LCA Study of Air Conditioners with an Alternative Refrigerant

Kazuta Yanagitani
Daikin Industries, LTD., Daikin Air-Conditioning R&D Laboratory
Kanaoka-cho 1304, Sakai, Osaka 591-8511
Phone: +81-722-57-8517, Fax: +81-722-52-8255
Email: kazuta.yanagitani@daikin.co.jp

Abstract

In the refrigeration and air conditioning industry, technologies to reduce environmental impact, such as global warming, ozone-layer depletion, and discharging industrial wastes, are getting much attention nowadays. This paper reports the Life Cycle Assessment (LCA) conducted to analyze two air conditioner units for residential use comparatively. One is a traditional model with HCFC22 being used for its refrigerant and the other is with HFC410A, that is considered to be a promising alternative for HCFC22 for now since it possesses no ozone-layer depleting potential when being emitted. As a result, the ozone-layer depleting effect can be eliminated completely by using HFC410A. In addition, the global warming effect gets reduced to a certain extent by using HFC410A, and furthermore, it gets reduced considerably by treating used refrigerants with a proper waste management. Moreover, a model with HFC32 as a refrigerant is compared to the one with HFC410A. It is proved that HFC32 is more effective refrigerant to reduce environmental burden that includes global warming effect.

Introduction

In 1997, the Kyoto Protocol specified hydrofluorocarbons (HFCs) as one of the regulated substances to be released into atmosphere due to their global warming effect. At that time, air conditioners with HFC as a refrigerant has just started to come onto the market because HFC has no ozone layer depleting potential and had been recognized as a promising alternative refrigerant of hydrochlorofluorocarbons (HCFCs). Since then, selection of refrigerants in the prospect of reducing global warming effect has been a focal issue of discussion in the refrigeration and air conditioning industry.

For that reason, LCA study is conducted to assess HFC and HCFC that are used as refrigerants of air conditioners comparatively. Specifically, a new model with HFC410A released for sale by Daikin Industries is assessed through its life cycle, and is compared with a traditional model with HCFC22. Due to the legislation, recovering and disposing used refrigerants properly at the end of their life cycle is now a demanded task in the industry. For that reason a combustion process of used HFC410A is assumed to be the disposal scenario of refrigerant in this study. Then, two values, 0% and 50%, are set for recovering ratio of the used refrigerant to estimate the effect of recovery. Since data quality of the refrigerants is a crucial factor in this study, the data of the refrigerants are taken from the actual measurements in their production stage and disposal stage. Finally a HFC32 model is assessed and compared to the HFC410A model to observe its effect of more reduction of global warming.

This LCA study is conducted by following the ISO14040 procedure taking each phase of Goal and Scope Definition, Inventory Analysis, Impact Assessment, and Interpretation.

Analysis

1. Goal and Scope Definition

The purpose of this LCA is to analyze environmental impact provided by HFC and HCFC used as refrigerants of air conditioners comparatively, especially in the views of global warming and ozone layer depletion. For this purpose, two air conditioner units of 4kW are prepared. One unit is a new model with HFC410A for its refrigerant, and the other is a traditional model with HCFC22. The HFC410A model owns an additional technology of energy saving when being used that overcomes inferior properties of the refrigerant.

For the scope of LCA, a flowchart of products' life cycle model shown in Figure 1 is modeled. As shown, LCA is applied to the entire life cycle of the product that consists of 5 fundamental stages, Materials Production, Manufacture of Products, Products Transport, Use, and Disposal of Products. Necessary data for the analysis, that are input resources and output substances are accumulated in each of those stages. Among those stages, Use stage is known to provide relatively large impact to the environment due to large amount of electricity consumption, therefore operating time is important factor of the analysis. It is assumed the products are used 8 hours per day both during heating and cooling seasons, and their life cycle is 8 years, based on our survey. Also, because recovering used refrigerants from waste products is now a demanded task in the industry, two values are set for the ratio of recovering refrigerant in the Disposal Stage of the HFC410A model, that is shown in Figure 2, to analyze the effect of recovering the refrigerant and disposing properly.

●***Scenario A:*** *0% of the refrigerant is recovered from a waste product.*

●***Scenario B:*** *50% of the refrigerant is recovered, and treated by combustion process.*

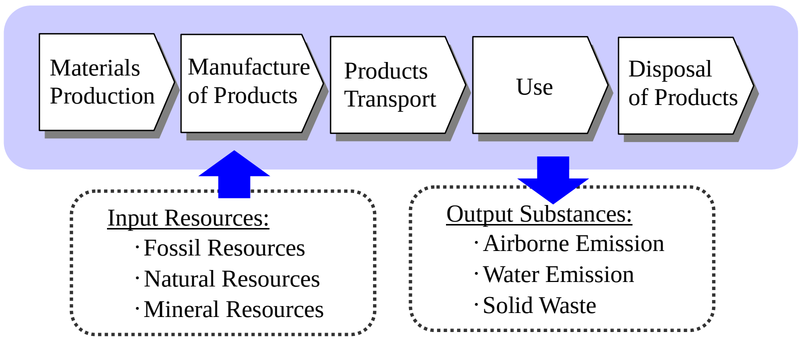

Figure 1. Product Life Cycle Model and Accumulated Data

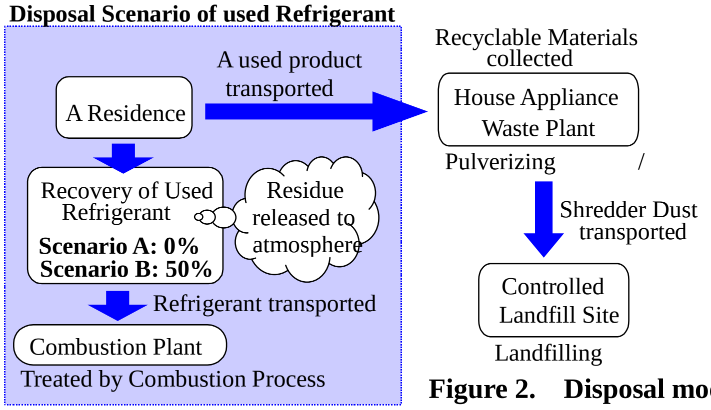

Figure 2. Disposal model of used products

2. Inventory Analysis

2.1 Data Collection

The data of input resources and output substances are accumulated in each of the 5 stages shown in Figure 1. Those accumulated data are analyzed by using LCA databases. The databases referred in this case study are “NIRE-LCA Ver.2” developed by National Institute of Advanced Industrial Science and Technology (AIST). However, data related to refrigerants are not listed in the database, and also these data require precision in order for accurate analysis of the products. For those reasons, those refrigerants related data, described below, are collected in the actual measurements, and any databases are not referred to.

●*Production of Refrigerants (HCFC22 and HFC410A)*

The data of input resources and output substances are collected in the production process of refrigerants in the chemical plant of Daikin Industries.

●*Disposal of Refrigerants*

The data are collected in the experimental combustion process of used refrigerants in the pilot plant of Daikin Industries. This process consists of two steps, that are incineration of refrigerants and neutralization of the acids formed during the incineration.

2.2 Result of Analysis from the collected data

CO2 emission is focused in this analysis because that provides direct impact of global warming. Here, the HCFC22 model and the HFC410A model are comparatively analyzed in terms of CO2 emission in their life cycles, and shown in Figure 3.

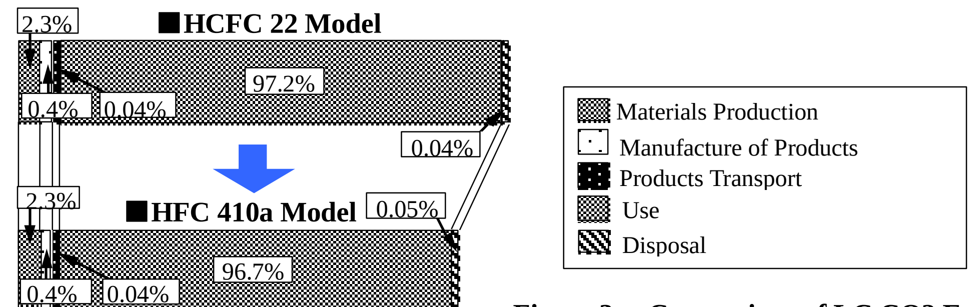

Figure 3. Comparison of LC CO2 Emission

As shown in Figure 3, the Use Stage takes the largest amount of CO2 emission in the life cycles of the both models.

Total CO2 emission by the HFC410A model in its life cycle is 13.3% less than that of HCFC22 model. This is due to the additional energy-saving technology of the HFC410A model’s hardware.

3 Impact Assessment

3.1 Comparison of HCFC22 model and HFC410A model

First, global warming effects of the two models are analyzed comparatively for Impact Assessment that is the primary goal of the study. The global warming effect is expressed in CO2 equivalent kg using GWP of 100 years for the analysis. Figure 4 shows the comparison result of two models through their life cycles.

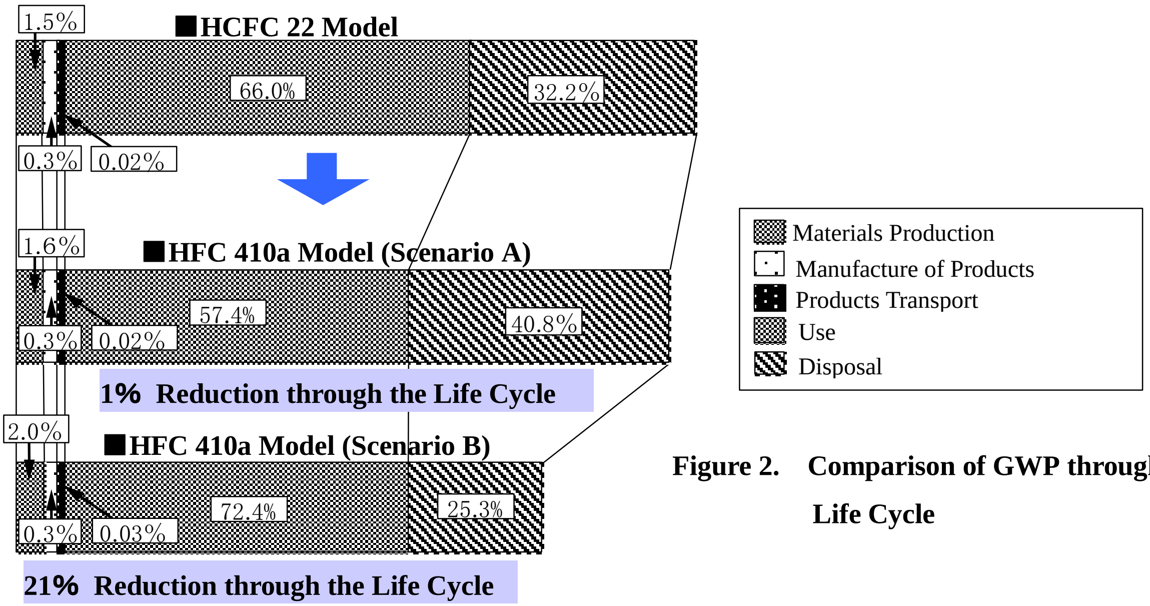

Figure 2. Comparison of GWP through Life Cycle

One of the characteristics these graphs indicate is that the ratio in the Disposal Stage is considerably higher than that of CO2 emission shown in the graphs in Figure 3. This is because of the effect from used refrigerants released into atmosphere. Also, by comparing the HCFC22 model and the HFC410A model with Scenario A in Figure 4, GWP value of the HFC410A model in the Use Stage is slightly lower than that of the HCFC22 model, and this is due to the energy-saving technology of the HFC410A model. On the other hand, GWP value of the HFC410A model in the Disposal Stage is slightly higher than that of the HCFC22 model because it contains more amount of the refrigerant than the HCFC22 model. And total GWP values of the HFC410A models through its life cycle is turned out to be only 1% lower than that of the HCFC22 model. Therefore, next, the HFC410A model with Scenario B is compared to the HCFC22 model. As shown in Figure 4, GWP value in the Disposal Stage is remarkably lower than that of the HCFC22 model, and it results with 21% reduction of GWP value through its life cycle. This result proves that it is successful in reducing global warming effect to recover the used refrigerant and dispose it properly.

Finally, the two models are comparatively assessed through their life cycles in the LC impact categories listed in Table 1, along with global warming effect. Table 1 also shows the characterization values in those categories for the assessment. The comparison result is shown in the graph in Figure 5.

Table 1. Characterization Values of Impact Categories

Impact Categories	Characterization Values
Global Warming Effect	GWP (CO_2 = 1)
Ozone Layer Depletion	ODP (CFC11 = 1)
Acidification	AP (SO_2 = 1)
Air Pollution	Inverse Values of Emission Standards（Unit:Nm3）
Water Pollution	Inverse Values of Emission Standards（Unit:L）
Energy Consumption	Calorific Values of Fuels（Unit：MJ/kg）

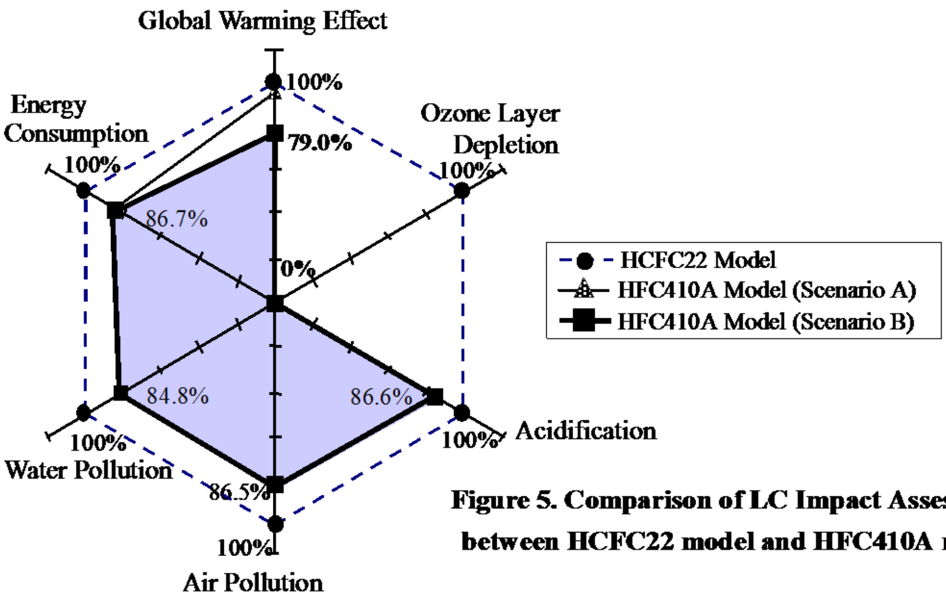

Figure 5. Comparison of LC Impact Assessment between HCFC22 model and HFC410A model

The graph shows relative ratio of the HFC410A model to the HCFC22 model. From the figure, complete abolition of ozone layer depleting effect by the HFC410A model is confirmed. Also, the graph shows that the HFC410A model can reduce impact in all of the other categories that are acidification, air pollution, water pollution, and energy consumption, in the range of 84.8% to 86.7%. This reduction is mostly due to the effect of energy-saving technology of the model. With regard to global warming effect, effect given by HFC410A model is only 1% lower than that of the HCFC22 model if the used refrigerant is not recovered. However, 21% reduction is in prospect if 50% of the used refrigerant is recovered and disposed properly, as discussed prior.

3.2 Additional Study -Assessment of HFC32 Model-

As a result of comparative assessment of HCFC22 model and HFC410A model, it is proved that HFC410A model provides less impact to environment including global warming effect than HCFC22 model. Furthermore, it has often been discussed that HFC32's can possibly become upcoming alternative refrigerant in the future from the viewpoint of reducing environmental impact. This refrigerant, HFC32 itself has no ozone layer potential and much less global warming potential than HCFC22 or HFC410A as shown in Table 2. Also, it has superior property to the other refrigerants that contributes to energy saving of the air conditioning systems when being used. Although HFC32 is slight flammable, the technology development of HFC32 has been progressed in Daikin Industries. Based on the experimental data conducted in Daikin Industries, HFC32 model is assessed and is compared to HCFC22 model and HFC410A model. Figure 6 shows the result of it.

Table 2. Comparison of three refrigerants

	Ozone Depleting Potential (ODP)	Global Warming Potential (GWP)
HCFC22	0.055	1500
HFC410A	0	1730
HFC32	0	650

(IPCC95)

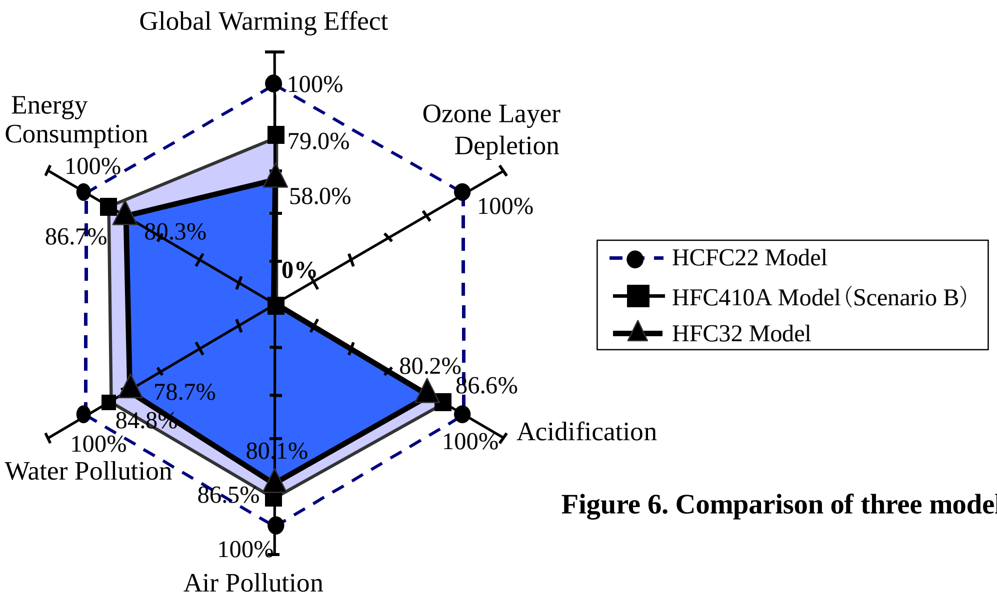

Figure 6. Comparison of three models

As shown in Figure 6, HFC32 model has no effect of ozone layer depletion just like HFC410A model. Also, HFC32 model can reduce environmental impact even more than HFC410A model in all the categories especially in global warming effect. The figure shows HFC32 can reduce global warming effect down to 58.0% comparing to HCFC22 model. This reduction is by reason of the energy saving effect of HFC32 when being used, and also decreased amount of the refrigerant in the system. As a result, it is proved that HFC32 is more effective refrigerant to reduce environmental impact than HFC410A.

4. Interpretation（Conclusion）

The purpose of this LCA study is to analyze environmental impact provided by HFC410A as a refrigerant of air conditioners as a comparison with HCFC22, especially in the views of global warming and ozone-layer depletion. As a result of comparing two models, ozone-layer depleting effect is totally eliminated by using HFC410A. Global warming effect can be largely reduced if recovery of the used refrigerant is assumed. From these results, the conversion from HCFC to HFC used as a refrigerant for air conditioners can become one practical solution for global environmental protection in the refrigeration and air conditioning industry. Moreover, HFC32 model has potential to reduce more global warming effect than HFC410A model. In the future, two key subjects can be proposed to reduce global warming effect to use HFC. One is to establish a society in order to make it possible to recover high ratio of the used refrigerant. The other is to decrease the amount of the refrigerant contained in a product with maintaining high performance of the product when being used.

Future Scheme

Ever since the Kyoto Protocol held in 1997, the refrigeration and air conditioning industry, as well as other industries, has been demanded to take specific actions for reducing global warming effect such as technologies development of energy saving of products, alternative refrigerant, and recovery of used refrigerant. With regard to alternative refrigerant, currently it is at the phase of changing from HCFC22 to HFC410A used for room air conditioners, and its effect is confirmed in this case study. However, further discussion is now required for possible refrigerants in the future to reduce more global warming effect to meet the goal of the Protocol. In order to consider HFC32 as a possible solution of the alternative refrigerant, product safety issue needs to be carefully discussed, and measures against its slight flammability must be well prepared. Since changing refrigerant from one to another depends on strategic decision of corporate, the conclusion can't be drawn from a single viewpoint. But at least from environmental viewpoint, HFC32 is superior refrigerant to HFC410A that is concluded in this study. And for that reason, HFC32 is well worth consideration as an option of future refrigerants.

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