Informing the Evolution of HVAC Refrigerants

Northeast Energy Efficiency Partnerships (NEEP) Webinar

April 21, 2021

About NEEP

A Regional Energy Efficiency Organization

One of six REEOs funded in-part by U.S. DOE to support state and local efficiency policies and programs.

Northeast Energy Efficiency Partnerships

"Assist the Northeast and Mid-Atlantic region to reduce building sector energy consumption 3% per year and carbon emissions 40% by 2030 (relative to 2001)"

Mission

We seek to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities.

Vision

We envision the region's homes, buildings, and communities transformed into efficient, affordable, low-carbon, resilient places to live, work, and play.

Approach

Drive market transformation regionally by fostering collaboration and innovation, developing tools, and disseminating knowledge

Building Decarbonization → 3 Key Elements

Advanced Electric Technologies

Space/Water Heating – Heat Pumps

Deep Energy Efficiency

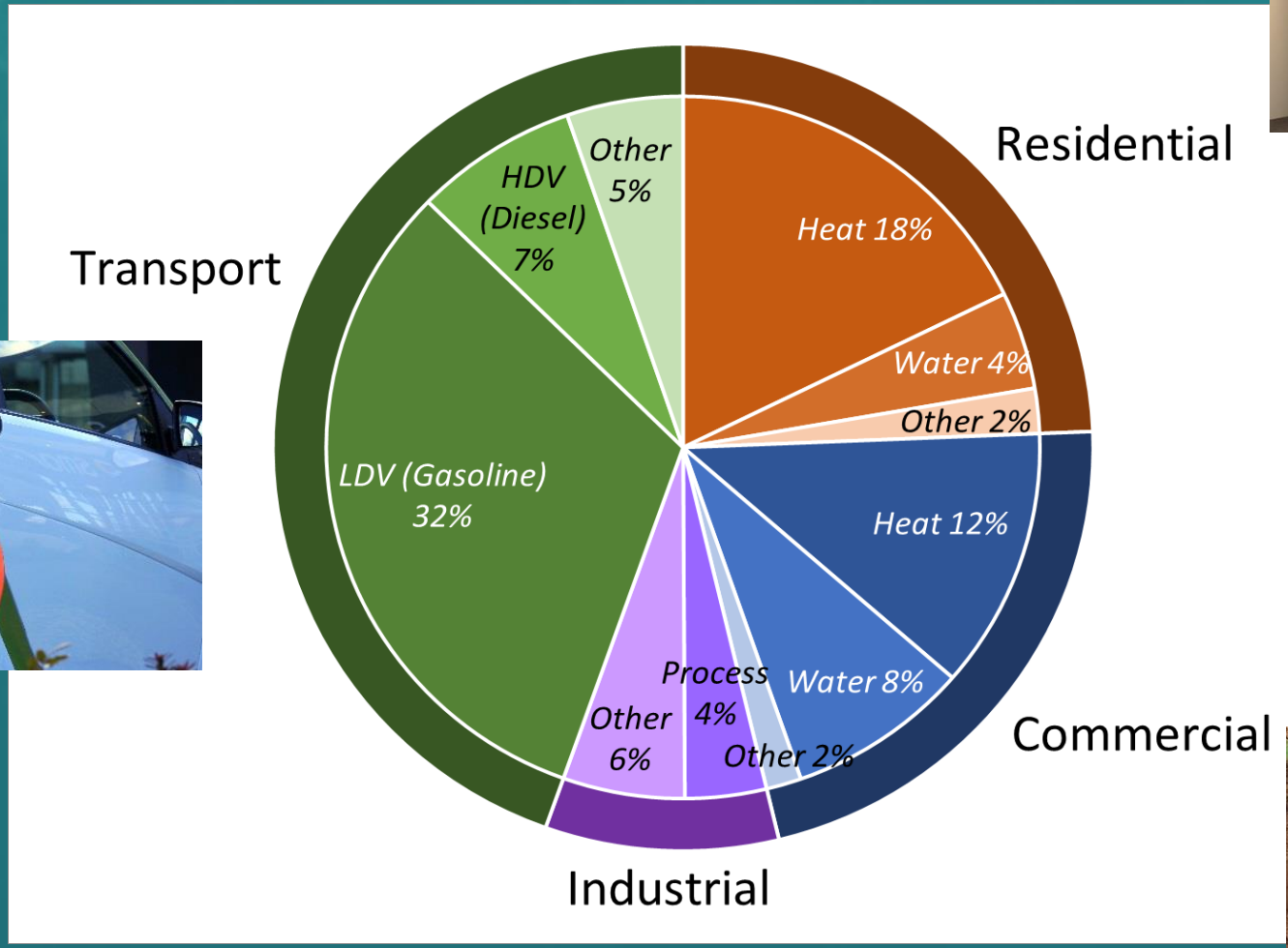
Thermal Improvements

Grid Integration

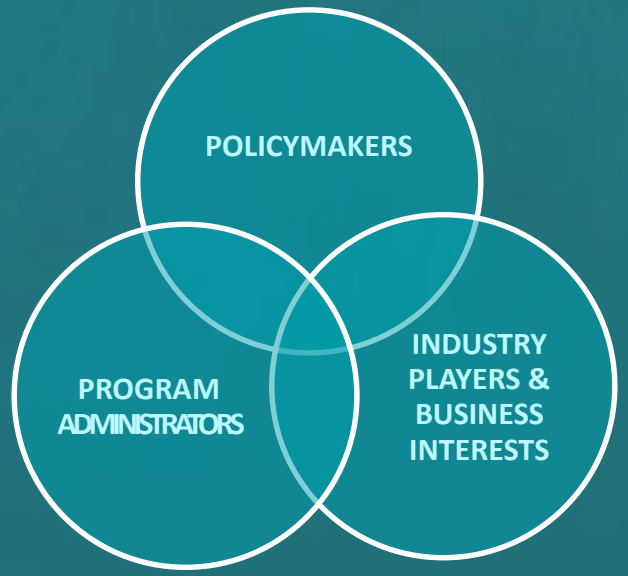
Flexible use of Low-Carbon Electricity

Northeast Strategic Electrification Action Plan – NEEP 2018

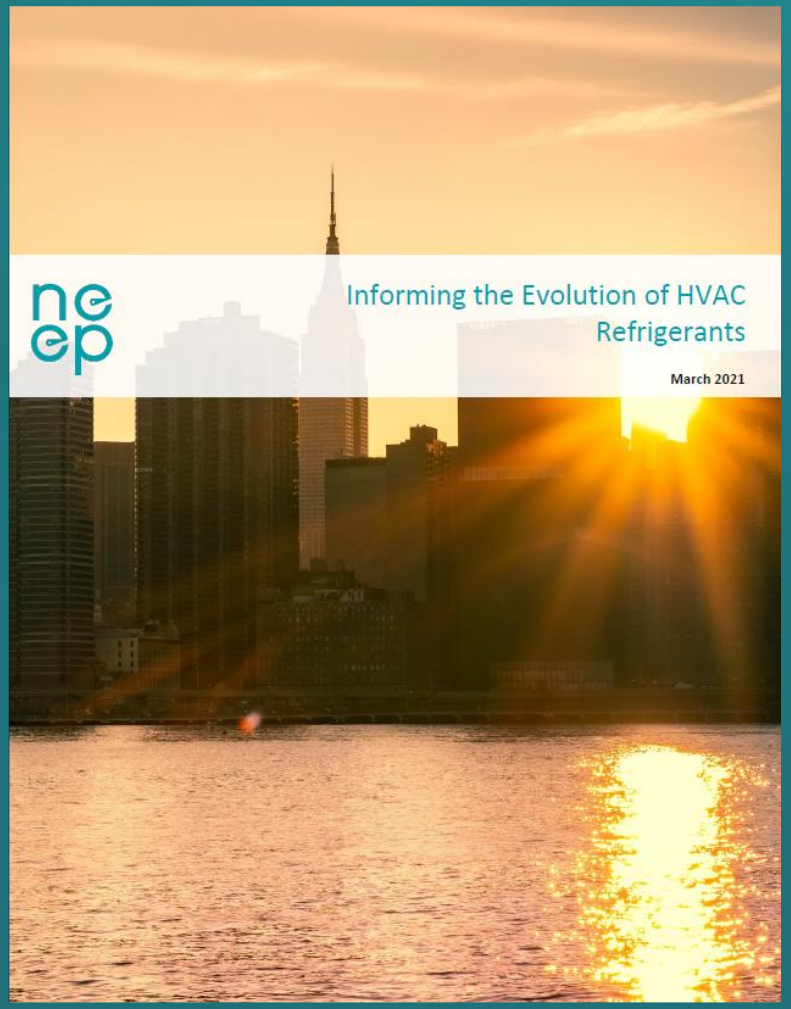
Electrification Opportunities



Regional Heating Electrification Market Transformation Initiative



Whitepaper- Informing the Evolution of HVAC Refrigerants



Visit NEEP's Website to access and download

www.neep.org

Ben Hiller

Technical Manager, NEEP

History of HVAC Refrigerants

Date	Event	New Refrigerants
1902	Invention of the modern air conditioner	Ammonia, Sulfur Dioxide, Methyl Chloride
1928	Invention of Freon to increase safety	CFCs
1987	Montreal Protocol to phase out Ozone Depletion Potential (ODP)	HFCs and HCFCs
2016	Kigali Amendment to phase down Global Warming Potential (GWP)	HFOs and HCFOs
2020	AIM Act to phase down HFC production 85% over 15 years	

Low Pressure Refrigerants – Easy to replace

Pressure	Type	Refrigerant	Toxicity	Flammability	ODP	GWP
Low	CFC	R-11	A	1	1	4,660
	HCFC	R-123	B	1	0.01	79
	HFO	R-514A	B	1	0	2
	HCFO	R-1233zd	A	1	0	1

Medium Pressure Refrigerants – Easy to replace

Pressure	Type	Refrigerant	Toxicity	Flammability	ODP	GWP
Medium	CFC	R-12	A	1	1	10,200
	HFC	R-134a	A	1	0	1,300
	HFO	R-513A	A	1	0	573
	HFO	R-1234ze	A	2L – BV 0.0	0	1
	HFO	R-1234yf	A	2L – BV 1.5	0	1

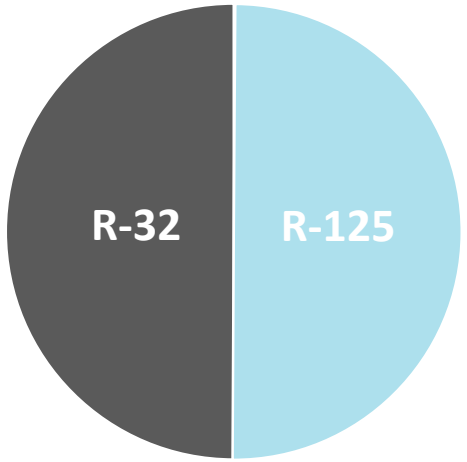
High Pressure Refrigerants – Challenging to replace

Pressure	Type	Refrigerant	Toxicity	Flammability	ODP	GWP
High	HCFC	R-22	A	1	1	1,810
	HFC	R-410A	A	1	0	1,924
	HFC	R-466A	A	1	0	733
	HFC	R-32	A	2L – BV 6.7	0	677
	HFC	R-454B	A	2L – BV 5.2	0	467
	HFC	R-152a	A	2 – BV 23	0	138
		R-290 (Propane)	A	3 – BV 40	0	5

Decreasing GWP

R-410A

1,924 GWP

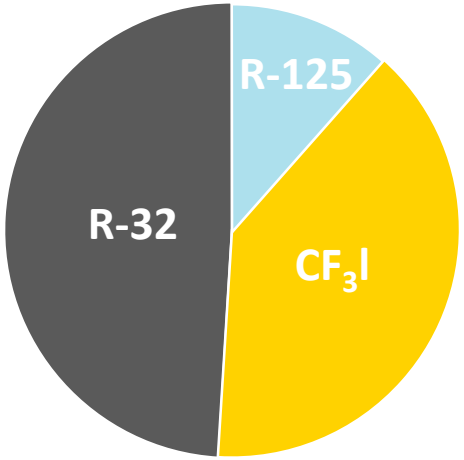


50% R-32

50% R-125

R-466A

733 GWP



49% R-32

39.5% CF_3I

11.5% R-125

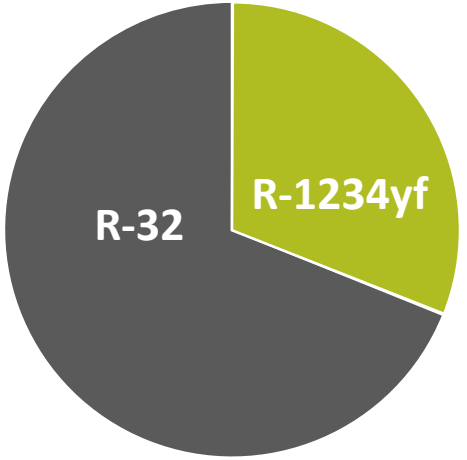
R-32

677 GWP

100% R-32

R-454B

467 GWP



68.9% R-32

31.1% R-1234yf

Jean Samuel (JS) Rancourt

Principal, DXS New England (Daikin Representatives)

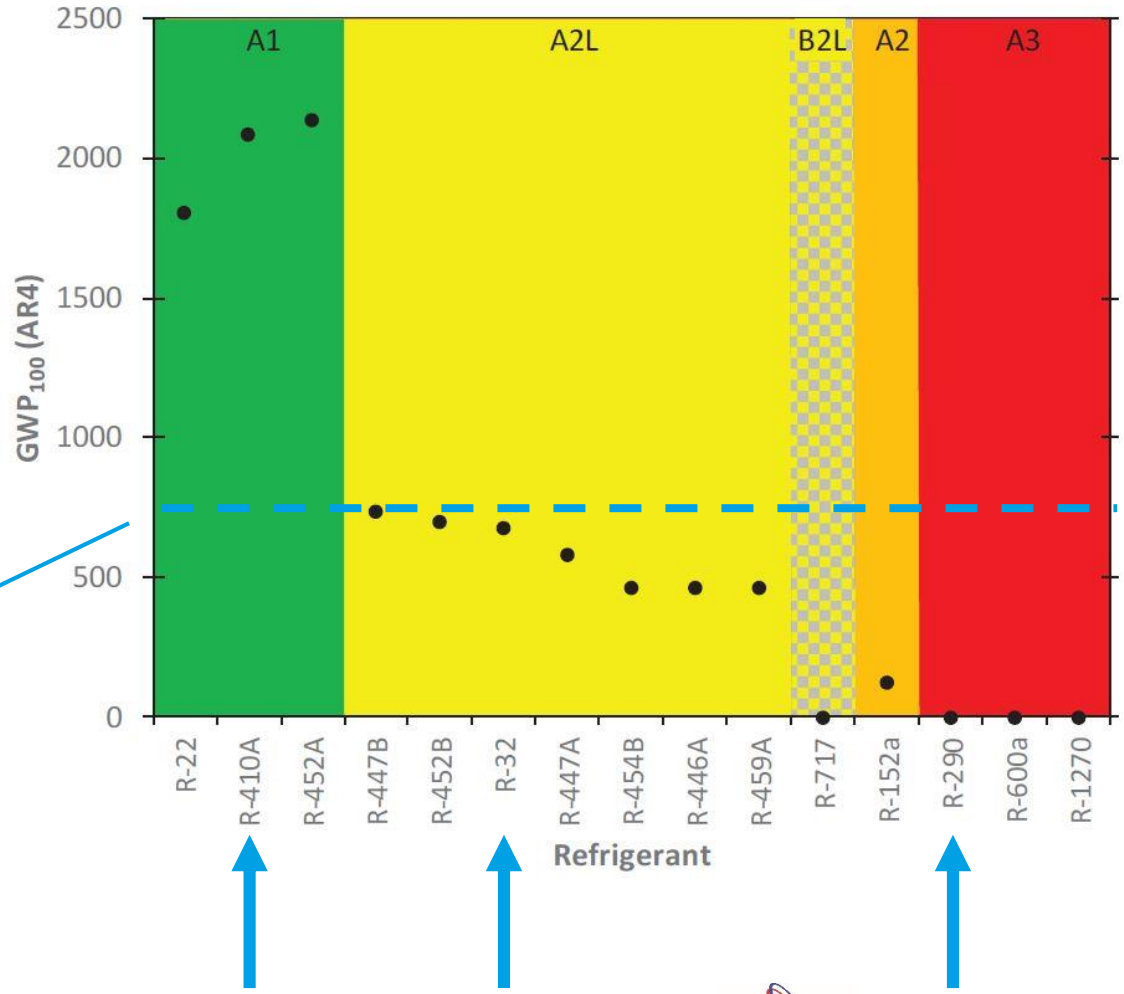
Agenda

- The ‘Low GWP A1’ challenge
- A2L flammability & safety standards
- Refrigerant emissions vs full building LCCP

The low GWP R-410a alternative challenge

Low GWP Class A1

- Flammability and GWP are essentially inversely proportional
- As you add Fluorine based chemicals, you decrease flammability, but increase GWP



California CARB 750 GWP maximum

https://www.achrnews.com/articles/141733-understanding-a2l-refrigerants-for-air-conditioners

R-410a Alternatives

R-32

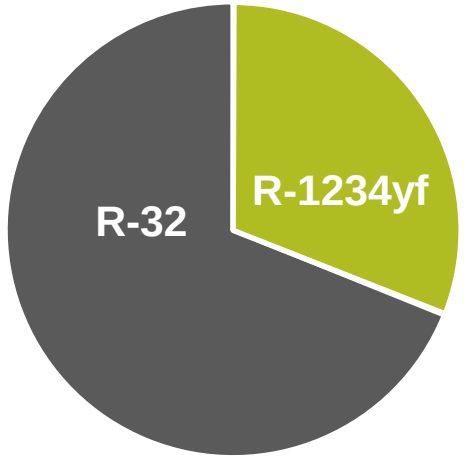
677 GWP

Class: A2L

- Capacity (quantity)
- Efficiency
- Availability
- Ownership / Patent

R-454B

467 GWP

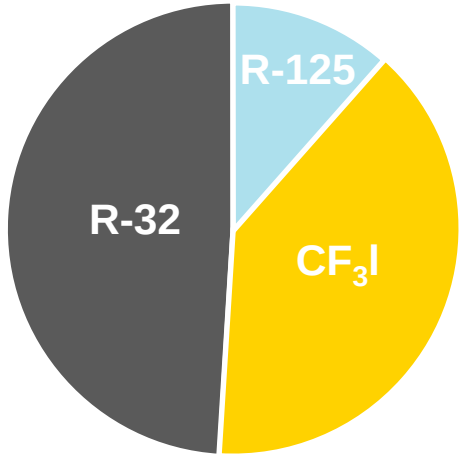


Class: A2L

- Capacity (quantity)
- Efficiency
- Availability
- Ownership / Patent

R-466A

733 GWP



Class: A1

- Capacity (quantity)
- Efficiency
- Availability (CF_3I)
- Ownership / Patent

R-32

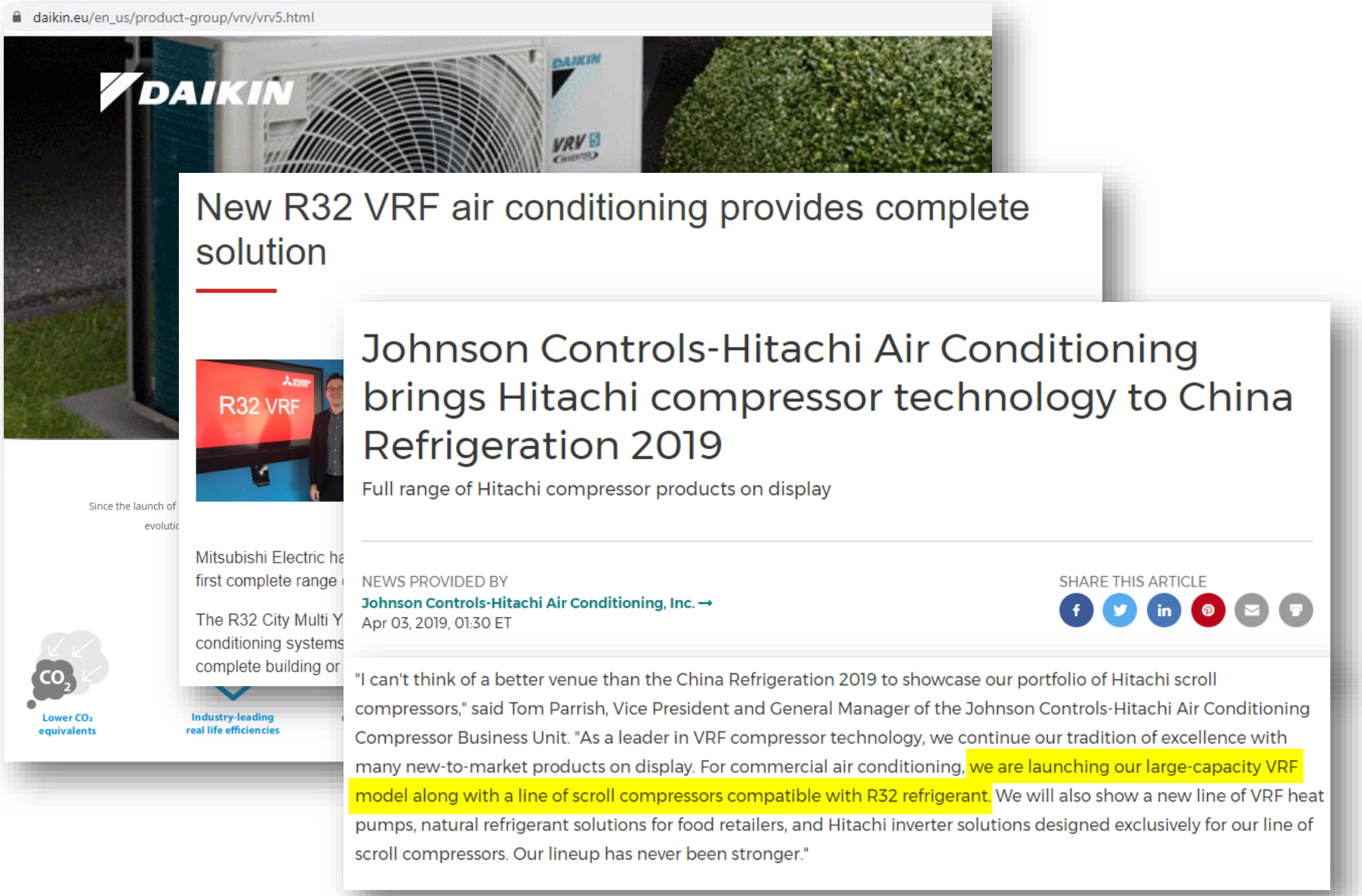
Daikin is highly involved with R-32

- 2011: Offered free access to 93 patents to emerging countries
- 2012: Launched first global R-32 residential equipment in Japan
- 2015: Expanded free patent access globally

But – this is not just Daikin

https://www.daikin.com/patent/r32/

R-32 VRV



https://www.daikin.eu/en_us/product-group/vrv/vrv5.html

Agenda

- The ‘Low GWP A1’ challenge
- **A2L flammability & safety standards**
- Refrigerant emissions vs full building LCCP

Refrigerant Classification

ASHRAE 34

ASHRAE Standard 34 – Designation and Safety Classification of Refrigerants

Higher Flammability	A3	B3
Lower Flammability	A2	B2
	A2L*	B2L*
No Flame Propagation	A1	B1
	Lower Toxicity	Higher Toxicity

Flammability

- All refrigerants can be combusted when put into a high-energy situation such as a fire

- Class 1: no flame propagation (at testing standard of 140F)
  - Class 2 & 3 have flame propagation at 140F
- Class 2: lower flammability
- Class 3: higher flammability (LFL < 0.10 kg/m3 or Heat of Combustion HOC > 19 kJ/g)

*New flammability subclass for class 2 refrigerants that burn very slow
2L have slow velocities; <10 cm/sec ~ 20ft/minute

ASHRAE Standard 34 – Designation and Safety Classification of Refrigerants

Refrigerant Classification

ASHRAE 34

R-410A, the most common air conditioning refrigerant in use globally today, is not actually "non-flammable." It is ASHRAE-listed as an A1 refrigerant, meaning that it has no flame propagation at 63°C.

R-410A behaves very similarly to R-32 especially when exposed to higher temperatures (e.g., a fire impacting AC equipment).[2 3]

As confirmed by AHRI research[4], it takes three failures in a system to ignite an A2L refrigerant used in air conditioning equipment. Failures required include the following:

a. There would have to be a significant refrigerant leak.
b. The leak would have to be sufficient to reach the lower flammability limit (LFL) concentration. LFL concentrations for A2Ls are above 10%.
c. There would have to be an open flame or a high energy ignition source where the concentration is sufficient to ignite A2L refrigerants.

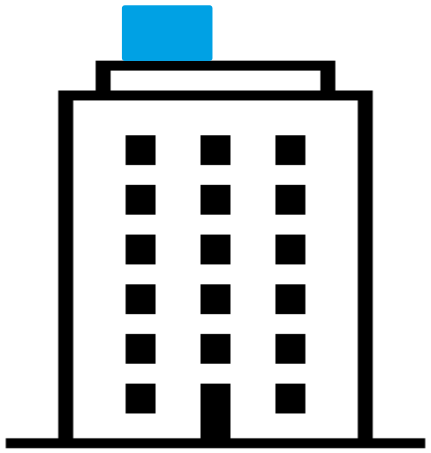
1. http://www.ahrinet.org/App_Content/ahri/files/Resources/AHRI_SRTTF_Low_GWP_Refrigerants_FAQs.pdf

Refrigerant Classification

ASHRAE 15

ASHRAE Standard 15 – Safety Standard for Refrigeration Systems

- Application standard with a focus on health & safety
- Version currently followed by U.S. building codes (2013 or 2016) does NOT allow class A2L refrigerants in 'high probability systems' (or A2, A3, B1, B2, B3)
  - *refrigerant coils in air stream = 'high probability systems'*



Outdoor chillers: A2L's OK

- Not high-probability
- Heating (ASHP) challenges (cost, efficiency, operational cost, hydronic management)

Small systems: A2L's OK

- Low refrigerant charge

VRV / ASHP: A2L's not ok

- High-probability

Refrigerant Classification

ASHRAE 15

7.6 Group A2L *Refrigerants* for Human Comfort. High-probability systems using Group A2L *refrigerants* for human comfort applications *shall* comply with this section.

7.6.1 *Refrigerant Concentration Limits*

7.6.1.1 *Occupied spaces shall* comply with Section 7.2.

7.6.1.2 Unoccupied spaces with *refrigerant* containing equipment, including but not limited to *piping* or tubing, *shall* comply with Section 7.2 except as permitted by Section 7.6.4.

A2L

Refrigerant Classification

ASHRAE 15

7.6.2.3 A *refrigerant detector shall* be provided in accordance with Section 7.6.5 where any of the following apply:

b. Turn off the *compressor* and all other electrical devices, excluding the control power transformers, control systems, and the supply air fan. The supply air fan *shall* continue to operate for at least five minutes after the *refrigerant detector* has sensed a drop in the *refrigerant* concentration below the value *specified* in Section 7.6.5(b).

c. Any device that controls airflow located within the product or in ductwork that supplies air to the *occupied space shall* be fully open. Any device that controls airflow *shall* be *listed*.

d. Turn off any heaters and electrical devices located in the ductwork. The heaters and electrical devices *shall* remain off for at least five minutes after the *refrigerant detector* has sensed a drop in the *refrigerant* concentration below the value *specified* in Section 7.6.5(b).

ASHRAE Standard 15 – Safety Standard for Refrigeration Systems

ASHRAE 15

RCL

- Introduces Refrigerant Concentration Limit (RCL) to ensure safety in case of a complete refrigerant discharge in the smallest occupied space
  - Analyzes toxicity, oxygen deprivation and flammability
  - Worse case maximum concentration determines the RCL

- R-410a
  1. Low toxicity
  2. No flame propagation at 140F (A1)
  3. Oxygen deprivation determines the RCL
  - RCL of R-410a = 26 lbs / mcf

Oxygen Percentage Available	Symptoms
21	Normal conditions, no effect.
19.5	OSHA oxygen-deficient atmosphere.
17	Muscular impairment, rapid breaths.
12	Dizziness, headache, rapid fatigue.
9	Unconsciousness.
7 to 6	Death within a few minutes.

Altitude equivalent [ft] Of effective oxygen %
0
2,000
5,500
14,500
22,000
29,000

ASHRAE 15

RCL

7.6 Group A2L *Refrigerants* for Human Comfort. High-probability systems using Group A2L *refrigerants* for human comfort applications *shall* comply with this section.

7.6.1 *Refrigerant Concentration Limits*

7.6.1.1 *Occupied spaces shall* comply with Section 7.2.

7.6.1.2 Unoccupied spaces with *refrigerant* containing equipment, including but not limited to *piping* or tubing, *shall* comply with Section 7.2 except as permitted by Section 7.6.4.

A2L

ASHRAE 15

RCL

7.2 Refrigerant Concentration Limits. The concentration of *refrigerant* in a complete discharge of each independent circuit of high-probability systems *shall not* exceed the amounts shown in ASHRAE Standard 34 [2], Table 4-1 or 4-2, except as provided in Sections 7.2.1 and 7.2.2 of this standard. The volume of *occupied space shall* be determined in accordance with Section 7.3.

Exceptions to 7.2:

1. *Listed* equipment containing not more than 6.6 lb (3 kg) of *refrigerant*, regardless of its *refrigerant* safety classi-

A2L

ASHRAE Standard 15 – **2019**

ASHRAE 15

RCL

Table 4-1 Refrigerant Data and Safety Classifications

Refrigerant Number	Chemical Name[a,b]	Chemical Formula[a]	OEL[f], ppm v/v	Safety Group	RCL[c] (ppm v/v)	RCL[c] (lb/Mcf)	RCL[c] (g/m^3)	Highly Toxic or Toxic[d] Under Code Classification
Methane Series								
11	trichlorofluoromethane	CCl_3F	1000	A1	1100	0.39	6.2	Neither
12	dichlorodifluoromethane	CCl_2F_2	1000	A1	18,000	5.6	90	Neither
12B1	bromochlorodifluoromethane	$CBrClF_2$						Neither
13	chlorotrifluoromethane	$CClF_3$	1000	A1				Neither
13B1	bromotrifluoromethane	$CBrF_3$	1000	A1				Neither
14[e]	tetrafluoromethane (carbon tetrafluoride)	CF_4	1000	A1	110,000	25	400	Neither
21	dichlorofluoromethane	$CHCl_2F$		B1				Toxic
22	chlorodifluoromethane	$CHClF_2$	1000	A1	59,000	13	210	Neither
23	trifluoromethane	CHF_3	1000	A1	41,000	7.3	120	Neither
30	dichloromethane (methylene chloride)	CH_2Cl_2		B1				Neither
410A[i]	R-32/125 (50.0/50.0)	(+0.5, –1.5/+1.5, –0.5)	1000	A1	140,000	26	420	Neither
32	difluoromethane (methylene fluoride)	CH_2F_2	1000	A2L	36,000	4.8	77	Neither
40	chloromethane (methyl chloride)	CH_3Cl		B2				Toxic
41	fluoromethane (methyl fluoride)	CH_3F						Neither
50	methane	CH_4	1000	A3				Neither

Refrigerant Classification

ASHRAE 15

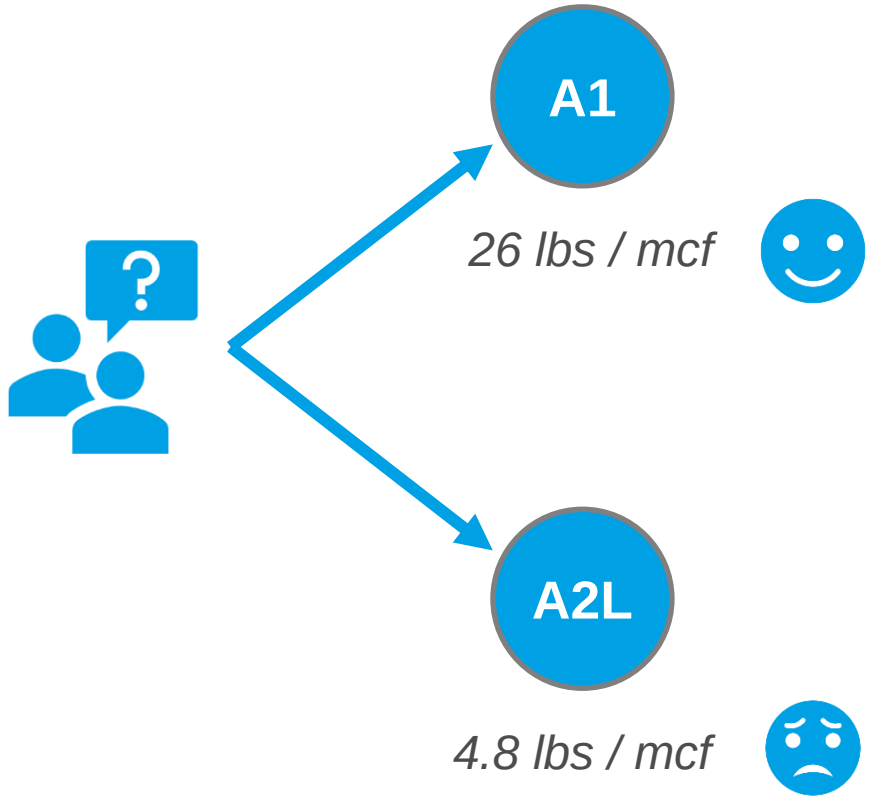
ASHRAE Standard 15 – **2019**

7.3 Volume Calculations. The volume used to convert from *refrigerant concentration limits* to *refrigerating system* quantity limits for *refrigerants* in Section 7.2 *shall* be based on the volume of space to which *refrigerant* disperses in the event of a *refrigerant* leak.

7.3.1 Nonconnecting Spaces. Where a *refrigerating system*, or a part thereof, is located in one or more enclosed *occupied spaces* that do not connect through permanent openings or HVAC *ducts*, the volume of the smallest *occupied space shall* be used to determine the *refrigerant* quantity limit in the system. Where different stories and floor levels connect through an open atrium or mezzanine arrangement, the volume to be used in calculating the *refrigerant* quantity limit *shall* be determined by multiplying the floor area of the lowest space by 8.2 ft (2.5 m).

7.3.2 Ventilated Spaces. Where a *refrigerating system*, or a part thereof, is located within an air handler, in an air distribution *duct* system, or in an *occupied space* served by a mechanical ventilation system, the entire air distribution system *shall* be analyzed to determine the worst-case distribution of leaked *refrigerant*. The worst case or the smallest volume in which the leaked *refrigerant* disperses *shall* be used to determine the *refrigerant* quantity limit in the system, subject to the following criteria.

7.3.2.1 Closures. Closures in the air distribution system *shall* be considered. If one or more spaces of several arranged in parallel can be closed off from the source of the *refrigerant* leak, their volumes *shall not* be used in the calculation.



Refrigerant Classification

ASHRAE 15

ASHRAE Standard 15 – **2022 (Proposed addendums for 2022)**

- Isolation valves
- Definition of ‘releasable charge’ (no longer the full system charge)
- Definition of connected spaces and ventilation openings
- Introduction of ‘safety mitigation measures’ to increase RCL

Equipment standards also need to follow:

UL 1995
- Current standard for safety of VRV and ASHP equipment
- Currently under the 4th edition, valid until 2024

UL 60335-2-40[1]
- New standard, becomes mandatory in 2024
- Based on IEC 60335-2-40 (but more conservative)
- Introduces factory installed refrigerant leak detection as part of the equipment, and its testing

https://www.ul.com/news/understanding-ul-60335-2-40-refrigerant-detector-requirements

Codes & Standards on A2L

- Model building codes first need to adopt these new standards
  - Universal Mechanical Code (UMC)
  - International Mechanical Code (IMC)
- The 2021 round of these model codes have rejected A2L
- Next round is 2024 (work starts now)

- State / County / Local codes need updates (1-8 years)
  - Based on one of the model codes
- Some states (CA, WA) considering no longer using the model codes in order to incorporate A2L

Flammability & Safety

Overview

- A2Ls and A1s essentially pose the same risk during a building fire (at high temps), especially when considering the oil mixed in them
- Allowing A2Ls comes with a series of new safety requirements
- Therefore, an R32 VRV system is arguably safer than an R410a VRV system during a building fire

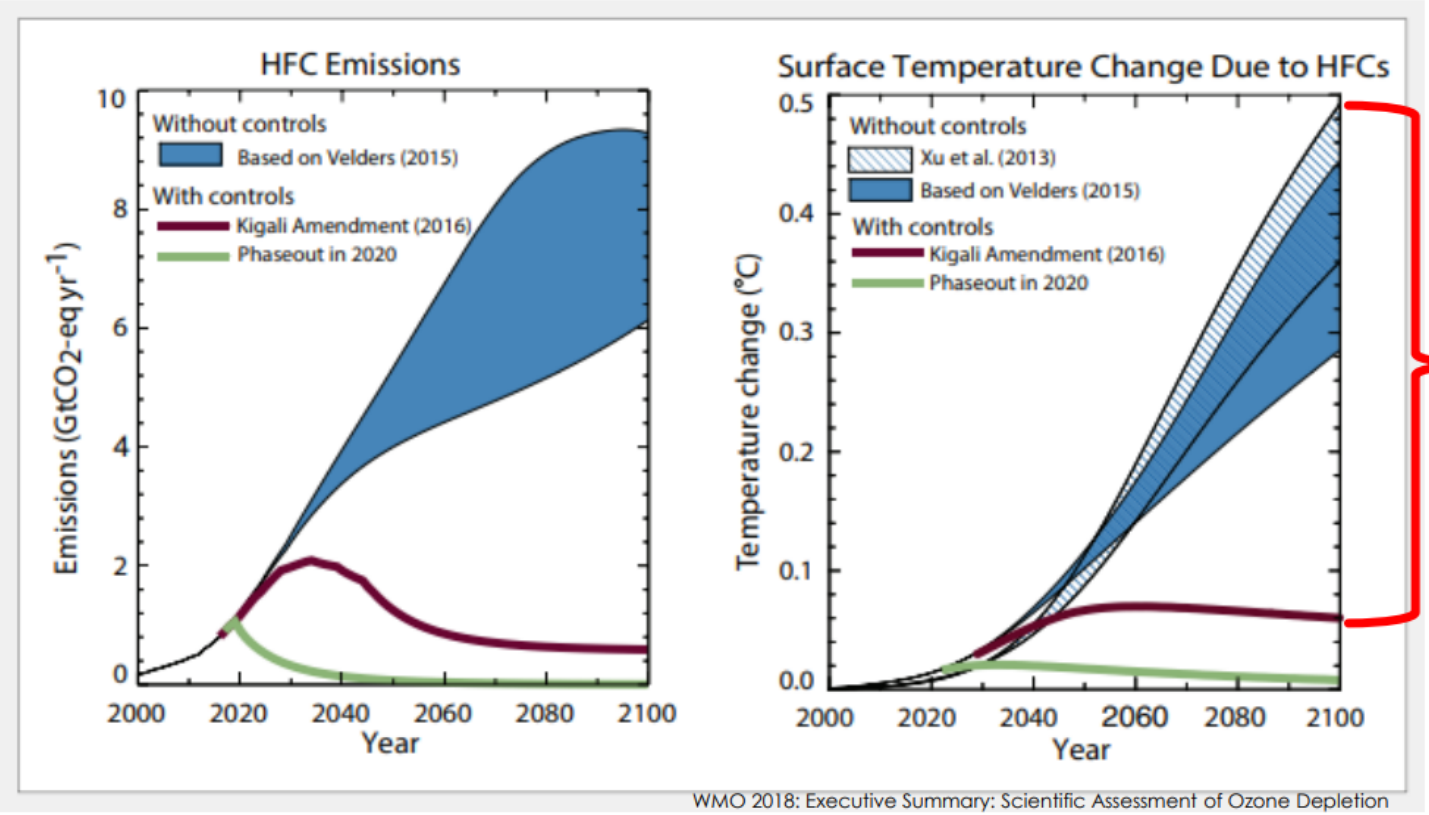
1. http://www.ahrinet.org/App_Content/ahri/files/Resources/AHRI_SRTTF_Low_GWP_Refrigerants_FAQs.pdf
2. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2554&context=iracc

Agenda

- The ‘Low GWP A1’ challenge
- A2L flammability & safety standards
- **Refrigerant emissions vs full building LCCP**

The importance of reducing refrigerant emissions

A global HFC phasedown is expected to avoid up to 0.5°C of global warming by 2100

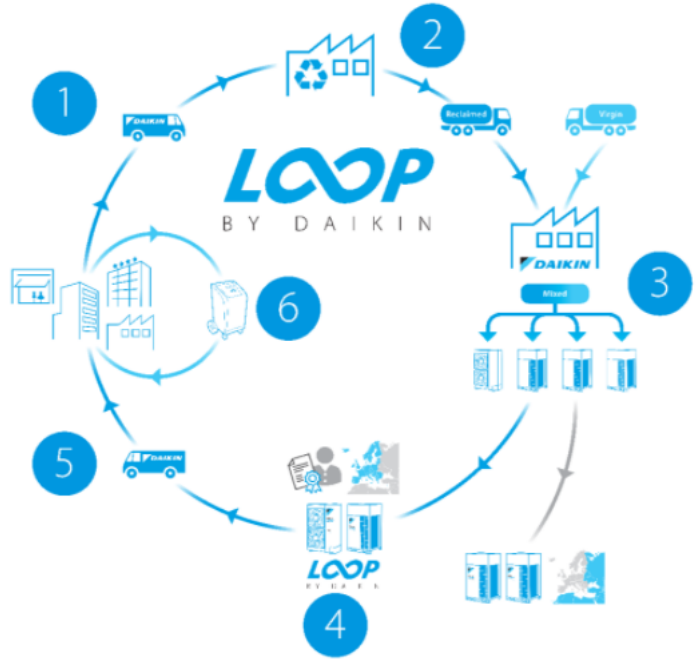


WMO 2018: Executive Summary: Scientific Assessment of Ozone Depletion

Daikin Europe Initiatives

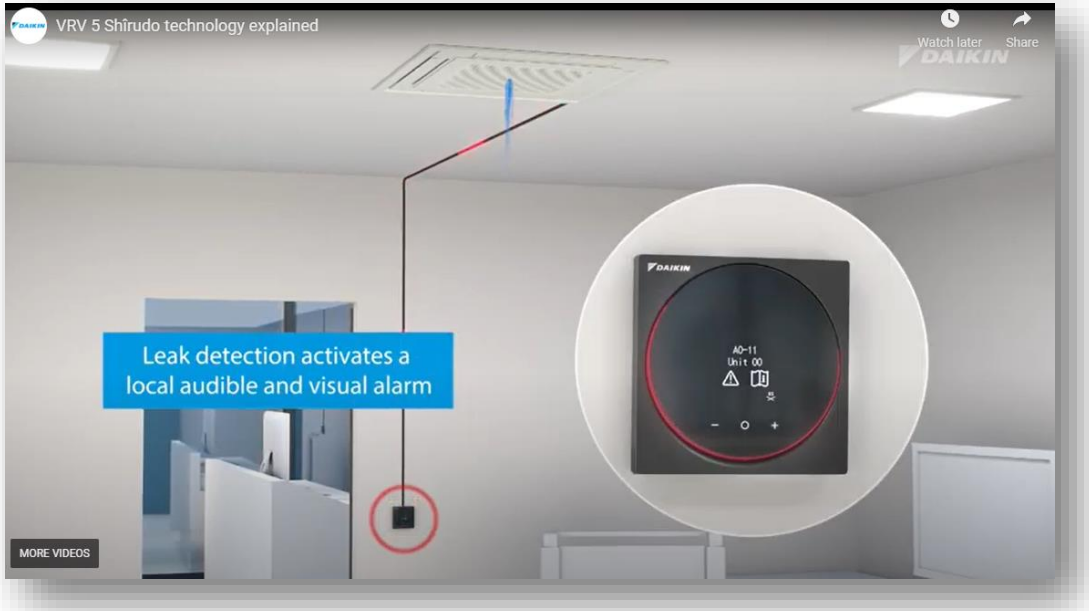
LOOP

Refrigerant recovery program



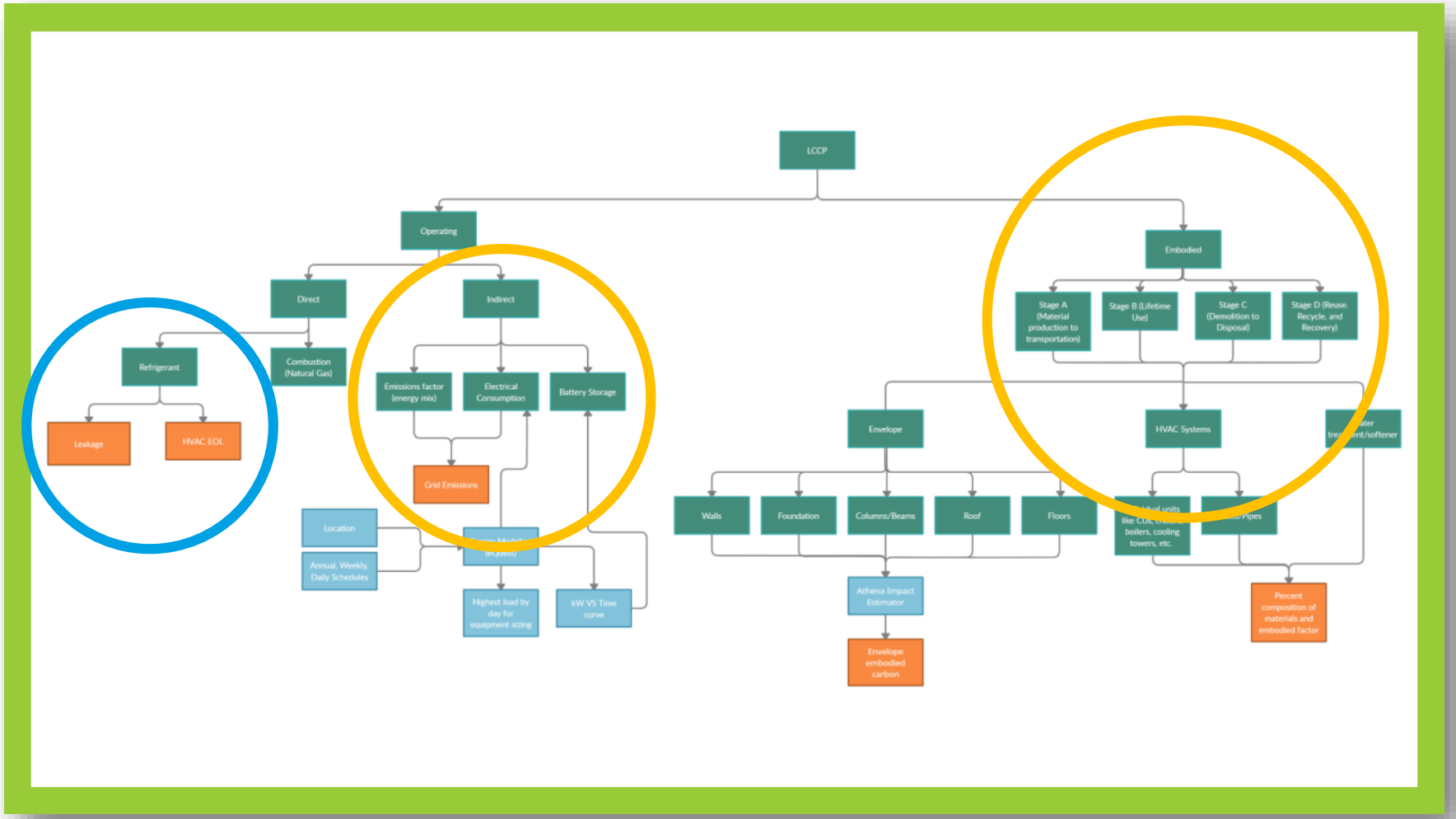
Shîrudo

Refrigerant management to increase safety & RCL

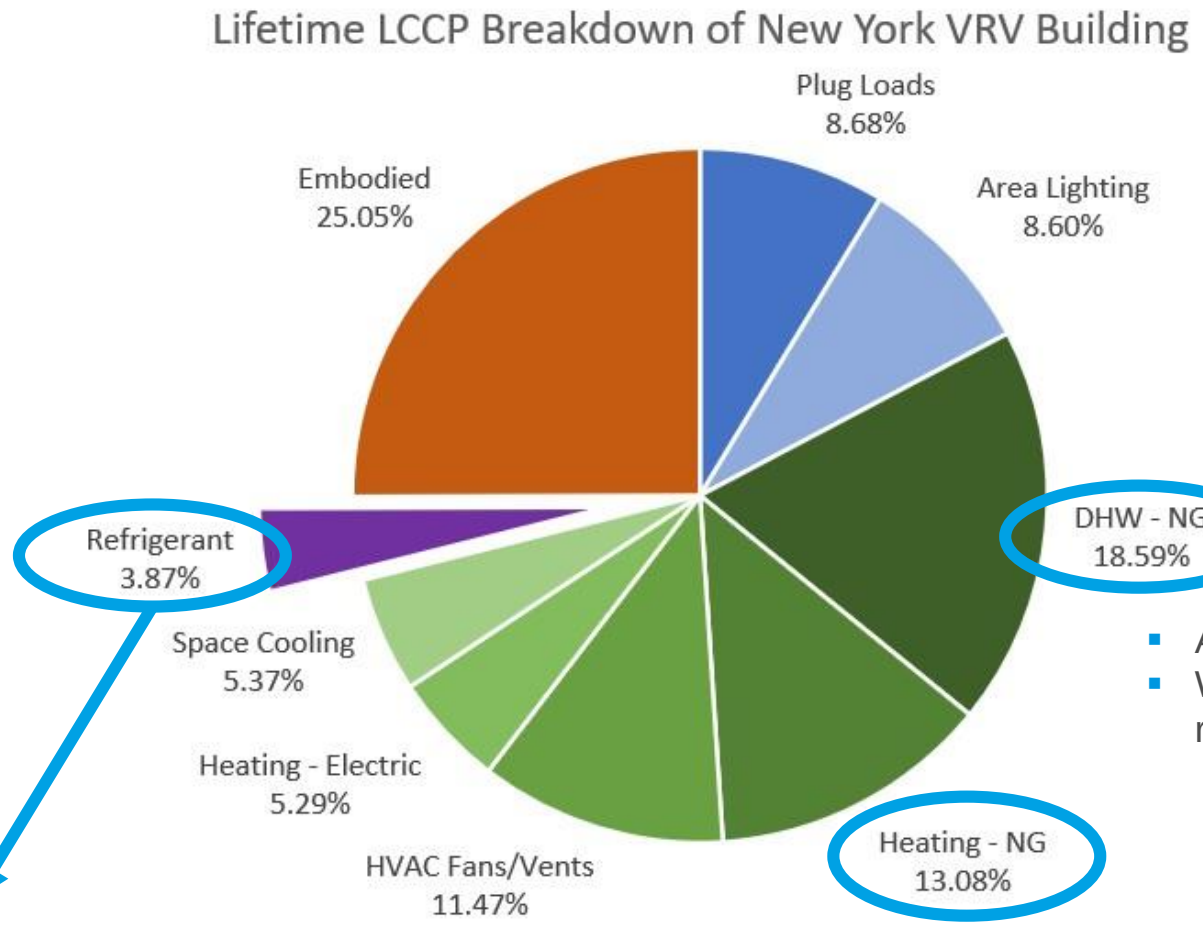


Relative Impacts

Looking at the full Life Cycle Climate Performance of buildings (30 year emission profile)



Environmental



- A2W ASHP
- Waste Water heat recovery

- VRV driven ERVs
- High efficiency air-side energy recovery

- Get A2Ls allowed in buildings
- Install quality
  - Pre-qualify contractors
- Proper maintenance
- Proper controls & alarms

Suzanne Hagell

Manager, Greenhouse Gas Mitigation, Office of Climate Change,
New York State Department of Environmental Conservation

NEW YORK STATE | Department of Environmental Conservation

NEW YORK
STATE OF
OPPORTUNITY

Department of
Environmental
Conservation

State Policy and HFCs

Current and future considerations

NEEP: Informing the Evolution of HVAC Refrigerants
Suzanne Hagell
NYSDEC Office of Climate Change
April 21, 2021

Key considerations: NY Perspective

- State and federal GHG reduction requirements
  - Very steep reductions = No simple tradeoffs
  - Impacts of consumption targets on emissions scenario
- Growing interest in Short-Lived Climate Pollutants
  - Application of the 20-Year Global Warming Potential
  - Methane and hydrofluorocarbons are a bigger piece of the pie
- “Phasing” needed to reach 2050 goals
  - Near-term versus long-term transitions
  - Evaluating role of leak management, codes, and R&D

Current NYSDEC HFC Policies

6 NYCRR Part 494: NY “SNAP” Rule

- NY joined US Climate Alliance States in adopting EPA SNAP Rules 20 and 21. Went into effect January 01, 2021.

NYSDEC is taking input on:

- Next steps for Part 496, other policies and programs
- HFC emissions accounting and forecasting
- Aligning with other states and EPA/Kigali

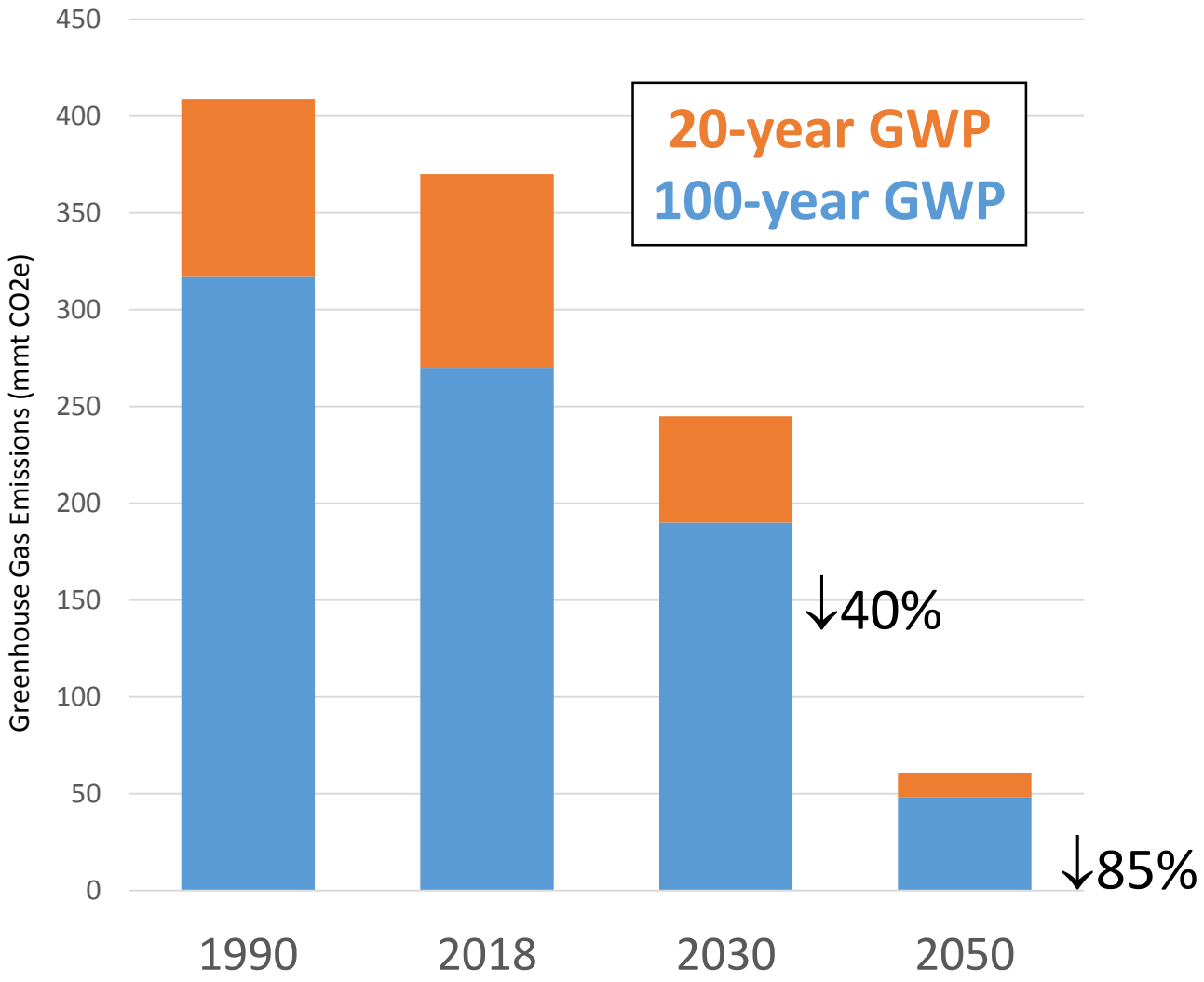
Climate Leadership and Community Protection Act

Requires a Scoping Plan and regulations to meet the most aggressive GHG reduction goals of any major economy.

- **40% reduction by 2030**
- **85% reduction by 2050**
- **Net zero by 2050**

+ Codifies clean energy targets and commitments to environmental justice and just transition

New York's Statewide GHG Emission Limits



The Climate Act's "New Math":

- One change is 20-year GWP

Impact of a 20-year GWP

- Increases HFC total 55%
- Makes HFCs a bigger part of the remaining budget

NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

Draft 2018 (not final)

Developing the Scoping Plan

- The Climate Action Council shall identify and recommend regulatory and other actions to ensure the GHG goals are met.

Advisory panels:

1. transportation
2. land use and local government
3. housing and energy efficiency
4. energy-intensive industries
5. power generation
6. agriculture and forestry
7. waste

Additional Groups:

- Climate Justice
- Just Transition

++ Environmental Justice Advisory Panel (consults with all groups)

Advisory Panel Recommendations

Panels considered recommendations related to:

- Expanding prohibitions on new equipment (NYS SNAP)
- Committing to code updates
- Refrigerant management and reporting
- End-of-Life refrigerant recovery
- Supporting R&D, training and outreach
- Alignment with EPA and AIM Act

Next step: Climate Action Council will review and draft the Scoping Plan.

Implementing the Scoping Plan – NYSDEC

By 2024, DEC shall promulgate regulations that, for example:

- Ensure 2030 and 2050 emission limits will be met
- Prioritize disadvantaged communities

Meeting this deadline requires early action.

Expanding the NYS SNAP will be one component.

Considering Near versus Long-Term

Potential “Phases” towards 2050

1. Acting on What’s Ready Now
   - Transition to lowest-GWP possible now
   - Manage leakage and EOL
2. Enabling Lower-GWP Options
   - Address state and local building codes, then lower the allowable GWP
3. Final Transition
   - Ultimate goal is zero and ultra-low GWP options that are not yet available

Thank You

Suzanne Hagell

Office of Climate Change

NYS Department of Environmental Conservation

625 Broadway, Albany, NY 12233

Climate.regs@dec.ny.gov

Connect with us:

Facebook: www.facebook.com/NYSDEC

Twitter: twitter.com/NYSDEC

Flickr: www.flickr.com/photos/nysdec

NEW YORK STATE | Department of Environmental Conservation

Questions?

Upcoming Events

Summit Sessions	Under Development for 2021
Smart Energy Homes and Buildings 2021	Thursday, August 19
Heating Electrification Workshop 2021	Wednesday, October 27 & Thursday October 28

Allies Network

For more information, contact Ben Hiller

bhiller@neep.org