STUDY ON THE ACTUAL USAGE OF RESIDENTIAL AIR CONDITIONERS FOR LCCP EVALUATION

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ABSTRACT

To select the optimal refrigerant from next-generation candidates, it is necessary to evaluate GHG emissions over the entire lifecycle of the equipment (LCCP evaluation). In this report, to provide baseline data for future LCCP evaluations, we conducted surveys on residential air conditioners in Europe and Asia to gather information on real-world usage conditions (operating periods, operating hours, product lifetimes, etc.) required to calculate GHG emissions during the equipment's usage stage. Using this data, we further calculated operating hours by outdoor temperature for each target city, necessary for deriving annual energy consumption.

Keyword: Low GWP refrigerants, Greenhouse gas, Life cycle climate performance, Residential air conditioners

1. INTRODUCTION

To select the optimal refrigerant from next-generation candidates, it is important to evaluate GHG emissions (hereafter simply "emissions") over the entire lifecycle of the equipment, rather than merely assessing GWP. Life cycle assessment (LCA) covers emissions across the entire product lifecycle, from direct and indirect emissions in the material manufacturing process to emissions generated in the dismantling process. Among these sources, Eq. (1) represents the "direct emissions from refrigerant release," while Eq. (2) represents the "indirect emissions from product use and refrigerant manufacturing." The sum (3), life cycle climate performance (LCCP) [1]. The LCCP Evaluation Study Working Group considers LCCP evaluation, which focuses on the impact of refrigerants, to be the appropriate evaluation index for refrigeration and air-conditioning products.

$$\text{Direct Emissions} = GWP \times C \times ALR \times L + GWP \times C \times EOL \tag{1}$$

$$\text{Indirect Emissions} = EM \times L \times AEC + RFM \times C \tag{2}$$

$$LCCP = \text{Direct Emissions} + \text{Indirect Emissions} \tag{3}$$

M any of the parameters in Eq. (1) and Eq. (2) can be obtained to some extent through literature research. However, annual energy consumption (AEC), which has a significant impact on LCCP evaluation results, is difficult to determine because it depends on product usage specific to each city (country), such as cooling and heating periods and daily operating hours, as well as differing outdoor temperatures. In addition, product lifetime (L) is scarcely known in overseas contexts, creating the challenge that accurate LCCP evaluation has been difficult until now.

LCCP evaluations have been conducted in the past [2][3]. However, for example, in India (Mumbai), the evaluation estimated operating hours by multiplying the annual hours of outdoor temperatures that require cooling in Mumbai by the operation ratio in India's performance standards. This approach does not reflect actual operating periods or the outdoor temperatures at operating hours.

Therefore, in anticipation of conducting LCCP evaluations globally in the future, we carried out surveys on operating periods, operating hours, and product lifetimes for residential air conditioners, targeting cities (countries) in Europe and Asia. Based on this, we calculated the average hourly operating hours per air conditioner during the operating period. Furthermore, using published outdoor temperature data for each target city (country), we accumulated the average operating hours per air conditioner at 1 °C outdoor temperature intervals throughout the operating period. Based on this data, we derived operating hours by outdoor temperature that reflect actual usage required for the AEC calculations. In this paper, we report on the conducted survey, methods for examining usage, results, and future initiatives.

2. QUESTIONNAIRES, TARGET CITIES, AND SAMPLE SIZE

The questionnaire form used in the survey is shown in Fig. 1. The yellow-shaded sections in the form are to be filled out by respondents. To ensure ease of implementation, the survey was conducted using both paper-based forms and Microsoft Forms. The questionnaire covered the following: room usage, type of cooling and heating equipment used, number of weekly holidays, cooling and heating operating periods, average operating hours, and lifetime of the product purchased. The survey was conducted between March 12, 2024, and July 4, 2025.

Table 1 shows the target cities where the survey was

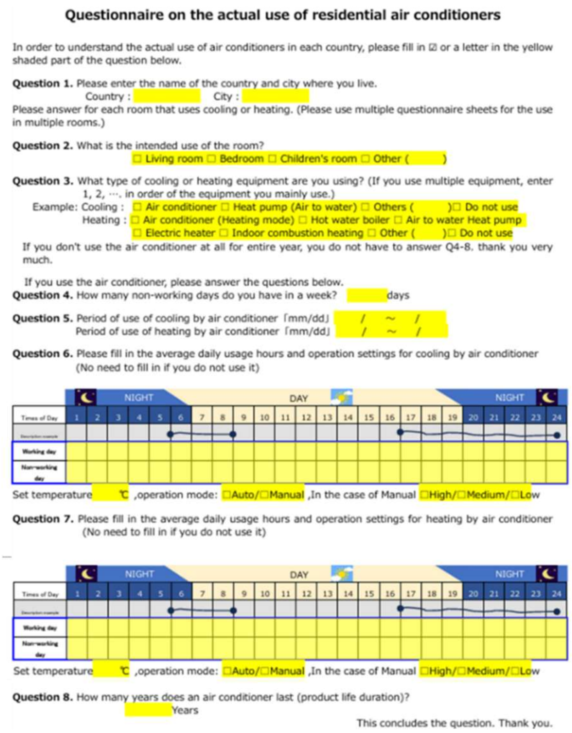


Fig.1 Questionnaire

conducted, along with the final sample sizes used for examining actual usage. The target countries consisted of Asian regions that require primarily cooling only and have major room air conditioner markets, as well as Bordeaux (France) and Tokyo (Japan) for regions that require both cooling and heating. The survey was conducted primarily among employees of residential air conditioners manufacturer.

Although more responses were collected than shown in Table 1, we narrowed down our analysis to living rooms (including living-dining-kitchen spaces) in each household where residential air conditioners were the primary cooling or heating equipment. As a result, the final sample sizes used in the study are those shown in Table 1.

Table 1 Target cities and sample size

Region	Europe	Asia				
Country	France	Japan	India	Vietnam	Thailand	Malaysia
City	Bordeaux	Tokyo	Delhi	Ho Chi Minh	Bangkok	Kuala Lumpur
Sample size	10	71	9	11	37	11

3. METHODS FOR EXAMINING USAGE IN TARGET CITIES

The methods of analyzing usage from the questionnaire data are described below.

· Cooling and heating operating periods

Table 2 shows the results for cooling operations in Tokyo (Japan). For the reported operating start and end dates, the average day count from January 1 of a normal (non-leap) year was calculated. These averages were then used to determine the typical operating start and end dates in each target city.

Table 2 Example of cooling operation in Tokyo (Japan)

Period of use		Number of days from January 1	
Start	End	Start	End
April 1	September 30	90	272
June 15	September 15	165	272
⋮	⋮	⋮	⋮
June 1	September 30	151	272
May 1	October 15	120	287
Average number of days		159.01	274.73
Rounded number of days		159	275
Actual Date		June 9	October 3

· Average operating hours per unit

For each reported operating hour in the questionnaire, a value of "1 (h)" was assigned if the unit was operating and "0 (h)" if not operating. The average value across samples was then calculated to obtain the average operating hours per unit for each hour in each target city. As an example, Table 3 shows the results for weekday and holiday cooling operations in Tokyo (Japan). Finally, the bottom row shows the weighted average operating hours per unit (including weekdays and holidays). Summing these values up from 0:00 to 23:00 yields 13.46 hours, which is the daily operating hours in Tokyo. (According to the survey results, all target cities had two holidays per week.)

· Outdoor temperature data used

As shown in Table 4, for Tokyo (Japan), hourly outdoor temperature data for 2023 was downloaded from the Japan Meteorological Agency website [4]. For the other target cities, hourly outdoor temperature data for 2023 were extracted from datasets provided by the U.S. National Centers for Environmental Information (NCEI) [5], collected from international airports located in or near each city. Since the timestamps in this database are recorded in Coordinated Universal Time (UTC), time zone adjustments were applied to align the outdoor temperature with local standard time for each target city. In addition, daylight saving time adjustments were applied for Bordeaux (France). Specifically, from January 1, 2023, the time difference with UTC was set to +1 hour. On the daylight saving start date, March 26, 2023, at 2:00 AM local time, the difference was changed to +2 hours, and after the end date, October 29, 2023 at 3:00 AM, it was reset to +1 hour. The database had missing data of up to about 1.9%. In such cases, missing outdoor temperature values were estimated by linear interpolation using adjacent hourly data.

· Lifetime of the purchased product

Since responses depend on user perception and the distribution is highly skewed, the median was adopted as the representative value instead of the mean.

Table 3 Example of cooling operation in Tokyo (Japan)

Working day

Times of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
No.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No.3	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
No.71	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
Average operating time per unit(h)	0.46	0.46	0.45	0.41	0.41	0.48	0.65	0.66	0.44	0.30	0.27	0.27	0.27	0.28	0.30	0.31	0.37	0.42	0.62	0.85	0.90	0.94	0.87	0.73

Non-working day

Times of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
No.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No.71	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
Average operating time per unit(h)	0.49	0.49	0.46	0.41	0.41	0.45	0.58	0.69	0.70	0.70	0.77	0.79	0.75	0.75	0.76	0.76	0.79	0.83	0.86	0.93	0.93	0.93	0.86	0.72

Weighted Average

Times of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Average operating time per unit(h)	0.47	0.47	0.45	0.41	0.41	0.47	0.63	0.67	0.51	0.41	0.41	0.42	0.40	0.41	0.43	0.44	0.49	0.54	0.69	0.87	0.91	0.94	0.87	0.73

Table 4 Data source of outdoor temperature

Region	Europe	Asia				
Country	France	Japan	India	Vietnam	Thailand	Malaysia
City	Bordeaux	Tokyo	Delhi	Ho Chi Minh	Bangkok	Kuala Lumpur
Time difference from UTC (Coordinated Universal Time)	March 26-October 28:+2h Other than the above:+1h	+9 (h)	+5.5 (h)	+7 (h)	+7 (h)	+8 (h)
Data source	National Centers for Environmental Information	Japan Meteorological Agency	National Centers for Environmental Information			
Measurement point	Bordeaux Merignac International Airport	Tokyo Observatory	Indira Gandhi International Airport	Tan Son Nhat International Airport	Don Mueang International Airport	Kuala Lumpur International Airport

· Calculation of operating hours by outdoor temperature per unit

Table 5 shows how operating hours by outdoor temperature were calculated, using the cooling operation period in Tokyo (Japan) as an example. For the entire cooling operation period (June 9 to October 3), we summed the average operating hours per unit at 1 °C outdoor temperature intervals on an hourly basis. This calculation produced the operating hours by outdoor temperature during the cooling period, as shown in Fig. 2.

Table 5 Example of cooling operation in Tokyo(Japan)

yyyy/mm/dd time	Outdoor temperature (℃)	Average operating hours per unit (h)
2023/6/9 0:00	18.5	0.47
2023/6/9 1:00	18.4	0.47
2023/6/9 2:00	18.9	0.45
2023/6/9 3:00	19.0	0.41
2023/6/9 4:00	19.5	0.41
2023/6/9 5:00	19.5	0.47
2023/6/9 6:00	19.8	0.63
2023/6/9 7:00	19.1	0.67
2023/6/9 8:00	19.1	0.51
2023/6/9 9:00	19.7	0.41
2023/6/9 10:00	19.9	0.41
⋮	⋮	⋮
2023/10/3 15:00	25.3	0.44
2023/10/3 16:00	24.9	0.49
2023/10/3 17:00	24.8	0.54
2023/10/3 18:00	24.1	0.69
2023/10/3 19:00	23.7	0.87
2023/10/3 20:00	23.5	0.91
2023/10/3 21:00	23.3	0.94
2023/10/3 22:00	23.6	0.87
2023/10/3 23:00	23.3	0.73

June 9, 2023

October 3, 2023

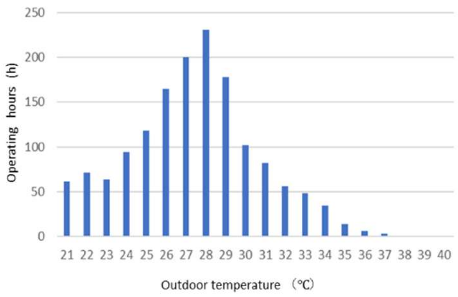


Fig.2 Operating hours for outdoor temperature at cooling operation period in Tokyo (Japan)

4. RESULTS AND DISCUSSION ON USAGE

Using the methodology described earlier, we examined actual usage in the target cities. Table 6 presents the results for heating-and-cooling regions, and Table 7 presents those for cooling-only regions, showing operating periods, operating hours, and operating hours by outdoor temperature for cooling or heating. Based on the operating hours by outdoor temperature shown in Tables 6 and 7, we can calculate AEC using ISO 16358. By multiplying this AEC by product lifetime (L), we can calculate the indirect emissions from power consumption during use, which are necessary for LCCP evaluation. In addition, product lifetime (L) enables calculation of direct emissions from refrigerant release during use.

[RESULTS AND DISCUSSION ON COOLING OPERATION]

· Cooling operation hours in Asia's cooling-only regions
In cooling-only regions such as Ho Chi Minh (Vietnam), Bangkok (Thailand), and Kuala Lumpur (Malaysia), cooling is used year-round due to the tropical climate, resulting in long cooling operation hours. Cooling operation hours are longest in Bangkok, followed by Ho Chi Minh and Kuala Lumpur. However, as shown in Table 8, the average operation hours per unit indicate that residential air conditioners are not operated during daytime hours on weekdays in Ho Chi Minh and Kuala Lumpur. Considering lifestyle differences between urban and suburban areas, it is reasonable to conclude that the average annual cooling operating hours in cooling-only tropical regions of Asia is around 4,100 hours.

· Cooling operation hours in heating-and-cooling regions
Cooling operation hours are found to be limited to about 20 to 40% of those in Asia's cooling-only regions due to the restricted operating period.

· Lower outdoor temperature limit for cooling operation
No significant differences were observed in the lower outdoor temperature limit for cooling operation between the surveyed Asian cooling-only regions and Tokyo (Japan). In these Asian regions, cooling operation is considered to be generally conducted when outdoor temperatures exceed a certain threshold, regardless of the specific country or city. For reference, at outdoor temperatures below 20 °C, where ISO 16358 defines cooling load as 0, Tokyo (Japan) had the most cooling operation hours. However, this figure accounted for only 3.0% of total cooling hours, compared to 1.4% or less in other Asian cooling-only regions. In contrast, Bordeaux (France) showed 22.4% of cooling hours below 20 °C, suggesting that cooling operation is performed even at

Table 6 Actual usage (cooling and heating region)

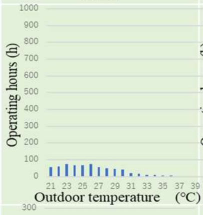
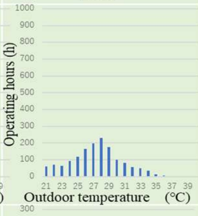
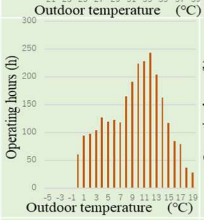
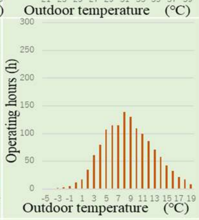
Region		Europe	Asia
Country		France	Japan
City (Climate zone)		Bordeaux (Temperate)	Tokyo (Temperate)
Operating period	Cooling	May 26-September 4	June 9-October 3
	Heating	October 17-March 23	November 13-March 18
Operating hours (h)	Cooling	866	1574
	Heating	2654	1381
	Annual	3520	2955
Operating hours by outdoor temperature (h)	Cooling		
	Heating		
Product lifetime (years)		–	12

Table 7 Actual usage (cooling only region)

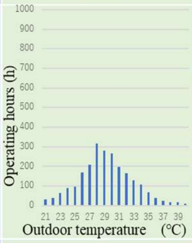
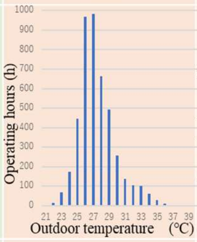
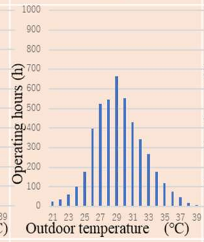
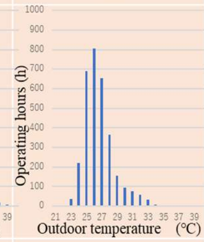
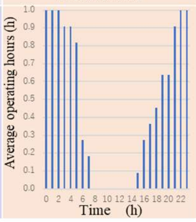
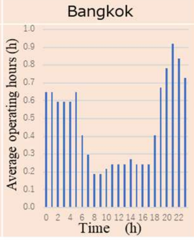
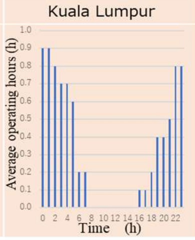
Region		Asia			
Country		India	Viet Nam	Thai	Malaysia
City (Climate zone)		Delhi (Temperate)	Ho Chi Minh(Tropical)	Bangkok (Tropical)	Kuala Lumpur(Tropical)
Operating period	Cooling	April 1-October 11	January 1-December 31	January 1-December 31	January 1-December 31
	Heating	–	–	–	–
Operating hours (h)	Cooling	2380	4513	4598	3207
	Heating	–	–	–	–
	Annual	2380	4513	4598	3207
Operating hours by outdoor temperature (h)	Cooling				
Product lifetime (years)		8	10	10	10

Table 8 Average operating hours per unit (Working day)

Region		Asia		
Country		Viet Nam	Thai	Malaysia
City		Hochiminh	Bangkok	Kuala Lumpur
Average operating hours per unit (h)	Cooling			

low outdoor temperatures (likely with room air conditioner set temperatures below 20°C).

[RESULTS AND DISCUSSION ON HEATING OPERATION]

· Upper outdoor temperature limit for heating operation
For heating operation, the evaluation was limited to Bordeaux (France) and Tokyo (Japan), and no significant difference was found in the upper outdoor temperature limit. For reference, at outdoor temperatures above 17 °C, where ISO 16358 defines heating load as 0, heating operation accounted for 4.5% of total heating hours in Tokyo (Japan) and 7.1% in Bordeaux (France). Although heating operation hours in Bordeaux (France) were about twice those in Tokyo (Japan), analysis of average operating hours per unit indicated that the higher frequency of 24-hour continuous operation in Bordeaux was the main reason.

[RESULTS AND DISCUSSION ON PRODUCT LIFETIME]

· In Asia's cooling-only regions, product lifetimes were 10 years for Ho Chi Minh (Vietnam), Bangkok (Thailand), and Kuala Lumpur (Malaysia), 8 years for Delhi (India), and 12 years for Tokyo (Japan). For reference, the Cabinet Office's Consumer Confidence Survey [6] (April 2021) reported an average service life of 13.2 years for residential air conditioners, which is generally consistent with our findings.

5. CONCLUSION AND FUTURE WORK

To enable global LCCP evaluations in the future, we conducted surveys on operating periods, operating hours, and product lifetimes for residential air conditioners in European and Asian cities (countries). In addition, using published annual outdoor temperature data for each city, we derived operating hours by outdoor temperature reflecting actual usage, leading to the following findings:

(1) Although cooling operation hours vary among survey targets in tropical Asian regions, the average is estimated at around 4,100 hours.
(2) No significant differences were observed in the lower outdoor temperature limit for cooling operation among the Asian cooling-only regions surveyed and Tokyo (Japan). (Cooling operation is rarely performed below 20°C.) In contrast, in Bordeaux (France), 22.4% of total cooling hours occurred at below 20 °C, suggesting that cooling is performed even at low outdoor temperatures.
(3) For heating operation, no significant difference in the upper outdoor temperature limit was observed between the evaluation targets of Bordeaux (France) and Tokyo (Japan).
(4) For product lifetimes, the results were 10 years for Ho Chi Minh (Vietnam), Bangkok (Thailand), and Kuala Lumpur (Malaysia), 8 years for Delhi (India), and 12 years for Tokyo (Japan).

Going forward, we aim to improve data accuracy by supplementing the surveys as needed, while advancing LCCP evaluations for target cities (countries) to establish indicators for selecting the optimal refrigerant from next-generation candidates.

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NOMENCLATURE

C	: Refrigerant charge, kg
L	: Average lifetime of equipment, years
ALR	: Annual leakage rate (% of refrigerant charge), %
EOL	: End of life refrigerant leakage (% of refrigerant charge), %
GWP	: Global Warming Potential, kg CO_{2e} / kg
AEC	: Annual energy consumption, kWh
EM	: CO2e produced per unit kWh of electricity, kg CO_{2e} / kWh
RFM	: Refrigerant manufacturing emissions, kg CO_{2e} / kg

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LCCP 評価のためのルームエアコンの使用実態の検討
Study on the actual usage of residential air conditioners for LCCP evaluation

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To select the optimal refrigerant from next-generation candidates, it is necessary to evaluate GHG emissions over the entire lifecycle of the equipment (LCCP evaluation). In this report, to provide baseline data for future LCCP evaluations, we conducted surveys on residential air conditioners in Europe and Asia to gather information on real-world usage conditions (operating periods, operating hours, product lifetimes, etc.) required to calculate GHG emissions during the equipment's usage stage. Using this data, we further calculated operating hours by outdoor temperature for each target city, necessary for deriving annual energy consumption.

Key Word: Low GWP Refrigerants,Greenhouse gas,Life Cycle Climate Performance, Residential air conditioners

1．はじめに

次世代候補冷媒から最適な冷媒を選択するためには、単なる GWP 評価ではなく機器のライフサイクル全体における GHG (Greenhouse Gas)の排出量（以下､単に排出量という）評価が重要である。製品に使用される材料製造工程の直接および間接排出量から製品解体工程の排出量に至るまで，製品の全ライフサイクルに関連する排出量を網羅しているのが LCA (Life Cycle Assessment)である。このうち Eq. (1)で表される「冷媒放出に係わる直接的な排出量」ならびに Eq. (2)で表される「製品使用段階と冷媒製造工程の間接的な排出量」を抜き出し､それらを合計した指標が Eq. (3)で表される LCCP(Life Cycle Climate Performance）[1]である。LCCP 評価検討 WG では冷凍空調製品に対する評価指標としては冷媒の影響に着目した LCCP 評価が適していると考えている。

$$\text{Direct Emissions}=GWP\times C\times ALR\times L+GWP\times C\times EOL \quad (1)$$

$$\text{Indirect Emissions} = EM\times L\times AEC + RFM\times C \quad (2)$$

$$LCCP = \text{Direct Emissions} + \text{Indirect Emissions} \quad (3)$$

Eq. (1) および Eq. (2)のパラメータの多くは文献調査などにより、ある程度数値を把握することが可能であるが、年間エネルギー消費量 AEC は LCCP 評価結果への影響が大きいにもかかわらず、対象都市固有の製品の使い方（冷房および暖房の運転期間、1 日における運転時刻）および対象都市毎に異なる外気温の影響を受けるため、把握することが困難であった。加えて、製品の寿命期間 L についても海外における数値はほとんど知られておらず、結果としてこれまで正確な LCCP 評価は難しいという課題があった。

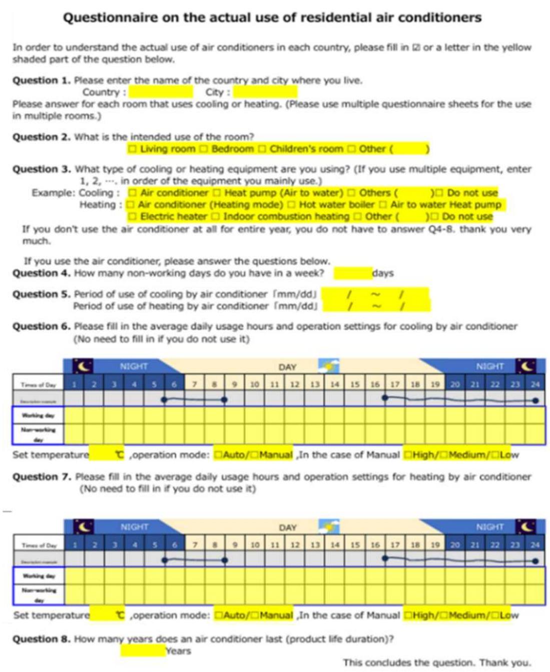
従来から LCCP 評価は実施されている [2] [3]が、例えば India (Mumbai)での評価は、Mumbai での 1 年間における冷房が必要な外気温毎の発生時間に対して India の性能規格における運転比率を乗じて外気温毎の運転時間を推定したものであり、実際の運転期間や運転時刻の外気温を反映した結果とはなっていない。

そこで、将来グローバルに LCCP 評価を実施することを想定し、ルームエアコンを対象として、

運転期間、運転時刻、製品の寿命期間について欧州およびアジア地域を対象都市としてアンケート調査を実施した。これをもとに、運転期間における1時間毎のエアコン1台当たりの平均運転時間を算出した。さらに、対象都市において公表されている外気温データをもとに運転期間全体において1時間間隔で外気温1℃毎にエアコン1台当たりの平均運転時間を積算することにより、年間エネルギー消費量 AEC の算出に必要な製品の使用実態に合わせた外気温毎の運転時間を導出した。本稿では実施したアンケート調査および使用実態の検討方法、検討結果および今後の取組みについて報告する。

２．アンケート内容と対象都市、サンプルサイズ

実施したアンケートの紙面を Fig. 1 に示す。アンケートの黄色塗り部は調査対象者が記入する部分である。調査は実施の容易さを考慮して、紙面と Microsoft Forms を用いた方法を併用することで行った。アンケート内容は対象の部屋の用途、使用している冷房および暖房機器の種類、1 週間における休日日数、冷房および暖房の運転期間、平均的な運転時間帯、購入した製品の寿命期間である。アンケート調査は March 12, 2024 - July 4, 2025 の期間に実施した。


Questionnaire on the actual use of residential air conditioners

In order to understand the actual use of air conditioners in each country, please fill in ☑ or a letter in the yellow shaded part of the question below.

Question 1. Please enter the name of the country and city where you live.
Country : City :
Please answer for each room that uses cooling or heating. (Please use multiple questionnaire sheets for the use in multiple rooms.)

Question 2. What is the intended use of the room?
☐ Living room ☐ Bedroom ☐ Children's room ☐ Other ( )

Question 3. What type of cooling or heating equipment are you using? (If you use multiple equipment, enter 1, 2, ···. in order of the equipment you mainly use.)
Example: Cooling : ☐ Air conditioner ☐ Heat pump (Air to water) ☐ Others ( )☐ Do not use
Heating : ☐ Air conditioner (Heating mode) ☐ Hot water boiler ☐ Air to water Heat pump ☐ Electric heater ☐ Indoor combustion heating ☐ Other ( )☐ Do not use
If you don't use the air conditioner at all for entire year, you do not have to answer Q4-8. thank you very much.

If you use the air conditioner, please answer the questions below.
Question 4. How many non-working days do you have in a week? days

Question 5. Period of use of cooling by air conditioner 「mm/dd」 / ～ /
Period of use of heating by air conditioner 「mm/dd」 / ～ /

Question 6. Please fill in the average daily usage hours and operation settings for cooling by air conditioner
(No need to fill in if you do not use it)

Set temperature ℃ ,operation mode: ☐Auto/☐Manual ,In the case of Manual ☐High/☐Medium/☐Low

Question 7. Please fill in the average daily usage hours and operation settings for heating by air conditioner
(No need to fill in if you do not use it)

Set temperature ℃ ,operation mode: ☐Auto/☐Manual ,In the case of Manual ☐High/☐Medium/☐Low

Question 8. How many years does an air conditioner last (product life duration)?
Years

This concludes the question. Thank you.

Fig. 1 Questionnaire

Table 1 にアンケート調査を実施した対象都市と最終的に使用実態の検討に使用したサンプルサイズを示す。対象国についてはルームエアコンの市場規模が大きく主に冷房専用地域であるアジア地域に加えて、冷暖房併用地域である Bordeaux (France)および Tokyo (Japan)とした。また、アンケートは主にルームエアコンメーカーの従業員を対象として実施した。

サンプルサイズについては実際に回収したサンプルは Table 1 より多かったが、各家庭で主に使用するリビング、リビングダイニング、リビングダイニングキッチンを対象とし、かつ主たる冷房あるいは暖房機器がルームエアコンである対象に絞り込んで検討を行ったため、結果として Table 1 に示すサンプルサイズとなっている。

Table 1 Target cities and sample size

Region	Europe	Asia				
Country	France	Japan	India	Vietnam	Thailand	Malaysia
City	Bordeaux	Tokyo	Delhi	Ho Chi Minh	Bangkok	Kuala Lumpur
Sample size	10	71	9	11	37	11

３．対象都市における使用実態の検討方法

アンケート回収後のデータ分析による使用実態の検討方法について、以下に述べる。

・冷房運転期間および暖房運転期間

一例として Tokyo (Japan)における検討例を Table 2 に示す。アンケートで回答された運転期

Table 2 Example of cooling operation in Tokyo

Period of use		Number of days from January 1	
Start	End	Start	End
April 1	September 30	90	272
June 15	September 15	165	272
⋮	⋮	⋮	⋮
June 1	September 30	151	272
May 1	October 15	120	287
Average number of days		159.01	274.73
Rounded number of days		159	275
Actual Date		June 9	October 3

間開始日、運転期間終了日に対して、平年（うるう年でない年）の January 1 からの各々の日数の平均値に相当する日を対象都市における平均的な運転開始日および運転終了日として運転期間を決定した。

・製品 1 台当たりの平均運転時間

アンケートの回答において運転している時刻は 1 (h)運転、運転していない時刻は 0 (h)運転として、サンプルの平均値を計算することで、対象都市における当該時刻における 1 台当たりの平均運転時間を算出する。一例として、Tokyo (Japan)における平日および休日の冷房運転時の検討例を Table 3 に示す。最終的に製品 1 台当たりの平日、休日を含めた加重平均運転時間が最下行になり、これを 0 時から 23 時まで合計すると東京における 1 日の運転時間である 13.46 (h)となる。（アンケートの結果、すべての対象都市にて 1 週間のうち休日は 2 日の結果であった）

・使用した外気温データ

外気温データは Table 4 の通り Tokyo (Japan)については気象庁ホームページ [4]における 2023 年 1 年間の 1 時間ごとの外気温データをダウンロードして用いた。その他の対象都市については米国政府の機関である National Centers for Environmental Information (NCEI)のホームページ [5]で提供されている対象都市内あるいはその近郊の国際空港における外気温データをダウンロードした上で、2023 年 1 年間の 1 時間毎のデータのみを抽出して使用した。なお、本データベースの時刻は UTC (Coordinated Universal Time) にて記載されているため、対象都市毎に UTC との時差を考慮して対象都市の標準時における外気温を対応させるようにした。加えて Bordeaux (France)についてはサマータイムの対応を行った。具体的には年初である January 1,

Table 3 Example of cooling operation in Tokyo (Japan)

Working day

Times of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
No.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No.3	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
No.71	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
Average operating time per unit(h)	0.46	0.46	0.45	0.41	0.41	0.48	0.65	0.66	0.44	0.30	0.27	0.27	0.27	0.28	0.30	0.31	0.37	0.42	0.62	0.85	0.90	0.94	0.87	0.73

Non-working day

Times of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
No.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No.71	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
Average operating time per unit(h)	0.49	0.49	0.46	0.41	0.41	0.45	0.58	0.69	0.70	0.70	0.77	0.79	0.75	0.75	0.76	0.76	0.79	0.83	0.86	0.93	0.93	0.93	0.86	0.72

Weighted Average

Times of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Average operating time per unit(h)	0.47	0.47	0.45	0.41	0.41	0.47	0.63	0.67	0.51	0.41	0.41	0.42	0.40	0.41	0.43	0.44	0.49	0.54	0.69	0.87	0.91	0.94	0.87	0.73

Table 4 Data source of outdoor temperature

Region	Europe	Asia				
Country	France	Japan	India	Vietnam	Thailand	Malaysia
City	Bordeaux	Tokyo	Delhi	Ho Chi Minh	Bangkok	Kuala Lumpur
Time difference from UTC (Coordinated Universal Time)	March 26-October 28:+2h Other than the above:+1h	+9（h）	+5.5（h）	+7（h）	+7（h）	+8（h）
Data source	National Centers for Environmental Information	Japan Meteorological Agency	National Centers for Environmental Information			
Measurement point	Bordeaux Merignac International Airport	Tokyo Observatory	Indira Gandhi International Airport	Tan Son Nhat International Airport	Don Mueang International Airport	Kuala Lumpur International Airport

2023 以降は UTC との時差を+1 (h)、現地時間でサマータイム開始日の March 26, 2023, 2:00 AM に UTC との時差を+2 (h)に変更し、終了日の October 29, 2023, 3:00 AM 以降は UTC との時差を+1 (h)に戻した。また、本データベースにおいては最大 1.9%程度のデータの欠落があったが、その場合は、前後の時刻における外気温データから線形補完することで欠落した外気温を推定した。

・購入した製品の寿命期間
回答が使用者の感覚に依存し、分布が大きく偏っているいるため、代表値としては平均値ではなく中央値を採用した。

・製品 1 台当たりの外気温毎の運転時間の算出
外気温毎の運転時間算出方法について Table 5 に Tokyo (Japan)の冷房運転期間の場合を例として示す。冷房運転期間 (June 9 - October 3)全体において 1 時間間隔で外気温 1℃毎に製品 1 台当たりの平均運転時間を積算することにより、

Table 5 Example of cooling operation in Tokyo (Japan)

yyyy/mm/dd time	Outdoor temperature (℃)	Average operating hours per unit (h)
2023/6/9 0:00	18.5	0.47
2023/6/9 1:00	18.4	0.47
2023/6/9 2:00	18.9	0.45
2023/6/9 3:00	19.0	0.41
2023/6/9 4:00	19.5	0.41
2023/6/9 5:00	19.5	0.47
2023/6/9 6:00	19.8	0.63
2023/6/9 7:00	19.1	0.67
2023/6/9 8:00	19.1	0.51
2023/6/9 9:00	19.7	0.41
2023/6/9 10:00	19.9	0.41
⋮	⋮	⋮
2023/10/3 15:00	25.3	0.44
2023/10/3 16:00	24.9	0.49
2023/10/3 17:00	24.8	0.54
2023/10/3 18:00	24.1	0.69
2023/10/3 19:00	23.7	0.87
2023/10/3 20:00	23.5	0.91
2023/10/3 21:00	23.3	0.94
2023/10/3 22:00	23.6	0.87
2023/10/3 23:00	23.3	0.73

June 9, 2023
October 3, 2023

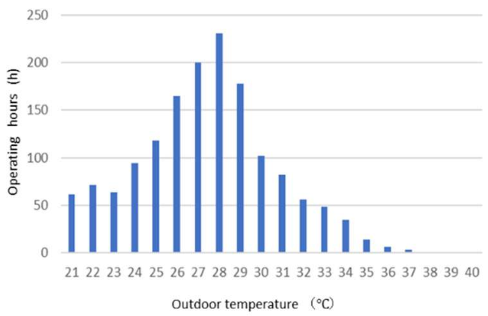


Fig.2 Operating hours for outdoor temperature at cooling operation period in Tokyo (Japan)

Fig.2 に示すような冷房運転期間における外気温毎の運転時間を求めた。

４．使用実態の検討結果および考察

前述の検討方法により、具体的に対象都市での使用実態の検討を行った。Table 6 に冷暖房併用地域、Table 7 に冷房専用地域の使用実態（冷房および暖房の運転期間、運転時間および外気温毎の運転時間）の検討結果を示す。Table 6 および Table 7 に示した外気温毎の運転時間をもとに、ISO 16358 により年間エネルギー消費量 AEC を算出し、これに製品の寿命期間 L を乗じることで LCCP 評価に必要な使用時の電力消費による間接排出量の算出が可能となる。加えて、製品の寿命期間 L により冷媒放出に係わる使用時の直接排出量の算出も可能となる。

【冷房運転に関する結果と考察】

・アジアの冷房専用地域の冷房運転時間
冷房専用地域の内、Ho Chi Minh (Viet Nam),

Table 6 Actual usage (cooling and heating region)

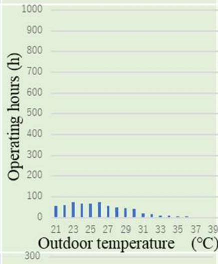
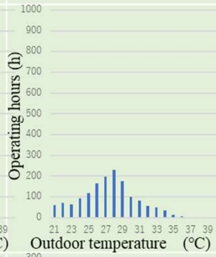
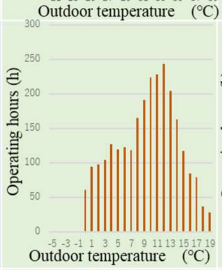
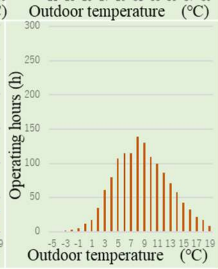
Region		Europe	Asia
Country		France	Japan
City（Climate zone）		Bordeaux (Temperate)	Tokyo（Temperate)
Operating period	Cooling	May 26-September 4	June 9-October 3
	Heating	October 17-March 23	November 13-March 18
Operating hours (h)	Cooling	866	1574
	Heating	2654	1381
	Annual	3520	2955
Operating hours by outdoor temperature (h)	Cooling		
	Heating		
Product lifetime (years)		–	12

Table 7 Actual usage (cooling only region)

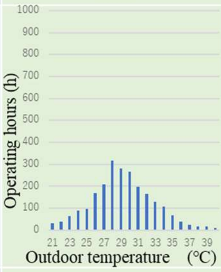
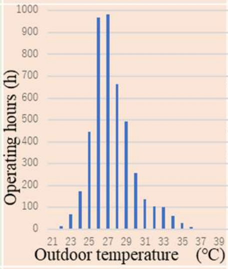
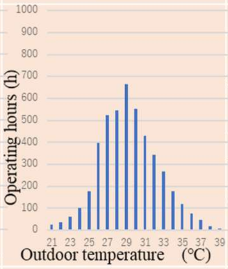
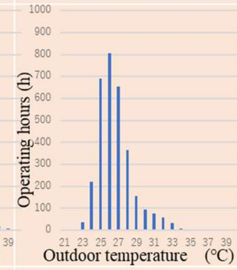
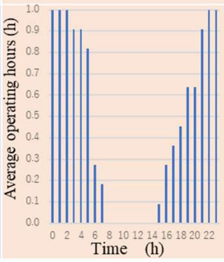
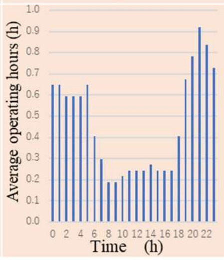
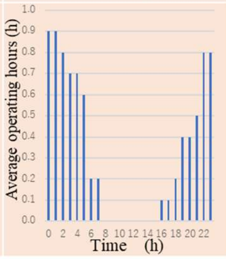
Region		Asia			
Country		India	Viet Nam	Thai	Malaysia
City（Climate zone)		Delhi（Temperate)	Ho Chi Minh(Tropical)	Bangkok (Tropical)	Kuala Lumpur(Tropical)
Operating period	Cooling	April 1-October 11	January 1-December 31	January 1-December 31	January 1-December 31
	Heating	–	–	–	–
Operating hours (h)	Cooling	2380	4513	4598	3207
	Heating	–	–	–	–
	Annual	2380	4513	4598	3207
Operating hours by outdoor temperature (h)	Cooling				
Product lifetime (years)		8	10	10	10

Table 8 Average operating hours per unit (Working day)

Region		Asia		
Country		Viet Nam	Thai	Malaysia
City		Hochiminh	Bangkok	Kuala Lumpur
Average operating hours per unit (h)	Cooling			

Bangkok (Thai), Kuala Lumpur (Malaysia)については熱帯気候で 1 年を通じて冷房を使用するため、結果として冷房運転時間も長いことがわかる。また、冷房運転時間は Bangkok，Ho Chi Minh，Kuala Lumpur の順番で長いが、Ho Chi Min，Kuala Lumpur について Table 8 に示す製品 1 台当たりの平均運転時間を見ると、平日の昼間にルームエアコンは運転されていないことがわかる。この差異は都市部／郊外などの居住地による生活様式などの差も含まれていることを踏まえて、アジアの熱帯気候における冷房専用地域の年間冷房運転時間は平均的に 4100(h)程度と見るのが妥当と考える。

・冷暖房併用地域の冷房運転時間

冷房運転時間は、運転期間が限定されていることによりアジアの冷房専用地域に対して 20-40%程度に留まることがわかる。

・冷房運転使用時の外気温の下限値について

今回アンケート調査対象としたアジアの冷房専用地域および Tokyo (Japan)において、冷房運転使用時の外気温の下限値には大きな差異は見られなかった。これらのアジア地域では、対象都市に拘わらず、おおよそ一定の外気温の下限を上回る外気温範囲において冷房運転が行われると考えられる。参考までに ISO 16358 で冷房負荷 0 を定義している外気温 20℃以下における冷房運転時間は Tokyo(Japan)

が最大であるものの冷房運転時間全体の 3.0%に留まり、他のアジアの冷房専用地域では 1.4%以内であった。一方、Bordeaux (France)においては 22.4%であることから、ここでは 20℃以下の低外気温でも冷房運転されている（ルームエアコンの設定温度を 20℃以下で使用していると推定）ことが示唆される。

【暖房運転に関する結果と考察】

・暖房運転使用時の外気温の上限値について
暖房運転に関する今回の評価対象は、Bordeaux (France)および Tokyo (Japan)のみであるが、暖房運転使用時の外気温の上限値には大きな差異は見られなかった。参考までに ISO 16358 で暖房負荷 0 を定義している外気温 17℃以上における暖房運転時間は Tokyo(Japan)が暖房運転時間全体の 4.5%、Bordeaux (France)においては 7.1%であった。また、Bordeaux(France)の暖房運転時間が Tokyo(Japan)の約 2 倍となっているが、製品 1 台当たりの平均運転時間を分析した結果、Bordeaux (France)は Tokyo (Japan)に比べ 24（h）連続運転の頻度が高いことがその主要因であると考える。

【製品の寿命期間に関する結果と考察】

・アジアの冷房専用地域である Ho Chi Minh (Viet Nam), Bangkok (Thai), Kuala Lumpur (Malaysia)においては 10 年、Delhi (India)は 8 年、Tokyo (Japan)は 12 年の結果であった。参考までに内閣府の消費動向調査（2021 年 4 月）[6]によるとルームエアコンの平均使用年数は 13.2 年であり、おおよそ整合していると考える。

５．結言および今後の取組み

将来的にグローバルに LCCP 評価を実施することを目的として、ルームエアコンを対象として、運転期間、運転時刻、製品の寿命期間について欧州およびアジア地域を対象都市としてアンケート調査を実施した。さらに、公表されている当該都市の年間の外気温データをもとに製品の使用実態に合わせた外気温毎の運転時間を導出し、以下の見解を得た。

(1) アジアの熱帯気候における冷房運転時間については調査対象によりばらつきはあるものの、平均的には 4100 (h)程度であると推定する。

(2) 冷房運転時の外気温の下限値については、今回アンケート調査対象としたアジアの冷房専用地域および Tokyo (Japan)において大きな差異は見られなかった。（外気温 20℃以下では、ほとんど運転しない）一方、Bordeaux (France)においては外気温 20℃以下における冷房運転時間は冷房運転時間全体の 22.4%であり、20℃以下の低外気温でも冷房運転されていることが示唆される。

(3)暖房運転使用時の外気温の上限値については、今回の評価対象である Bordeaux (France)および Tokyo (Japan)においては大きな差異は見られなかった。

(4) 製品の寿命期間について、 アジアの冷房専用地域である Ho Chi Minh (Viet Nam), Bangkok (Thai), Kuala Lumpur (Malaysia)においては 10 年、Delhi (India)は 8 年、Tokyo (Japan)は 12 年であった。

今後は、必要に応じてアンケート調査の補強による精度向上を図るとともに、対象都市に対する LCCP 評価を進め、次世代候補冷媒から最適な冷媒を選択するための指標としたい。

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記号

C	: Refrigerant charge, kg
L	: Average lifetime of equipment, years
ALR	: Annual leakage rate (% of refrigerant charge), %
EOL	: End of life refrigerant leakage (% of refrigerant charge), %
GWP	: Global Warming Potential, kg CO_{2e} / kg
AEC	: Annual energy consumption, kWh
EM	: CO2e produced per unit kWh of electricity, kg CO_{2e} / kWh
RFM	: Refrigerant manufacturing emissions, kg CO_{2e} / kg

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