



Oct 19
2017







Newly Developed Refrigerants for Refrigeration, meeting Global Warming Regulations

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What is DAIKIN

Sales Breakdown by Division

Total 2,044 billion yen (fiscal 2016:consolidated)

| | | | |
|--|------------------|---|--|
| Air Conditioning and Refrigeration Business | 1,835.4 (90%) |  次世代エアコン うるさら7 |  |
| Chemicals Business | 156.8 (8%) |  |  |
| Other (Oil Hydraulics, Defense Systems, etc.) | 51.8 (2%) |  |  呼吸調整器 ライトテックDS13 融剤回収装置 ライトテック-3X |

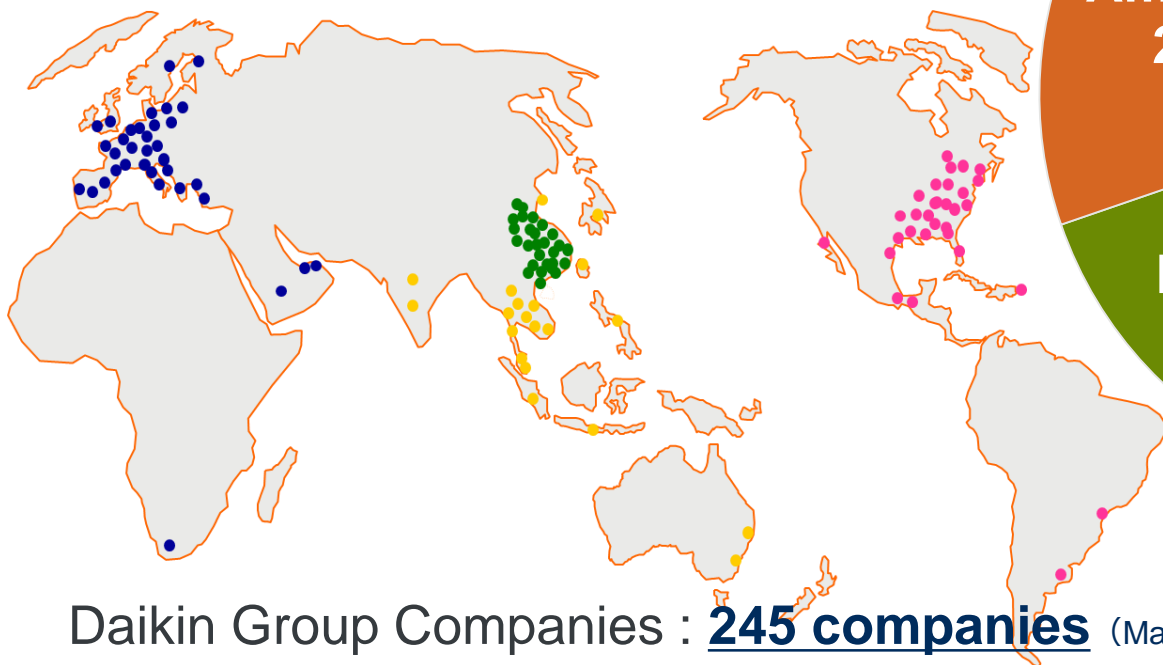
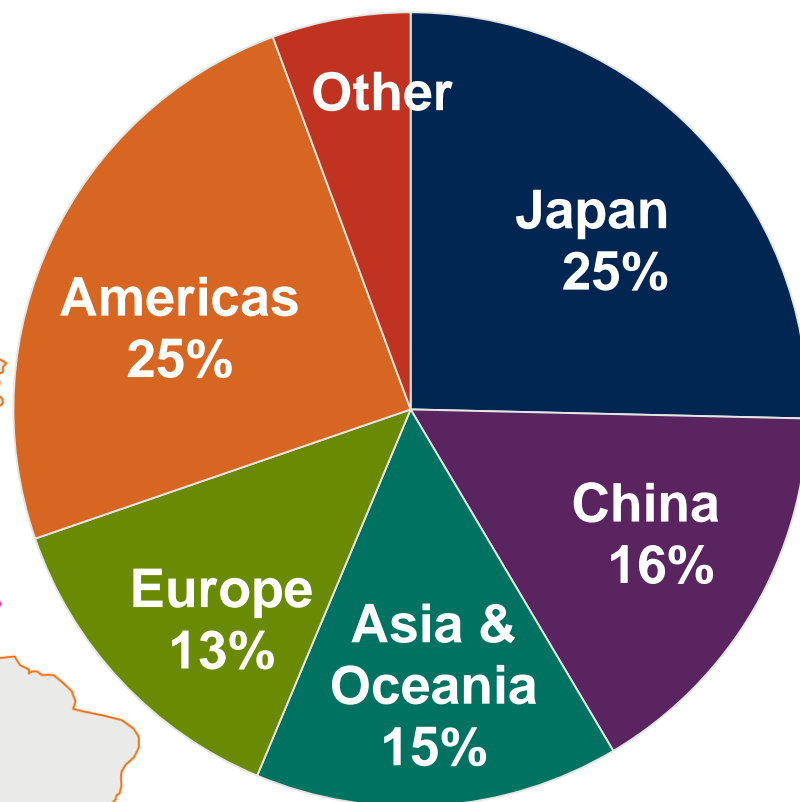
Sales Breakdown by Global Region

Ratio of Overseas Sales 75% (fiscal 2016:consolidated)

(billion yen)

Japan 518.5 (25%)

Overseas 1,525.5 (75%)



What is Fluorocarbon

What is Fluorocarbon ?

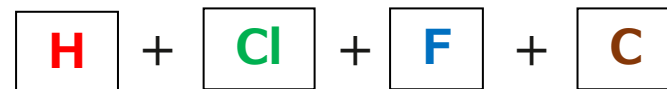
Fluorocarbon

Fluorocarbon is a chemical compound part or all of whose hydrogen of hydrocarbon including methane, ethane and propane were replaced with fluorine (sometimes involving chlorine or other halogens).

CFC (Chloro fluoro carbon)



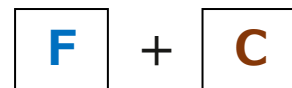
HCFC (Hydro chloro fluoro carbon)



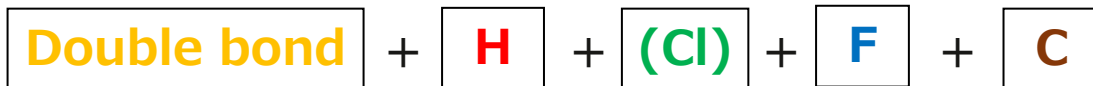
HFC (Hydro fluoro carbon)



PFC (Per fluoro carbon)



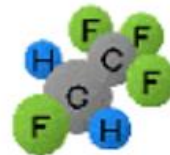
HFO (Hydro fluoro olefin)



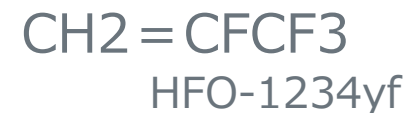
CFC-12



HCFC-22

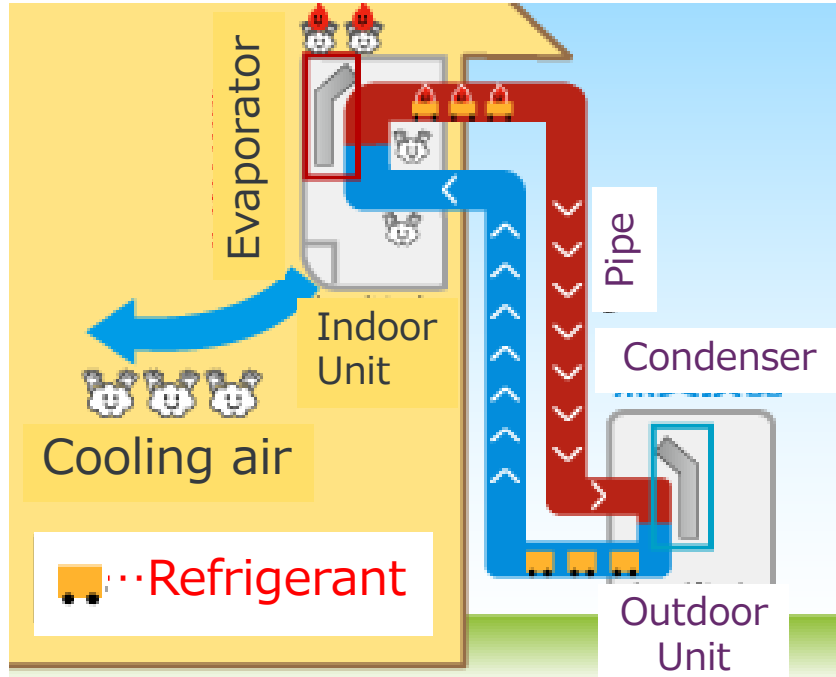


HFC-134a



What is Fluorocarbon ?

Fluorocarbon



- Clear and non-smelled gas
- High stability
- Non corrosive
- Non flammable
or Slightly flammable
- Low toxic
- Easier to evaporate



Fluorocarbon is suitable
for refrigerant



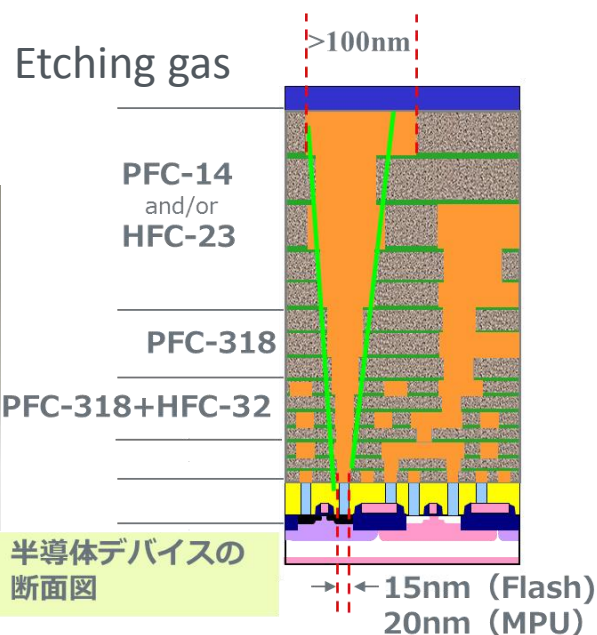
What is Fluorocarbon ?

Applications of fluorocarbon

| | |
|-------------------|---|
| 1) Refrigerant | Air-conditioning, Mobile air conditioning, Commercial/Industrial refrigerator, etc... |
| 2) foaming agents | Heat insulating materials, etc... |
| 3) Solvent | Cleaning agent, Solvent, etc... |
| 4) Blowing agent | Dust blower, Aerosol |
| 5) Others | Fire extinguisher, Etching gas, etc... |



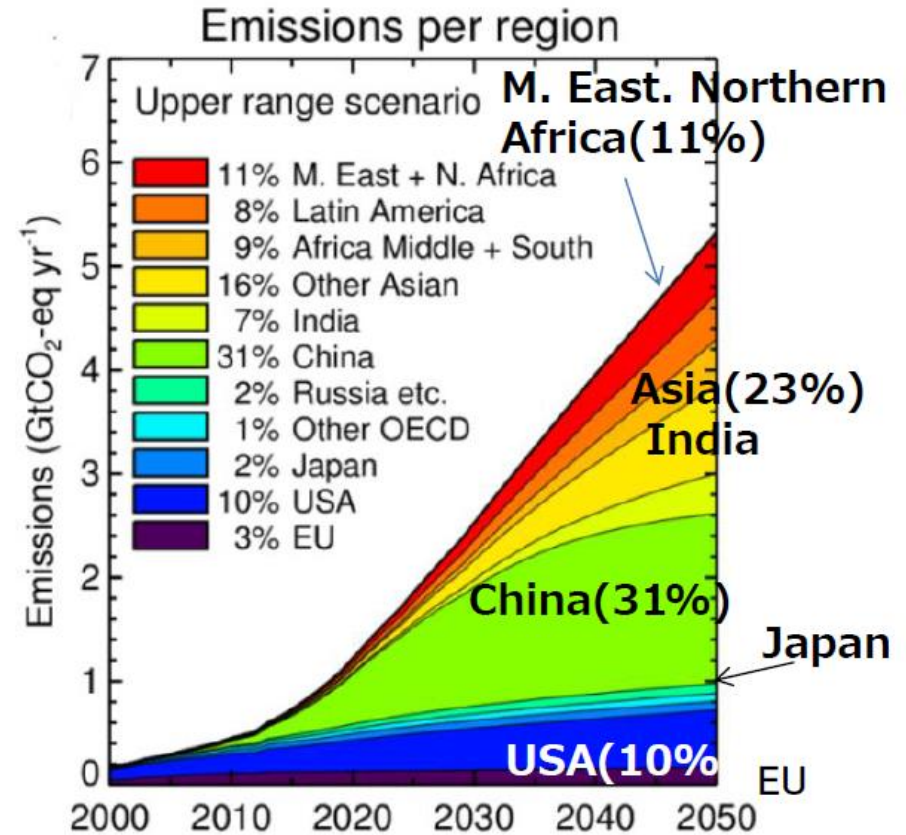
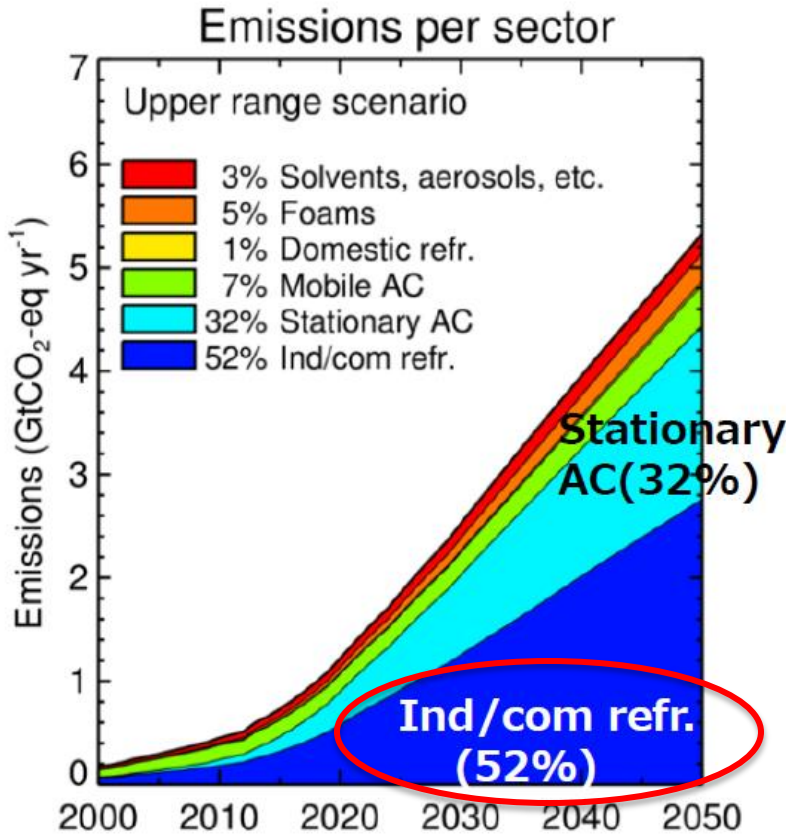
Refrigerant



Blower
HFC-227

Environmental Regulations

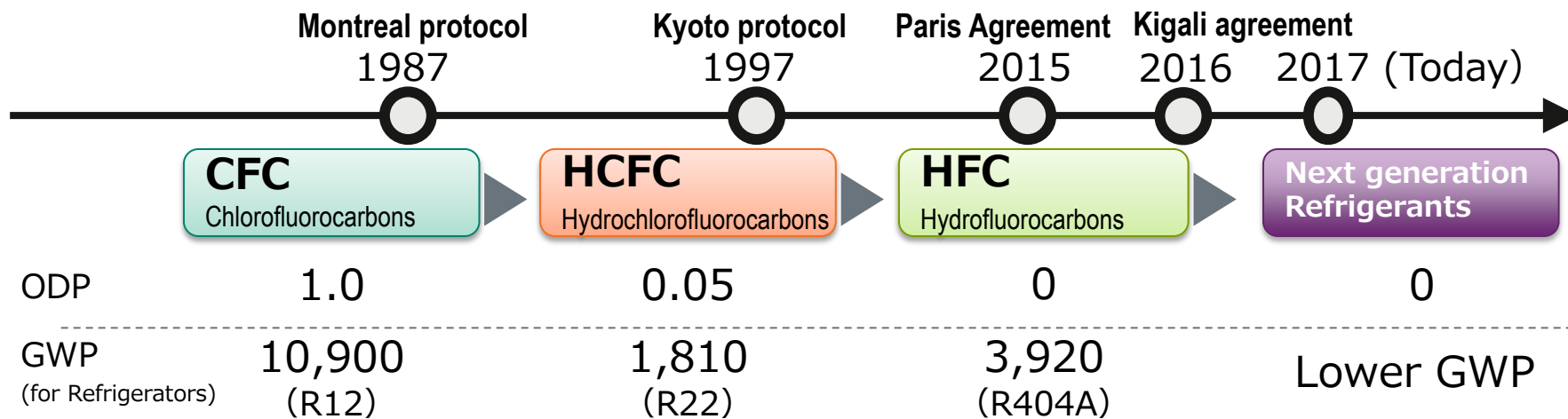
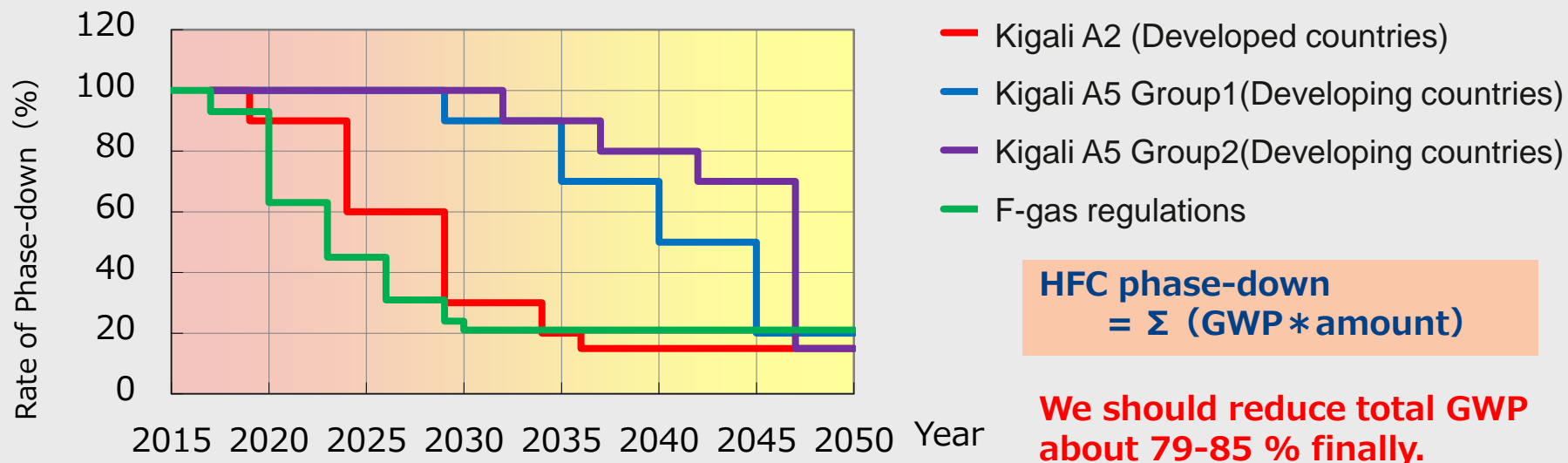
- Worldwide HFC emissions are increasing as replacements of ozone depleting CFCs and HCFCs
- HFC emissions could reach 5 GtCO₂ yr in 2050(BAU)



Source : Future atmospheric abundances and climate forcing from scenarios of global and regional HFC emissions, Velders et al., October 2015

1) Regulations of HFC phase-down

HFC Phase Down and F-gas regulations



2. The limit of GWP for each applications

◆EU (F-gas regulations) : HFC phase-down and the limit of GWP

| Applications | GWP | Start |
|--|-----------------------------------|-------------------------|
| Commercial fridge & freezers | GWP<2500 GWP<150 | 2020/1/1 ~ 2022/1/1~ |
| Stationary refrigeration (Except under -50°C) | GWP<2500 | 2020/1/1 ~ |
| Commercial Multipack centralised refrigeration | GWP<150 (or cascade < GWP1500) | 2022/1/1~ |

◆The Japanese Act on Rational Use and Proper Management of Fluorocarbons

| Applications (RETAIL FOOD REFRIGERATION) | GWP | Start |
|---|----------|-----------|
| Condensing unit and Stationary refrigeration unit | GWP<1500 | 2025/4/1~ |

◆ **USA (SNAP)** : Various HFCs will be unlisted in various end-uses.

| End-Uses (RETAIL FOOD REFRIGERATION) | | Substitutes | Decision |
|--------------------------------------|--|---|--------------------------|
| New | Supermarket Systems | R404A, R507A , R407B, R421B, R422A, R422C, R422D, R428A, R434A, HFC227ea | 2017/1/1 ~ |
| | Remote Condensing Units | | 2018/1/1 ~ |
| | Stand-Alone Equipment Medium Temp. < 2200 Btu/hr Medium Temp. ≥ 2200 Btu/hr Low Temp. | R410A, R407C, R407F etc... are contained in Stand-Alone equipment | 2019/1/1 ~ |
| | | | 2020/1/1 ~ 2020/1/1 ~ |
| | Vending Machines | R134a, R404A, R507A etc... | 2019/1/1 ~ |
| Retrofit | Supermarket Systems Remote Condensing Units | R404A, R507A , R407B, R421B, R422A R422C, R422D, R428A, R434A | 2016/7/20~ |
| | Vending Machines, Stand-Alone Equipment | R404A, R507A | |

The points for selecting refrigerants

We have to assess four key factors when making the best balanced refrigerant choice for each application.

Must be safe through entire lifecycle (transport, install, use, servicing, recovery)



Safety

Must be non-ODS and lower global warming impact including the potential to be recycle



Environmental Impact



Energy Efficiency



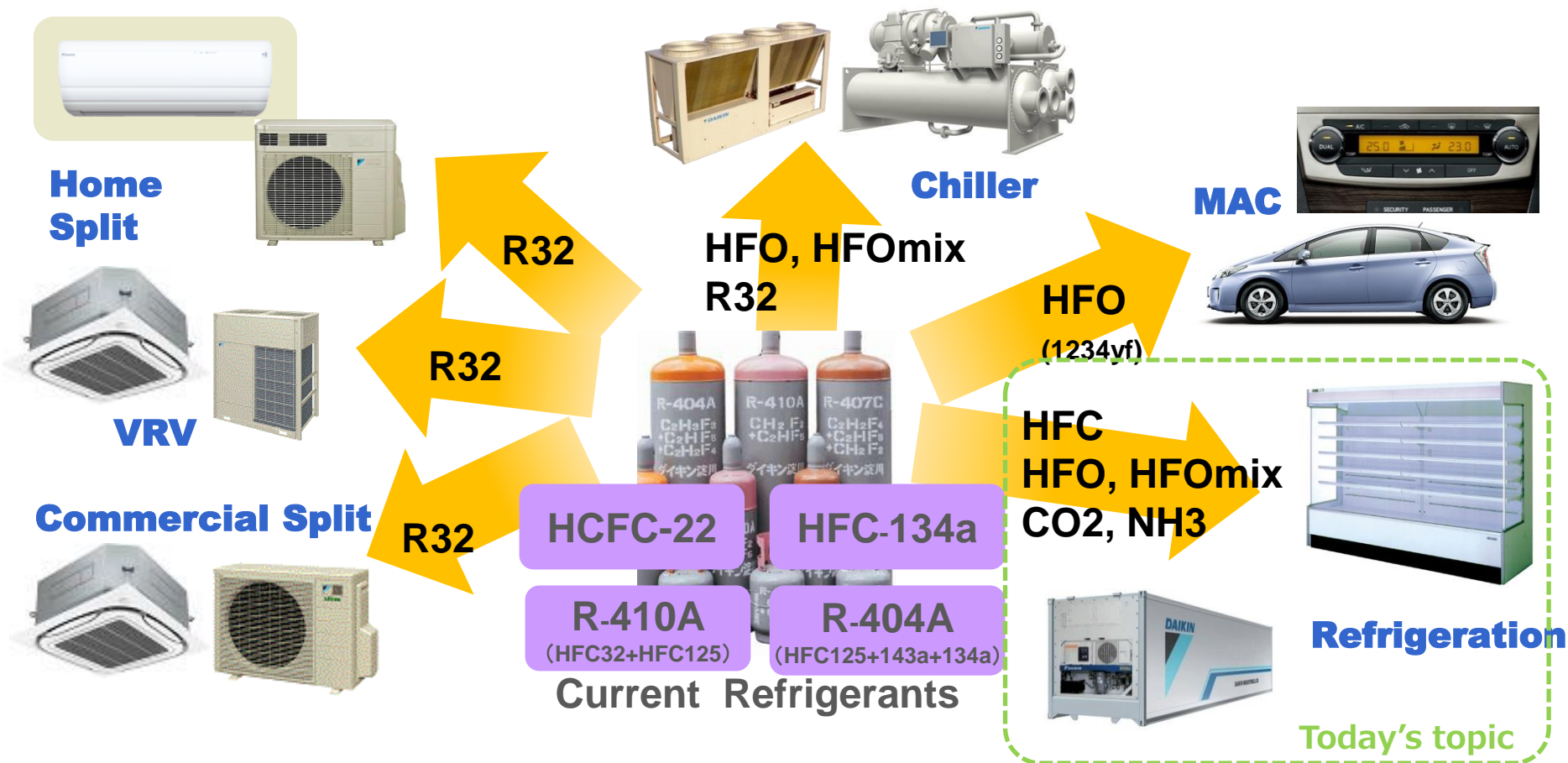
Cost-Effectiveness

Is a critical consideration , both in seasonal efficiency as well as in peak periods.

Is important to provide consumers access to affordable solutions for their homes and business

Next Generation Refrigerants

- There is **NO one-size-fits-all solution**.
- We should select a refrigerant which is most suitable for each application and area.



New Refrigerants approved by ASHRAE (2013~)

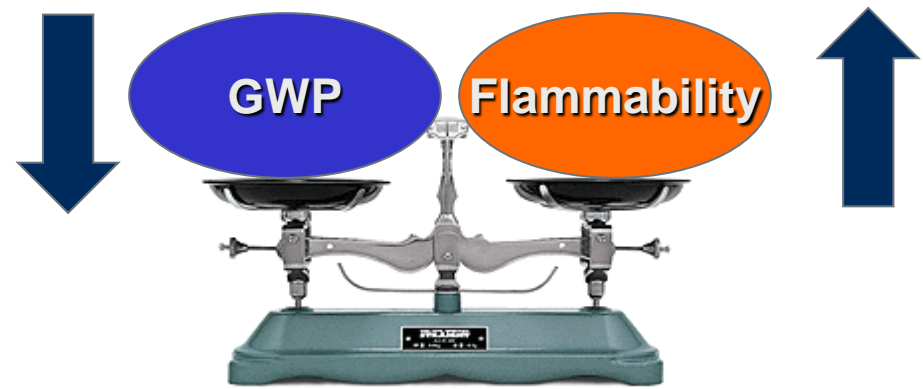
| Name | Composition | mass % | Class | GWP |
|-------------|--------------------------------|----------------------------|-------|------|
| 407G | R-32/125/134a | 2.5/2.5/95.0 | A1 | 1463 |
| 407H | R-32/125/134a | 32.5/15.0/52.5 | A1 | 1495 |
| 444B | R-32/152a/1234ze(E) | 41.5/10.0/48.5 | A2L | 295 |
| 445A | R-744/134a/1234ze(E) | 6.0/9.0/85.0 | A2L | 134 |
| 446A | R-32/1234ze(E)/600 | 68.0/29.0/3.0 | A2L | 461 |
| 447A | R-32/125/1234ze(E) | 68.0/3.5/28.5 | A2L | 583 |
| 447B | R-32/125/1234ze(E) | 68.0/8.0/24.0 | A2L | 740 |
| 448A | R-32/125/1234yf/134a/1234ze(E) | 26.0/26.0/20.0/21.0/7.0 | A1 | 1390 |
| 449A | R-32/125/1234yf/134a | 24.3/24.7/25.3/25.7 | A1 | 1400 |
| 449B | R-32/125/1234yf/134a | 25.2/24.3/23.2/27.3 | A1 | 1412 |
| 449C | R-32/125/1234yf/134a | 20.0/20.0/31.0/29.0 | A1 | 1251 |
| 450A | R-134a /R-1234ze(E) | 42.0/58.0 | A1 | 604 |
| 451A | 1234yf/134a | 89.8/10.2 | A2L | 149 |
| 451B | 1234yf/134a | 88.8/11.2 | A2L | 164 |
| 452A | 32/125/1234yf | 11.0/59.0/30.0 | A1 | 2140 |
| 452B | 32/125/1234yf | 67.0/7.0/26.0 | A2L | 698 |
| 452C | 32/125/1234yf | 12.5/61/26.5 | A1 | 2220 |
| 453A | R-32/125/134a/227ea/600/601a | 20.0/20.0/53.8/5.0/0.6/0.6 | A1 | 1765 |
| 454A | R-32/1234yf | 35.0/65.0 | A2L | 239 |
| 454B | R-32/1234yf | 68.9/31.1 | A2L | 466 |
| 454C | R-32/1234yf | 21.5/78.5 | A2L | 148 |
| 455A | R-744/32/1234yf | 3.0/21.5/75.5 | A2L | 148 |
| 456A | R32/R134a/R1234ze(E) | 6/45/49 | A1 | 687 |
| 457A | R32/R1234yf/R152a | 18/70/12 | A2L | 139 |
| 458A | R32/R125/R134a/R227ea/R236fa | 20.5/4.0/61.4/13.5/0.6 | A1 | 1650 |
| 459A | R32/R1234yf/R1234ze(E) | 68/26/6 | A2L | 460 |
| 459B | R32/R1234yf/R1234ze(E) | 21/69/10 | A2L | 145 |
| 460A | R32/R125/R134a/R1234ze(E) | 12/52/14/22 | A1 | 2103 |
| 460B | R32/R125/R134a/R1234ze(E) | 28/25/20/27 | A1 | 1352 |
| 461A | R125/R143a/R134a/R227ea/R600a | 55.0/5.0/32.0/5.0/3.0 | A1 | 3588 |
| 462A | R32/R125/R143a/R134a/R600 | 9.0/42.0/2.0/44.0/3.0 | A2 | 2249 |
| 513A | 1234yf/134a | 56.0/44.0 | A1 | 631 |
| 513B | 1234yf/134a | 58.5/41.5 | A1 | 596 |
| 514A | R1336mzz(Z)/R1130(E) | 74.7/25.3 | B1 | 7 |
| 515A | R1234ze(E)/R227ea | 88.0/12.0 | A1 | 393 |
| R516A | R1234yf/R134a/R152a | 77.5/8.5/14.0 | A2L | 142 |
| R1233zd(E) | R1233zd(E) | 100 | A1 | 5 |
| R1234yf | R1234yf | 100 | A2L | 4 |
| R1234ze(E) | R1234ze(E) | 100 | A2L | 6 |
| R1336mzz(E) | R1336mzz(E) | 100 | A1 | 32 |
| R1336mzz(Z) | R1336mzz(Z) | 100 | A1 | 9 |
| R1132a | R1132a | 100 | A2 | <1 |
| R1224yd(Z) | R1224yd(Z) | 100 | A1 | <1 |

ASHRAE Safety class

- A** -Low toxic
- B** -High toxic
- 1** - Non flammable
- 2L** - Slightly flammable
- 2** -Flammable
- 3** -Higher flammable

Flammability of 2L Refrigerants

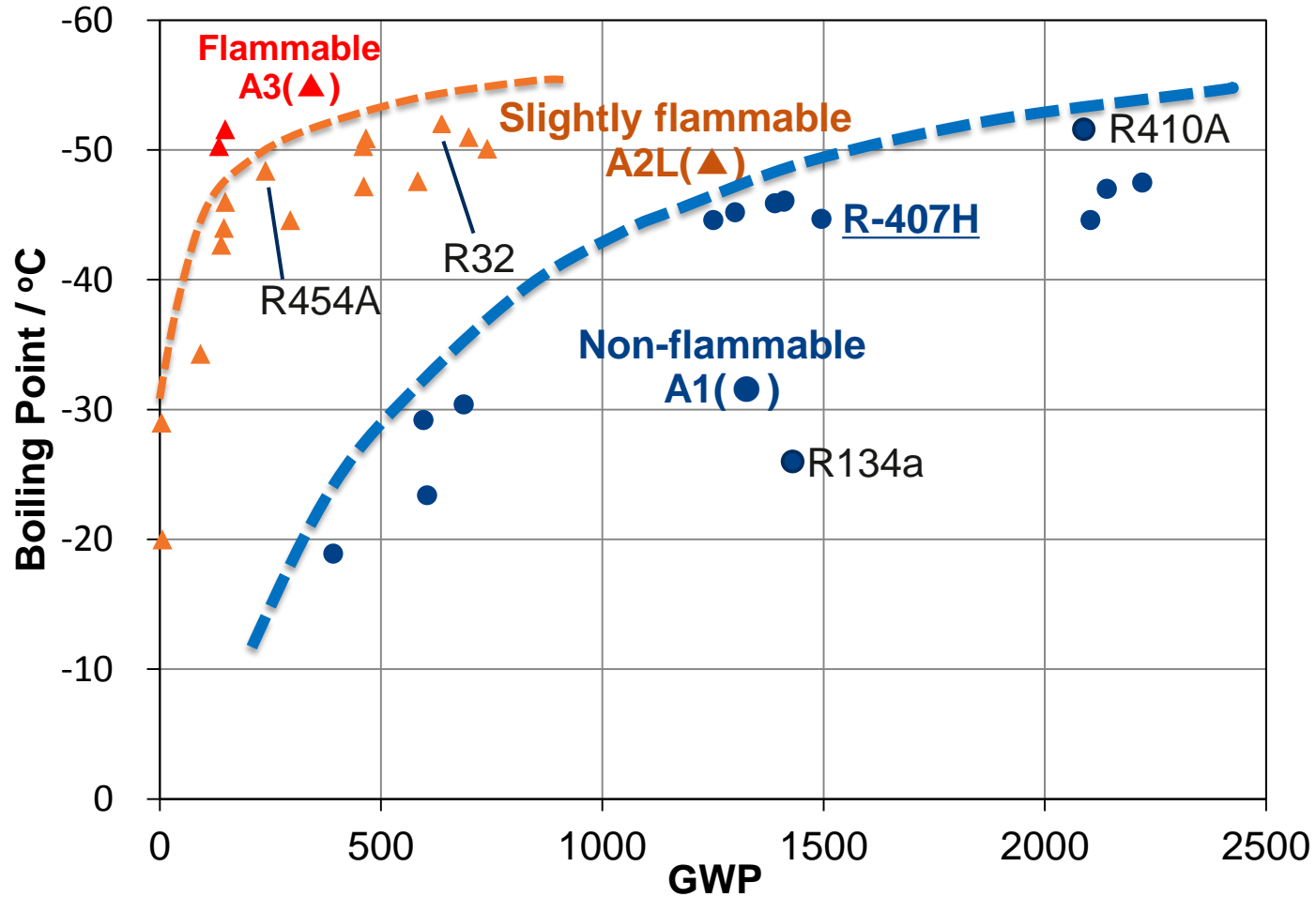
- **Trade off** relation between **GWP** and **Flammability**
- Unavoidable physical and chemical phenomena



2L classification by ASHRAE

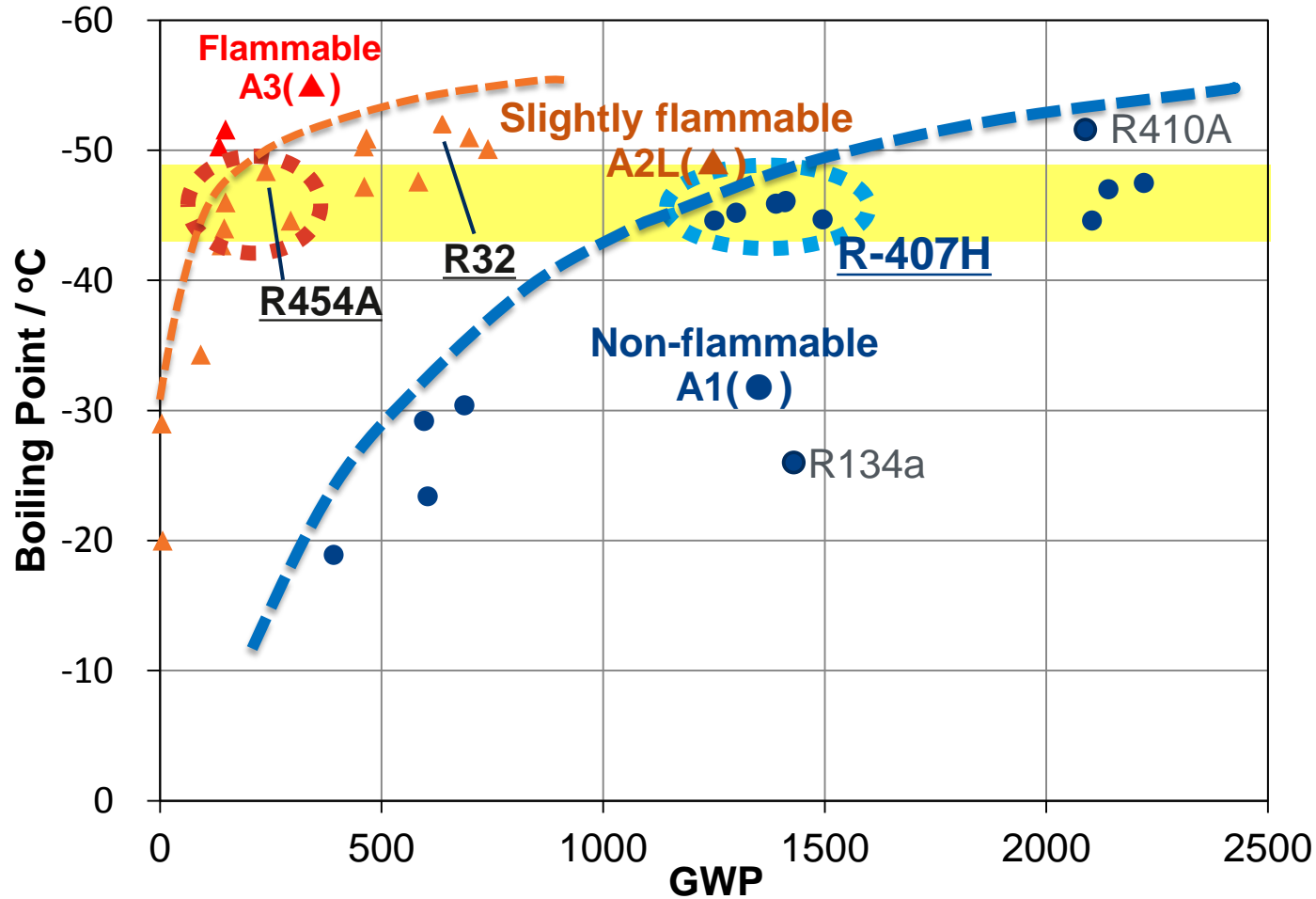
| Class | Class 1 No-Flammable | Lower flammable | Class 2 | Class 3 Higher flammable |
|---------|-------------------------|---|---------|-----------------------------|
| | | Class 2L Burning Velocity (≤ 10 cm/s) | | |
| Example | CO2 R410A R22 | R32 R1234yf Ammonia (Higher toxic) | R152a | Propane |

New Alternative Refrigerants



Lower b.p.(High pressure), Lower GWP increase flammability

New Alternative Refrigerants

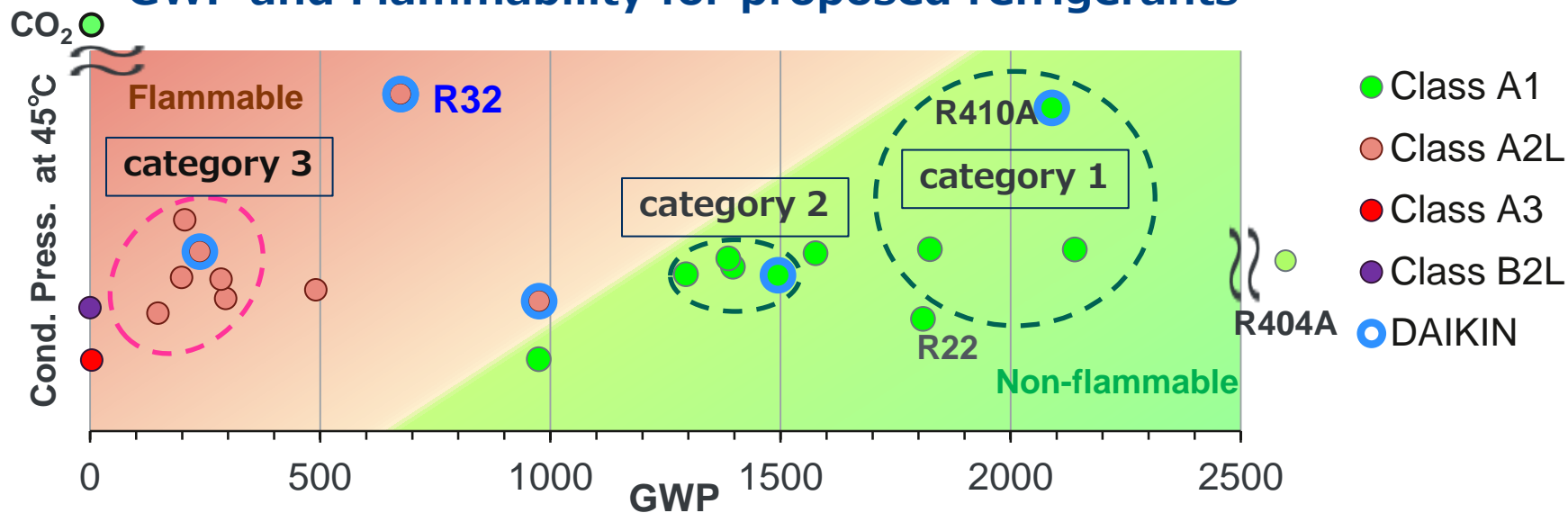


Lower GWP refrigerants are proposed in the same b.p. and flammability categories. They are near the borderline.

R404A, R22 Alternatives For Refrigeration

Proposed Refrigerant for Refrigeration

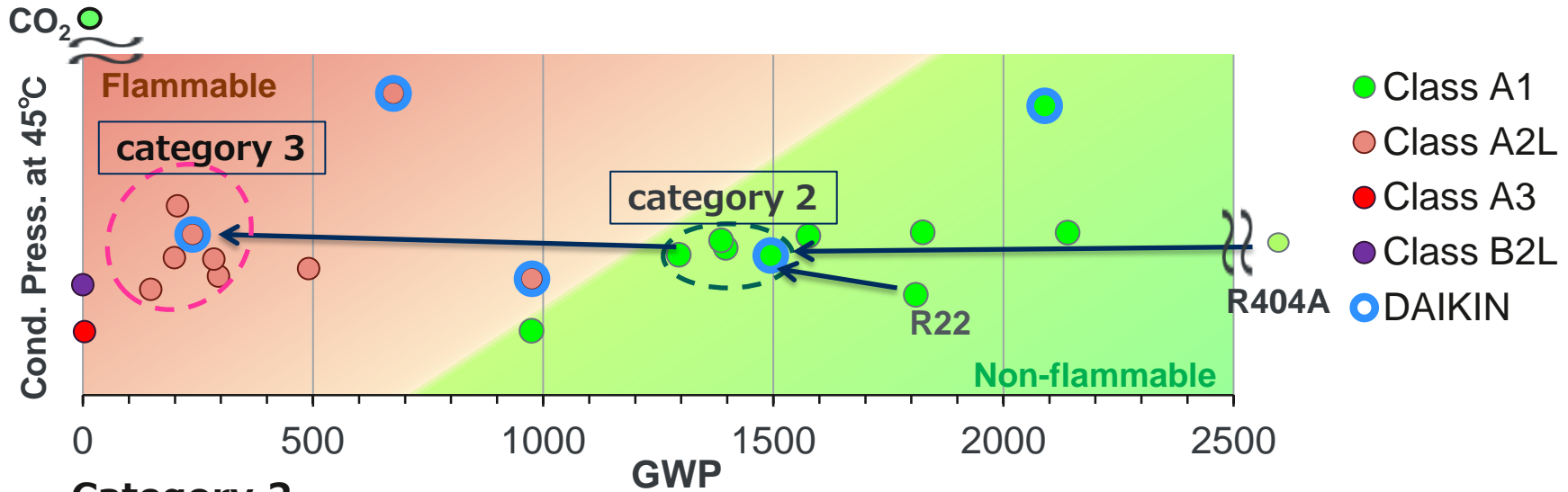
GWP and Flammability for proposed refrigerants



| Category | GWP | Flammability | Corresponding to regulation | Characteristic of GWP |
|----------|-------------|--------------|--------------------------------|------------------------|
| 1 | ≤ 2000 | 1 | Europe GWP<2500 (From 2020) | Half GWP of R404A |
| 2 | ≤ 1500 | 1 | Japan GWP<1500 (From 2025) | Less than GWP of R22 |
| 3 | ≤ 300 | 2L | Future | Less than 10% of R404A |

Choice of Alternative for Refrigeration Refrigerant

One scenario example of many
: R404A, R22 ⇒ Category2 ⇒ Category3



Category 2

| | R407H | R449A | R448A |
|--------------|-------|-------|-------|
| Flammability | A1 | A1 | A1 |
| GWP* | 1495 | 1397 | 1387 |

ASHRAE Safety class

A -Low toxic

B -High toxic

1 - Non flammable

2L - Slightly flammable

2 -Flammable

3 -Higher flammable

Category 3

| | R454A | R455A | R444B | R457A |
|--------------|-------|-------|-------|-------|
| Flammability | A2L | A2L | A2L | A2L |
| GWP* | 239 | 148 | 295 | 139 |

* IPCC AR4

DAIKIN alternative refrigerants for R404A

One scenario example of many
: R404A, R22 ⇒ Category2 ⇒ Category3

| | Category 3 | Category 2 | | |
|--------------|------------------|--------------------|------------------|-------------|
| | <u>R454A</u> | <u>R407H</u> | R404A | R22 |
| Composition | R32/R1234yf | R32/R125/R134a | R125/R143a/R134a | R22 |
| | HFC/HFO | <u>Only HFCs</u> | | |
| ODP | 0 | 0 | 0 | 0.055 |
| GWP * | <u>239 (237)</u> | <u>1495 (1380)</u> | 3920 (3940) | 1810 (1760) |
| ASHRAE Class | A2L | <u>A1</u> | A1 | A1 |

* IPCC AR4 (AR5)

**DAIKIN launched R407H in March 2017.
R407H is already on sale in Japan, EU, US.**

PRODUCT LAUNCH OF [R407H] REFRIGERANT FOR REFRIGERATION SYSTEMS
(March 8, 2017, Dainippon Sumitomo Refrigerant & Air Conditioning Co., Ltd. (DSC))
 DSC has announced the launch of R407H refrigerant, which has approximately 62% lower global warming potential (GWP) than commonly used R404A refrigerant.

Current R404A, a high-GWP refrigerant is widely used in refrigeration equipment in supermarkets, warehouses, and various other applications. Local international regulations are in place or planned to limit the GWP of gases used in refrigeration systems, for example:

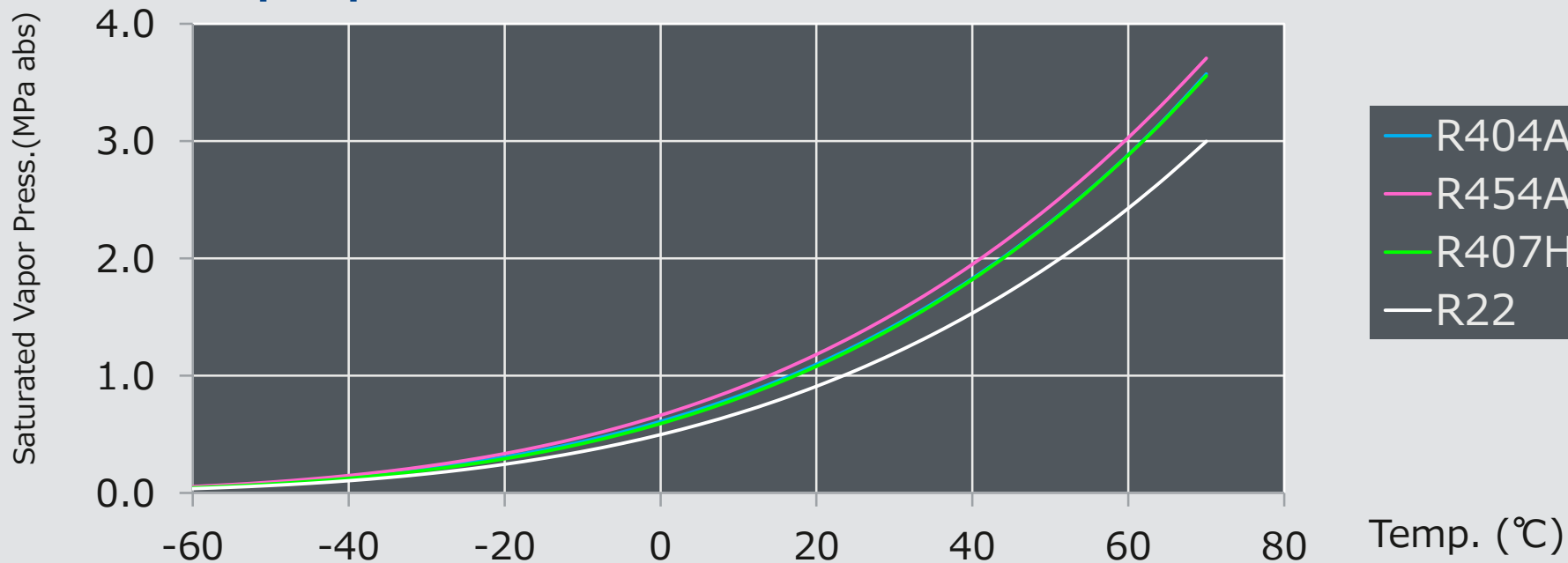
- Japan's Act on Rational Use and Proper Management of Fluorocarbons on a target date of 2020 to achieve a market volume-weighted average GWP less than 1800 for Commercial Use and Refrigeration Units.
- The European Union's revised F-gas regulation¹⁾ prohibits refrigerants with GWP 2000 or more for Standalone Refrigeration Equipment.
- The US Environmental Protection Agency (EPA) has listed R404A as unacceptable after 2020 for Retail Food Refrigeration and Vending Machines, and 2022 for new cold storage warehouse in their Significant New Alternatives Policy (SNAP) program²⁾.

With increasing regulation on HFCs, there is a greater demand for refrigerants that are safe to use, energy efficient, allow for easy and economical conversion and can comply with the various regulations around the globe.

Daiikin has developed a non-flammable, lower-GWP, and non-Azeotropic refrigerant R407H (GWP 1495). Compared to R404A which is commonly used today, R407H has a 62% lower GWP, and based on testing conducted by various equipment manufacturers and converted to real-world use equivalent in low temperature, and improvement in medium temperature in efficient (COP³⁾. In addition, R407H has similar working pressure to R404A and can be considered as an alternative to address an operational needs with limited modifications.

Daiikin will offer R407H as a replacement for R404A refrigeration systems, but also has an extensive development program to bring even lower GWP refrigerants to the cooling and heating industry.

Saturated vapor pressure of R404A alternatives



| Temp. (°C) | Saturated Vapor Press. (MPa) | | | |
|------------|------------------------------|-------|-------|------|
| | R404A | R454A | R407H | R22 |
| -30 | 0.21 | 0.23 | 0.20 | 0.16 |
| 0 | 0.61 | 0.66 | 0.59 | 0.50 |
| 30 | 1.43 | 1.53 | 1.41 | 1.19 |
| 45 | 2.04 | 2.20 | 2.03 | 1.73 |
| 60 | 2.89 | 3.03 | 2.88 | 2.43 |

The saturated vapor pressure of R407H are similar to R404A and a little higher than R22.

The history of refrigerants has been walking with environmental regulations. Until now, from the viewpoint of protecting the ozone layer, from now on, from the viewpoint of prevention of global warming, **high GWP refrigerants will disappear from the market in the near future.**

We should select a refrigerant which is most suitable for each application and area based on the key factors **“Safety, Environmental impact, Energy efficiency, Cost-effectiveness”**.

We developed **the new lower GWP refrigerant “R407H”** as a alternative refrigerant to R404A.

Which has also **economically superior** and **efficiency** to users.

We continue to develop new refrigerants that are environmentally friendly and can contribute to society and users.

Thank you for your kind attention.

