

**HERAKLION 2019**

**7th International Conference on  
Sustainable Solid Waste Management**



**UTM**  
UNIVERSITI TEKNOLOGI MALAYSIA

**Fluorocarbon Refrigerant  
Management in Selected ASEAN  
Countries:  
Refrigerant Leakage & Recovery  
Potential Rate**

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# Environmental Sound Management of Fluorocarbon (FC) Refrigerant

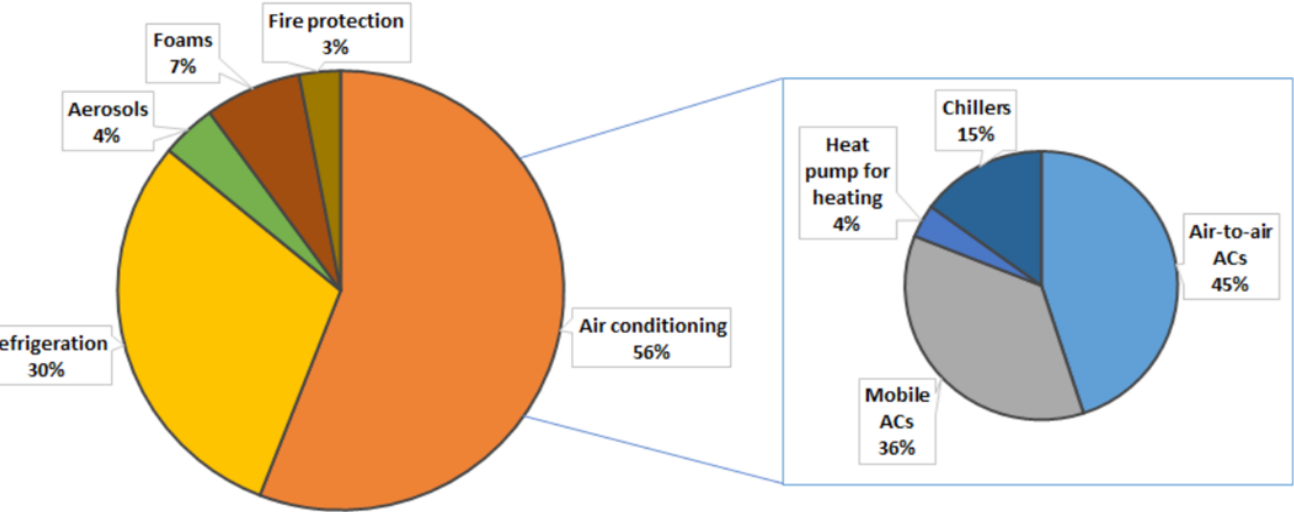


Fluorocarbons (FCs, HCFC, HFCs) are used as refrigerant for temperature exchange equipment

(Example: Refrigeration units, food showcases, unit coolers, air conditioner, chiller etc)



The demand of air conditioning and refrigerant is increasing as the world warms and as wealth increases

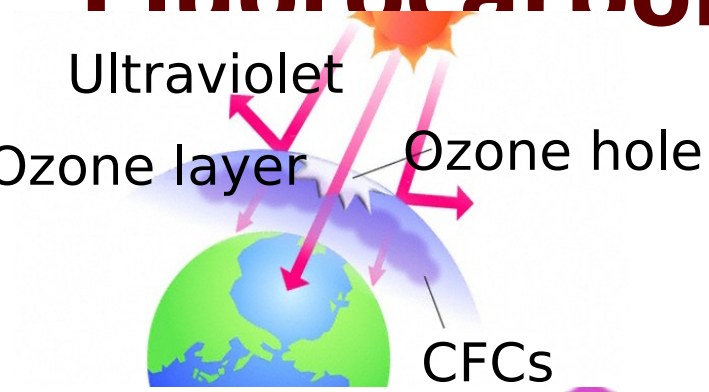


Market using HFCs, % of tonnes CO<sub>2</sub>e in 2012 (UNEP Ozone Secretariat., 2015)

Country	Room AC Demand (thousand units)		Refrigerant
	2010	2015	
World Total	73,420	79,389	R-22 dominant (Other Asia Total)
Malaysia	751	789	R-22 dominant, R-32 (starting)
Indonesia	1493	2109	R-22, R-410A, R-32 (~33%)
Thailand	957	1268	R-22, R-32 (~50%)
Vietnam	670	1546	R-22 (~60%), R-32 (~20%)

Details of room AC demand and refrigerant used in 2015 (Shah et al., 2017)

# Fluorocarbon (FC) Refrigerant



## 2<sup>nd</sup> Generation

### Hydrochlorofluorocarbon (HCFC)

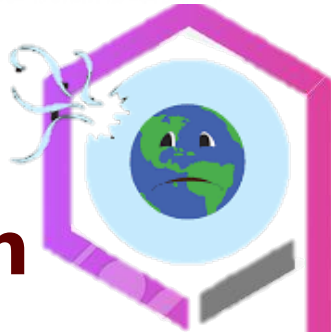
- R-22, R123
- STOP import 2020
- Totally ban 2040

## 4<sup>th</sup> Generation

### Hydrocarbon (HC); Hydrofluoroolefin (HFO)

- NO Ozone Depleting Potential

## Ozone Depletion



CFC



HCFC



HFC



HC  
HFO



## Global Warming

## 1<sup>st</sup> Generation

### Chlorofluorocarbon (CFC)

- R-11, R-12, R-500
- Invented in 1920s
- Ban from 2010

## 3<sup>rd</sup> Generation

### Hydrofluorocarbon (HFC)

- R-32, R-134s, R-410a
- Low Ozone Depleting Substances
- High Global Warming Potential
- Control under Kigali Amendment 2016

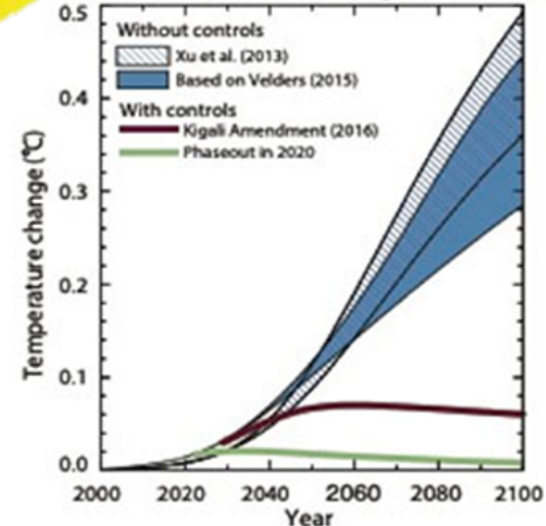
**MONTREAL PROTOCOL**

caring for all life under the sun

Montreal Protocol

(January, 1989)

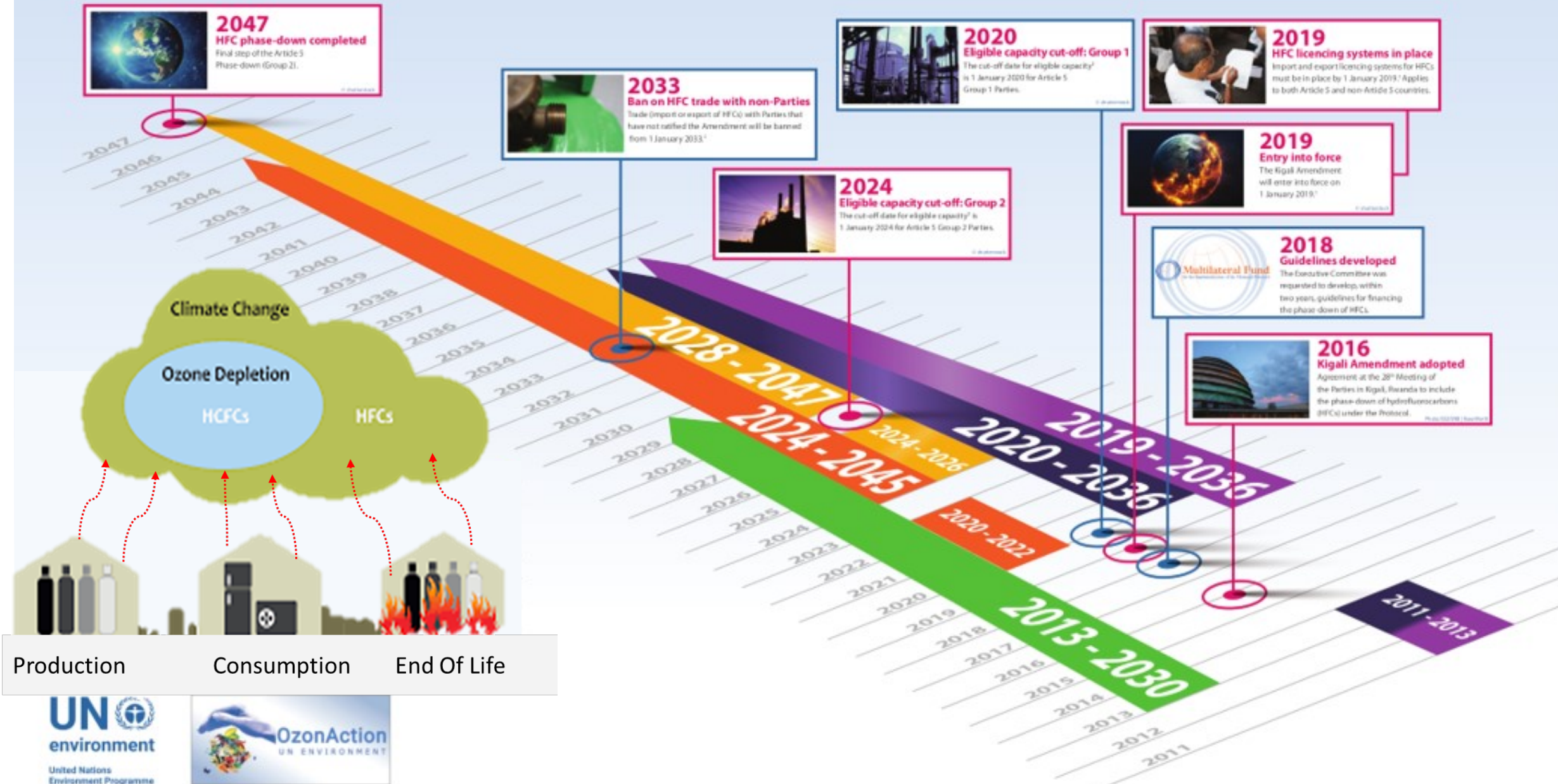
Surface Temperature Change Due to HFCs



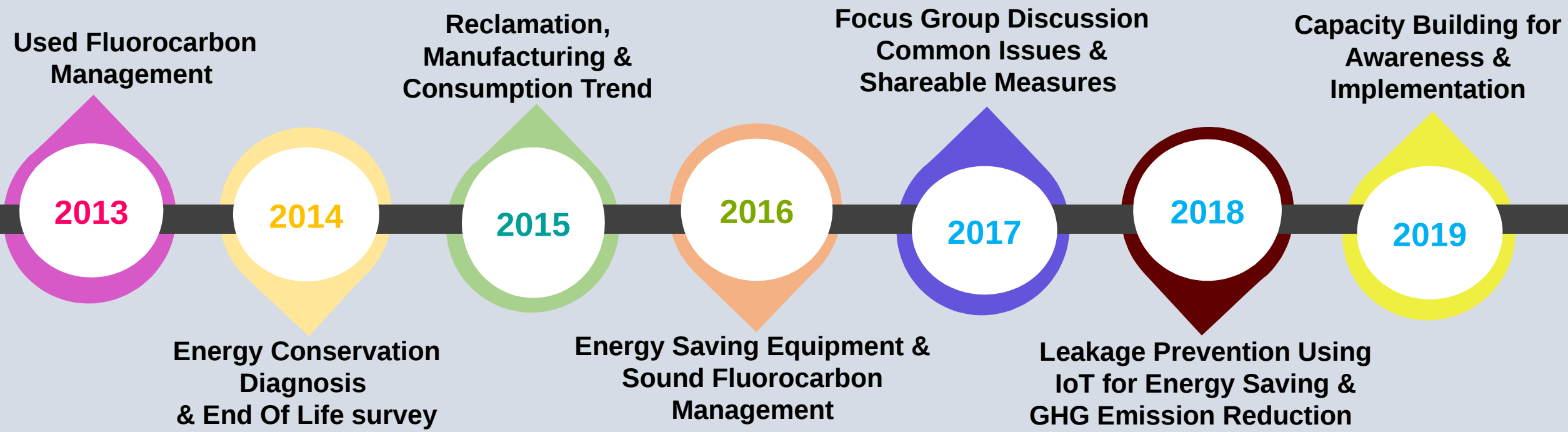




# The Path from Kigali: HFC Phase-Down Timeline

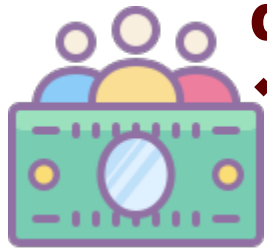






# Case Study 1 : Cross Country Analysis in Southeast Asia Indonesia, Malaysia, Thailand and Vietnam

## Government (19 departments/offices)



- ❖ National ozone units and their supervisory authorities, energy efficiency-related departments, waste

## Academia (8 universities)



- ❖ Specialists in policies and technologies for refrigerants and

## Others

- ❖ UNEP, UNDP, JICA etc



## Indonesia, Malaysia,

## Associations/Institutes (14 entities)



- ❖ Equipment manufacturers, servicing/maintenance technicians, waste operators, green

## Private companies (11 companies)

- ❖ Equipment manufacturers, gas traders, waste handlers, recycling and transportation companies, FCs



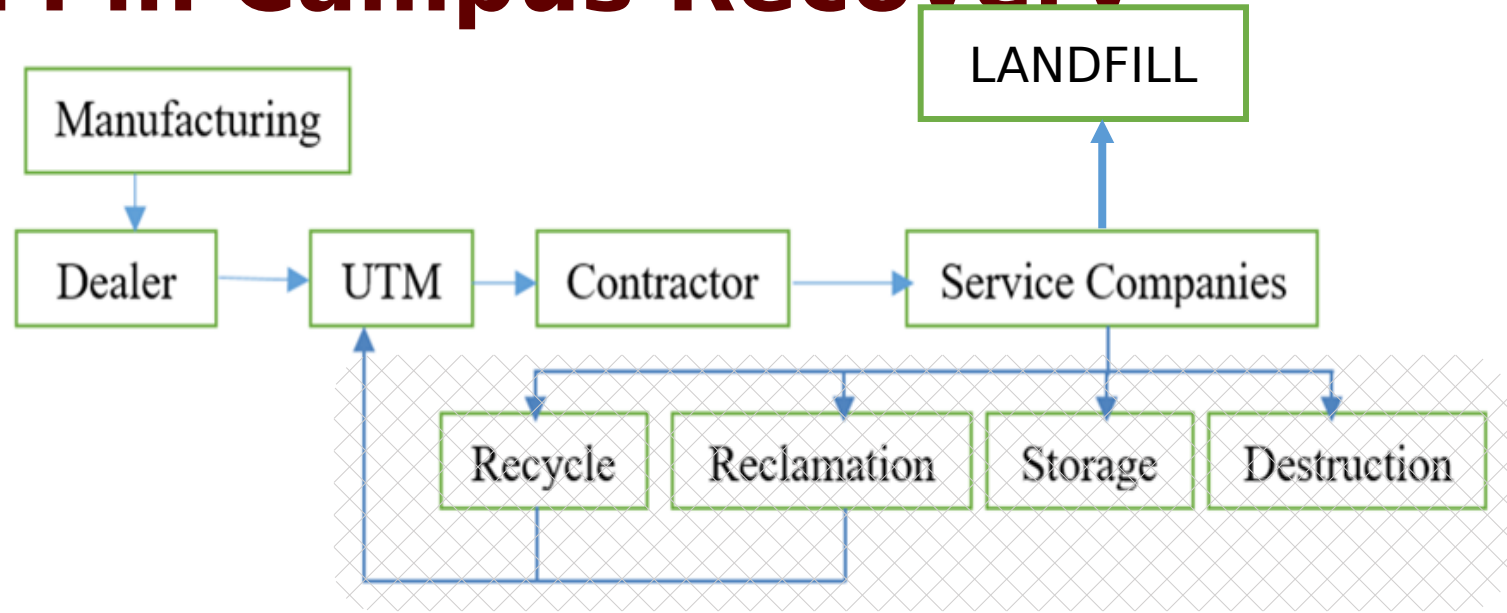
# Case Study 1 : Common Issues Indonesia, Malaysia, Thailand & Vietnam



- Not aware of the importance of proper treatment of FCs
  - Not aware energy saving potential from leakage control
  - All 4 countries have no regulation to mandate FCs recovery from used equipment
  - ✓ Only 1 gas recovery facility in each country hence high cost for destruction and transportation cost
  - ✓ Not clear who pays for collection and treatment cost
  - The Montreal Protocol fund not covering installation cost for destruction facility
  - Managing and monitoring collection and proper treatment of FCs become challenging due to presence of informal sector
  - Few cross ministerial/ department discussions have been realized on the issue of the proper treatment of FCs
- Example: DOE Air Division, Waste-related



# Case Study 2: UTM in Campus Recovery Potential Rate



N	Reclaimed Amount	Amount
0		
1	Transported weight (kg)	311.5
2	Processed weight (kg)	202.0
3	Final net weight (kg)	160.0
	Total percentages loss (%)	20.79
	Recoverable R-123 (HCFC)	79.21
	(%)	

Reclaimed amount and percentage loss



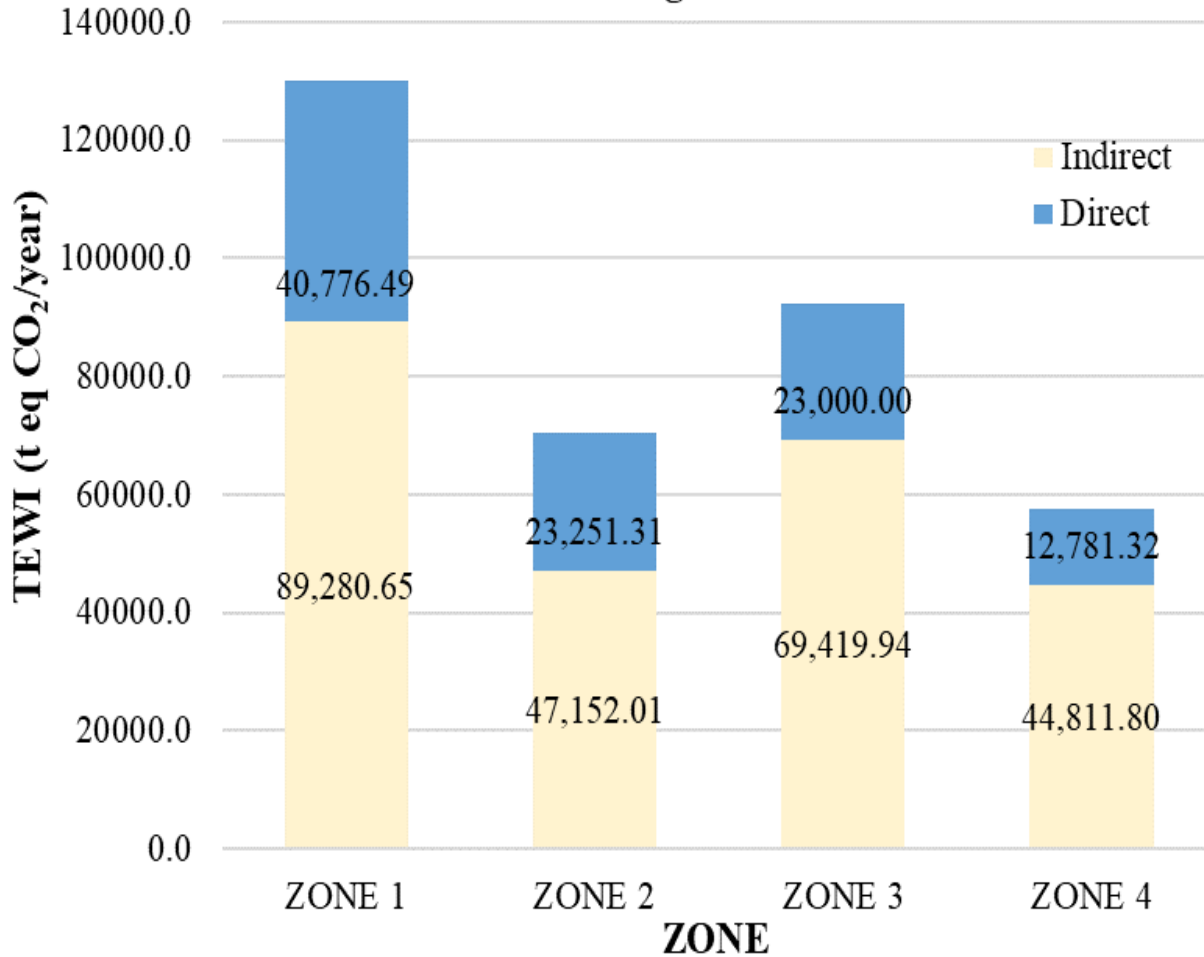
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SURVEY ON FUTURE PROMOTION OF  
ENERGY SAVING EQUIPMENT AND  
POTENTIAL RECOVERY OF FLOUROCARBON



# Case Study 2: UTM in Campus Warming Impact and Leakage Rate

TEWI for various refrigerant combinations



Total Equivalent Warming Impact (TEWI) in campus

$$\begin{aligned}
 \text{TEWI} &= \text{GWP (direct; refrigerant leaks incl. EOL)} \\
 &+ \text{GWP (indirect; operation)} \\
 &= (\text{GWP} \times m \times L_{\text{annual}} \times n) + \text{GWP} \times m \times (1 - \alpha_{\text{recovery}}) + \\
 &(\text{E}_{\text{annual}} \times \beta \times n)
 \end{aligned}
 \tag{Equation 1}$$

Where:

- GWP = Global Warming Potential of refrigerant, relative to CO<sub>2</sub> (GWP CO<sub>2</sub> = 1)
- L<sub>annual</sub> = Leakage rate p.a. (Units: kg)
- n = System operating life (Units: years)
- m = Refrigerant charge (Units: kg)
- α<sub>recovery</sub> = Recovery/recycling factor from 0 to 1
- E<sub>annual</sub> = Energy consumption per year (Units: kWh p.a.)
- β = Indirect emission factor (Units: kg CO<sub>2</sub> per kWh)

$$\text{Leak rate (\%/year)} = \frac{\text{Weight of refrigerant added over past 365 days}}{\text{Weight of refrigerant in full charge}} \times 100\%
 \tag{Equation 2}$$

# Way Forward

## Before

Fluorocarbon Measures  
= ODS Measures

Climate Change Measures  
= Mitigation (including Energy Efficiency) and Adaptation Measures

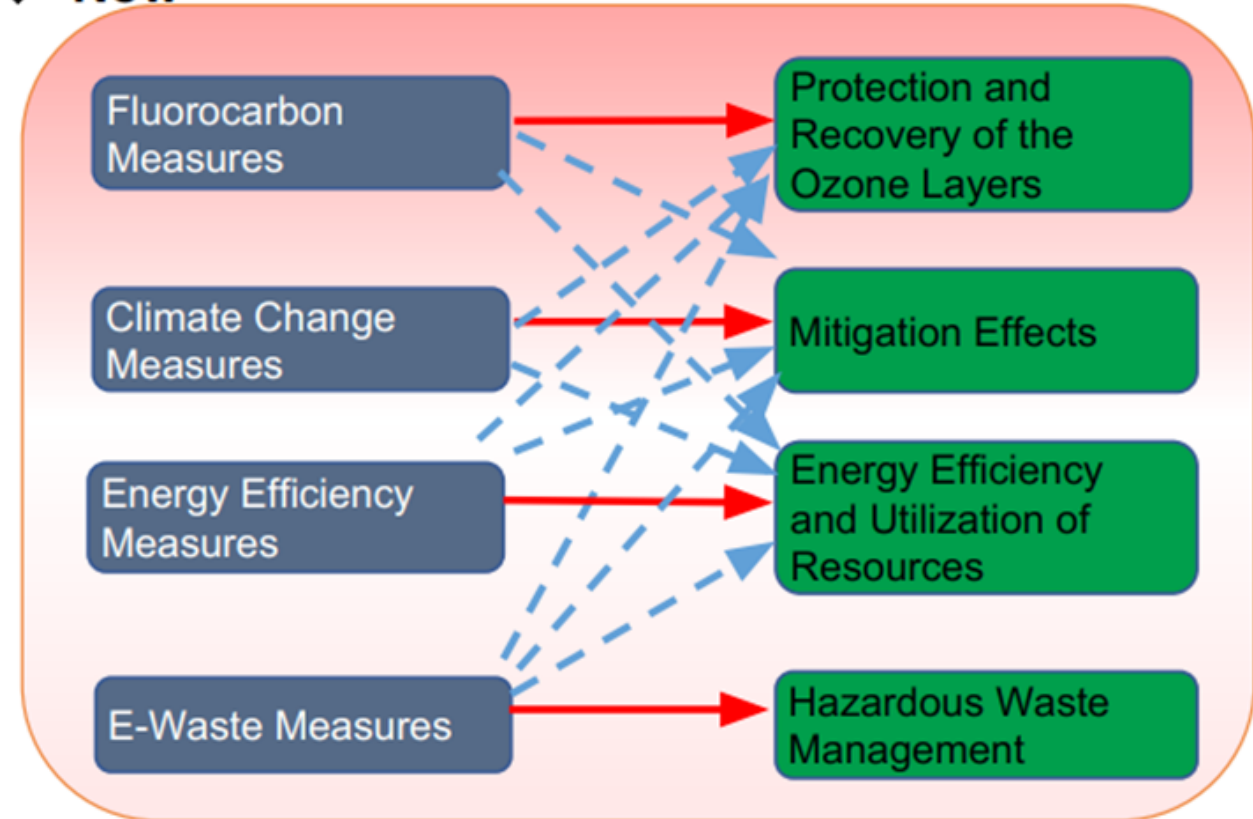
Energy Efficiency (EE) Measures  
= EE Measures (energy & costs) +  
Climate Change Measures (NDC\*)

E-Waste Measures  
= Hazardous Waste Measures and  
Utilization of Resources

## Expected Effects

Limited to individual  
Treatment

## ◆ Now

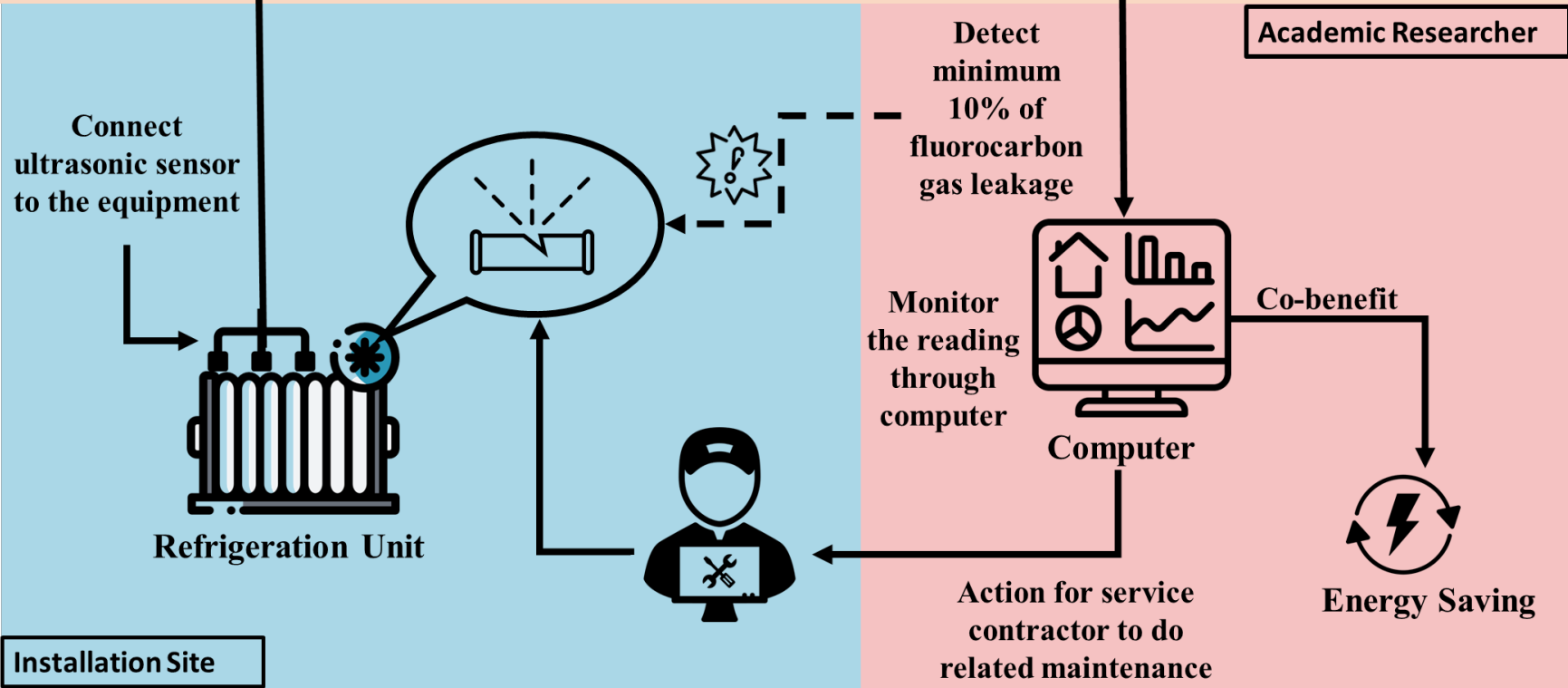
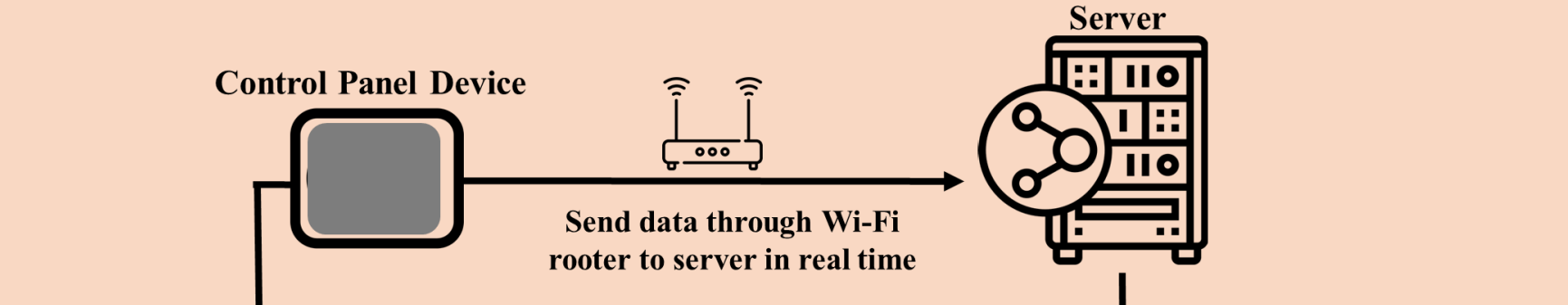


## ◆ Expected Effects

Recovery of Ozone Layers + Climate Benefits  
+ Promotion of Energy Efficiency  
+ Realization of Proper Disposal of E-waste

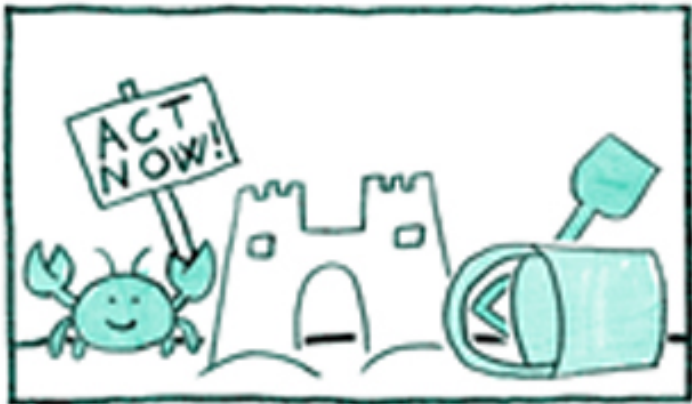
# Way Forward: Fluorocarbon Gas Leakage Monitoring By Using IoT For Energy Saving Co-benefit

Technology Developer



Installation Site





BY 2050 HFCs COULD CAUSE



12% OF ALL THE  
**WARMING**  
IN THE WORLD

**THANK  
YOU**