Risk Governance Project Annual Report (H27)

Refrigerants and Air Conditioning Technology:

Flows, Stocks and Environmental Benefits of Refrigerant Substitution in Household Refrigerator in Japan

Mianqiang Xue
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Graduate School of Engineering, Osaka U., Japan

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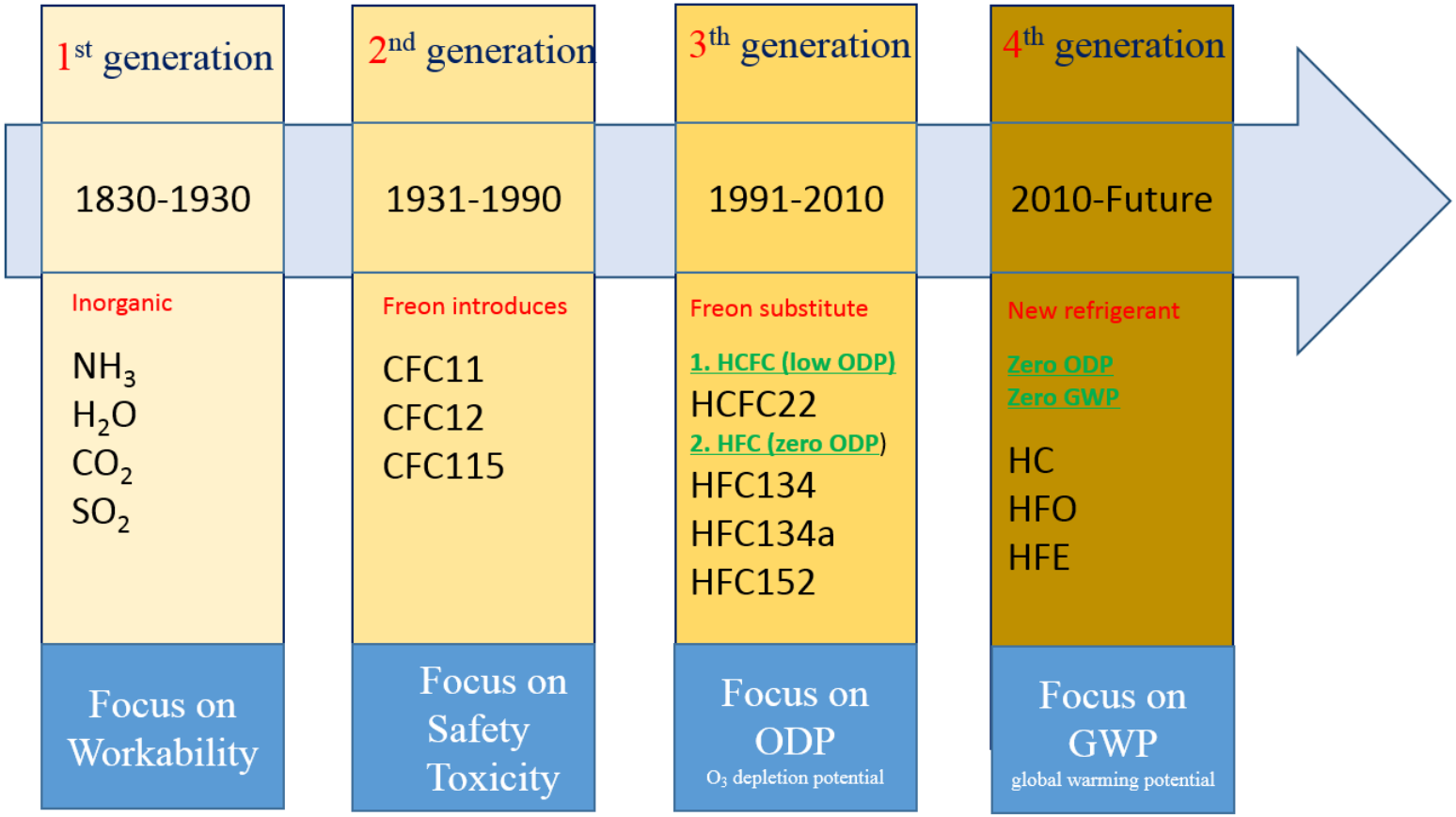
Outline

1. **Research background**
2. Stock and risk model building
3. Application to refrigerator sector
4. Future tasks

Research background

Refrigerant development process



** CFC: chlorofluorocarbons; HFC: hydrofluorocarbons; HC: hydrocarbon*
** HFO: hydrofluoroolefins; HFE: hydrofluoroether*
** GWP: global warming potential; ODP: ozone depletion potential*

Research background

■ Refrigerants in household refrigerator sector

Refrigerants	Formula	Time	Charge ratio(g/L)	GWP (kg CO_2-eq)	ODP (kg CFC11-eq)
R-12 (CFC)	CCl2F2	1952-1996	0.43	10900	0.82
R-134a (HFC)	CH2FCF3	1993-2022	0.39	1370	0
R-600a (HC)	CH(CH3)2CH3	2003-2030	0.2	20	0

R-134a and R-600a were the alternative options for R-12 in refrigerator. There is no other new matured alternatives with high energy efficiency and low cost.

■ Motivation

1. ODP -Ozone depletion potential

<Montreal Protocol>
(モントリオール議定書)

2. GWP -Global warming potential

<Kyoto Protocol>
(京都議定書)

Understanding the time dependent stock of refrigerator and refrigerant contained in them, and estimating the dynamic environmental impact of refrigerant are important for policy making associated with refrigerant management.

Research background

■ Current dynamic stock estimation method

(1) Bottom-up method: *directly sum up the products or chemicals (10%).*

Data including household number and products owned per household is needed.

Household number & Product per household ⇨ Stock

(2) Top-down method: *derive the stock from input flow (90%).*

Data including the input flow of product and output flow or life span is needed.

Input flow & Output flow or lifespan ⇨ Stock

Research background

■ Existing stock estimation

Refrigerants	R-12	R-134a	R-600a	Environmental benefits of substitution
Stock and emission estimation	PRTR (Use and Disposal phase)	-	-	-

The Japanese PRTR(Pollutant Release and Transfer Register) system estimate the stock and emission of R-12. However, the stock of their substituents and the environmental benefits was not examined.

■ Objectives

(1) To estimate the dynamic flow and stock of refrigerator and refrigerants contained in them;

(2) To assess the environmental benefits of refrigerant substitution

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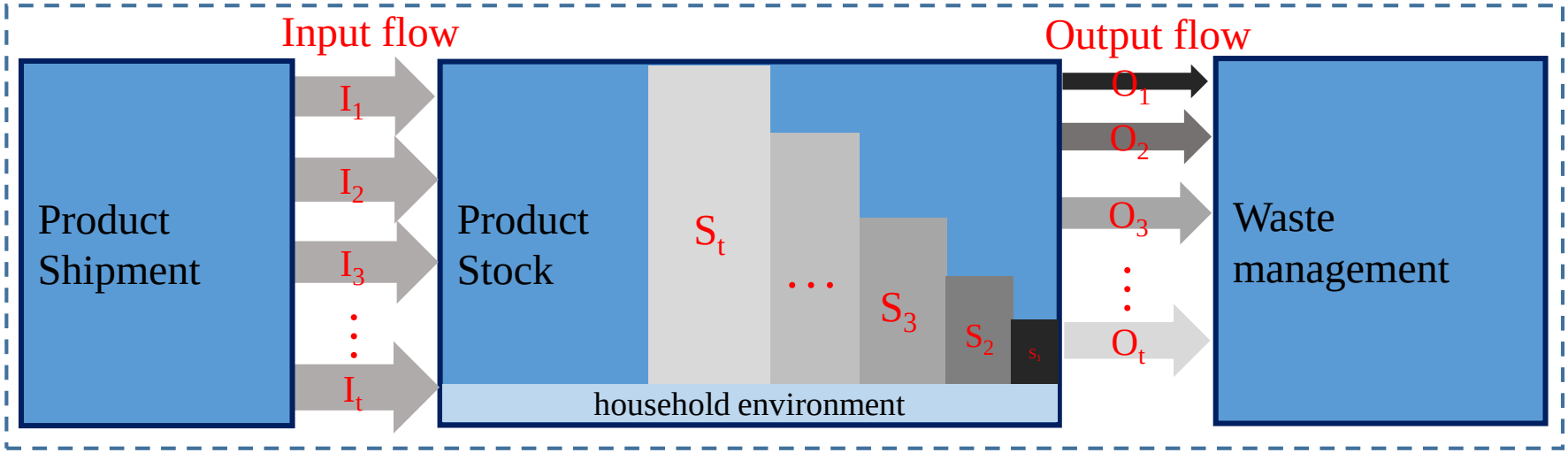
Refrigerator stock model



Model of flow and stock of refrigerator

1. Lifespan distribution of refrigerator (cumulative distribution of Weibull distribution)

$$P(t,t_0) = 1 - e^{-(\frac{t-t_0}{\beta})^{\alpha}}$$

$P(t,t_0)$: the probability that refrigerator was discarded
t: evaluation year
t_0: purchase year

2. Stock of refrigerator

$$S(t) = \sum I(t_0) \cdot [1 - P(t,t_0)]$$

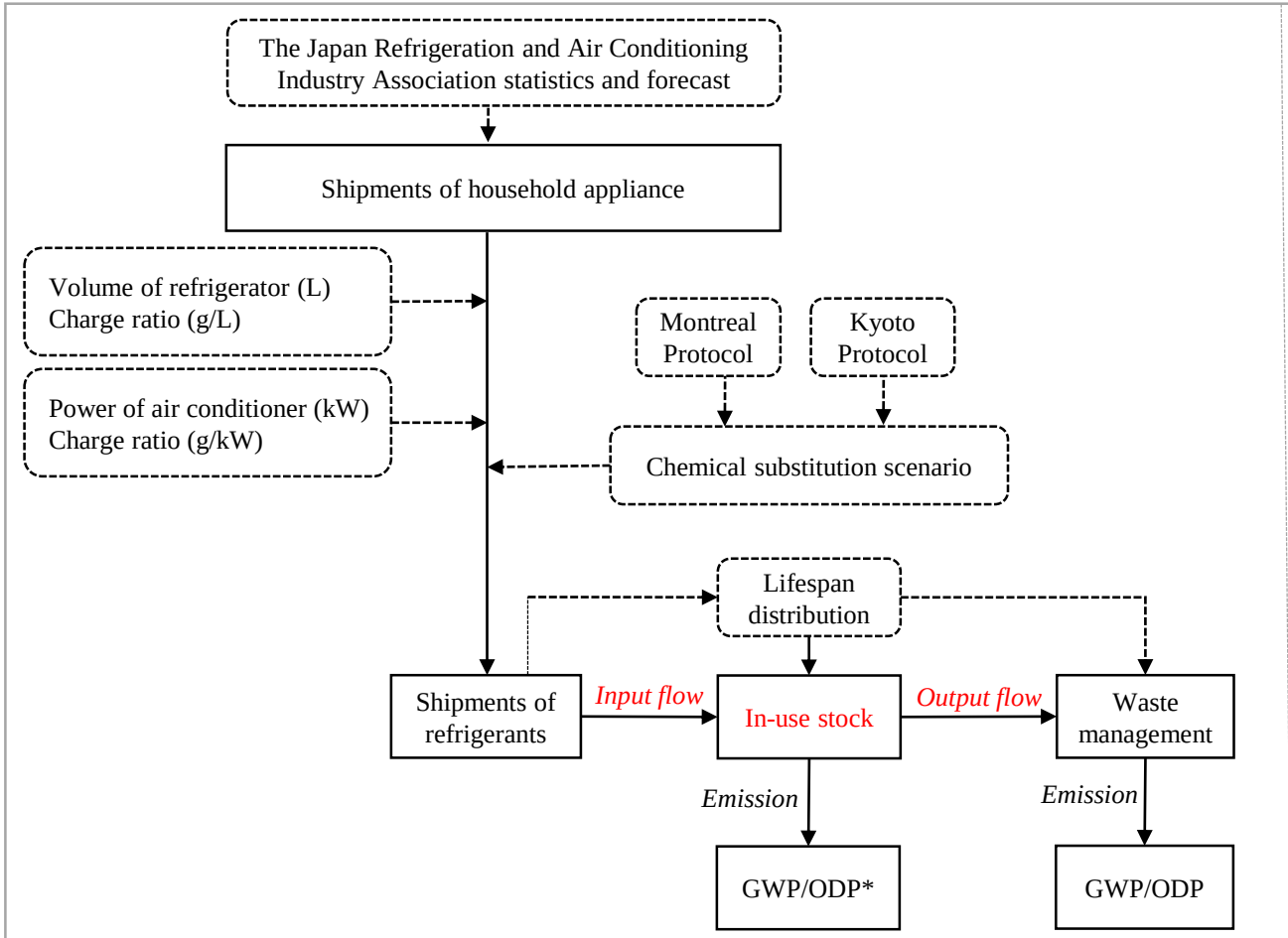
$S(t)$: stock of refrigerator
$1-P(t,t_0)$: complementary Weibull function, the probability that refrigerator remained in use phase

3. Output flow of refrigerator

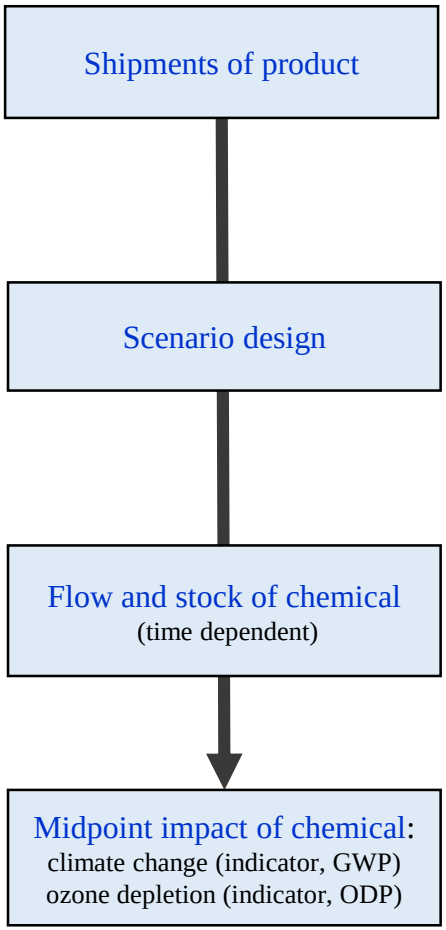
$$O(t) = I(t) - [S(t) - S(t-1)]$$

$O(t)$: Output flow of refrigerator

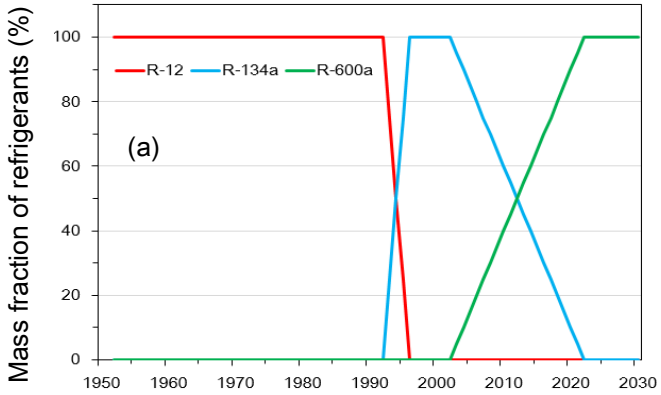
Refrigerant risk model



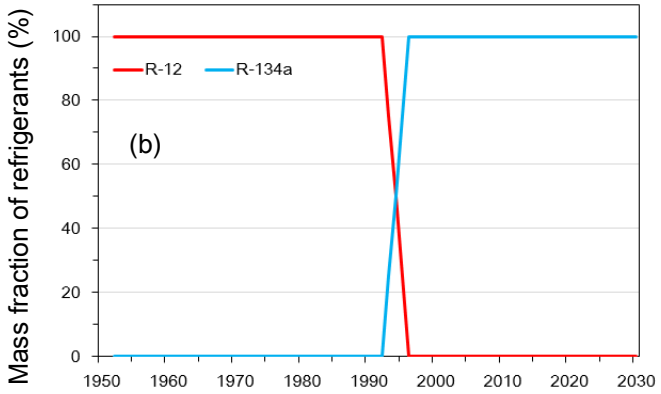
*GWP: global warming potential; ODP: ozone depletion potential.



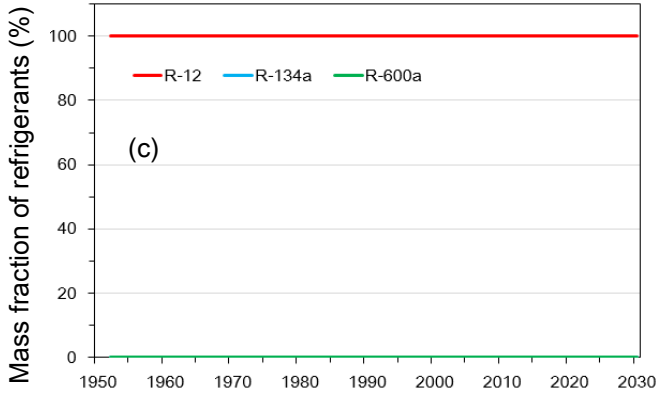
Refrigerant substitution scenario design



(a) Scenario A was designed according to real situation in Japan with some assumptions: R-12 was replaced by R-134a during 1993 to1996, R-134a was replaced by R-600a during 2003 to 2022.



(b) Scenario B: R-12 was replaced by R-134a. After then, all refrigerator use R-134a. By comparing with scenario A, we can evaluate the environmental benefits of replacement of R-134a with R-600a.



(c) Scenario C: there was no replacement. R-12 was used all the time. By comparing with scenario B, we can evaluate the environmental benefits of replacement of R-12 with R-134a.

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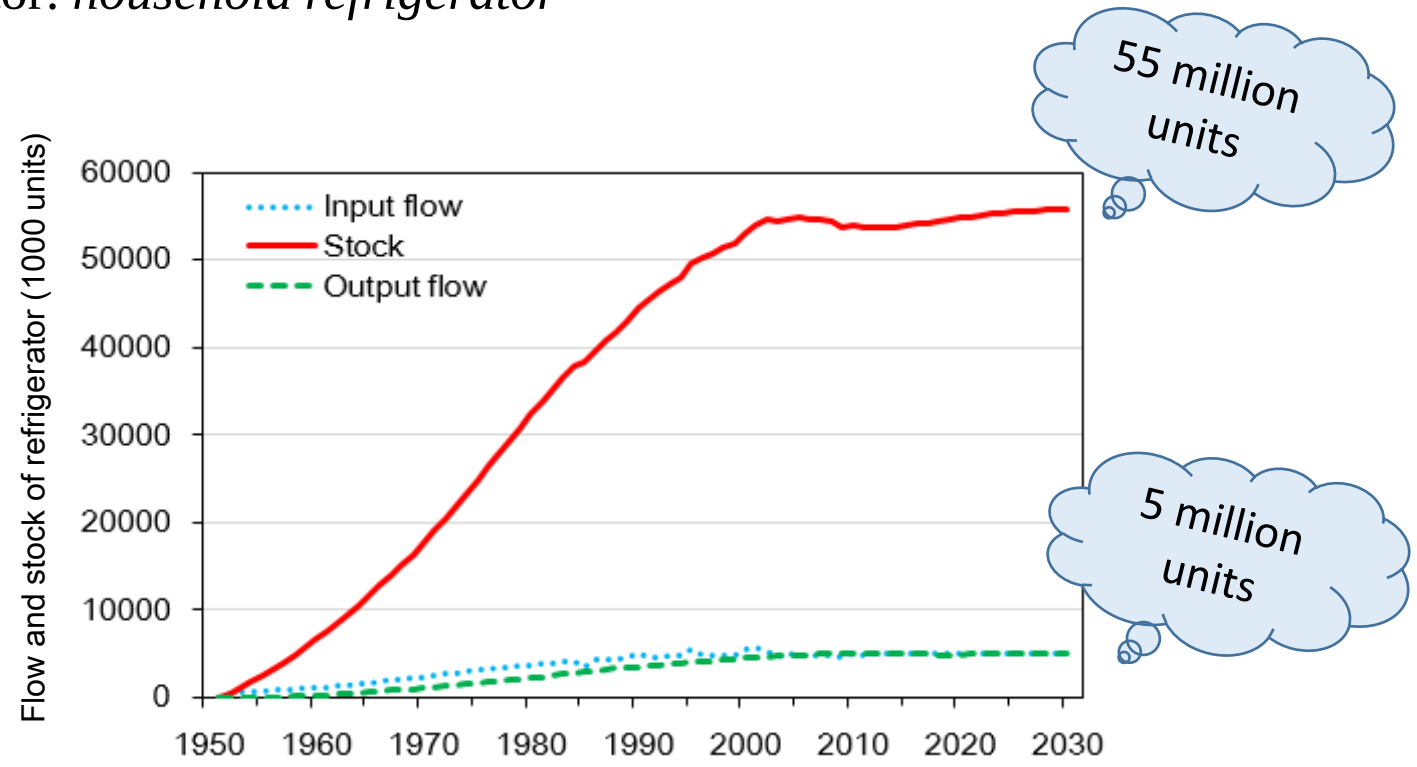
Flow and stock of refrigerator

1. Country: *Japan*

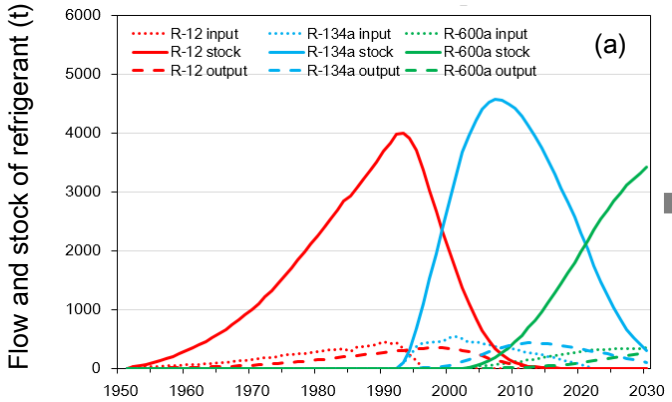
2. Time scope: *1952-2030*

3. Sector: *household refrigerator*



Time dependent input flow, stock and output flow of household electric refrigerator in Japan from 1952 to 2030

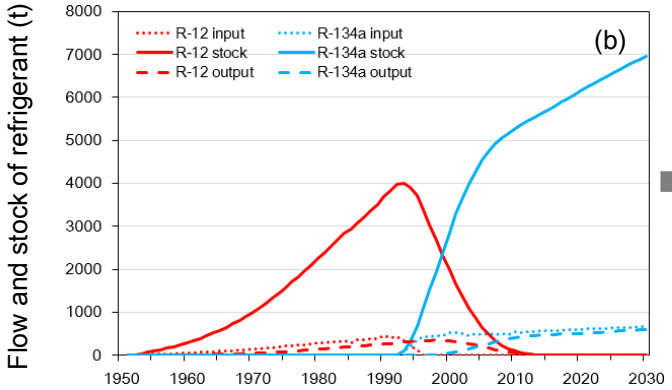
Flow and stock of refrigerants



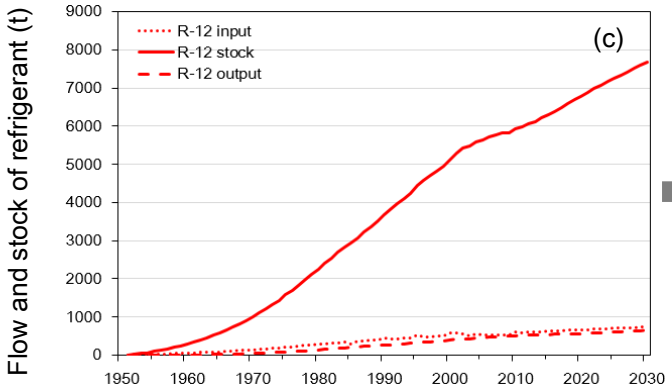
Magnitudes: the stock is 8-12 times greater than input flow and output flow.

Delayed effect: the peak of stock was 3-7 years later than that of input flow; the output flow peak was 3-7 years later than that of stock.

Implication: the risk of chemical stock need be paid more attention due to its large quality and long residence time.

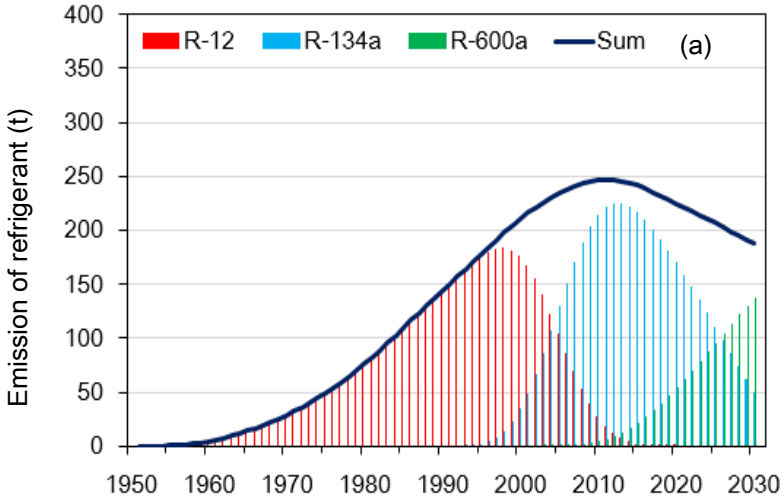


The first dramatically increase could be attributed to the increase of R-134a entering into the use phase. The subsequent slow increase was resulted from the increase of average volume of refrigerator.



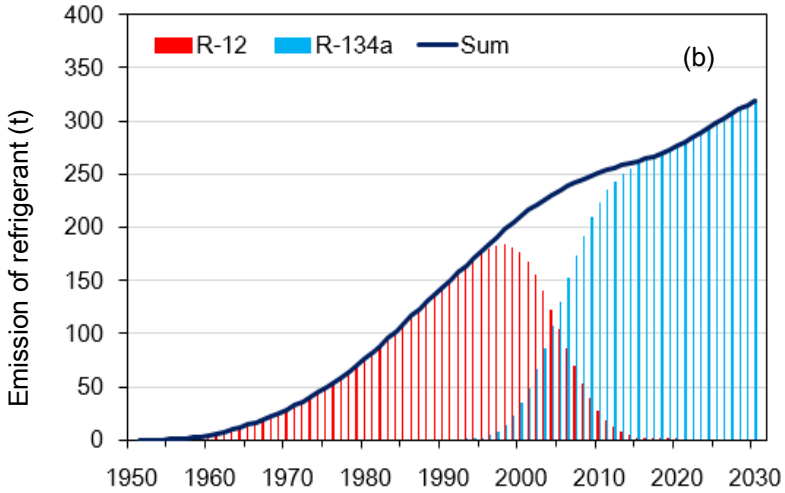
The stock of R-12 will reach 7667 t in 2030. In this case, the refrigerant would pose greatest impact on ozone depletion and climate change.

Emission of refrigerants



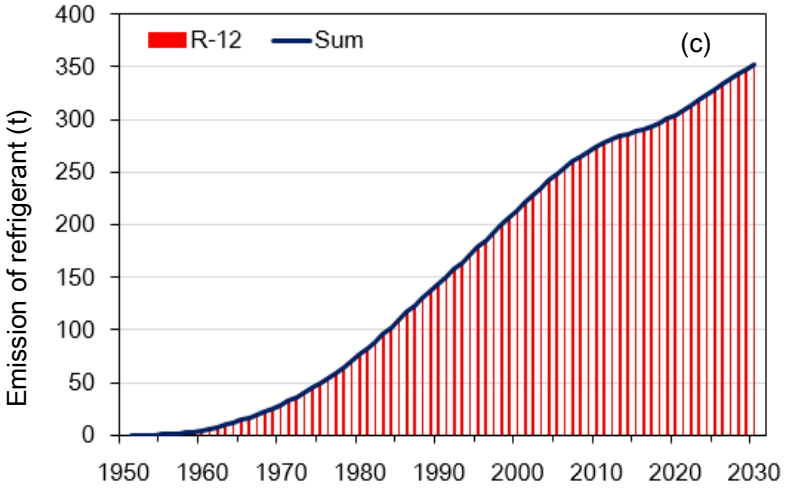
Scenario A

(44% R-12, 44% R-134a, 12% R-600a)



Scenario B

(40% R-12, 60% R-134a)



Scenario C

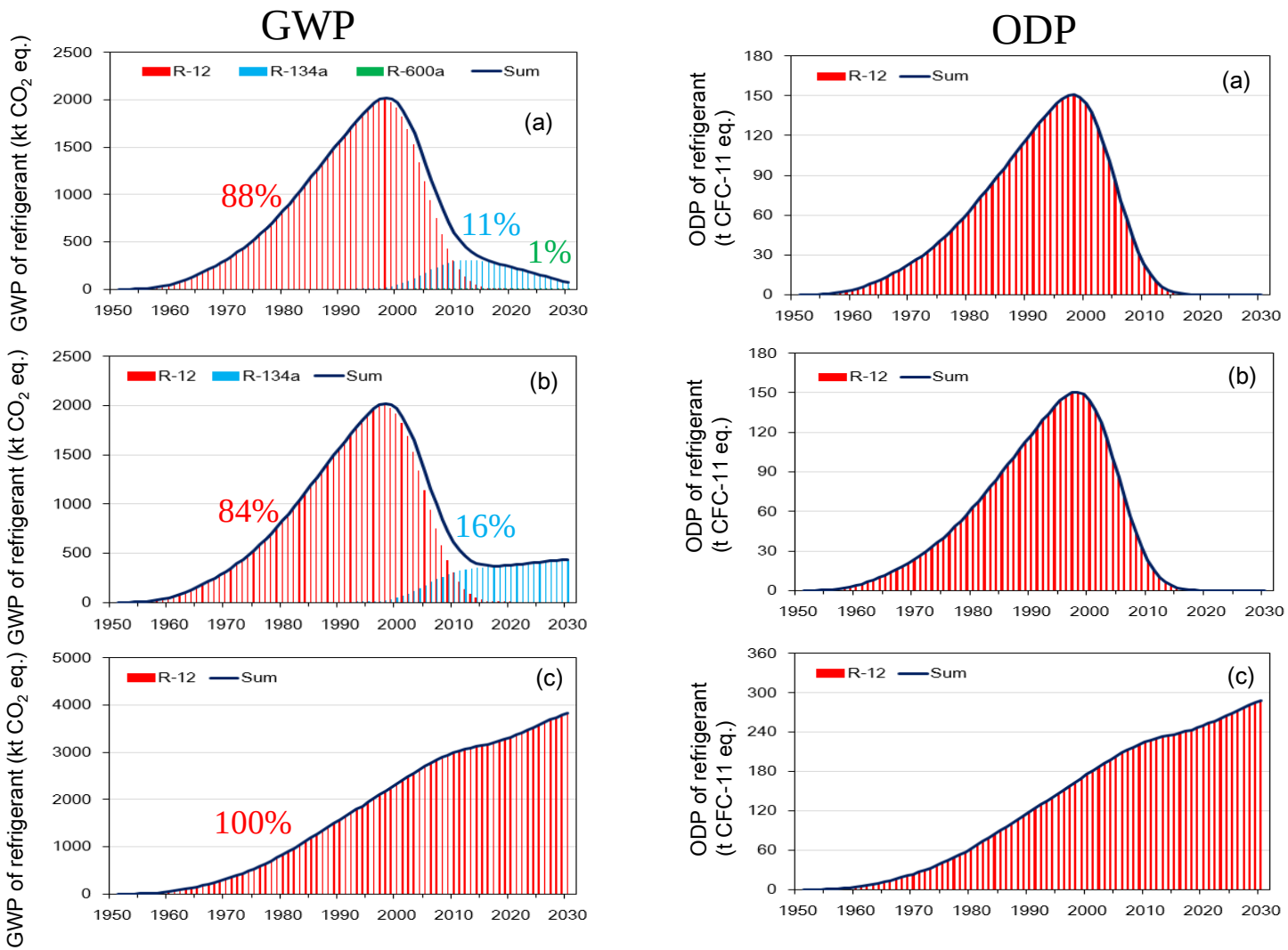
(100% R-12)

GWP and ODP of refrigerants

Scenario A

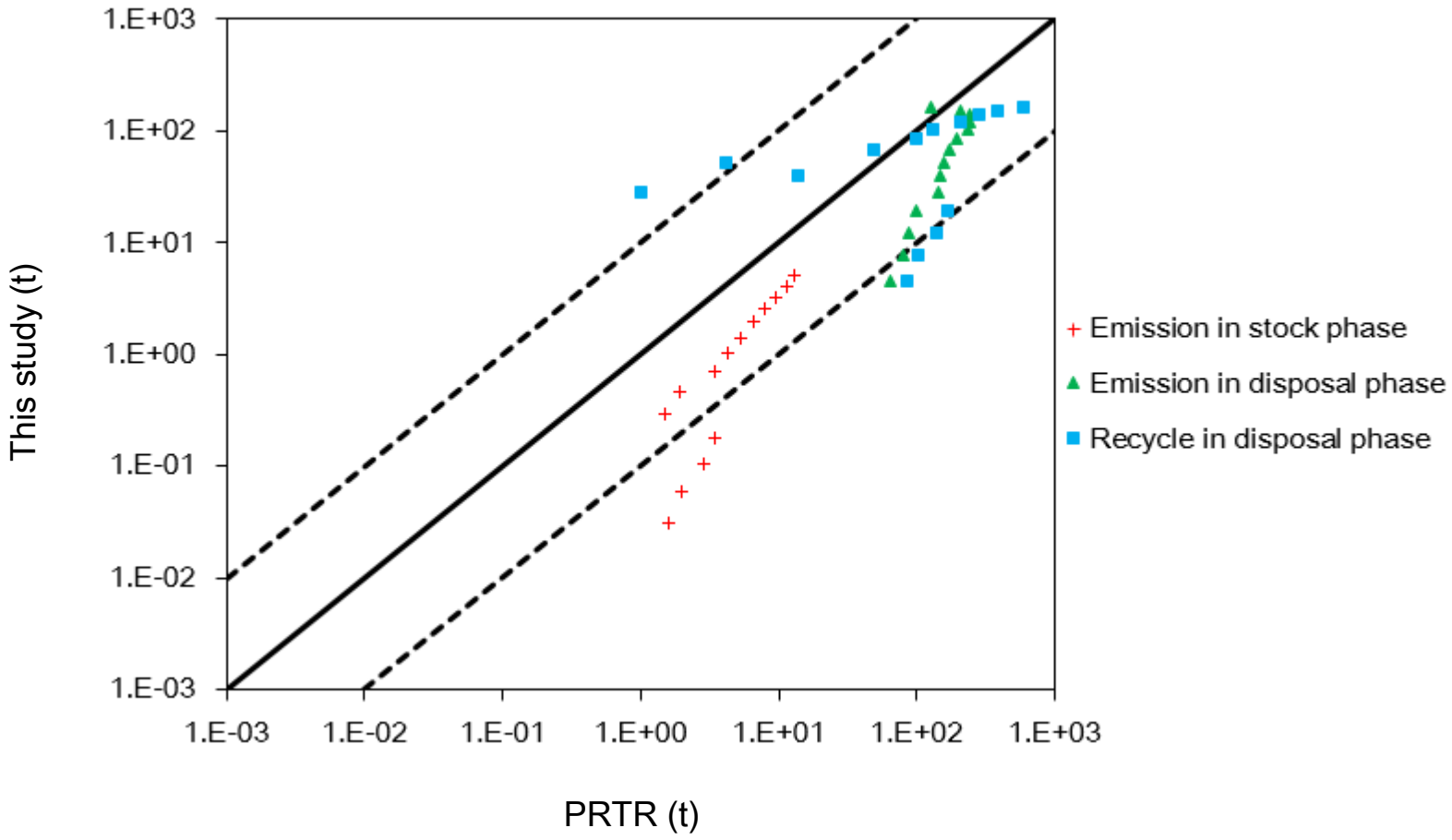
Scenario B

Scenario C



Refrigerant replacement		Replace R-12 by R-134a	Replace R-134a by R-600a
Environmental Benefits	GWP	75229 kt CO_2 eq.	3392 kt CO_2 eq.
	ODP	6388 t CFC-11 eq.	0 t CFC-11 eq.

Model validation



Comparison of R-12 emission from household refrigerator in Japan from 2001 to 2014

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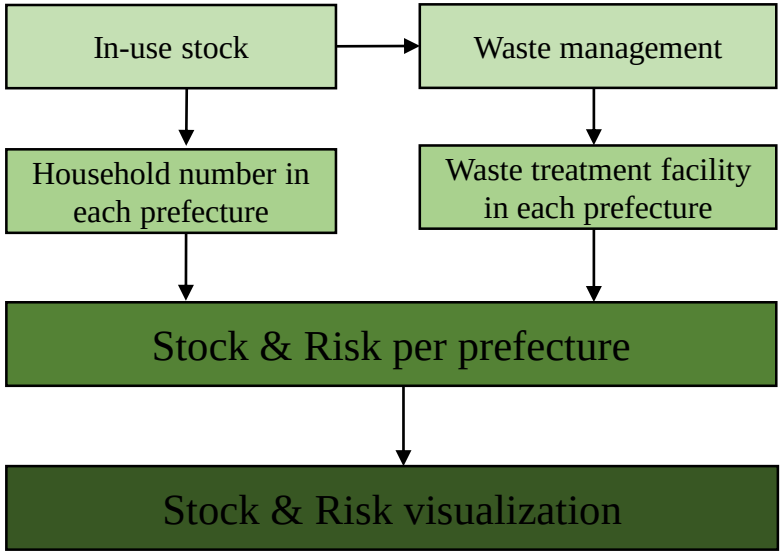
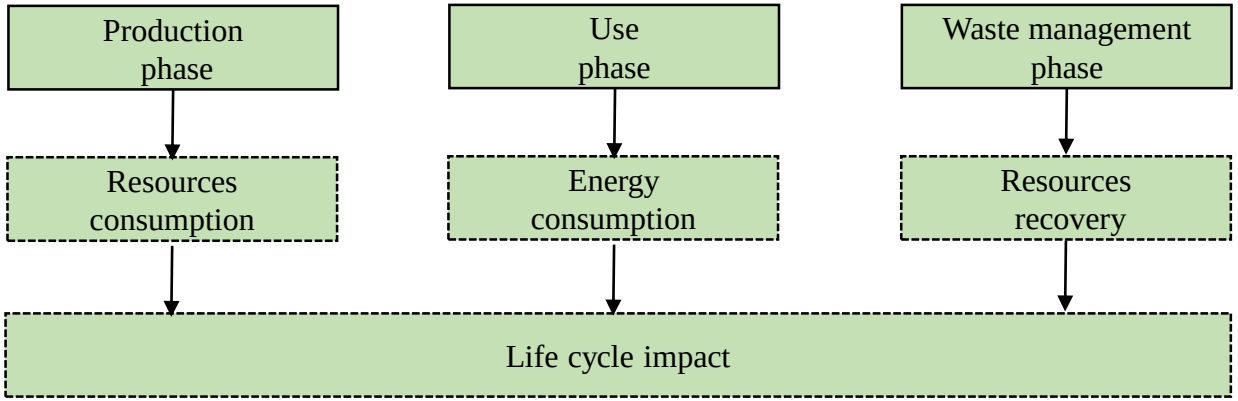
4. **Future tasks**

Future tasks

(1) Spatial distribution of stock and risk



(2) Life cycle impact assessment



Future tasks

(3) Extend application to other sectors

Household refrigerator sector
R-12 => R-134a => R-600a

Household air conditioner sector
R-22 => R-410a => R-32

Mobile air conditioner sector
… …

Industrial refrigerator sector
… …

Commercial refrigerator sector
… …

Transport refrigerator sector
… …

Thank you for your attention!