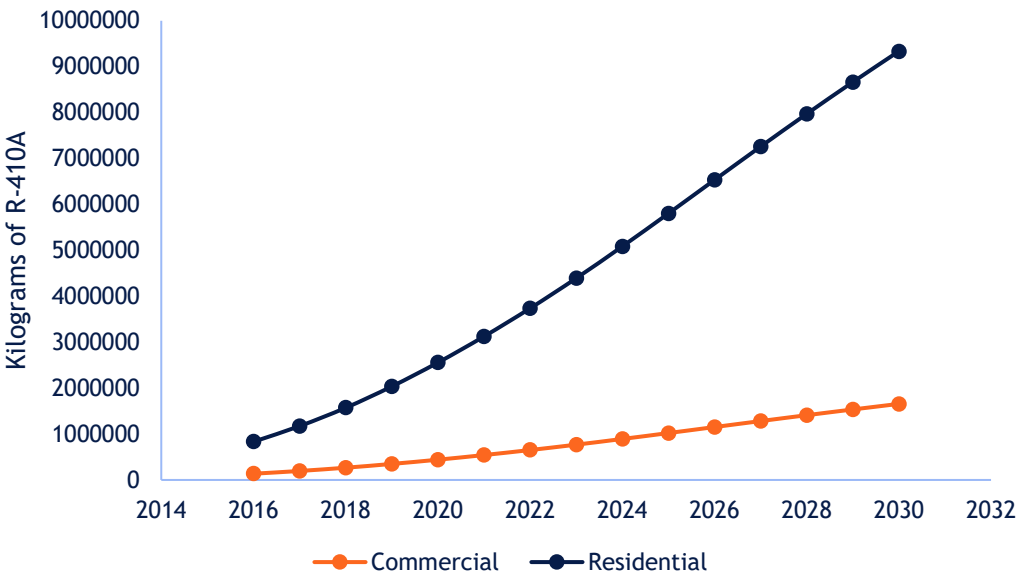


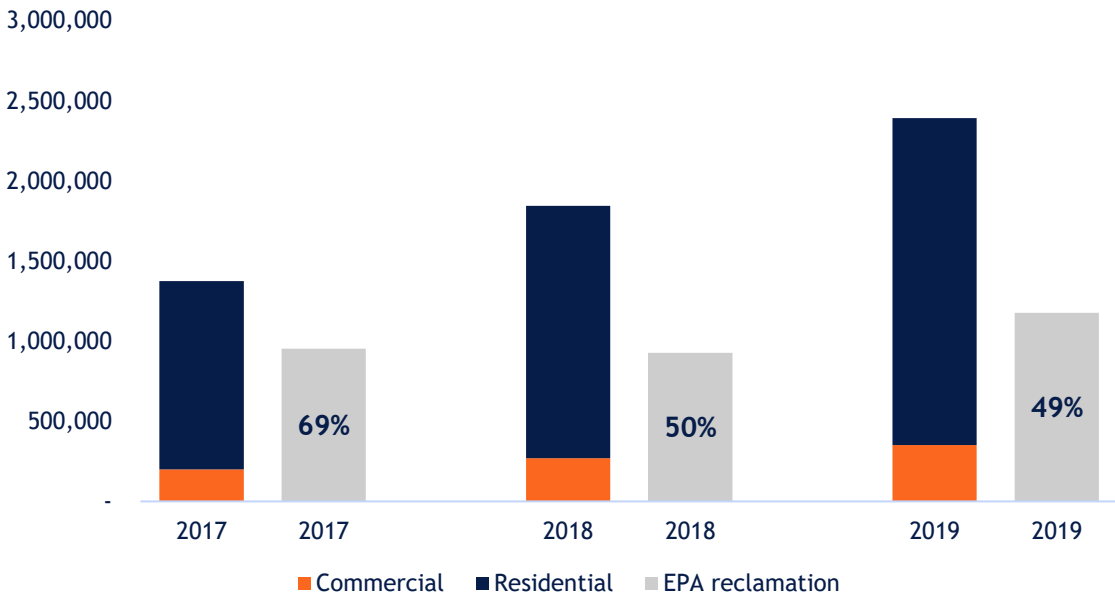
USING CARB CHARGE SIZES

R-410A RECLAMATION RATE (EXC. INDIVIDUAL ACS)

R-410A available for reclaim in decomissioned AC units (excluding individual AC units)



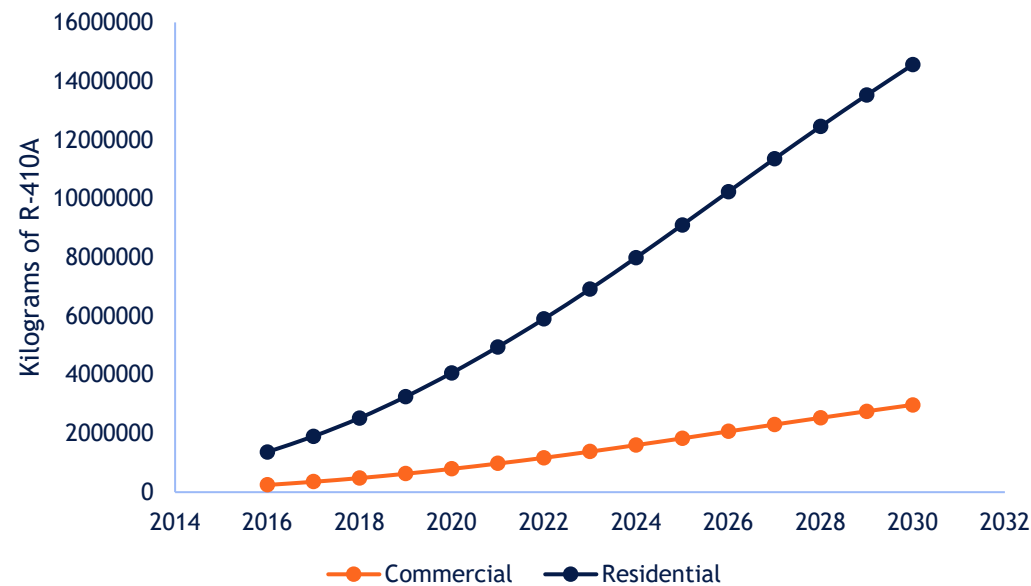
The reclamation rate of R-410A (excluding individual units)



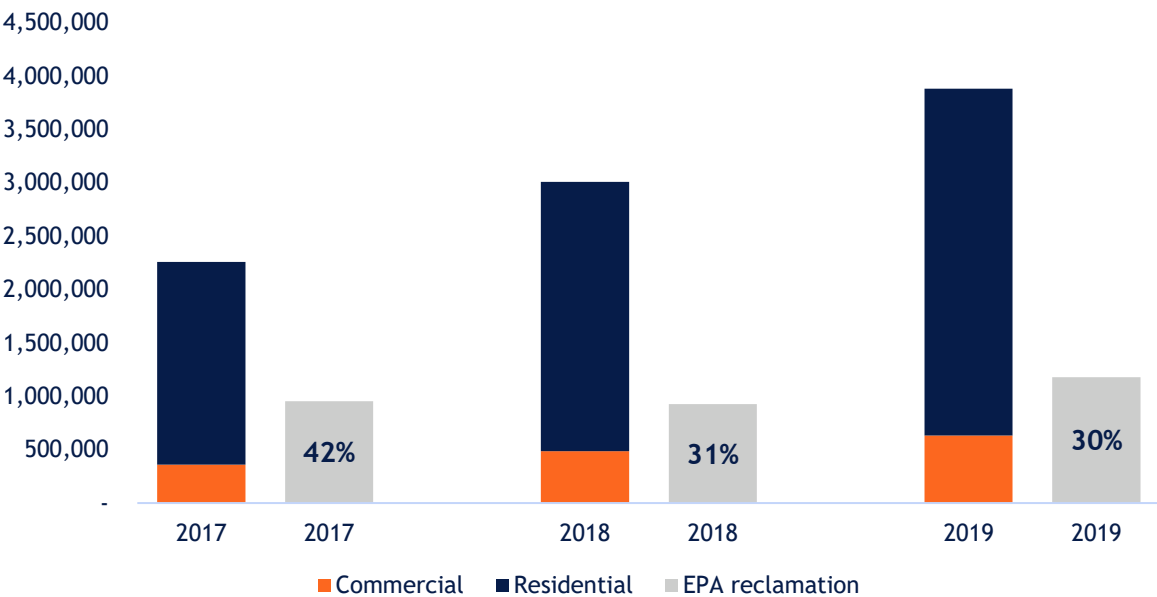
R-410A (metric tonnes)	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	836	1,176	1,575	2,040	2,559	3,127	3,740	4,394	5,087	5,804	6,533	7,259	7,971	8,663	9,335
Commercial	140	200	270	353	445	546	655	771	895	1,023	1,154	1,284	1,412	1,536	1,657

R-410A RECLAMATION RATE (EXC. INDIVIDUAL ACS)

R-410 available for reclaim in decommissioned AC units (excluding individual units)



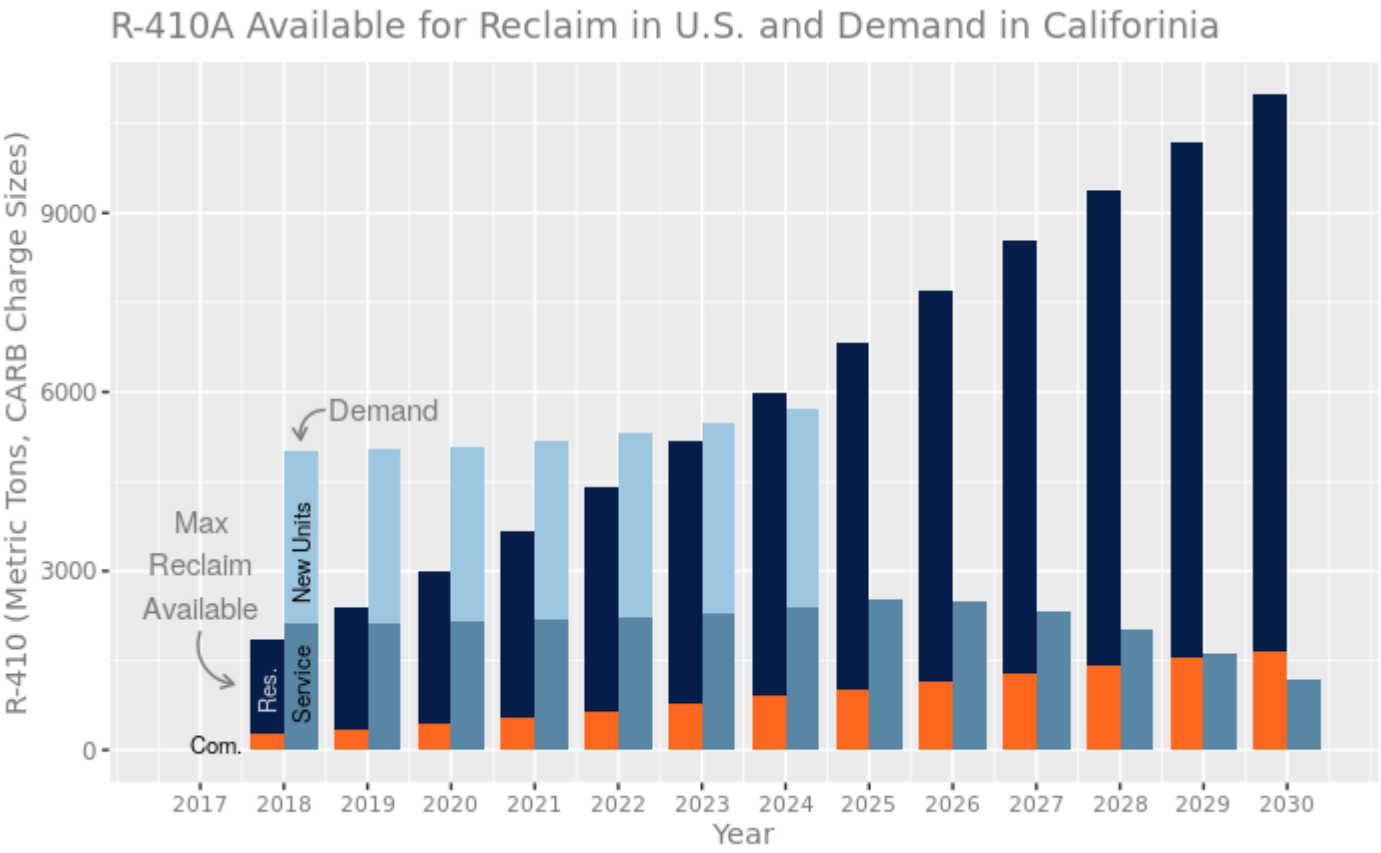
The reclamation rate of R-410A (excluding individual units)



R-410A (metric tonnes)	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	1,365	1,899	2,522	3,249	4,060	4,946	5,899	6,916	7,990	9,102	10,230	11,353	12,454	13,523	14,559
Commercial	251	359	485	632	797	978	1,174	1,383	1,605	1,835	2,069	2,302	2,531	2,754	2,972

USING CARB CHARGE SIZES

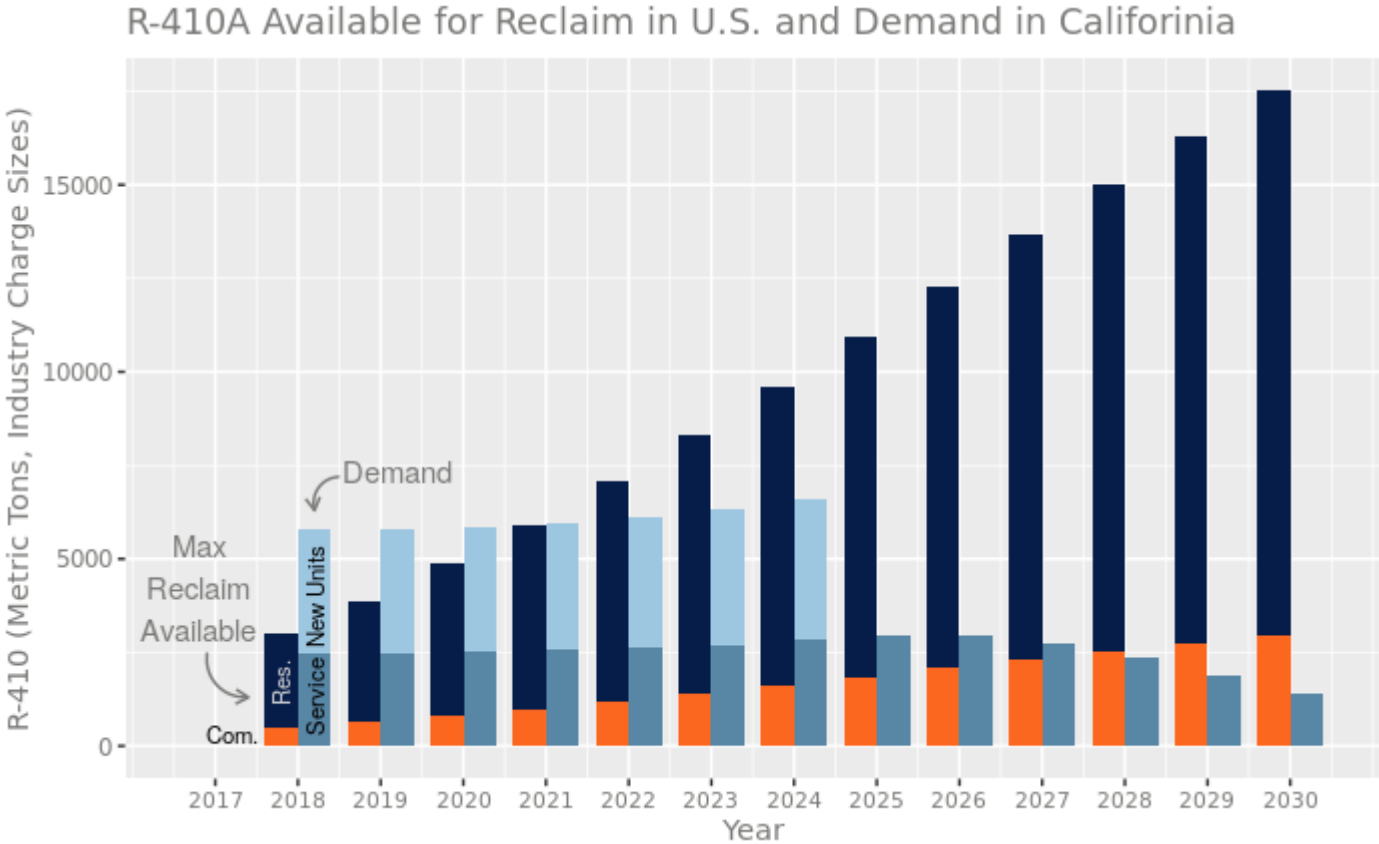
R-410A U.S. RECLAIM
AVAILABLE AND
CALIFORNIA DEMAND



	R-410A Reclaim Available in U.S. (Metric Tonnes)		R-410A Demand in CA (Metric Tonnes)	
	Residential	Commercial	New Units	Service
2023	4,394	771	3,168	2,304
2024	5,087	895	3,300	2,400
Total	11,147		11,172	

USING INDUSTRY CHARGE SIZES

R-410A U.S. RECLAIM
AVAILABLE AND
CALIFORNIA DEMAND



	R-410A Reclaim Available in U.S. (Metric Tonnes)		R-410A Demand in CA (Metric Tonnes)	
	Residential	Commercial	New Units	Service
2023	6,916	1,383	3,604	2,710
2024	7,990	1,605	3,754	2,822
Total	17,894		12,891	

R-410A INSTALLED STOCK IN 2020

AHRI estimates

- Assumption of 20 year equipment lifetime: 418,083 tonnes
- Assumption of 17.5 year equipment lifetime: 381,523 tonnes
- Assumption of 15 year equipment lifetime: 345,114 tonnes
- Estimate based on RECS and CBECS data: **355,908 tonnes**

Anthesis estimates

R-410A (metric tonnes)	CARB charge sizes	Industry charge sizes
Residential	180,042	270,923
Commercial	34,677	57,852
TOTAL	214,719 tonnes	328,775 tonnes

METHODOLOGY

Anthesis were asked by AHRI to independently estimate the volume of R-410A present in air conditioning (AC) units & heat pumps (HP) currently installed in the US.

To do this, AHRI provided Anthesis with results from the EIA Commercial Buildings Energy Consumption Survey 2012 (CBECS) and Residential Energy Consumption Survey 2015 (RECS).

Two different methodologies were used to estimate the number of AC units & HPs currently installed in Commercial & Residential buildings.

The purpose of this is to then predict the potential flows of R-410A at end-of-life (EoL) in order to validate estimates of material available for reclaim.



2015

RESIDENTIAL AIR CONDITIONING SYSTEMS

RESIDENTIAL AC SYSTEMS

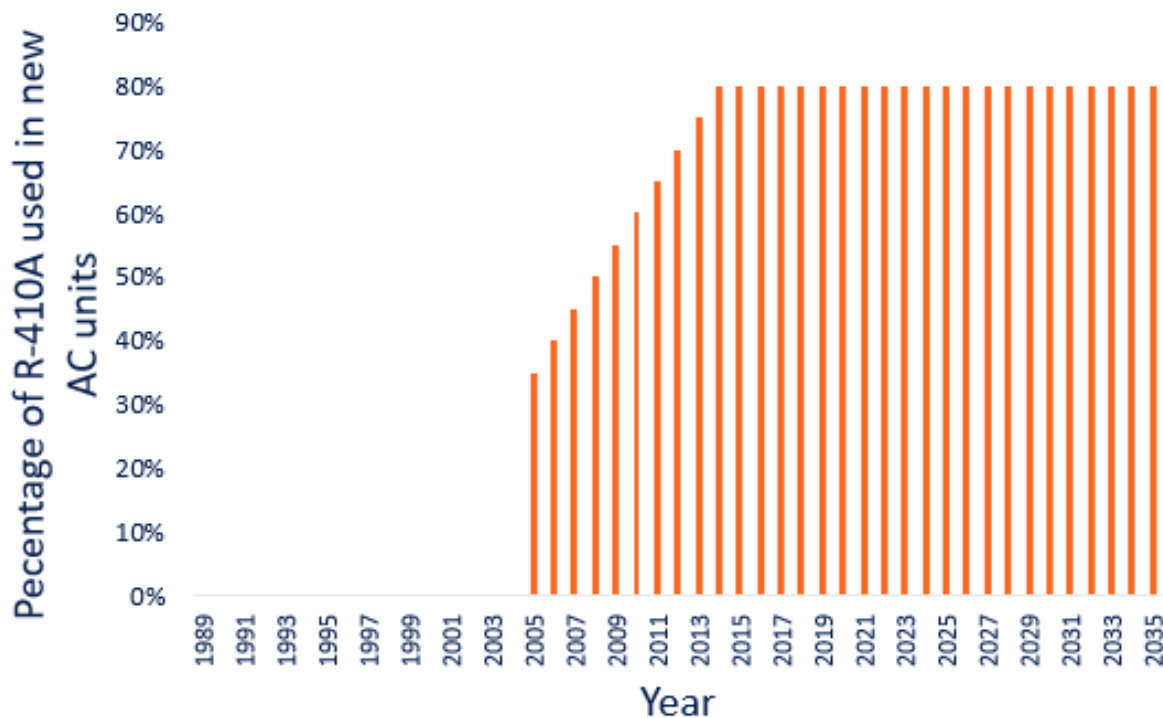
- The 2015 Residential Energy Consumption Survey (RECS) includes data on the number of 'Central air conditioning systems', 'Individual window/wall or portable units' and 'Both a central system and individual units' installed in the following age categories:
 - Less than 2 years old
 - 2 to 4 years old
 - 5 to 9 years old
 - 10 to 14 years old
 - 15 to 19 years old
 - 20 years or older (assumed to be 20 - 34 years)
- HPs are included with air conditioning units in the RECS data
- A model was developed to derive the number of AC units installed in each year from 1981 to 2030 with a constant CAGR
- A gaussian probability function for decommissioned AC units was developed to predict the future decommissioning rate of AC systems. It was essential that the same gaussian model could predict the current (2015) state of play.
- The age of installed AC units was used to estimate the volume R-410A present in AC units by assuming the proportion of R-410A used in new AC units each year (next slide)
- The charge size of R-410A in different AC units was used to calculate the bank of R-410A in existing ACs
- The consumption of R-410A through servicing was calculated from the leakage of R-410A from installed AC units
- The volume of R-410A available for reclaim was calculated by taking the charge size of AC units being decommissioned

Key assumptions

	Lifetime (years)	R-410A charge size (kg)	Annual leakage rate
Source >>	CARB	CARB	CARB
Central AC	15	3.7	5%
Individual AC	10	0.7	2%
Both*	13	2.2	3%

*All metrics for 'Both' were calculated by taking the average of Central AC and individual AC

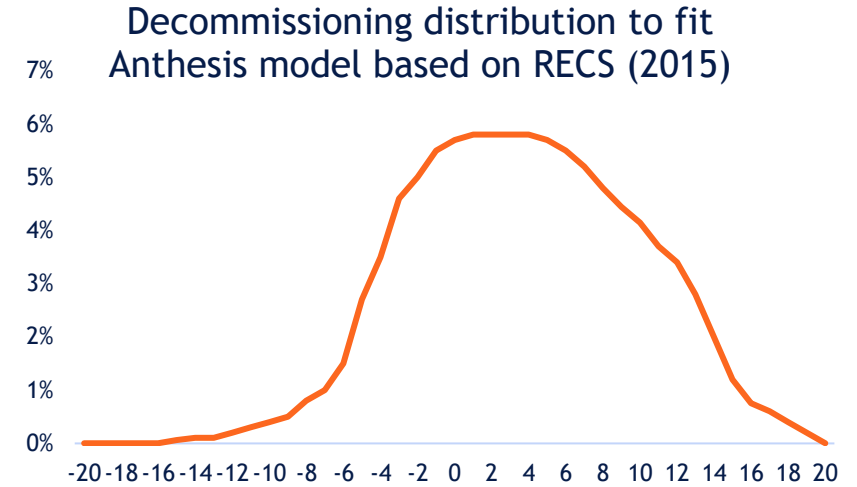
PROPORTION OF R-410A USED AS A REFRIGERANT



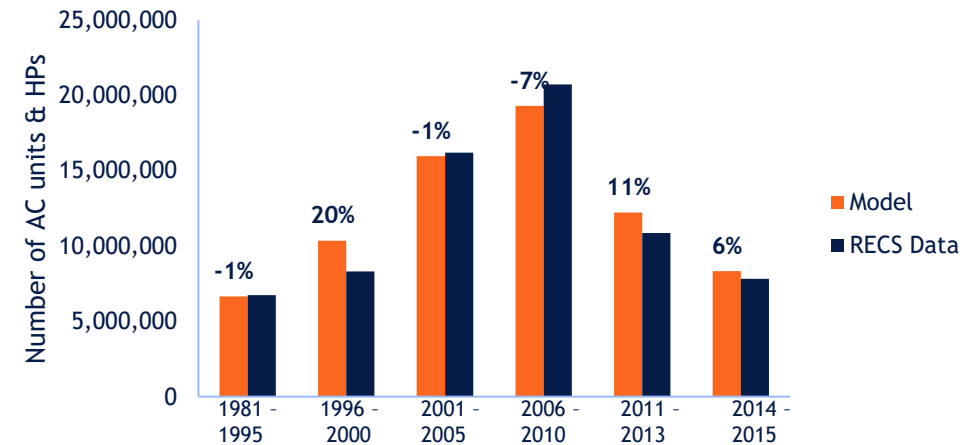
The model assumes that no R-410A was used before 2005

RESIDENTIAL CENTRAL AC SYSTEMS & INDIVIDUAL AC UNITS & HEAT PUMPS

- The decommissioning distribution function was derived through an iterative process which sought a probability function that, combined with estimates for the number of ACs & HPs installed in each year and a CAGR, could predict the 2015 AC installation numbers observed in the 2015 RECS data with the smallest error.
- The derived CAGR was 0.8%
- The RECS data did not include any information on installation dates for Individual AC units & HPs. Therefore, the distribution of Central AC systems & HPs in each age categories was applied to the Individual AC units & HPs.
 - The same decommissioning distribution model and CAGR were used for both AC & HP types

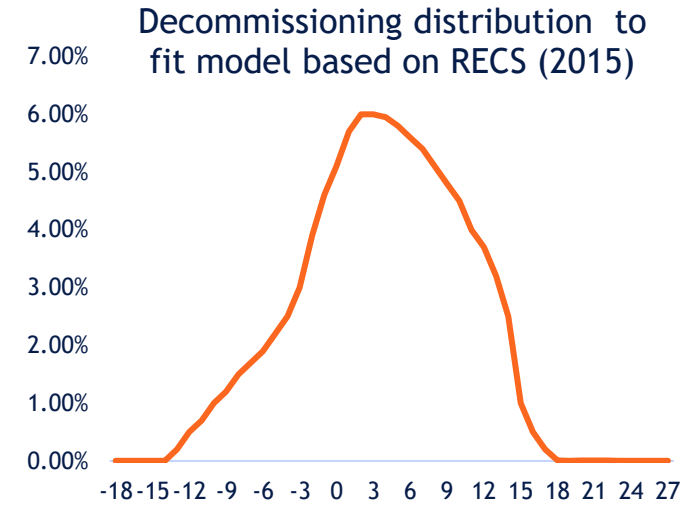


Comparison between model generated data and RECS data for 2015

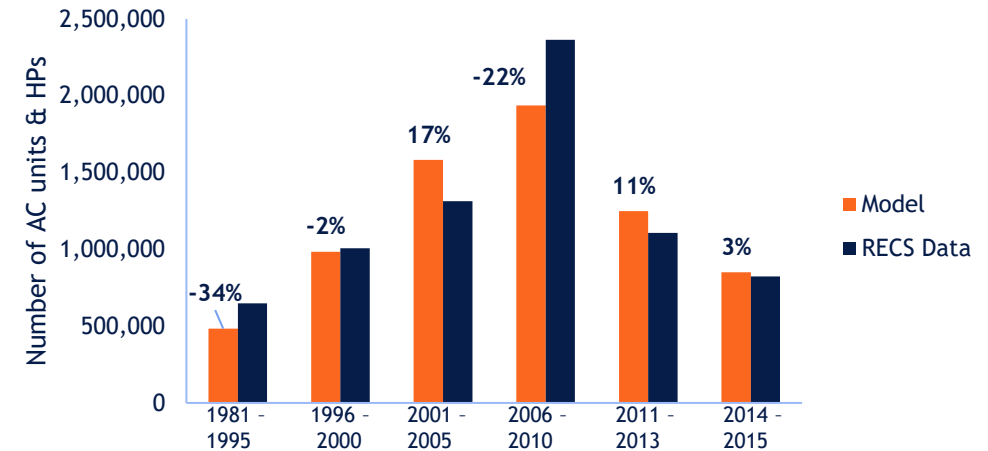


RESIDENTIAL BUILDINGS WITH BOTH CENTRAL & INDIVIDUAL UNITS

- This group represents a small proportion (6%) of the total number of ACs reported in the RECS data.
- The same methodology (previous slide) was used to derive the:
 - Decommissioning distribution
 - Number of ACs installed in any given year
 - CAGR
- Due to the large spike in number of AC units installed between 2006 and 2010, finding a decommissioning distribution and CAGR that fit the RECS data was challenging.
 - As a result, the error margins are higher for this subset of AC units
- The derived CAGR was 0.1%



Comparison between model generated data and RECS data



RESIDENTIAL

VARIANCE IN USING MODELLED VALUES FOR 2015

Overall the variance in the predicted total number of AC units for each category are within $\pm 3\%$

	Number of units in 2015 (RECS)	Modelled value of units in 2015	Percentage difference
Central air conditioning system	70,684,926	72,874,912	+3%
Individual window/wall or portable units	50,821,189	52,378,843	+3%
Both a central system and individual units	7,262,652	7,087,441	-2%

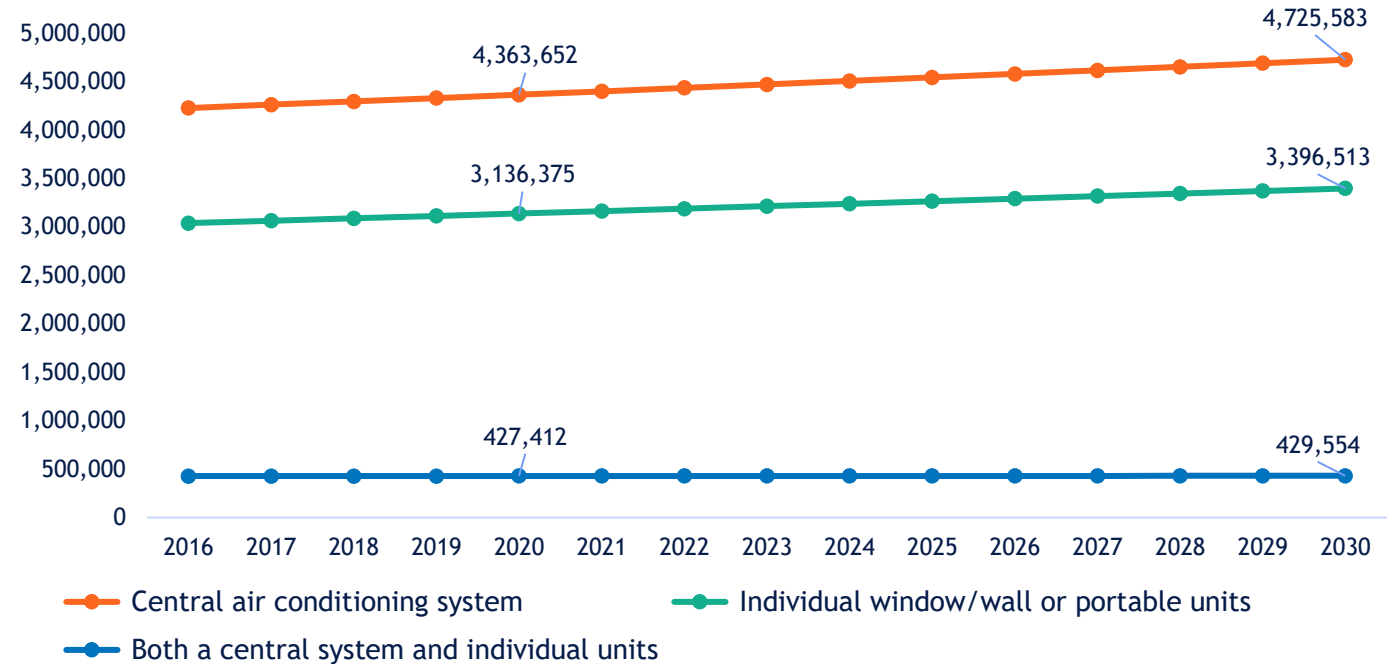
RESIDENTIAL

U.S. DEMAND FOR NEW AC UNITS

The model predicts that from 2021 to 2030 in the US:

- **45.6 million** new central AC systems will be installed
- **32.8 million** new individual AC systems will be installed
- **4.3 million** new ACs in residential buildings with both central and individual AC units will be installed

Demand for new AC units & heat pumps



RESIDENTIAL

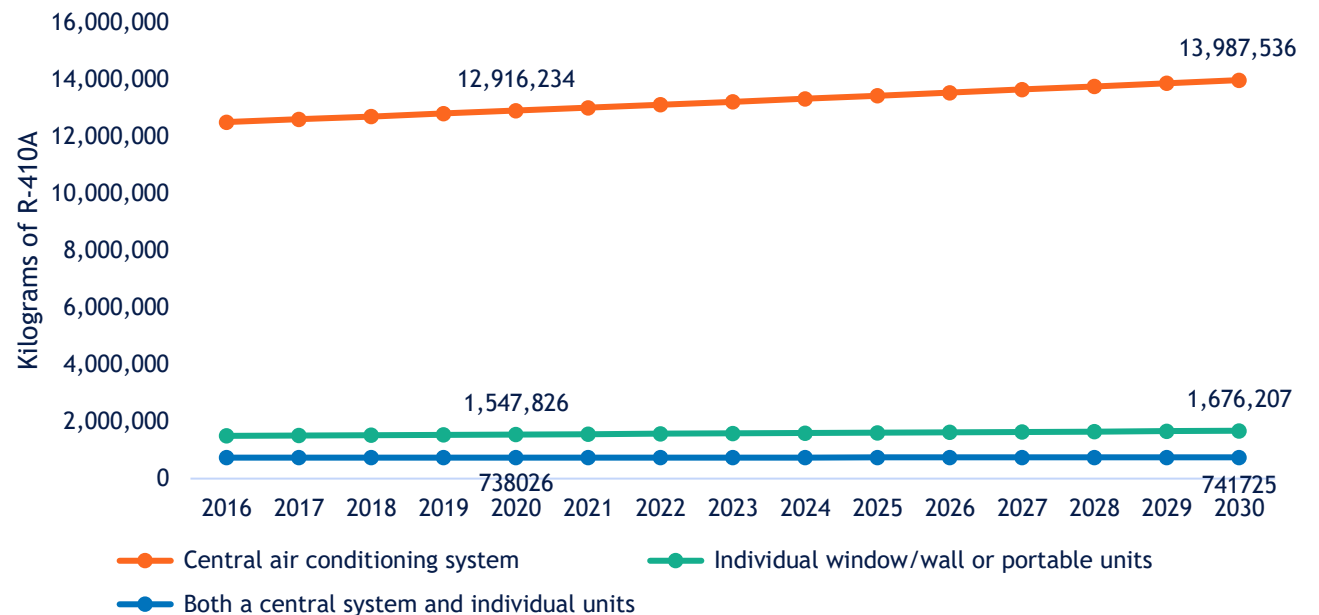
U.S. CONSUMPTION OF R-410A IN NEW AC SYSTEMS

The model predicts that from 2021 to 2030 in the US:

- 135 ktonnes of R-410A will be consumed in new central AC systems
- 16.2 ktonnes of R-410A will be consumed in new individual AC systems
- 7.4 ktonnes of R-410A will be consumed in new ACs in residential buildings with both central and individual AC units

The volume of R-410A consumed in new AC systems increases over time, in line with the CAGR for each AC type

R-410A consumed in new AC systems & heat pumps



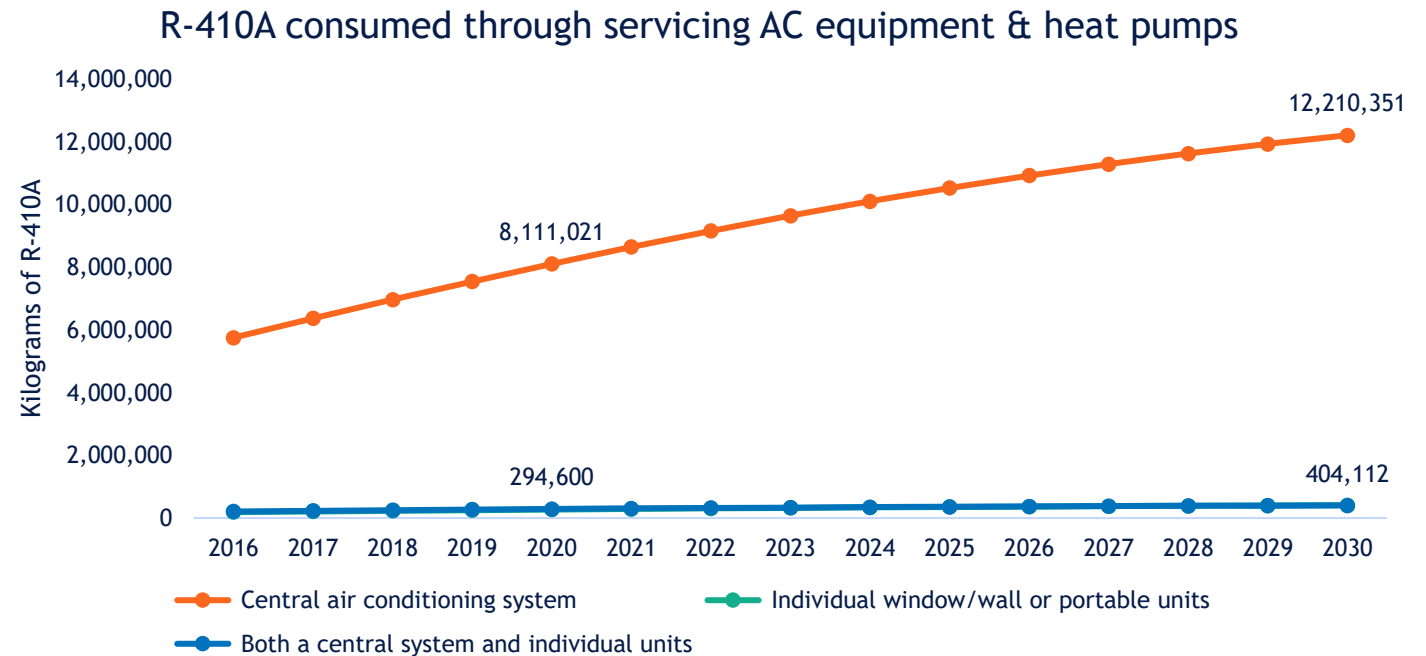
RESIDENTIAL

U.S. CONSUMPTION OF R-410A THROUGH SERVICING

Assuming a 1:1 relationship between leakage of R-410A and consumption of R-410A through servicing, the model predicts that from 2021 to 2030 in the US:

- **106.1 ktonnes** of R-410A will be consumed through servicing central AC systems
- **3.6 ktonnes** of R-410A will be consumed through servicing individual AC systems
- **3.7 ktonnes** of R-410A will be consumed through servicing AC in residential buildings with both central and individual AC units

Most R-410A is consumed through servicing central AC systems



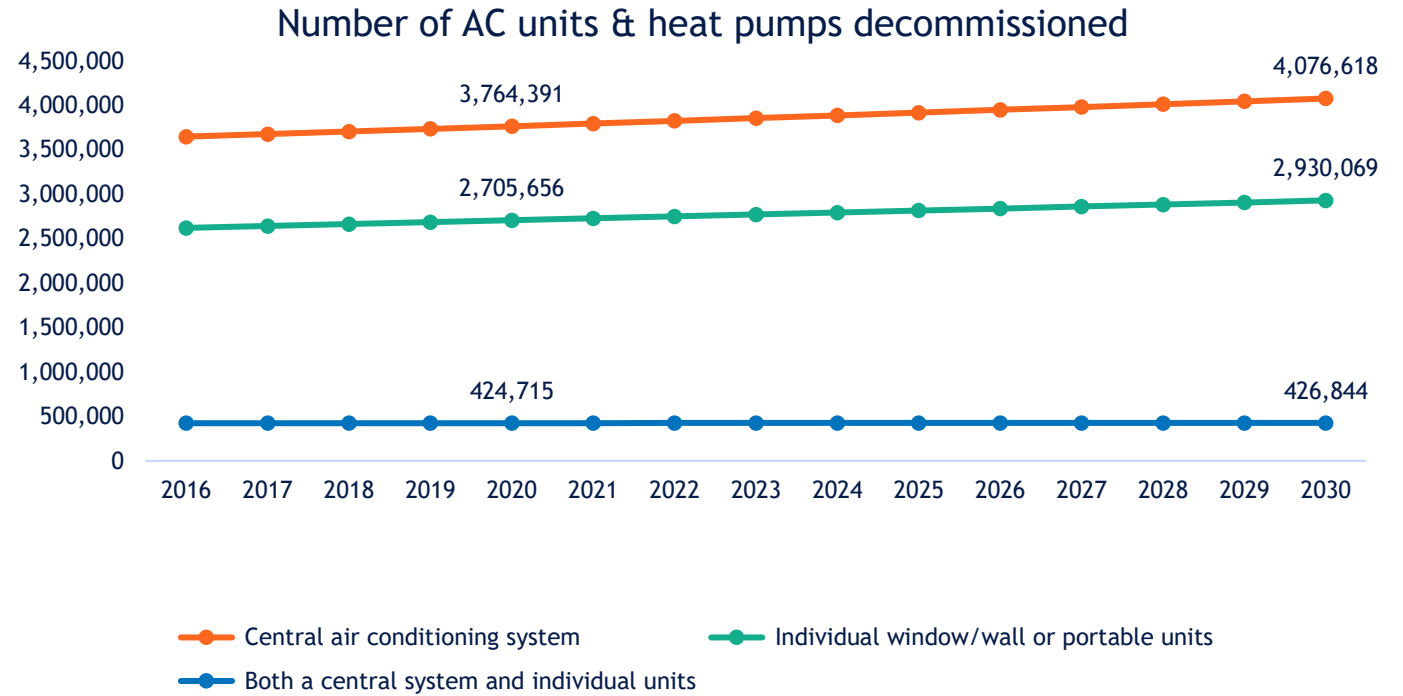
RESIDENTIAL

U.S. DECOMMISSIONED AC UNITS

The model predicts that from 2021 to 2030 in the US:

- **39.3 million** Central AC systems will be decommissioned
- **28.3 million** Individual AC units will be decommissioned
- **4.3 million** ACs in residential buildings with both central and individual AC units will be decommissioned

The number of AC units being decommissions is expected to rise in line with the CAGR



RESIDENTIAL

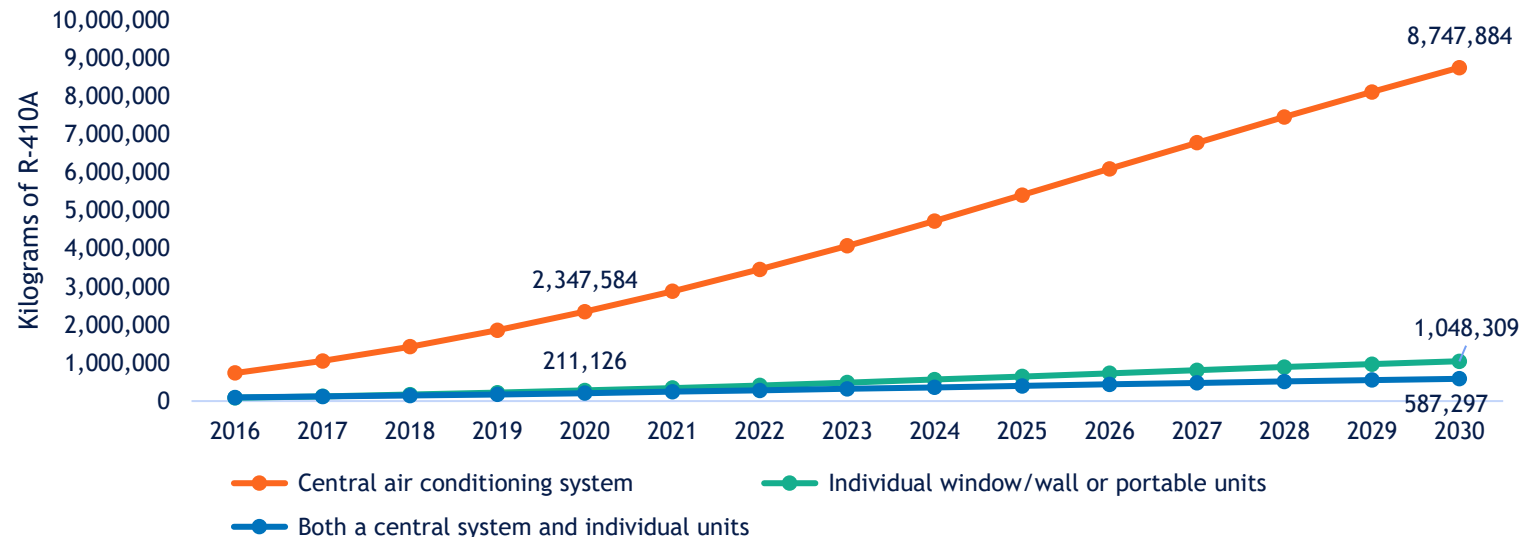
R-410A AVAILABLE FOR RECLAIM

Assuming a 100% reclamation factor, from 2021 to 2030, the model predicts that across the US:

- **57.7 ktonnes** R-410A will be available for reclaim in central AC systems
- **6.9 ktonnes** R-410A will be available for reclaim in individual AC systems
- **4.2 ktonnes** R-410A will be available for reclaim from residential buildings with both central and individual AC units

The vast majority of R-410A available for reclaim from residential buildings comes from central AC systems

R-410A available for reclaim from decommissioned AC units & heat pumps



2012

COMMERCIAL AIR CONDITIONING SYSTEMS

COMMERCIAL AC SYSTEMS & HEAT PUMPS

- The floor space in commercial buildings being cooled by different AC systems and HPs was calculated from the CBECS by multiplying the number of buildings with AC units or HPs by the building floor space which is cooled
- The floor space cooled by different AC units or HPs was converted to number of units using:
 - Cooling load (sqft/ton)
 - Required capacity (kW)
 - A utilisation factor of 70%

$$N_{2012} = \left(\frac{\text{Floorspace cooled}}{\text{Cooling load}} \right) \times \left(\frac{\text{Utilisation factor}}{\text{Refrigerant tons}} \right)$$

- The age distribution from the Central AC units in the RECS data was applied to the commercial data.
- From hereon, the commercial model worked in the same way as the residential model.

Key assumptions

	Lifetime (years)	R-410A charge size (kg)	Cooling load (sqft/ton)	Cooling capacity (kW)	Annual leakage rate
Source >>	CARB	CARB/ Industry average*	HVAC Systems Design Handbook	RTOC/ Industry average*	CARB
Air conditioner: Residential-type central	15	3.7	650	10.8	5%
Air conditioner: Individual	10	0.6	214	6.0	2%
Air conditioner: Packaged units**	20	19.3	214	553.5	9%
Heat pump cooling system: Packaged unit	20	25.2*	214	114.0*	7%
Heat pump cooling system: Split system	20	10.9*	214	114.0*	7%
Heat pump cooling system: Individual room heat pump	20	3.4*	214	27.7*	7%
Heat pump cooling system: Ductless mini-split	20	3.6*	214	12.7*	7%
Heat pump cooling system: Variable refrigerant flow	20	20.0*	214	114.0*	7%

**Packaged AC unit data was calculated by taking an average of the metrics given for the following AC types:

- From CARB data: Non-Residential AC 65kBTU-135kBTU and Non-Residential AC >135kBTU
- From RTOC data: Self-contained ducted commercial packaged rooftop

COMMERCIAL

VARIANCE IN USING MODELLED VALUES FOR 2012

Overall the variance in the predicted total number of AC units & HPs for each category are within $\pm 3\%$

	Number of units in 2012 (CBECS)	Modelled value of units in 2012	Percentage difference
Air conditioner: Residential-type central	4,661,850	4,781,753	+3%
Air conditioner: Individual	12,575,215	12,979,043	+3%
Air conditioner: Packaged units	831,469	853,884	+3%
Heat pump cooling system: Packaged unit	416,706	425,804	+2%
Heat pump cooling system: Split system	231,315	239,088	+3%
Heat pump cooling system: Individual room heat pump	671,433	680,830	+1%
Heat pump cooling system: Ductless mini-split	427,609	437,189	+2%
Heat pump cooling system: Variable refrigerant flow	38,189	38,937	+2%

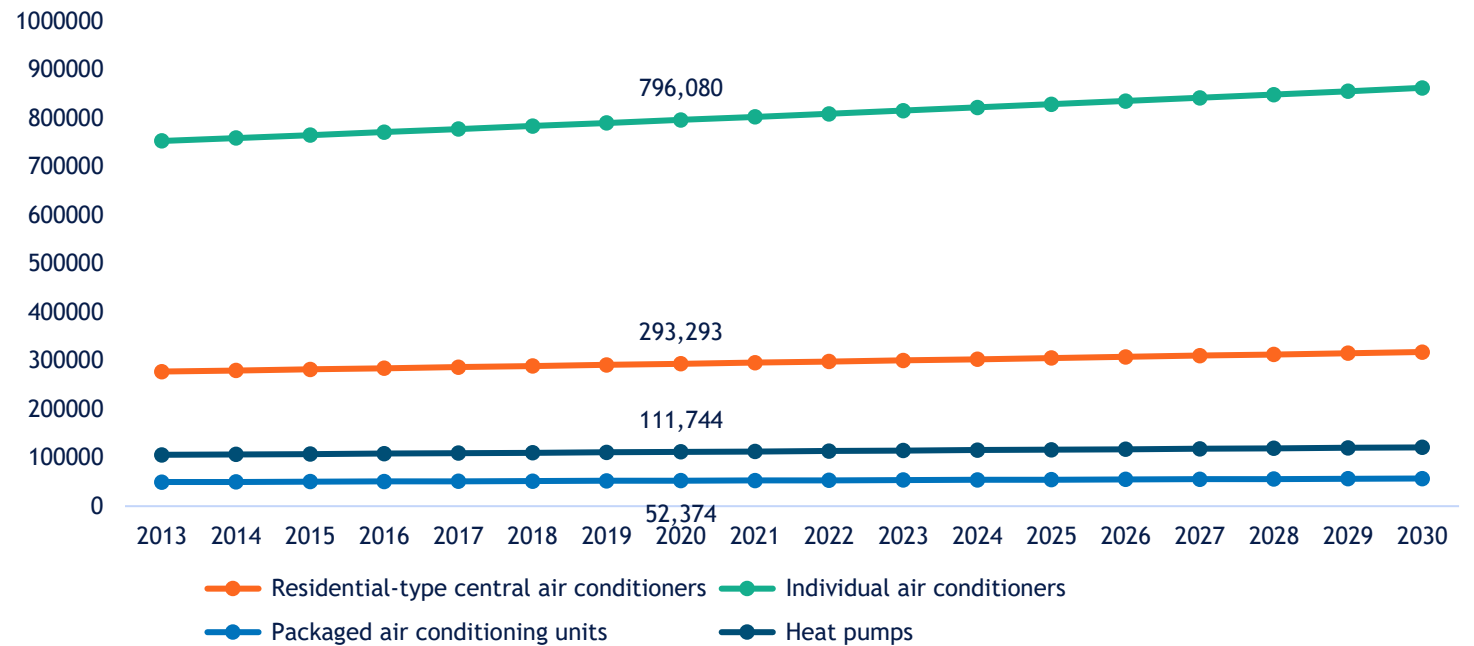
COMMERCIAL

U.S. DEMAND FOR NEW AC UNITS & HEAT PUMPS

The model predicts that from 2021 to 2030 in the US:

- **3.1 million** new central AC systems will be installed
- **8.3 million** new individual AC systems will be installed
- **0.5 million** new packaged AC systems will be installed
- **1.2 million** new HPs will be installed

Demand for new AC equipment & heat pumps



COMMERCIAL

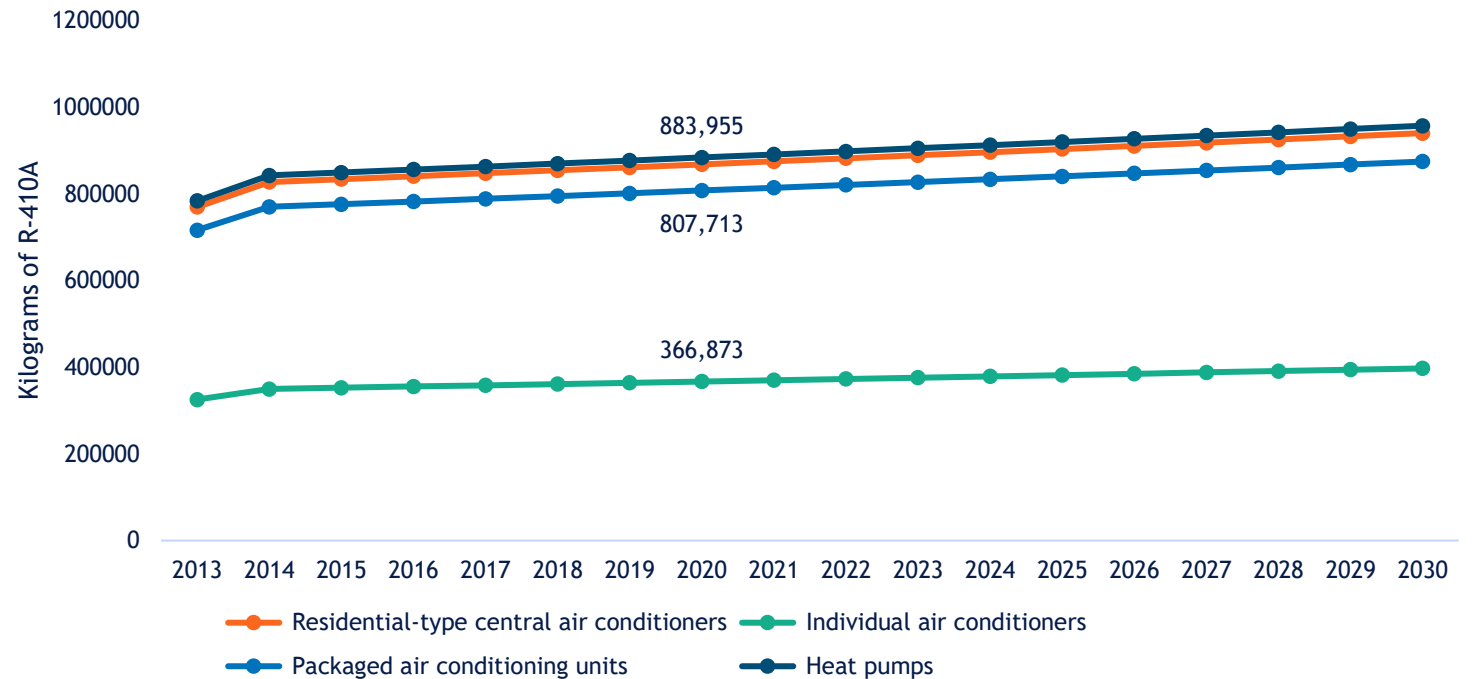
U.S. CONSUMPTION OF R-410A IN NEW AC SYSTEMS & HEAT PUMPS

The model predicts that from 2021 to 2030 in the US:

- 9.1 ktonnes of R-410A will be consumed in new central AC systems
- 3.8 ktonnes of R-410A will be consumed in new individual AC systems
- 8.4 ktonnes of R-410A will be consumed in new packaged AC systems
- 9.2 ktonnes of R-410A will be consumed in new HPs

The volume of R-410A consumed in new AC systems & HPs increases over time, in line with the CAGR for each AC type and increase in the proportion of R-410A used as a refrigerant

R-410A consumed in new AC equipment & heat pumps



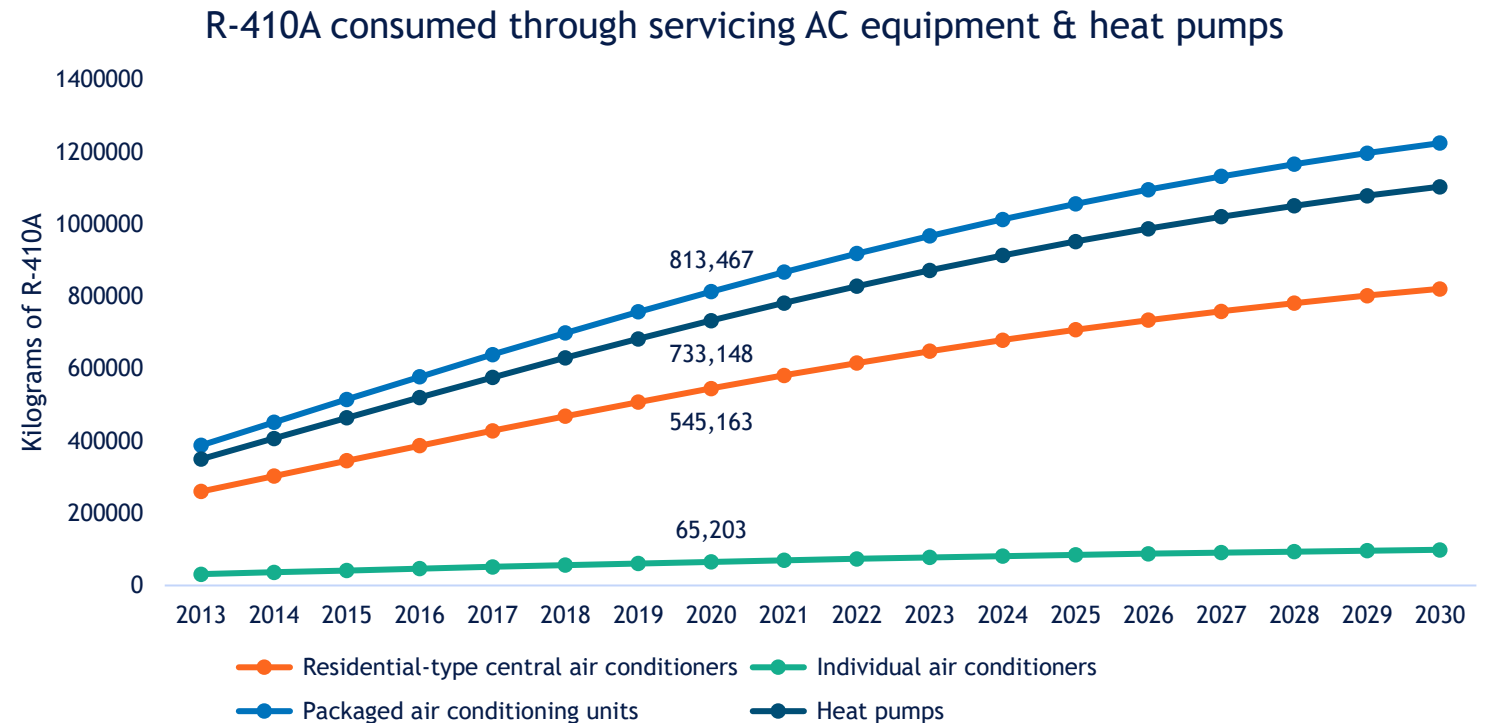
COMMERCIAL

U.S. CONSUMPTION OF R-410A THROUGH SERVICING

Assuming a 1:1 relationship between leakage of R-410A and consumption of R-410A through servicing, the model predicts that from 2021 to 2030 in the US:

- 7.1 ktonnes of R-410A will be consumed through servicing central AC systems
- 0.8 ktonnes of R-410A will be consumed through servicing individual AC systems
- 10.6 ktonnes of R-410A will be consumed through servicing packaged AC systems
- 9.6 ktonnes of R-410A will be consumed through servicing HPs

Most R-410A is consumed through servicing packaged and HPs



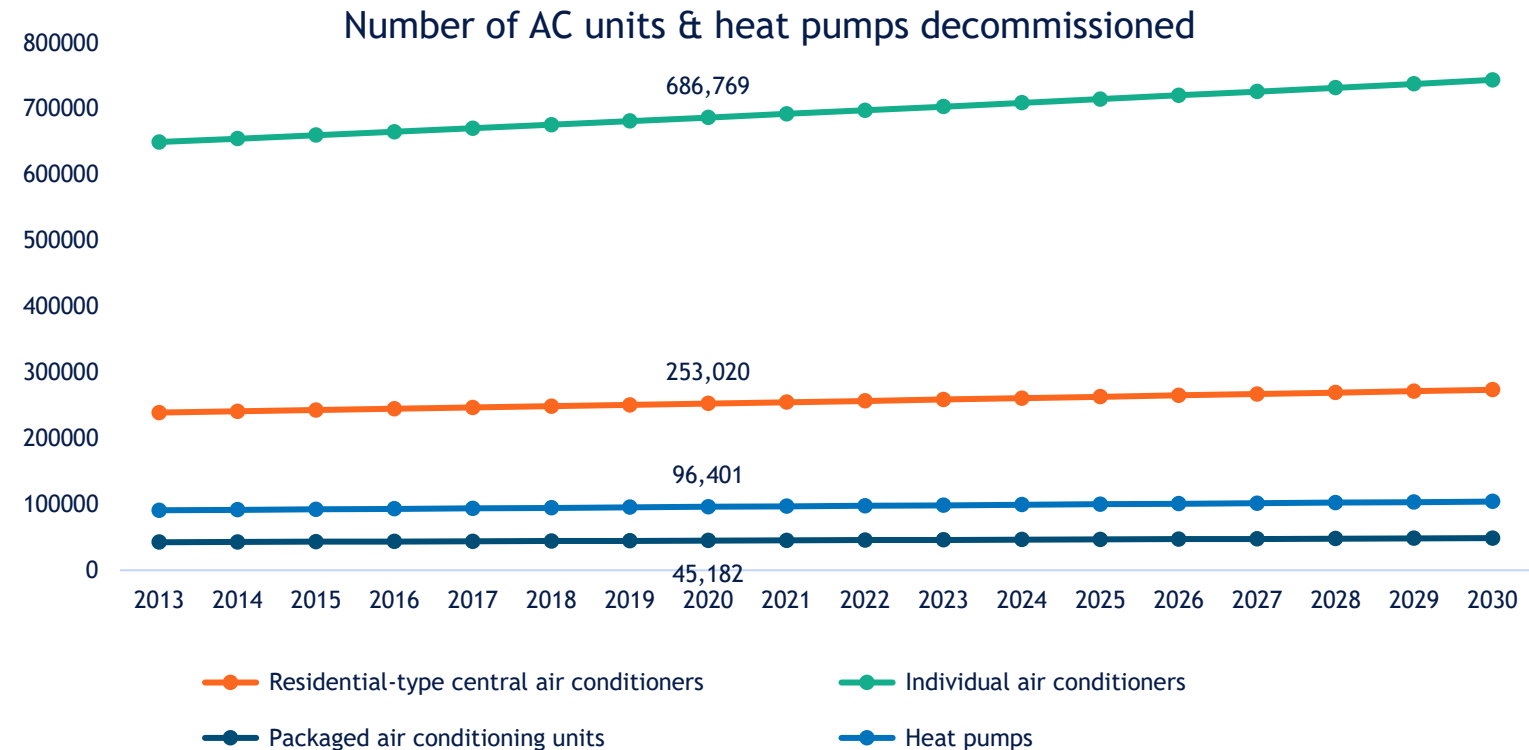
COMMERCIAL

U.S. DECOMMISSIONED AC UNITS & HEAT PUMPS

The model predicts that from 2021 to 2030 in the US:

- **2.6 million** Central AC systems will be decommissioned
- **7.2 million** Individual AC units will be decommissioned
- **0.5 million** Packaged ACs will be decommissioned
- **1.0 million** HPs will be decommissioned

The number of AC units & HPs being decommissions is expected to rise in line with the CAGR



COMMERCIAL

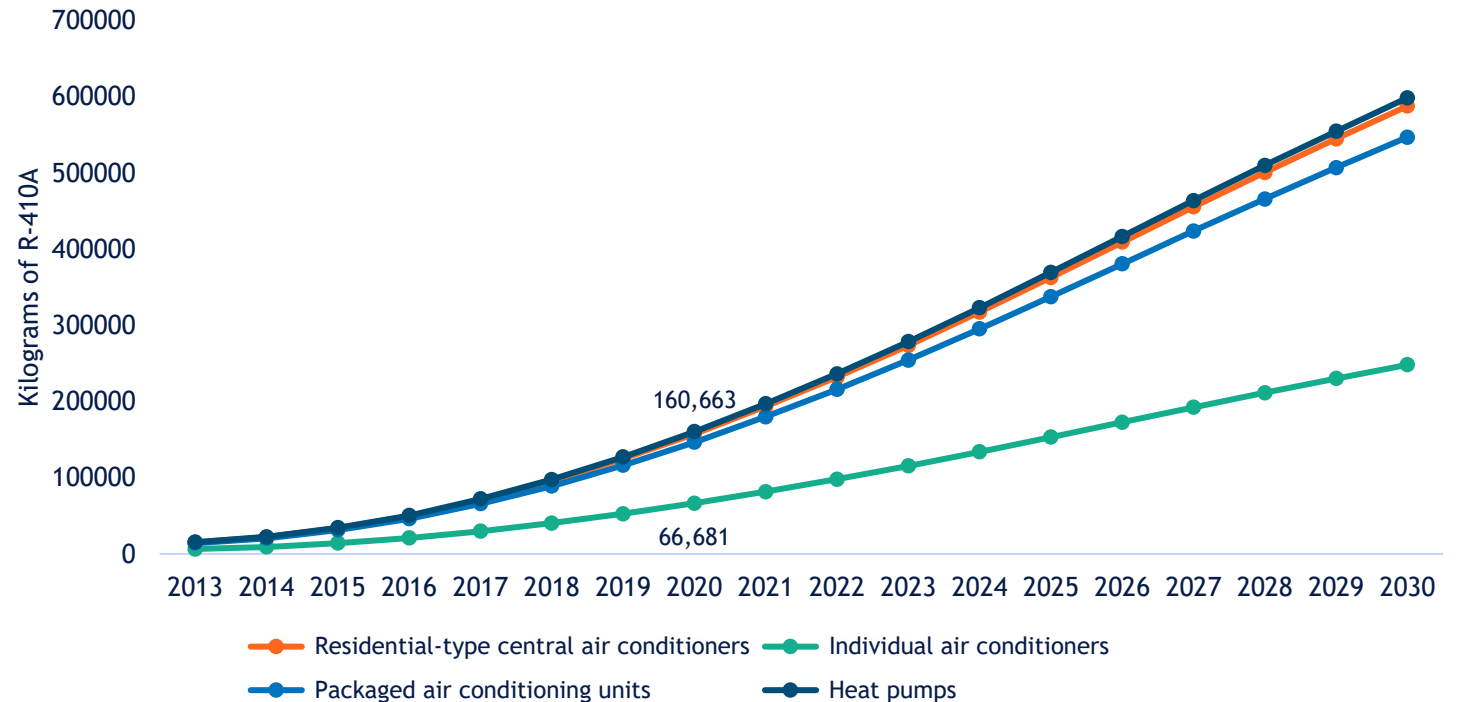
U.S. R-410A AVAILABLE FOR RECLAIM

The majority of R-410A available for reclaim from commercial buildings comes from central & packaged AC systems and HPs

R-410A available for reclaim from decommissioned AC equipment & heat pumps

Assuming a 100% reclamation factor, from 2021 to 2030, the model predicts that across the US:

- 3.9 ktonnes R-410A will be available for reclaim in central AC systems
- 1.6 ktonnes R-410A will be available for reclaim in individual AC systems
- 3.6 ktonnes R-410A will be available for reclaim from packaged AC systems
- 4.0 ktonnes R-410A will be available for reclaim from HPs



National-level & Pacific region

R-410A RECLAIM

COMMERCIAL & RESIDENTIAL

U.S. & PACIFIC R-410A AVAILABLE FOR RECLAIM

		INCLUDING INDIVIDUAL ACS & HPS		EXCLUDING INDIVIDUAL ACS & HPS	
		Using CARB charge sizes	Using industry average charge sizes	Using CARB charge sizes	Using industry average charge sizes
NATIONAL	2020 R-410A available (ktonnes)	3.4	5.3	3.0	4.9
	2030 R-410A available (ktonnes)	12.4	19.1	11.0	17.5
	2021 - 2030 R-410A available (ktonnes)	81.9	126.6	72.8	116.6
PACIFIC	2020 R-410A available (ktonnes)	0.4	0.6	0.4	0.5
	2030 R-410A available (ktonnes)	1.4	2.0	1.3	1.9
	2021 - 2030 R-410A available (ktonnes)	9.3	13.5	8.5	12.5

MATCHING RECS & CBECS EQUIPMENT CATEGORIES TO CARB DATA

RECS equipment category	CBECS equipment category	CARB SRIA equipment category	Baseline refrigerant	Lifetime	Average charge size (lbs)	Average charge size (kg)	Average annual leak rate (%)	End of life leak rate (%)
Individual AC units	Individual AC units	Room AC - window/wall	R-410A; R-32	12	2	1	2%	99%
		Room AC - portable	R-410A; R-32	10	2	1	1%	99%
		Room AC - PTAC/PTHP	R-410A; R-32	12	1	0.5	2%	99%
		Room AC - dehumidifiers	R-410A	5	1	0.5	1%	99%
Central AC system	Residential-type central AC systems	Residential AC	R-410A	15	8	4	5%	80%
N/A	Packaged AC systems	Non-Residential AC 65kBTU-135kBTU	R-410A	20	25	11	10%	56%
		Non-Residential AC >135kBTU	R-410A	20	60	27	7%	20%

MATCHING CBECS EQUIPMENT CATEGORIES TO OTHER SOURCES

CBECS equipment category	RTOC UN Report equipment category	Average capacity range (kW)
Individual AC units	Small self-contained window	6
	Small self-contained portable	
	Small self-contained through-the-wall	
	Small self-contained packaged terminal	
Residential-type central AC systems	Remote ducted split	11
Packaged AC systems	Self-contained ducted commercial packaged rooftop	554
N/A	Remote ducted commercial split	555
	Remote non-ducted split	9
	Remote non-ducted and ducted multi-split	152

CBECS equipment category	HVAC Systems Design Handbook Building type	Average cooling load (sqft/ton)
Residential-type central AC systems	Residence	650
Packaged AC systems & Individual AC units & Heat pumps	Classroom	225
	General office	325
	Conference room	150
	Clean room	200
	Hospital patient room	325
	Arenas, etc.	175
	Hotel meeting room	225
	Data processing room	90