Cost-effective Climate Benefits through Fluorocarbon Lifecycle Management (FLM) in China

Ziwei Chen[1,2], Pallav Purohit[2], Fuli Bai[1], Thomas Gasser[2], Yue He[2,3], Lena Höglund-Isaksson[2], Pengnan Jiang[1,2], Jianxin Hu[1]

1 College of Environmental Sciences and Engineering, Peking University, Beijing, China

2 International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

3 Institute of Carbon Neutrality, Sino-French Institute for Earth System Science, College of Urban and Environmental Sciences, Peking University, Beijing, China

chenziwei1998@stu.pku.edu.cn

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

Sharing is encouraged

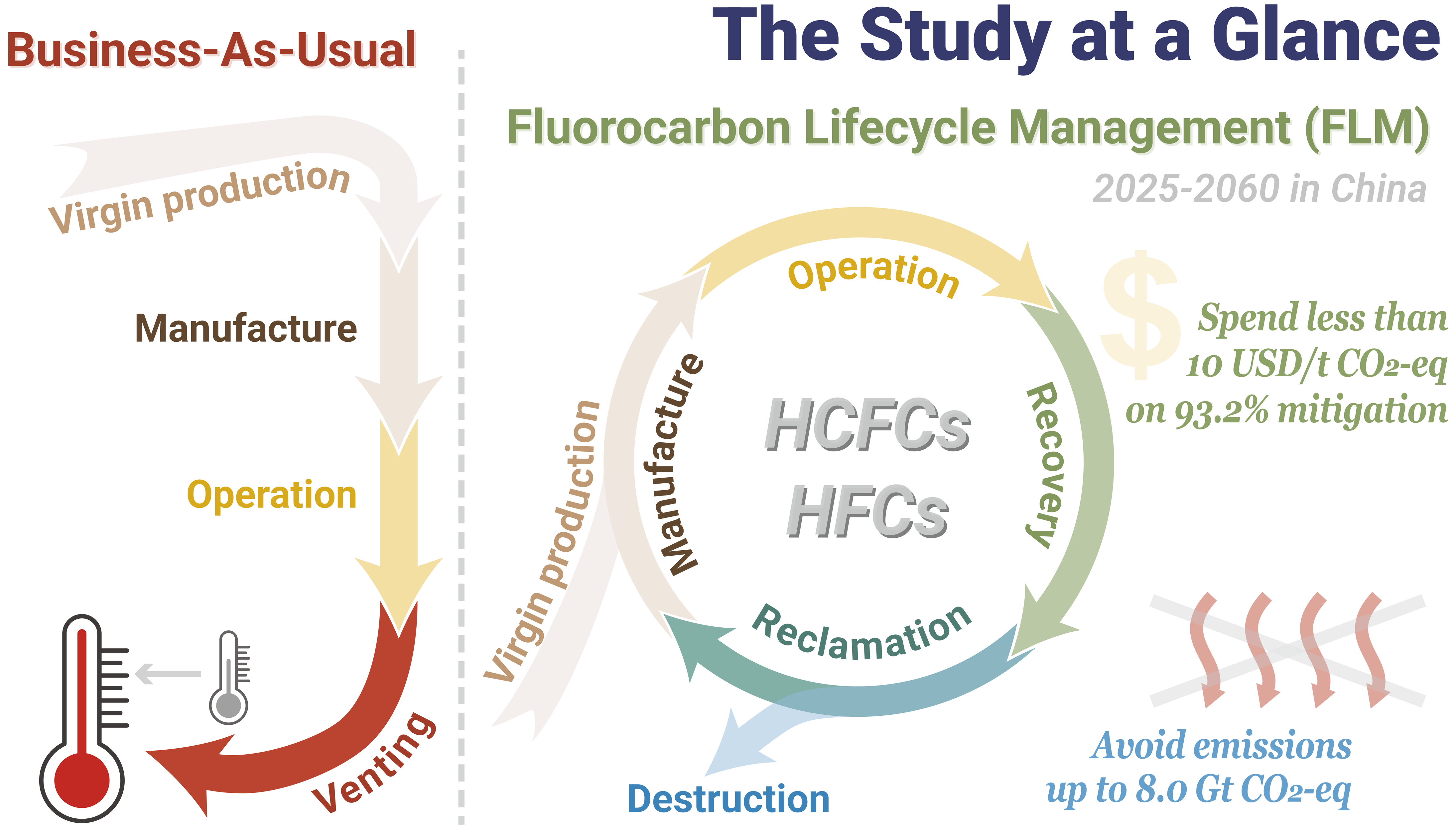
FLM is ...

a set of measures, including:
- leakage prevention
- recovery
- recycling
- reclamation
- destruction

targeting banked fluorocarbons, including:
- refrigerant
- foam blowing agent
- fire extinguishing agent

to minimize emissions from use through end-of-life.

The Study at a Glance



Motivation & Research Question

Growing reservoir of not-yet-emitted greenhouse gases

Hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) are potent greenhouse gases widely used in products and equipment, forming fluorocarbon “banks”. These banks — estimated at more than 24 Gt CO_2-eq globally[1] — continue to grow, and will be eventually released into the atmosphere if unmanaged. Yet, current international regulations do not require emission prevention from these sources.

Fluorocarbon lifecycle management (FLM) targets these overlooked emisisons.

As the world’s largest producer and consumer of HCFCs and HFCs, China could unlock substantial mitigation potential by implementing FLM.

So we ask:
How much climate benefit can we gain cost-effectively through managing fluorocarbon banks in China?

1. Reference: Theodoridi C, Hillbrand A, Starr C, Mahapatra A, Taddonio K. The 90 Billion Ton Opportunity: Lifecycle Refrigerant Management; 2022.
2. “GAINS” - Greenhouse gas and Air pollution Interactions and Synergies model developed at IIASA.

Methodology

Emission modeling, cost analysis, and climate impact analysis

Scenarios

Business-as-usual (BAU) - no FLM implemented, with fluorocarbon consumption following current phase-down/out schedule

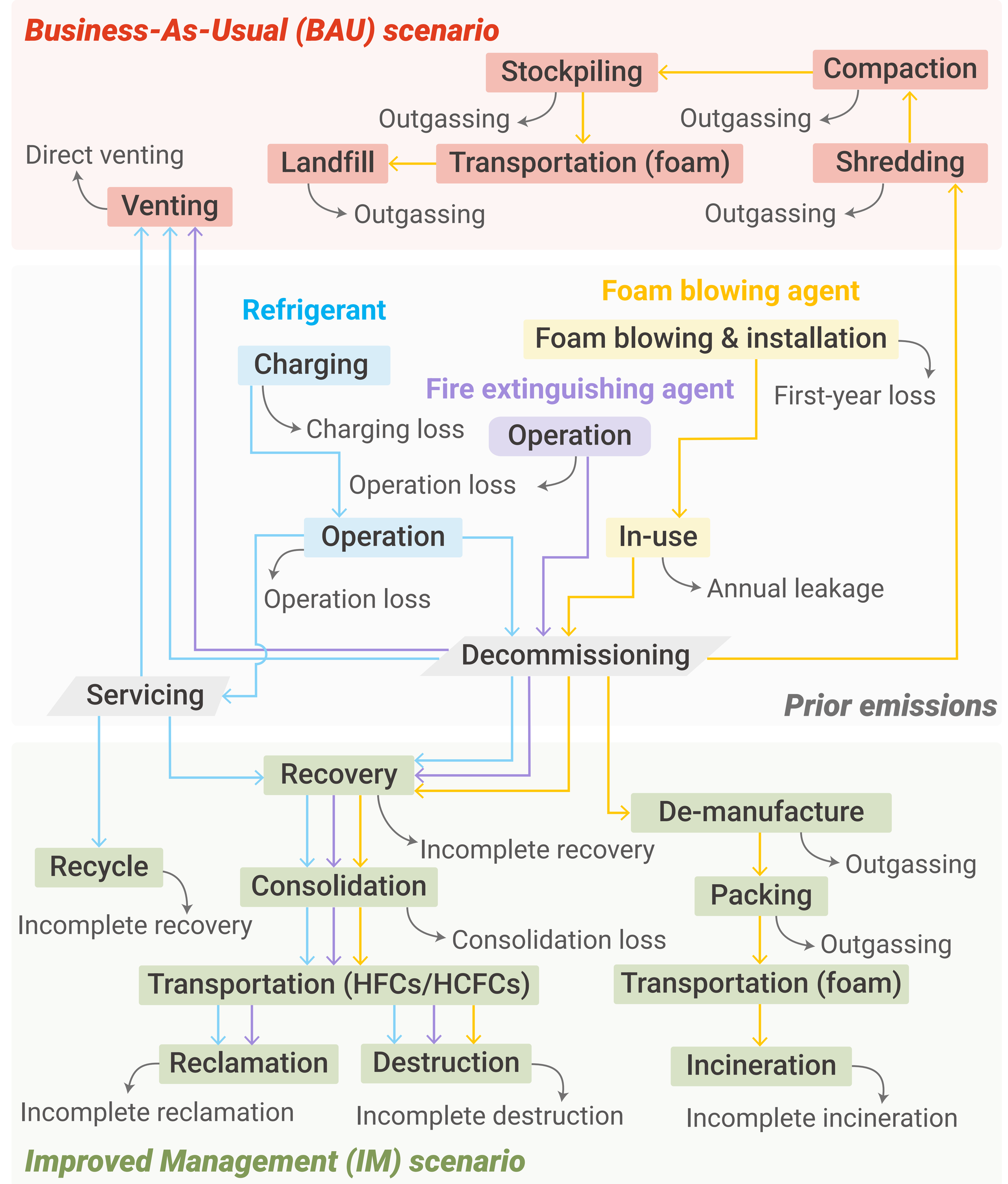
Improved Management (IM) - FLM implemented to different extent with varied maximum marginal abatement costs as constraints

Emission modeling Based on IPCC emission factor methods, we developed the Extended Lifecycle Emissions Framework (ELEF) with all emissive stages parameterized, enabling comparison across treatment measures and quantification of manageable banks.

Cost analysis Adapting the GAINS[2] framework with China-specific parameters, we estimated treatment costs and calculated marginal abatement costs as cost per ton of CO_2-eq reduced.

Climate impact analysis Impulse response functions (IRFs) incorporating climate-carbon feedbacks were used to translate emissions into radiative forcing and surface temperature change.

Fig. 1 The Extended Lifecycle Emissions Framework.



Results

1. China’s Fluorocarbon Bank, Reconstructed

- China currently holds 3.6 ± 0.1 Gt CO_2-eq of fluorocarbon banks.
- Banks are projected to peak at 4.5 ± 0.1 Gt CO_2-eq by 2034.
- By 2060, 1.1 ± 0.1 Gt CO_2-eq of fluorocarbon bank will persist, mainly from fire protection and commercial air conditioning sectors.

- Without FLM, annual emissions are projected to peak at 551.1 ± 7.6 Mt CO_2-eq in 2038.
- The share of manageable emissions increases over time as equipment retires.
- Over 50% of banked emissions could be prevented through effective management

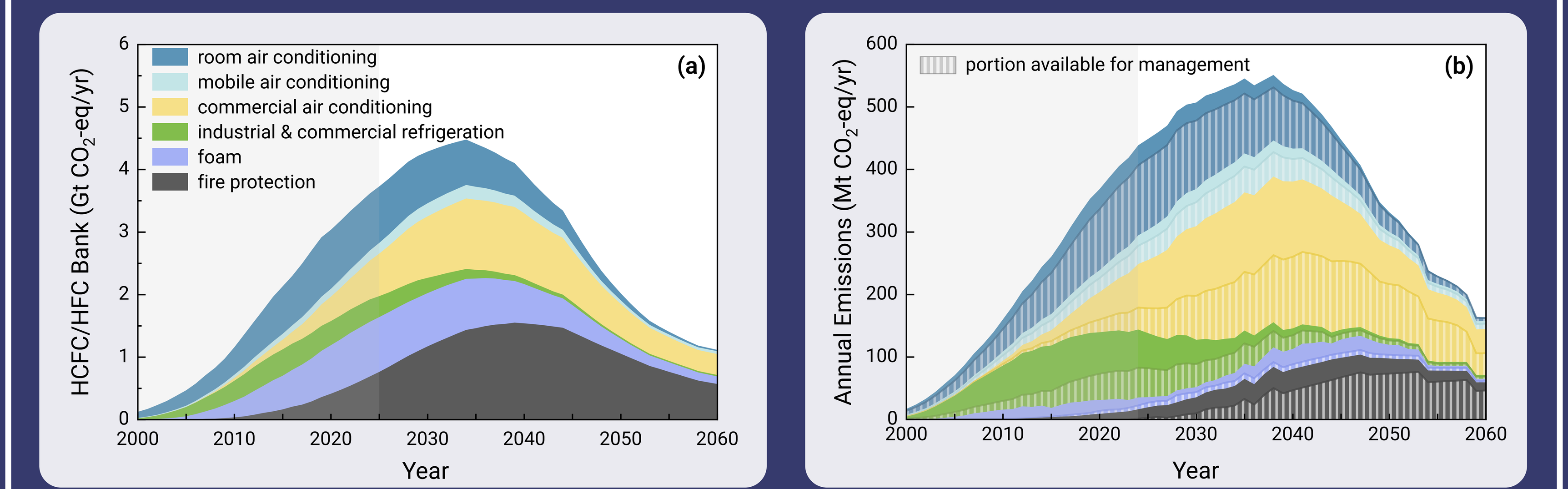


Fig. 2 (a) Historical (shaded) and projected fluorocarbon banks in China, segmented by sector. (b) Annual fluorocarbon emissions from their banks, with the striped area indicating the manageable emissions.

2. The Cost of Management

- Substantial emission reductions can be achieved at relatively low costs through FLM.
- In 2025, a reduction of 181.4 ± 2.6 Mt CO_2-eq can be achieved at costs below 5 USD/t CO_2-eq, representing 83.3% of the year’s maximum potential.
- Over 2025–2060, 93.2% of the maximum mitigation potential could be achieved through measures costing less than 10 USD/t CO_2-eq, totaling 18.9 billion USD.

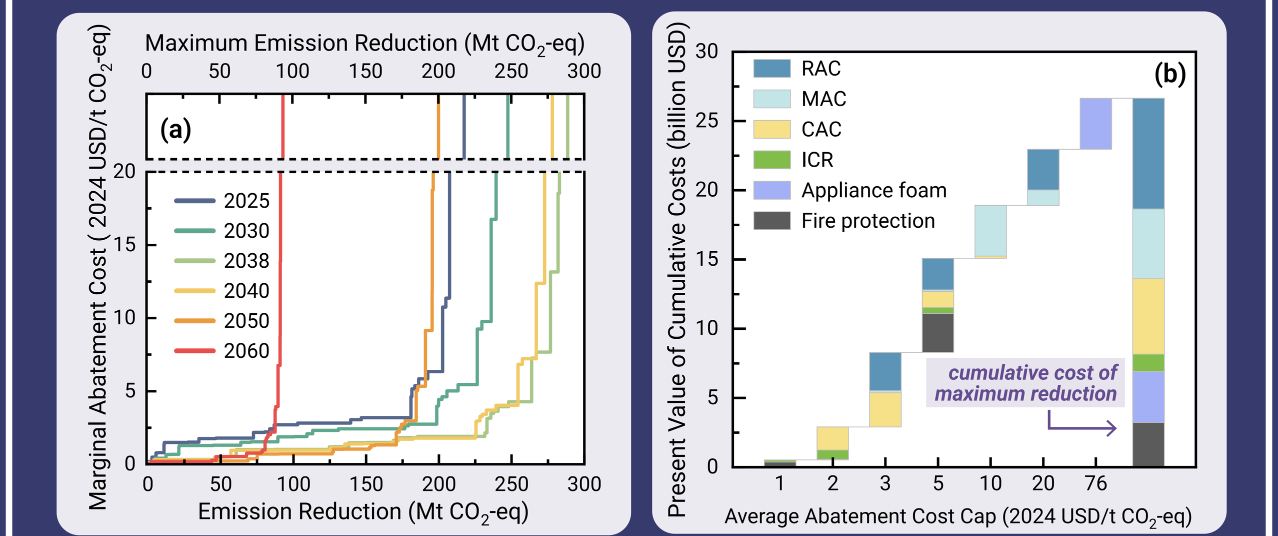


Fig. 3 (a) Marginal abatement cost curves for selected years, with the upper panel indicating the corresponding maximum emission reduction achievable. (b) Present value of cumulative costs under varying ambition levels during 2025-2060.

3. The Climate Benefits

- Cumulative emissions from servicing and decommissioning during 2025–2060 are estimated at 8.7 Gt CO_2-eq under BAU.
- Up to 8.0 Gt CO_2-eq could be avoided with full FLM, reducing emissions in most sectors to below 10% of baseline levels.
- Temperature increase from BAU emissions peaks at 13.55 ± 0.04 mK in 2050, falling to 12.31 ± 0.04 mK by 2060.
- Full FLM limits the peak to 6.17 ± 0.01 mK in 2048 and reduces 2060 warming to 5.34 ± 0.01 mK.

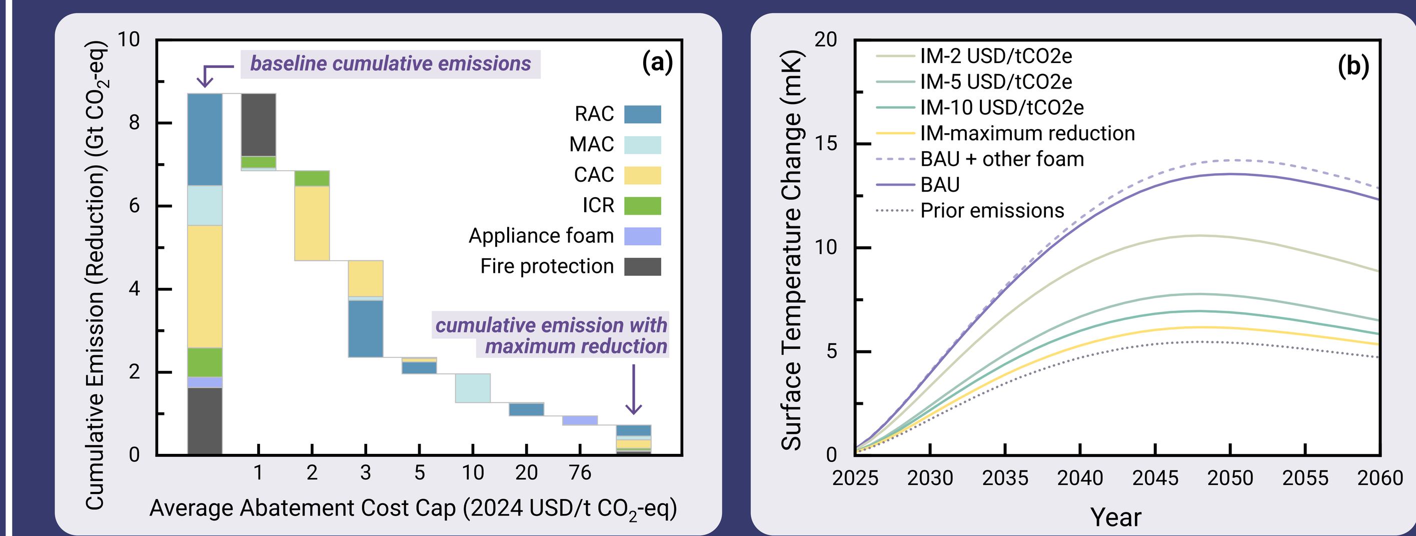


Fig. 4 (a) Cumulative emissions from equipment servicing and decommissioning in the BAU scenario (leftmost bar) and IM scenarios under varying ambition levels during 2025-2060, broken down by sector. (b) Surface temperature change induced by emissions across scenarios.