Project to develop Next-Generation Refrigerants and Refrigeration and Air-Conditioning Technology to achieve Energy Conservation and Mitigate Global Warming

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The New Energy and Industrial Technology Development Organization (NEDO) in Japan conducts research and development to establish safety and risk assessment methods for next-generation refrigerants used in commercial refrigeration and freezing equipment as well as residential air-conditioners. Support is provided for product development and the development of ultra-low GWP refrigerants to solve technical issues that hinder the practical application and dissemination of next-generation refrigerants.

Hydrofluorocarbons (HFCs), which have been developed as alternatives to CFCs and HCFCs and pose no risk of ozone layer depletion, are used as refrigerants for refrigeration and air-conditioning equipment and foaming agents. As the conversion progresses, HFC usage and emissions are increasing. However, HFCs have been designated as an emission reduction target under the Paris Agreement because they remain stable in the atmosphere long-term and have an extremely high greenhouse effect. In addition, at the 28th Conference of the Parties to the Montreal Protocol (MOP28) held in Kigali, Rwanda's capital, in October 2016, a new revision of the Montreal Protocol was adopted, which stipulates an obligation to reduce HFC production and consumption. The amendment requires developed countries to phase down HFC production and consumption by 85% from the 2011-2013 average by 2036. This goal cannot be achieved if existing refrigerants continue to be used. For this reason, there is an urgent need to develop refrigerants that have a minimal impact on global warming while being fit for purpose for current refrigeration and air-conditioning technologies (sometimes referred to as "next-generation refrigerants").

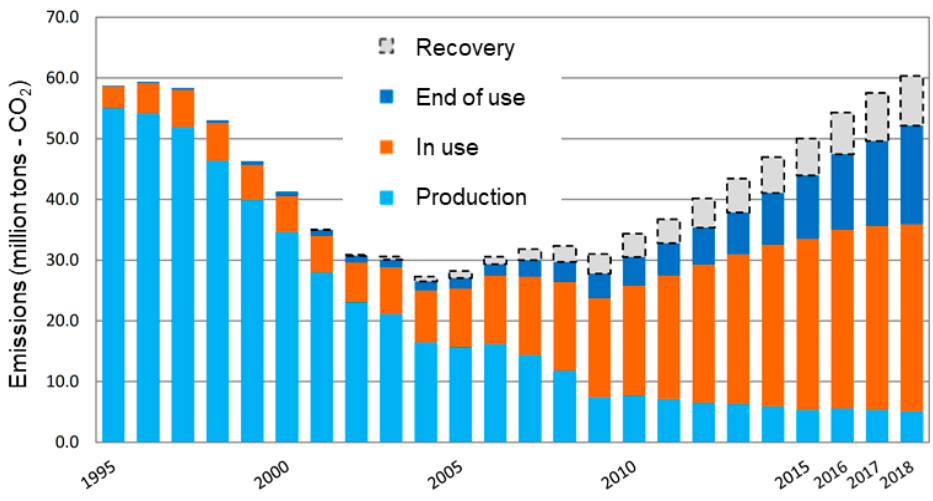

Figure 1. Changes in emissions of greenhouse gases (HFC, PFC, NF3, SF6) in Japan, by factor
Source: Ministry of Economy, Trade and Industry committee materials.

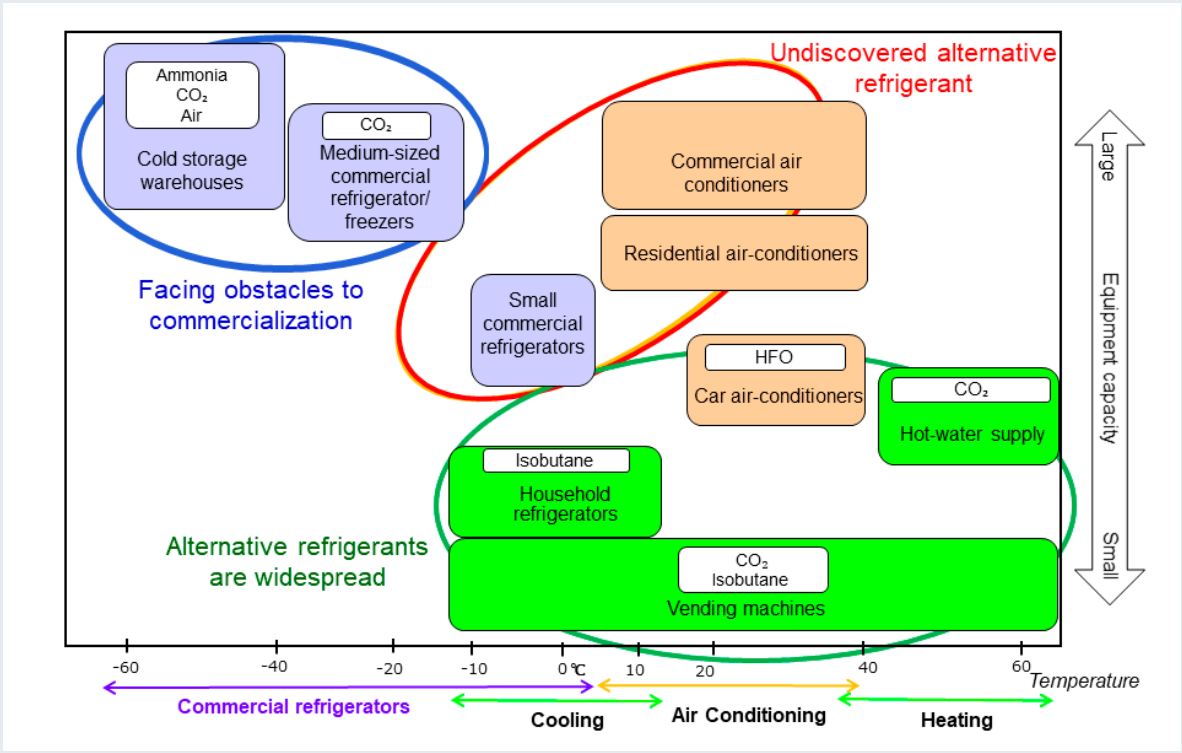

Figure 2. Development status of low-GWP refrigerant by application.

On the other hand, current next-generation refrigerant candidates face high technical hurdles to improve upon or even maintain performance equivalent to equipment using existing HFC refrigerants. They also have problems such as flammability and chemical instability. In Japan, HFC emissions account for more than 90% of emissions of the four types of greenhouse gases other than carbon dioxide. Eighty-three percent of HFC emissions come from refrigeration and air-conditioning equipment. Only 13% of the HFCs emitted from refrigeration equipment is recovered, and the rest is released into the atmosphere. Figure 1 shows four types of greenhouse gas emission sources. Emissions during manufacturing are decreasing, but emissions during use and at the end of use are increasing. Refrigerant recovery is not easy, so refrigerant conversion is an essential measure. Figure 2 shows the status of conversion to low-GWP refrigerants in Japan. Next-generation refrigerants for air-conditioning equipment and small- and medium-sized refrigeration equipment are still being sought.

Under these circumstances, in 2018, the New Energy and Industrial Technology Development Organization (NEDO) embarked on the following five-year project with the Ministry of Economy, Trade and Industry's support. In this project, we work to grasp the fundamental characteristics of next-generation refrigerants, establish safety and risk assessment methods, and work on the formulation of domestic safety standards and international standards. The aim is to contribute to the market launch of products by establishing a base for the development of energy-saving refrigeration and air-conditioning equipment that uses next-generation refrigerants. We carry out research and development to establish a safety and risk assessment method for next-generation refrigerants used in small- and medium-sized refrigeration and air-conditioning equipment, including commercial refrigeration equipment and residential air-conditioning equipment. The project budget is 2.45 billion JPY from 2018 to 2021 (2022 budget not yet determined).

R & D content and contractors

1 Elucidation of fundamental characteristics of next-generation refrigerants and development of evaluation methods.

1.1 Evaluation of thermal characteristics, heat transfer characteristics, and basic cycle performance of next-generation refrigerants used in small and medium-sized refrigeration and air conditioning equipment (Kyushu University).

Kyushu University is conducting the following research on the thermophysical properties of next-generation refrigerants in cooperation with several other research institutes: critical constants, vapour-liquid equilibria, PVTx properties, surface tension, sound velocity, viscosity, and thermal conductivity. Based on the physical property values measured in this project and other research data, the equation of state for a next-generation refrigerant is being developed. The characteristics of heat transfer by condensation and evaporation of next-generation refrigerants are measured for plate heat exchangers, flat

multi-port tubes, inner grooved tubes, and smooth circular tubes.

1.2 Safety evaluation of low-GWP, low-combustible refrigerant mixtures (National Institute of Advanced Industrial Science and Technology (AIST)).

In this research, a mixture of a highly combustible refrigerant having three or fewer carbon atoms, such as fluoroolefin, and a low-combustible refrigerant, such as fluoroalkane, is targeted as a next-generation refrigerant for refrigeration and air-conditioning equipment. Mixtures are selected considering total GWP, boiling point difference and availability, and the mixing rules for the combustion characteristics of the refrigerants are experimentally and accurately evaluated.

1.3 Research and development of practical evaluations for next-generation refrigeration and air conditioning technology using low-GWP refrigerants (Waseda University).

The purpose of this research is to develop technologies capable of high-accuracy theoretical and test evaluation of the performance of air-conditioning and refrigeration equipment that introduces next-generation refrigerants. A heat transfer model, void fraction model, expansion valve model, and compressor model are being developed targeting the refrigerant's flow characteristics in the equipment. Performance test equipment for split-air-conditioners and commercial refrigerators is being constructed, and performance evaluation techniques for the equipment are being investigated. Furthermore, to predict the performance of next-generation refrigerants, a performance simulator is being developed.

2 Development of safety/risk assessment methods for next-generation refrigerants

We examine the evaluation items necessary for the safety/risk assessment of flammable next-generation refrigerants and establish safety/risk assessment methods through numerical calculations, laboratory experiments, and outdoor experiments. Specifically, research including accident scenarios, refrigerant behavior during leaks, fire hazard assessments, ignition source assessments, explosion impact assessments, general hazard assessments, and allowable refrigerant charge amounts is conducted.

2.1 Development of safety/risk assessment method for next-generation refrigerants (University of Tokyo)

Refrigerant diffusion when a highly flammable refrigerant such as propane leaks from an air conditioner or a commercial reach-in display cabinet is numerically simulated. The maximum refrigerant charge and the stirring effects of the indoor unit fan are investigated. Research is conducted with the aim of eliminating compressor explosions caused by erroneous operation by service personnel during a split air-conditioner's pump down operation. Some HFO refrigerants may undergo a disproportionation reaction due to an electric short circuit in the compressor in high-temperature and high-pressure conditions, leading to a compressor explosion. Research is being conducted on the suppression of disproportionation reactions.

2.2 Establishment of physical risk evaluation method for combustion of next-generation refrigerants considering ignition sources in an actual use environment (Suwa University of Science)

In this research, equipment and phenomena capable of acting as ignition sources are extracted when a highly flammable hydrocarbon refrigerant, expected to serve as a next-generation refrigerant, is used. The extracted ignition sources are categorized by ignition mechanism, and a model of the ignition mechanism is constructed for each category. The ignitability of a propane/air mixture is tested with contact switches, power plugs, electric sparks when opening and closing relays, static electricity, and cigarettes.

2.3 Evaluation of full-scale physical hazards related to the combustion of refrigeration and air conditioning equipment using natural refrigerants (National Institute of Advanced Industrial Science and Technology (AIST))

Physical hazards are evaluated in the event of rapid leakage when propane is used as a refrigerant for split air-conditioners and commercial reach-in display cabinets. In combustion impact evaluations of reach-in display cabinets, a steel simulation room is set up at the field experiment site, propane is emitted and ignited, and a combustion evaluation experiment is conducted. In evaluations of the combustion effects of split air-conditioner indoor units, an ignition test is conducted by installing a steel container at the field test site.

3 Research on safety and risk evaluation of next-generation refrigerants (research project)

To efficiently link commissioned project results to industry safety standards and international standardization, we conduct trend surveys of regulations and standards. We organize committees for industry-academia-government collaboration to study the safety and risk assessment of next-generation refrigerants and disseminate the results both domestically and internationally in cooperation with commissioned projects. This research is outsourced to the Japan Society of Refrigerating and Air Conditioning Engineers.

4 Development of a next-generation refrigerant and its application technology

It is crucial to solve the technical problems that hinder the practical use and popularization of next-generation refrigerants. For that purpose, we conduct subsidy projects.

4.1 Development of a large cooling unit that utilizes natural refrigerant and ultra-low GWP refrigerant (Mitsubishi Electric Co.)

This research aims to apply carbon dioxide, a natural refrigerant with a low environmental load, to the cooling units for large refrigerated warehouses and to develop an inexpensive and highly efficient system. The development target is to have an annual COP of 100% or more and a selling price of at most 140% the price of a 60 horsepower refrigerator using R404A refrigerant.

4.2 Development of condensing unit technology adaptive to next-generation, low-GWP refrigerants (Toshiba Carrier Co., Ltd.)

In this research and development, a condensing unit using a low-GWP refrigerant is being developed. A suitable refrigerant is selected from HFO/HFC mixed refrigerants. The development goal is to improve rated equipment performance to a level equivalent to current equipment and improve annual equipment performance during actual operation by 5%.

4.3 Development of an energy-saving refrigerator system using CO_2 refrigerant (Panasonic Co.)

This project aims to promote the spread of carbon dioxide as a refrigerant in the field of commercial refrigerating equipment. The refrigerator's capacity can be increased by connecting the compressor units. An air-cooled heat exchanger unit that efficiently cools even with a high outside air temperature is being developed, and a system using the exhaust heat of the refrigerator is being designed. The project aims to create a refrigerator that can be applied to medium- and high-temperature regions.

4.4 Development of a mildly flammable refrigerant for direct expansion air conditioners with a GWP of 10 or less (Daikin Industries, Ltd.)

This project aims to develop a refrigerant for direct expansion air conditioners with a GWP of less than 10. As a target of refrigerant performance, the coefficient of performance is set to 90% or more of the current refrigerant, R410A. Regarding flammability and toxicity of the refrigerant, ASHRAE's safety category A2L is targeted.

Conclusion

Although next-generation refrigerants have been used in some applications, their use in other application areas has not yet become widespread. Considering the time needed for the dissemination of new technologies, to achieve the Kigali Amendment's goals, we will implement a wide range of measures based on new seed technologies and develop technologies in a variety of fields to support its dissemination as quickly as possible. It is indispensable to promote technological development for technical issues in order to overcome roadblocks to dissemination to technologies, improve efficiency, and expand the scope of application.

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