Japan’s fluorinated gases control policy as a measure of climate change mitigation in building sector

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Abstract. Japan has been a leading country who has taken on emission reduction measures of fluorocarbon gases. This paper introduces experience and modality of Japan's fluorocarbon control policy, particularly of the latest revision enforced by Act on Rational Use and Proper Management of Fluorocarbon. The act obliges owners of air conditioning/refrigeration units (here in after “equipment”) deal with fluorinated gases emissions both in usage phase and in decommissioning phase. This paper explains modality of the provisions stipulated in the act focusing on stakeholders of building, with explanation of supplemental efforts made voluntarily. It is explained that supplemental measures are vital in addition to the obligation, for the sake of ensuring the fluorocarbon emissions reduction measures completed. Besides, this paper explains in regard to expected greenhouse gases reduction by refrigerant leakage prevention in usage phase. Under Japan’s fluorinated gases control policy, owners of equipment must conduct inspection of each unit once a designated period to prevent leakage of fluorinated gases, as well as calculating and reporting seepage emissions of fluorinated gases used for refrigerant to government if it is more than a threshold. This obligation makes owners of equipment conscious of leakage emissions of fluorinated gases used for refrigerant, which result in leakage prevention. As effects of leakage prevention of fluorinated gases in building sector in Japan, both the estimated significance of emission reduction in retailing sector and results of the policy implementation in building sector are shown. Japan’s fluorocarbon emission control policy has been characteristic in world. Sharing the experience could contribute to setting up further HFCs emissions reduction measures, especially in Asia region where emissions of fluorinated gases used for refrigerant are expected to increase.

1. Introduction
In addition to energy related CO2 emissions, building sector has large stakes in fluorinated gases emissions. Because emissions of the HFCs, especially of ones used for substitutes for ozone-depleting substances, are expected to increase significantly [1], it is vital for stakeholders of buildings to take on measures to reduce fluorinated gases emissions with a view to contribution for mitigation of climate change. Being aware of the expected HFCs emissions increase, Japanese government have introduced policies requiring stakeholders, including ones of buildings, to address fluorinated gases emissions since the year of 1998.
Objective of this paper is 1) to explain experience and modality of Japan's fluorinated gases emission control policy focusing on building sector and 2) to examine estimated impact of latest revision of the policy addressing leakage prevention in usage phase of air conditioning/refrigeration units.

This paper also refers to Asian countries who are expected to be large fluorinated gases emitters in the future. It is intended to have implications for policy makers or stakeholders of buildings in those countries who are taking on addressing fluorinated gases emission control measures.

2. Rationale of fluorinated gases reduction for climate change mitigation

2.1. Significance of fluorinated gases emissions

Greenhouse gases (here in after “GHGs”) are those gases that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface. There are a number of GHGs identified by atmospheric academics and six gases are well-known as anthropogenic GHGs addressed by climate change countermeasure policy framework (e.g. Kyoto Protocol). They are namely carbon dioxide (CO2), methane (CH4), N2O, sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). Among the six, SF6, PFCs and HFCs are called fluorinated gases that contain fluorine atom in their molecular structure.

In addition, there are other fluorinated gases with significant global warming potential that is not addressed by climate change countermeasure policy framework, namely chlorofluorocarbon (CFCs) and hydro-chloro-fluoro-carbon (HCFCs). They are exempted from climate change countermeasure policy framework because they are already addressed by ozone depleting prevention policy framework represented by Montreal Protocol.

Figure 3 is a chart adapted from UNEP report[3] showing climate change mitigation outcome of CFCs and HCFCs reduction by Montreal Protocol and estimated magnitude of HFCs emissions in the future. According to the study, these fluorinated gases in total account for around 2 billion t-CO2 eq in 2010 and may increase by three times in the future.

![Figure 1. Estimated impact of fluorinated gases emissions reduction](image)

2.2. Emission sources of fluorinated gases

To take measures to address the fluorinated gases emissions increase, it is necessary to identify emission sources. For instance, there are following emission areas of HFCs according to IPCC documents[4].

- Solvents (non-aerosol)
- Aerosols (propellants and solvents)
- Foam blowing agents
- Refrigeration and Air Conditioning
- Fire protection
Among the HFCs emission sources, Refrigeration and Air Conditioning (refrigerant leakage from air-conditioning and refrigeration units) are going to be dominant according to an estimation by US EPA\(^1\) as shown in Figure 2. These compilations of data indicate significance of emissions of fluorinated gases used as refrigerant in air-conditioning/refrigeration units that is closely related to building sectors.

![Figure 2. Emissions estimation of HFCs used as substitute for ODS \(^1\)](image)

3. Fluorinated gases emissions control policies in Japan

3.1. History of fluorocarbon emission control law in Japan

Being aware of the significance of global warming effect by fluorinated gases emissions as shown in the previous section, Japan has continuously taken on introduction and revision of fluorinated gases emission control policy. Followings are the history of fluorinated gases emission control law in Japan.

1998 Household Appliances Recycling Law was enacted
- Recovery and destruction of fluorinated gases: from refrigerant of household refrigerator and room air-conditioner (enforced in 2001)

2001 Law concerning Recovery and Destruction of Fluorocarbon was enacted
- Recovery and destruction of fluorinated gases: form commercial refrigerator, freezer and air-conditioner (enforced in April 2002) automobile air-conditioner (enforced October 2002)
- Registry of fluorocarbon recovery operator, Report on recovery amount by fluorocarbon recovery operator, Approval of fluorocarbon destruction operator, Report on destruction amount by fluorocarbon destruction operator

2006 Law concerning Recovery and Destruction of Fluorocarbon revised
- Manifest records of process control regarding recovery and destruction of fluorinated gases from commercial use refrigerator, freezer and air-conditioner (enforced in 2008)

2013 Law concerning Recovery and Destruction of Fluorocarbon revised to Act on Rational Use and Proper Management of Fluorocarbon
- Preventive measure for leakage during using machine, regulation on charging (fluorocarbon recovery operator revised to fluorocarbon charging and recovery operator), regulation for manufacturer (enforced in 2015)
Japan started its fluorinated gases emissions reduction policy around the year of 2000, taking the opportunity of resource circulation policy introduction. Firstly, they started addressing leakage of refrigerant in household appliances disposal and then extended the scope to commercial appliances (revision in 1998 and 2001 legislation). It obliged disposers to collect fluorinated gases when disposing these equipment and recycle or destroy the gases chemically. When they introduced waste logistics tracking system using manifest record in resource circular policy, they also applied it to fluorinated gases (revision in 2006).

The latest revision in 2013 was to add measures to address leakage both in manufacturing phase and in usage phase. The former is addressed by obliging reporting and leakage inspection and the latter is addressed by regulating refrigerant procurement by equipment manufacturers. This revision was implemented being aware of significant increase of HFCs emissions in Japan as reported in its inventory report [5].

3.2. Outline of Act on Rational Use and Proper Management of Fluorocarbon

By the approach of policy revision shown in the previous section, Japan succeeded in enforcing following three pillars of fluorinated gases emission control policies enforced by now. Overview is shown in Figure 2.

![Figure 3. Outline of Act on Rational Use and Proper Management of Fluorocarbon](image)

3.2.1. Emissions control measure in production

In current fluorinated gases emission control policies in Japan, manufacturers and importers of air-conditioning/refrigeration units are required to commercialize those units with low GWP or non-fluorinated gases. GWP targets for fluorinated gases applied to respective categories are shown in Table 1. Manufacturers and importers are obliged to calculate weighted average of GWP of fluorinated gases applied to their products sold and the average GWP must comply with the target shown in Table 1.

| Categories                          | GWP Target | Target period |
|-------------------------------------|------------|---------------|
| Air conditioner for residential sector | 750        | 2018          |
| Packaged air conditioner for commercial sector | 750        | 2020          |
| Air conditioner for automobiles     | 150        | 2023          |
| Condensing unit                     | 1500       | 2025          |
| Central refrigeration unit          | 100        | 2019          |
3.2.2. Emissions control measures in usage phase

It is also required for users of air-conditioning/refrigeration units to address leakage of refrigerants consisting of fluorinated gases by inspection and management during the usage phase. It obliges users of the units to detect leakage from equipment periodically and report it to the government when the amount of leakage exceeds 1000t-CO2eq. (Government publish the report submitted by users.)

3.2.3. Emissions control measures in disposal process

When decommissioning and disposing home appliances, cars, and commercial air-conditioning/refrigeration units with refrigerants consisting of fluorinated gases, it is required to collect refrigerant from them and to recycle or destroy them chemically. Collected gases must be destroyed by approved destroyers. Owners of discarded commercial equipment are obliged to track the logistics to ensure the gases are delivered to approved destroyers.

4. Modality of fluorinated gases emission control policy in building sector

4.1. Measures to reduce refrigerant emissions in building sector

As written in previous chapter, emissions of fluorinated gases used for refrigerants are addressed by three approaches in building sector. Figure 3 shows a diagram that explains emissions paths from the point of building life cycle.

![Figure 3. Fluorinated gases emissions in building lifecycle](image)

There are two emissions paths of refrigerant and reduction methods in buildings as follows. One path is emissions in usage phase. Refrigerant circulates in pipes from compressor to indoor units in multi split system air conditioner when the equipment is in operation. Therefore, refrigerant may leak from pipes if there is containment failure. To prevent this type of leakage, it is necessary to make sure refrigerants are contained in pipes, by appropriate pipe arrangement or maintenance.

The other is emissions in and after decommissioning air-conditioning/refrigeration units. If buildings are scrapped without collecting refrigerant, all the used refrigerant are emitted into atmosphere. Therefore, building owner (to be accuracy, if air conditioners or refrigerators are attached to building) must make sure the building scraper collect used refrigerant and deliver it to approved destroyer. In additions, it is also effective to procure air conditioners or refrigerators with low GWP refrigerant because it can reduce global warming effect even if they are leaked.
Table 2. shows the whole picture of measures to reduce refrigerant emissions in building sector, with explanation of related stakeholders of building.

**Table 2. Measures to reduce refrigerant emissions in building sector**

| Building Lifecycle | Measures                                         | Related stakeholders of building                  |
|--------------------|--------------------------------------------------|---------------------------------------------------|
| Procurement        | - Procuring equipment with low GWP-refrigerant   | Building owner<br>Air-conditioning<br>refrigeration unit planner |
| Installation       | - Containment of refrigerants<br>(e.g. proper pipe arrangement) | Air-conditioning<br>refrigeration unit installer |
| Usage              | - Inspection of refrigerant leakage and maintenance | Building user<br>Building maintenance service provider |
| Removal            | - Demolition of building without refrigerants leakage | Building owner<br>Building scrapper |
| Disposal/Recovery  | - Delivering collected refrigerants to<br>proper destroying entities | Building owner<br>Building scrapper |

4.2. **Policy configurations in Japan**

In Japan, respective methods described in previous section are implemented with both the obligations and supplementing policy and measures. Table 3 shows policy instruments related to stakeholders of building.

For example, there is subsidy support as a supplemental policy to those who procuring conditioning/refrigeration units with low GWP refrigerant by the national government. It is also worthy of remark that it involves municipal government support and training and education by industry group who is familiar to maintenance technology.

**Table 3. Policy instruments implemented for stakeholders of building**

| Measures                                      | Policy instruments taken in japan                                                                 | Obligations | Supplemen ting efforts |
|-----------------------------------------------|-------------------------------------------------------------------------------------------------|-------------|------------------------|
| Procuring equipment with low-GWP refrigerant | GWP target for equipment manufacturer<br>Subsidizing low GWP refrigerant equipment buyer        | ✔           |                        |
| Making sure containment of refrigerants       | Training and education of containment of refrigerants by engineering association                 |             | ✓                      |
| Inspection of refrigerant leakage             | Obliging periodical detection of leakage from equipment<br>Obliging calculation and reporting amount of refrigerant leakage<br>Training and education of inspection by engineering association | ✔           |                        |
| Building scrapping without refrigerants leakage | Random inspection by municipal governments                                                        | ✔           |                        |
| Delivering collected refrigerants to<br>proper destroying entities | Obliging handling of manifest report to deliver collected refrigerants to proper Destroyer       | ✔           |                        |

*1 If equipment owner is the same as building owner, building owner is obliged
*2 Required to submit report to the national government if exceeding 1500t-CO2 eq
5. Effects of leakage prevention of fluorinated gases in usage phase of buildings

This chapter introduces effects of refrigerant leakage prevention focusing on usage phase of buildings, the result of which is observable through existing data.

5.1. Case study

Table 4. shows a case study of GHG emissions reduction showing comparison between fluorinated gas reduction measures and energy efficiency measures with condensing unit with 6 Horse Power. Condensing unit with 6 Horse Power is selected because it is popular category of equipment applied to refrigeration system in disseminated food and glossary supply chain represented by convenience stores or supermarkets in Japan.

For calculation of refrigerant emissions reduction effect, it is assumed that refrigerant leakage is reduced by a rate envisioned in Japan’s Global Warming Countermeasure Plan. For energy efficiency, it is assumed that EER of the condensing unit is improved with best available technology.

It is calculated that expected GHG reduction amount by refrigerant leakage prevention could be close to that of energy efficiency measures if R410A is assumed as refrigerant. GHGs reduction by refrigerant leakage prevention could be even more than that of energy efficiency measures if R404A is assumed.

The result implies that leakage prevention could make a large impact in a country like Japan where food and groceries supply chains are well deployed. It also implies that refrigerant leakage prevention is vital issue for condensing unit as enhancing energy efficiency of the equipment.

| Table 4. A case study with typical condensing unit (comparison of fluorinated gas reduction effect with energy efficiency) |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Data                                             | Value | unit | Source/assumption                                      |
| Estimated GHG reduction effect by refrigerant leakage prevention |       |     |                                                          |
| a Filled refrigerant amount                      | 10    | kg   | Approximate amount assuming condensing unit with 6 Horse Power |
| b GWP(R404A)                                     | 3,920 |      | IPCC 4th Assessment Report                              |
| c GWP(R410A)                                     | 2,090 |      | IPCC 4th Assessment Report                              |
| d Annual leakage rate of condensing unit in Japan | 13%   |      | Ministry of Economy, Trade and Industry, 2009            |
| e Expected refrigerant leakage reduction rate with the policy | 83%   |      | Japan’s Global Warming Countermeasure Plan (2016)         |
| Expected GHG Reduction (in case of R404A)        | 4.23  | t-CO2| =a*b*c*d/1000                                           |
| Expected GHG Reduction (in case of R410A)        | 2.26  | t-CO2|                                                          |
| Estimated GHG reduction effect by energy efficiency |       |     |                                                          |
| a Energy Efficiency Rate (EER) of best available condensing unit | 2.7   |     | A sample of a manufacturer (with capacity of 6 Horse Power) |
| b Energy Efficiency Rate (EER) of incumbent condensing unit | 2.55  |     |                                                          |
| c Typical energy consumption of condensing unit   | 30,000 | kWh/year | Approximate energy consumption per year of condensing unit with 6 horse power |
| d Average emissions factor of electricity in Japan | 0.000496 | t-CO2/kWh | General electric utility in Japan                        |
| e Expected GHG Reduction                          | 2.2   | t-CO2| =(a-b)*c*d                                              |
5.2. Results of the policy implementation

Because refrigerant gases seepage happens slowly in a long time, it is hard to monitor the amount of refrigerant gases leaked directly and individually as shown in a case study in 5.1. Therefore, Law concerning Recovery and Destruction of Fluorocarbon revised to Act on Rational Use and Proper Management of Fluorocarbon (here in after “the law”) stipulates monitoring methods utilizing amount of fluorinated gas added, substituting monitoring directly the amount of refrigerant gases leaked.

Japanese government is obliged to publish a report each year compiling reported amount of refrigerant gases seepage calculated in the method\textsuperscript{8}. According to the reports published since the act is enforced, the result of calculated amount of refrigerant gases leaked by large building asset owners is shown as in Table 5.

Table 5. Calculation result of refrigerant gases leakage by large building asset owners in japan [t-CO2 equivalent]\textsuperscript{8}

| FY   | R-11 | R-12 | R-22 | R-32 | R-123 | R-134a | R-401A | R-404A | R-407A | R-407C | R-407E | R-410A | R-410B | R-502 | Total |
|------|------|------|------|------|-------|--------|--------|--------|--------|--------|--------|--------|--------|-------|-------|
| 2015 | 3,106| 116  | 5,235| 2    | 11    | 888    | 91     | 1,115  | 135    | 1,133  | 11,310 |       |       |       | 23,635|
| 2016 | 3,342| 0    | 4,186| 1    | 31    | 516    | 46     | 28     | 1,292  | 8      | 8,304  | 4      | 1      | 17,772|
| 2017 | 1,201| 4,279| 7    | 8    | 1,981 | 34     | 316    | 8      | 1,235  | 26     | 10,862 | 15     | 9      | 19,992|

The total amount of refrigerant gases leaked by large building asset owners is decreased from FY2015 to FY2016, but increased from FY 2016 to 2017. The largest factor of the increase from FY 2016 to FY2017 is R134a. R134a is a type of refrigerant which is applied to large central chillers (e.g. turbo freezer) and it implies there was some incident that allowed refrigerant leakage in large scale, as written in the line of Entity C of Table6. Table6. shows examples of measures taken by some building asset owners in FY2017.

Table 6. Examples of measures taken by building asset owners actually reported in FY2017\textsuperscript{8}

| Entity A | Penetrating flaw detection, pressure resistance tests, and airtightness tests were conducted to confirm that there were no leaks. |
| Entity B | As efforts in daily inspection, the facility manager conducted patrol inspections three times daily. |
|          | In the case of patrolling, they check if the flow rate or the pressure is in the normal range. |
|          | If there is a decrease in the amount of refrigerant, a leak check (electronic gas detector) will work out promptly. |
| Entity C | Facing the incident that the refrigerant safety valve operates and refrigerant gas (R134a) leaked when the pressure inside the turbo chiller rises because of the heat transferred from hot water producer used in winter, we took measures as follows |
|          | 1) When the winter turbo chiller stops, the system valve should be closed so that heat convection does not occur in the cooling water piping. |
|          | 2) Alarm is installed to inform the disaster prevention center when coolant temperature rises. |
| Entity D | The amount of leakage increased because it was delayed to notice the leakage from the 17 years old screw chiller. There was deterioration in the connection with the equipment. We will eliminate leaks by maintaining with disassembly. |

The result implies it is yet to be achieved to reduce the refrigerant leakage in stable trend. However at least, it implies the policy promoted building owner’s consciousness of refrigerant leakage and measures that should be taken.
6. Conclusion

6.1. Implications from experiences in Japan
This paper introduced history and outline of Japanese fluorinated gas policies and modality of it in building sector. In addition, it examined the effect of leakage prevention of refrigerant focusing on usage phase which is observable through the data available. It is proved that the policy promoted building owner’s consciousness of refrigerant leakage and measures though it is yet to be achieved that the reduction of refrigerant leakage is in a constant trend. It is still desirable to continue promotion of building owners’ consciousness of refrigerant leakage prevention measures, especially in order to prevent leakage incident which is speculated to be substantial refrigerant leakage factor.

6.2. Significance of HFC emissions reduction in Asian countries in future
According to an estimation by US EPA, emissions of HFC used for refrigerant will increase sharply in Non-OECD Asian countries where cold chain and air conditioning units are disseminating as shown in Figure 4. In 2030, it is estimated the total emissions of HFCs used for refrigerant will be as much as 400 million CO2-eq.

![Figure 5. Estimated fluorinated gas emissions by Non OECD Asian countries](image)

It will be desirable to take leakage prevention measures of refrigerant fluorinated gases in building sector as well in those countries where emissions of fluorinated gases used for refrigerant are expected to increase. The experience of policy and measures of Japan written here could have implications for stakeholders in those countries.

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