TFA) and restriction as a polyfluorinated alkyl substance (PFAS) “forever chemical.”
- Track record suggests potential for significant unintended consequences (ozone layer > global warming > aquatic degradation next?)

Our program deliberately supports natural refrigerants only

Program Execution

- Long delay from program launch in 2017 to applications in 2019
  - Expected due to high system cost – supermarket profit margin ~1%
  - New projects have been proposed in Sacramento County and around the State from interested parties (stores, food processors)
  - “Retrofits” to naturals require entire new system (compressors, valves, coils, etc.) – very disruptive
- Two supermarket projects utilized the incentive:
  - Grocery Outlet & Raleys
  - Research plan adapted to leverage unique opportunity for comparison
- $125,000 APPA DEED grant secured to assist with incremental system cost, support research and technology transfer
  - NASRC instrumental in developing this application
- Two years of monitoring complete for both systems
- Program received APPA’s National Energy Innovator Award in June 2022

SMUD Spending

- Incentives:

Incentive	Raley's	Grocery Outlet	TOTAL
NRIP	$150,000	$73,921	$223,921
Savings by Design	$56,239	$13,294	$69,533
TOTAL	$206,239	$87,215	**$293,454**

- M&V: ~$300,000 projected (monitoring equipment + technical support)
- NASRC Case Studies / Training & Outreach: $12,750
- SMUD Staff Time/Overhead: ~$60,000 projected

Relatively modest utility investment to better understand significant potential benefits

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THANK YOU!

Grocery Outlet

- Publicly owned company (2019)
  - 423 stores, independently owned and operated, in 8 States.
  - 10% percent YOY Growth on Base Count

- Project drivers
  - CARB regulation: <150 GWP starting in 2022
  - Gather data and see how the system worked for future new stores.
  - Aggressive growth plan and commitment to comply with all state & federal requirements in future new stores

Project Overview- East Sac Store

The system selected: CO2 Transcritical with Adiabatic Condenser.

The HVAC is Main AHU with Condensing Unit. 448A

Incentive Overview

- Incentives played a substantial role.
- Locked-in budget a year before formal CAPEX request.
- Presented additional cost of the system to our CFO and showed how incentives would offset the increase.

Funding Source	Amount
SMUD NRIP (GHG savings)	$78,728
SMUD Savings by Design (Energy savings)	$13,294
APPA DEED Grant (SMUD & NASRC)	$125,000
Grand Total	**$217, 022**

100% of incremental system cost covered (based on initial quote)

Project Status

- Opening date: January 15, 2020
- Benefits
  - Reduced our GPW requirements for CARB.
  - Educate the Company on the new technology and determine the direction of CO2.
- Challenges
  - Installation and start-up of the new technology,
  - Maintenance challenges for Independent Operators.
    - We experienced more service calls than a traditional system during the first year. Mainly, oil failure issues and lost frozen products from frozen coffin cases.

Future Projects

- Role of Incentives in Meeting CARB Regulations
  - **Existing stores** – Very important, because we track ROI to all remodel projects minus end-of-life replacements.

- Are we moving forward with CO2?
  - In the California Region CO2 is our specification.
  - The Goal is to expand to other Regions.

M&V Methodology

- IPMVP Option B: Retrofit Isolation (All Parameter Measurement)
- Two grocery store chains participated in the study – Grocery Outlet and Raley's & BelAir
- Two sets of paired grocery stores (Comparison &Treatment) from each grocery store chains were selected for the study.
- Each of the paired sets included a comparison grocery store equipped with a conventional HFC refrigerant (R-404A). The Grocery Outlet treatment store is equipped with CO_2 (R-744) refrigeration system, while the BelAir treatment store uses Ammonia (R-717) as refrigerant and CO_2 (R-744) as heat transfer fluid.
- Long Term monitoring was performed (from July 2020 to March 2022) to study the performance of these systems.

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Grocery Outlet

	Pocket Area (Comparison Store)	E. Sacramento (Treatment Store)
Floor Area	23,200 ft^2	24,000 ft^2
System Type	Conventional DX Rack (HFC) System	Transcritical CO_2 Booster system
Condenser	Air-cooled	Adiabatic
Refrigerant	R-404A	R-744
Refrigerant GWP	3,922	1
Refrigerant Charge	600 lbs.	420 lbs.
Vintage	2013	2020

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Overview of the system

Comparison Store (GO, Pocket Area)

- The comparison store has conventional refrigeration system using R404A refrigerant.
- 23 refrigeration cases of varying sizes and temperatures, whose cooling load is rated at a total of 240.9 thousand BTUs per hour (MBH).
- Two 10 HP, two 7.5 HP, and a 6.5 HP for a total of 41.5 HP compressors and total nominal capacity of 284.4 MBH, serving various temperatures.
- There are also five air-cooled condensers of 433.8 MBH nominal capacity, located on the roof.

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Overview of the system

Treatment Store (GO, E. Sacramento)

- The treatment store's refrigeration system uses CO_2 (R-744) as a refrigerant.
- The refrigeration system is driven by four compressors: two 20 HP, a 3.5 HP, and a 2 HP, serving various temperatures.
- The refrigeration loads sum to a total of 404.5 MBH.
- The compressors' total capacity is 477 MBH and the condenser capacity is 547 MBH.

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Key Results

- The CO_2 Booster Adiabatic R-744 system was found to be superior to HFC conventional system in terms of energy efficiency, energy cost and CO_2-equivalent emissions impacts.
- The R-744 based refrigeration system used 27% less energy compared to the conventional HFC system, resulting in about 23% reduction in energy cost.
- The installation and equipment costs for the CO_2 Booster Adiabatic R-744 systems are approximately 24% higher than for the comparable conventional HFC system.
- The operating costs for the R-744 system is estimated to be lower than for the HFC system.

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Key Results

- The R-744 based refrigeration system reduced the CO_2 emissions by about 27% compared to its counterpart HFC conventional system.
- No leakage in refrigerant charge was reported for both systems, which is rare.
- If there was leakage at these stores, the natural systems advantage would have increased significantly to a 93% reduction using EPA's national average for leakage.

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Raley's & BelAir

	BelAir, Arena Blvd. (Comparison Store)	Raley's, Freeport Blvd. (Treatment Store)
Floor Area	68,487 ft^2	65,635 ft^2
System Type	2 Stage, Direct Drive	2 Stage, Direct Drive, CO_2 Liquid Overfeed
Refrigerant	R-404A (conventional HFC)	Ammonia (R-717) CO_2 (R-744) as circulating fluid
Refrigerant GWP	3,922	0 (R-717), 1 (R-744)
Refrigerant Charge	2,300 Lbs.	140 lbs. (R-717), 3,200lbs. (R-744)
Vintage	2006	2020

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Overview of the system

Comparison Store (BelAir)

- The comparison store has conventional compressors using R404A refrigerant.
- Two 75 HP, two 50 HP, and two 20 HP compressors for a total of 290 HP and total nominal capacity of 284.4 MBH, serving various temperatures.
- There are evaporatively-cooled condensers of 2,697 MBH nominal capacity.

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Overview of the system

Treatment Store (Raley's)

- The treatment store uses ammonia as the refrigeration working fluid and CO_2 as the circulating fluid.
- The disadvantage of this type of system is that additional heat exchangers are required, which creates performance loss and increased cost issues.
- The refrigeration system is driven by six compressors: four 50 HP, and two 15 HP compressors, serving various temperatures.
- The compressors' total capacity is 2,215 MBH.

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Key Results

- Raley's refrigeration system was found to be inferior to HFC conventional system in terms of energy efficiency, energy cost, and capital cost.
- The Raley's Ammonia/ CO_2 natural refrigeration system used 18% more energy compared to Bel Air's conventional HFC based system.
- The increase in refrigeration energy usage at Raley's Ammonia/ CO_2 system is due to heat transfer inefficiencies compared to a single-fluid system.
- The installation and equipment costs for Raley's Ammonia/CO_2 systems are approximately 18% higher than for the comparable Bel Air's HFC based system.

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Key Results

- The Bel Air operation team reported a leakage rate of 14% and Raley's reported significant dissipation of refrigerant charge during first year of operation.
- Although emissions associated with energy use were higher, the low GWP of Raley's natural refrigerant enabled it to maintain lower overall emissions when leakage was considered. Overall, Raley's Ammonia/ CO_2 system reduced CO_2 emissions by 74% compared to Bel Air's HFC based system.

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Conclusions

- Natural refrigeration systems have a positive environmental impact due to the reduced global warming potential of the refrigerants.
- The energy impact of natural refrigeration in the pair of Grocery Outlet stores was shown to be favorable, while the energy impact of natural refrigerants in the paired Raley's / Bel Air stores showed an increased energy use.
- More rigorous evaluation of refrigeration technology is needed with larger sample of stores for more accuracy and confidence in results.
- Raley's interacts with multiple other subsystems in the store shows numerous environmental benefits even if an efficiency reduction is observed for the refrigeration subsystem.
- Long-term maintenance data was not possible within this study period.
- There are approximately 4,000 grocery stores in California, with approximately 200 stores of various sizes in SMUD's service territory, so there is a great potential for this technology.

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