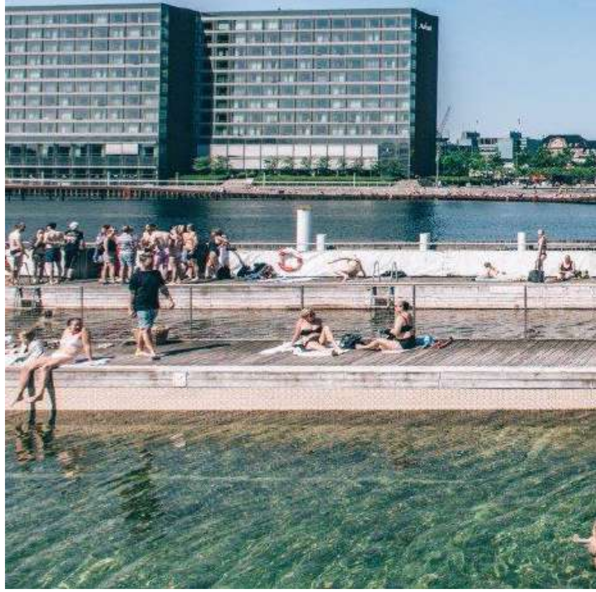

SCALING-UP GCF PROJECTS ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

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GREEN CLIMATE FUND

SCALING-UP GCF PROJECTS

ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

August 5, 2020 at 9:00 AM CEST

Dr German Velasquez (Jerry),

Director of Mitigation and Adaptation Division

Green Climate Fund (GCF)

Melanie Slade,

Senior Programme Manager, Energy Efficiency in Emerging Economies

International Energy Agency (IEA)

Lily Riahi,

Coordinator, Cool Coalition

United Nations Environment Programme (UNEP)

Patrick Blake,

Programme Management Officer, United for Efficiency (U4E)

United Nations Environment Programme (UNEP)

Nihar Shah

Presidential Director, Global Cooling Efficiency Program,

Lawrence Berkeley National Laboratory (LBNL)

Ambereen Shaffie,

President and Managing Partner, Shaffie Law and Policy,

Lawrence Berkeley National Laboratory (LBNL)

Eduardo Freitas,

Regional Manager, Division of Country Programming

Green Climate Fund (GCF)

Sabin Basnyat

Senior Energy Efficiency Specialist, Division of Mitigation and Adaptation,

Green Climate Fund (GCF)

UN environment programme

GREEN CLIMATE FUND

SCALING-UP GCF PROJECTS

ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

Opening remarks (5 minutes) - Dr German Velasquez (Jerry), Director of Mitigation and Adaptation Division, GCF

Overview of the Cooling Sector and its Climate Impact (10 minutes) – Melanie Slade, IEA

National Cooling Action Plans (10 minutes) – Lily Riahi, Cool Coalition, UNEP

MEPS, labels and supporting policies (10 minutes) – Patrick Blake, United for Efficiency initiative (U4E), UNEP

Opportunities for efficiency improvement by GCF with refrigerant transition under the Montreal Protocol (10 minutes) – Nihar Shah & Ambereen Shaffie, Lawrence Berkeley National Laboratory (LBNL)

Brief Introduction on the Readiness Support modality (10 minutes) – Eduardo Freitas, GCF

Questions and Answers (30 minutes)

Call to Action / Closing (5 minutes)

SCALING-UP GCF PROJECTS
ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

OPENING REMARKS

Dr German Velasquez (Jerry)

Director of Mitigation and Adaptation Division,

Green Climate Fund

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FUND

Overview of the
COOLING SECTOR AND ITS CLIMATE IMPACT

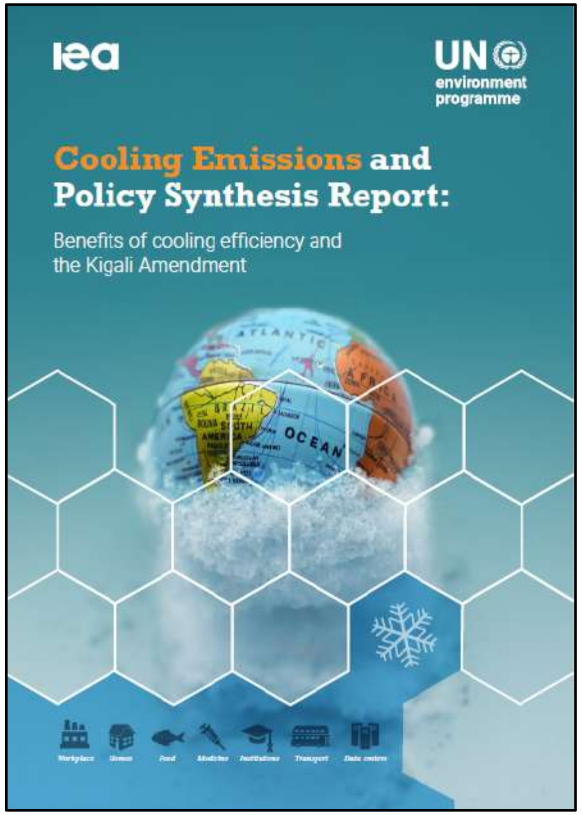
Melanie Slade,
Senior Programme Manager,
Energy Efficiency in Emerging Economies,
International Energy Agency

Scaling-up GCF projects: Cooling and climate

Melanie Slade, International Energy Agency

5 August 2020

UN-IEA Cooling Emissions and Policy Synthesis Report



iea

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Cooling Emissions and Policy Synthesis Report:

Benefits of cooling efficiency and the Kigali Amendment

Summary:

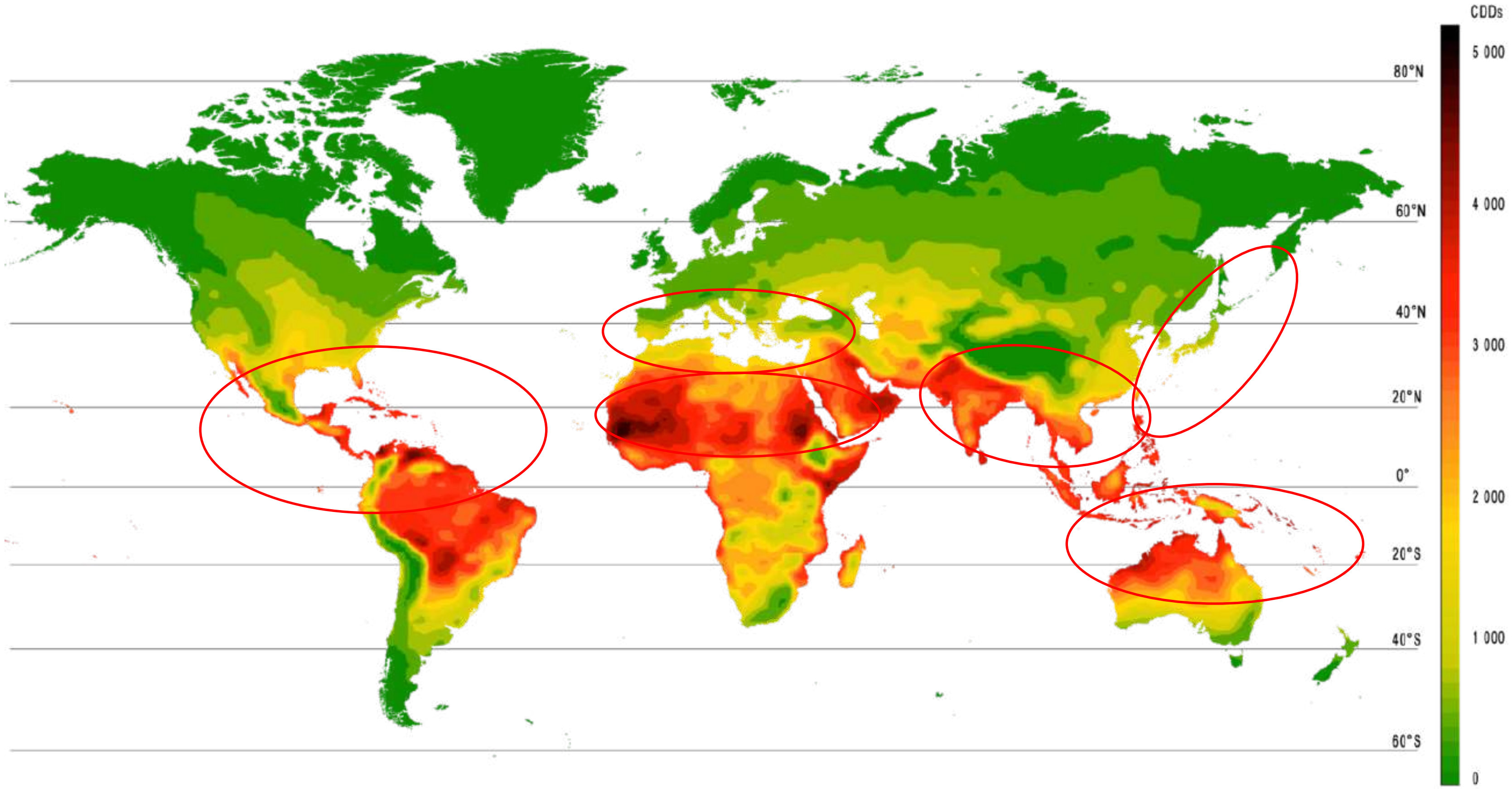
- Cooling needed for maintaining communities, fresh vaccines, food, energy supply, product economies
- Kigali Amendment to the Montreal Protocol aims to phase down HFCs and increase energy efficiency
- 3.6 billion appliances in use, need for 14 billion by 2050
- Action could avoid over 460 billion tonnes CO_2-eq
- Authoritative review with a 15-member steering committee, 30+authors, and 30+ technical reviewers

Available at:
https://www.iea.org/reports/cooling-emissions-and-policy-synthesis-report

> Global assessment of published evidence on the drivers and impact of the cold-chain on climate – energy, refrigerants and emissions

Keeping cool is a growing need

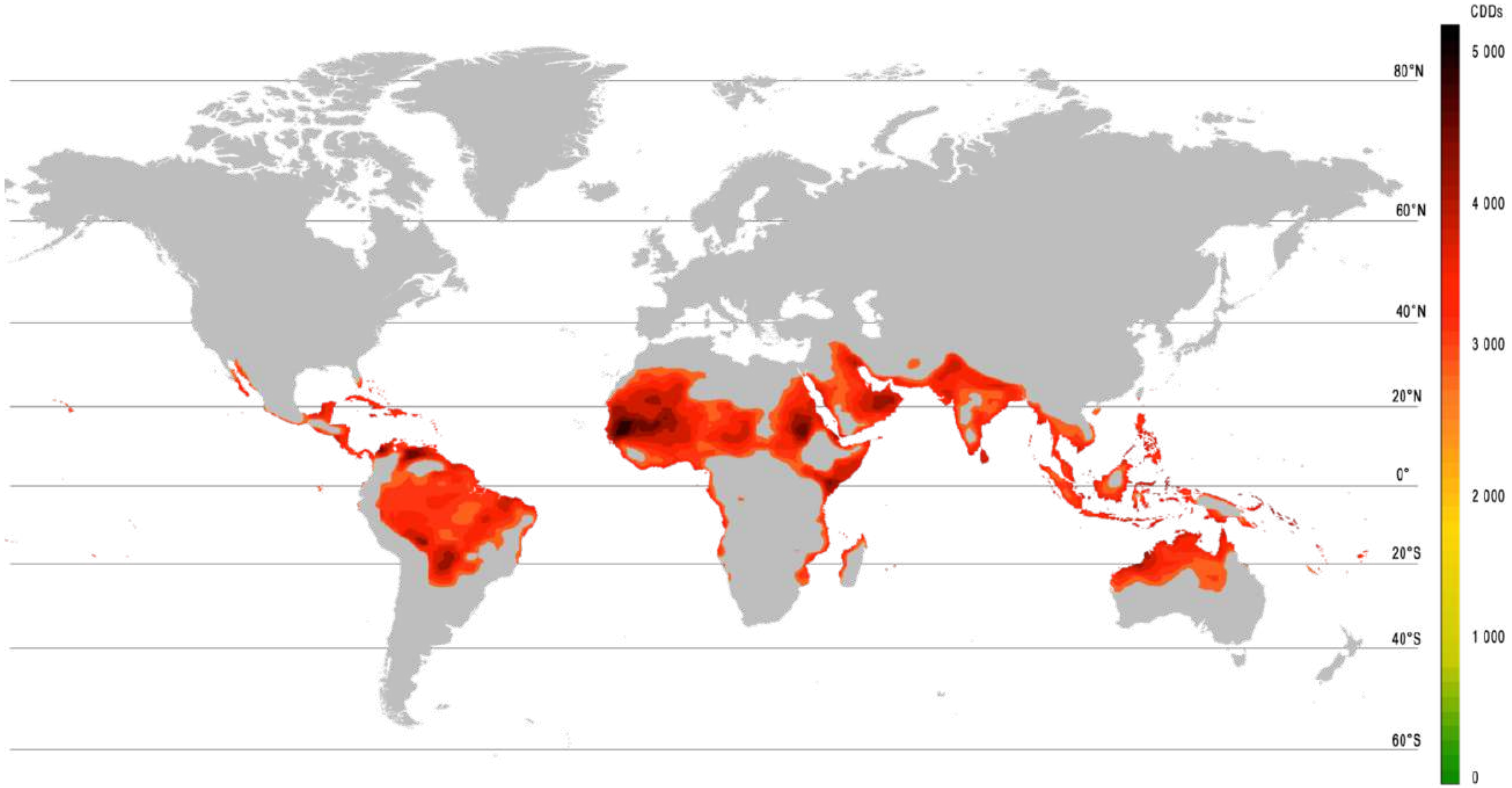
Mean annual cooling degree days (2007-17)



Air conditioning is being driven by increasing expectations of thermal comfort – as well as the need for cooling in buildings to be healthy and productive.

Access to cooling is a critical issue in some of the hottest places

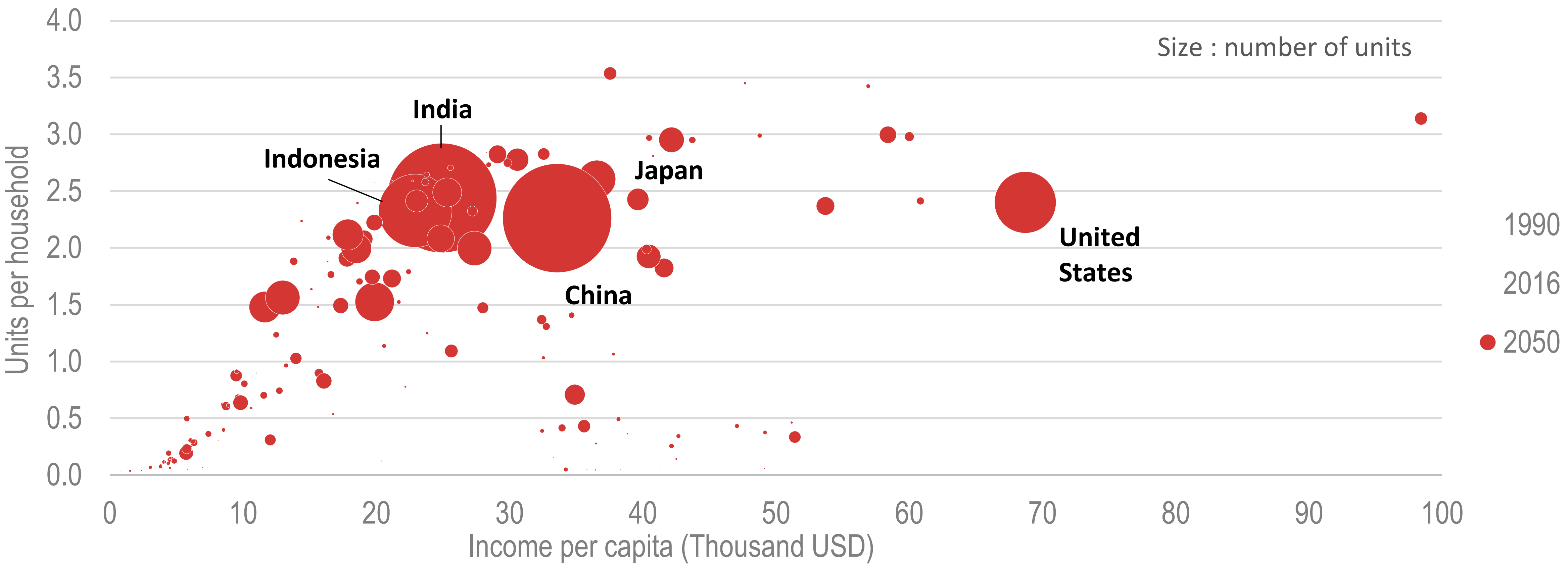
Cooling degree days in places with daily average temps above 25°C



There are around 2.8 billion people living in places where it is hot every single day. Only 8% of them have an air conditioner today.

AC ownership is expected to soar

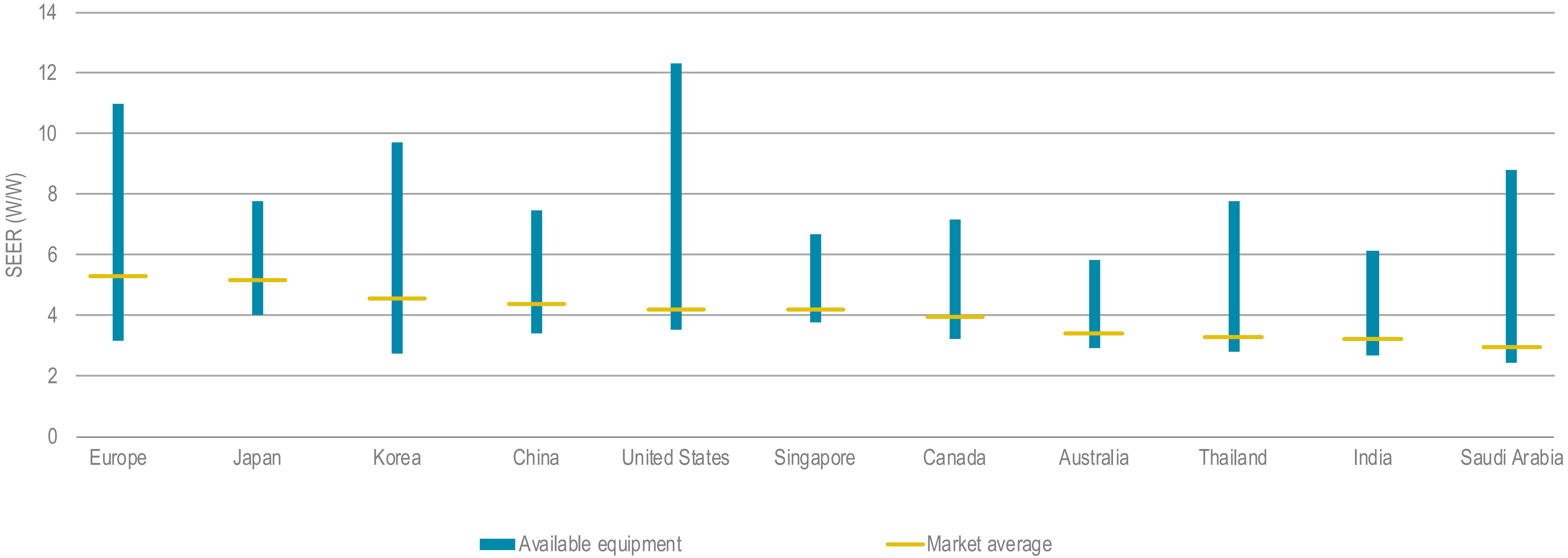
Evolution of global air conditioner ownership



By 2050, around 2/3 of the world's households could have an air conditioner. China, India and Indonesia will account for half of all AC units in buildings in 2050.

Markets are not keeping up with energy efficiency potential

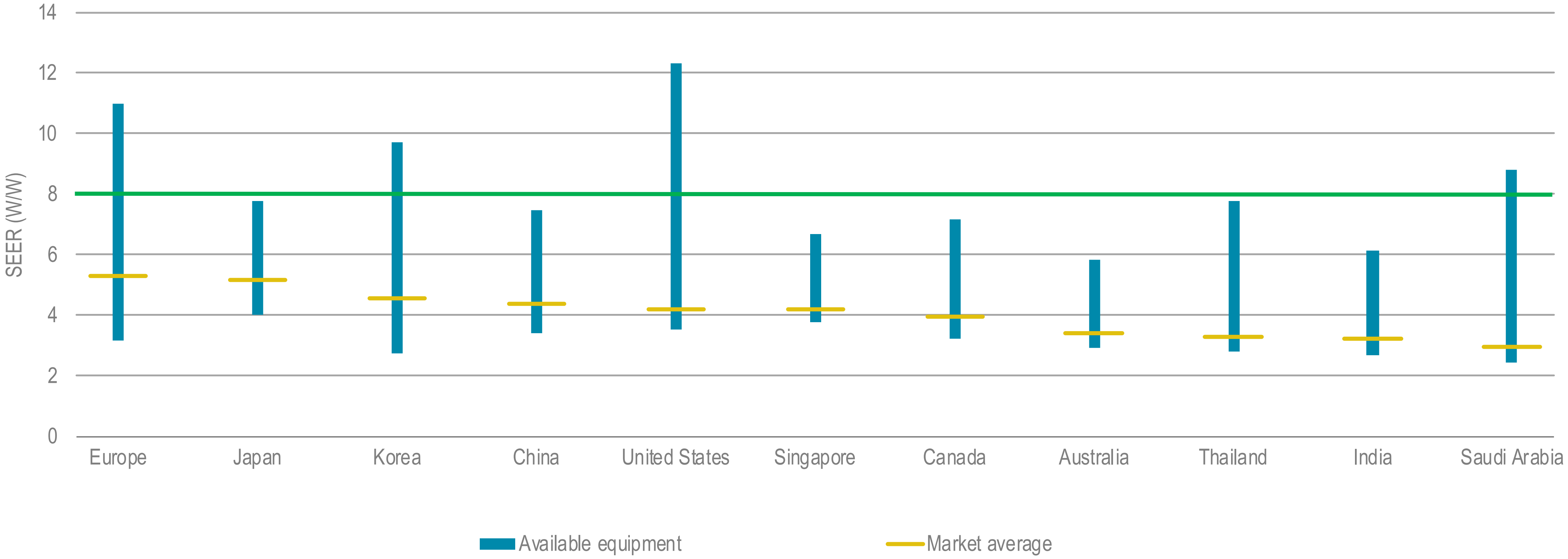
Energy performance of air conditioners already available in markets today



The average efficiency of air conditioners sold today is less than half of what is typically available on shelves – and one third of best available technology.

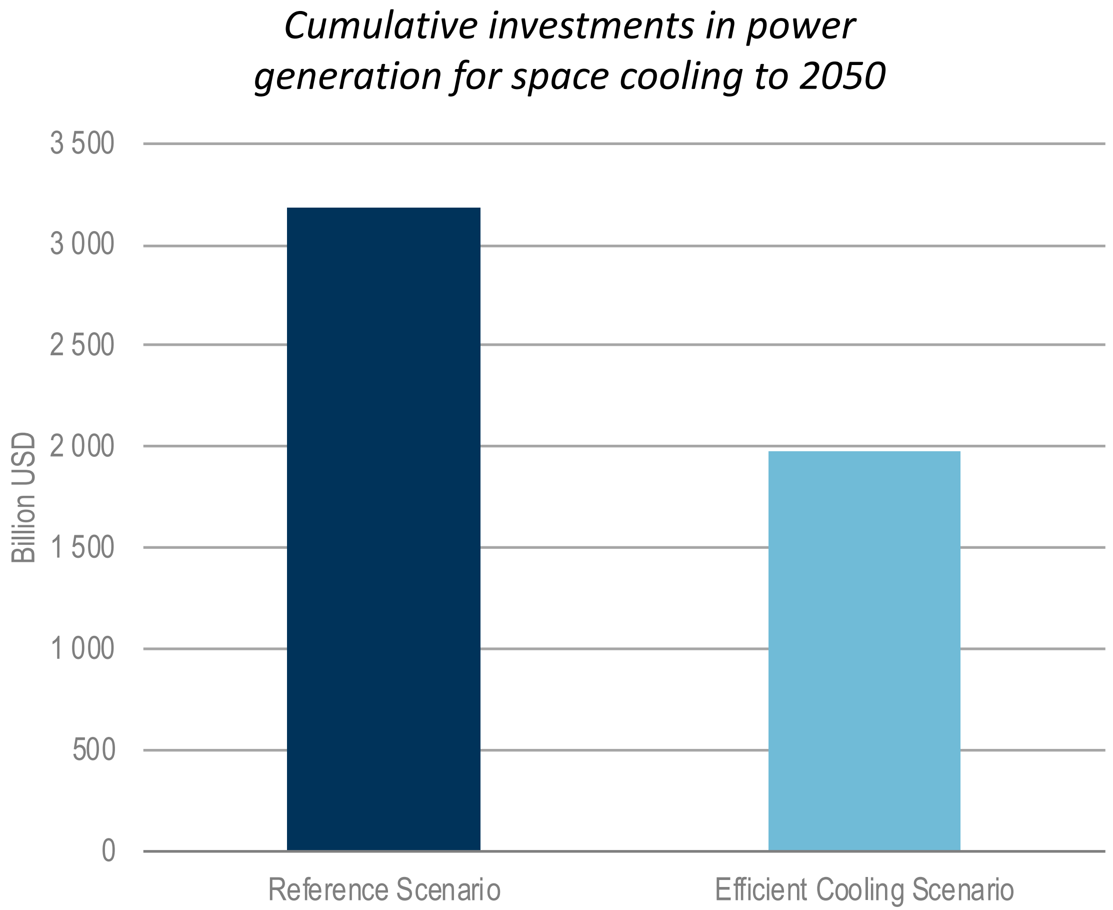
Global AC efficiencies must double overall by 2040

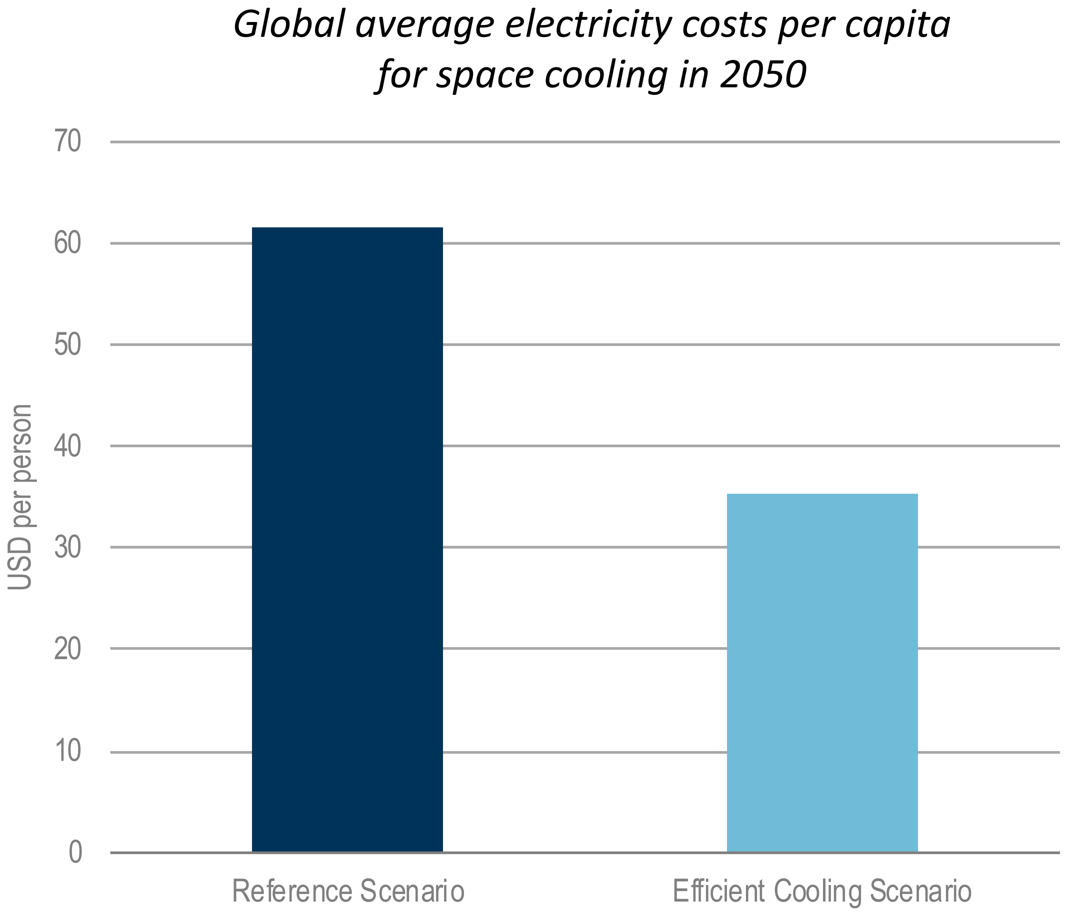
Energy performance of air conditioners already available in markets today



There are many markets where the efficiencies needed by 2040 are already available.

More efficient ACs can lessen the costs of new power generation

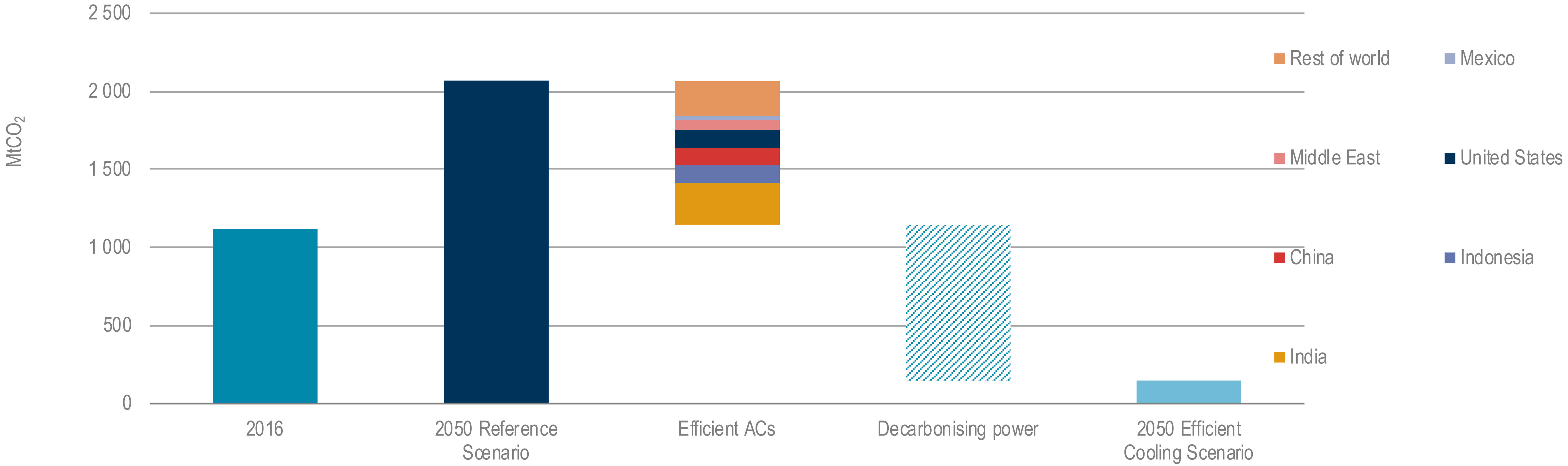




USD 1.2 trillion in power generation investments can be saved with more efficient ACs. Average per capita electricity costs for cooling would be almost halved and costly peak demand reduced.

More efficient ACs will help cut emissions

Contribution of more efficient space cooling on CO_2 emissions



More efficient ACs cut CO_2 emissions from space cooling in half. Efficiency also helps enable cleaner power – drastically reducing cooling-related emissions.

Summary and policy response

- Cooling appliance ownership and use is rising rapidly
    - Driven by need for cooling in a warming world and increasing wealth
    - Energy efficient products are already available and need not necessarily cost more to purchase

- Policy can improve the efficiency of new equipment:
    - Ratification and implementation of the Kigali Amendment
    - National cooling action plans
    - Building codes
    - Minimum Energy Performance Standards (MEPS), mandatory energy labelling and incentives

- Additional Investment in new energy efficient, climate friendly cooling is needed.
    - Opportunities include:
        - New financing models
        - COVID-19 pandemic recovery packages

NATIONAL COOLING ACTION PLANS

Lily Riahi,

Coordinator, Cool Coalition,
United Nations Environment Programme

Cool Coalition

UN environment programme

GREEN CLIMATE FUND

Scaling-up GCF Projects on Energy-Efficient and Climate Friendly Cooling: the Key Role of National Cooling Action Plans

August 5, 2020

Cool Coalition

Lily Riahi
Coordinator, Cool Coalition
UNEP, Lily.Riahi@un.org

Cool Coalition

COOLING ACCESS NEEDS TO INCREASE: KEY TO HEALTH & LIVELIHOODS

Cool Coalition

SOLUTION EFFICIENT CLIMATE-FRIENDLY COOLING

The GHG reduction potential is large

Phase-down of HFCs by 2100 under Kigal Amendment can achieve 0.4 of Avoided Warming
Integrating energy efficiency to accompany HFC phase down could **double the climate benefits**.

→ Over 4 decades **avoid equivalent to roughly 4-8 years of global GHG**, based on 2018 levels

It supports Sustainable Development Goals….

SUSTAINABLE DEVELOPMENT GOALS

- Zero hunger
- Health and Well-Being
- Affordable Clean Energy
- Decent Work & Economic Growth
- Climate Action
- Sustainable Cities and communities
- Poverty alleviation etc….

And Kigali Amendment and Paris Agreement Goals

Cool Coalition, official outcome of SG summit, is working with its 100 partners to **support to countries and industry take comprehensive action to meet growing demands for cooling in an efficient, climate-friendly manner,** contributing to the SDGs, the Kigali Amendment, and Paris Agreement.

National Cooling Action Plans key area of action

Cool Coalition

HOW TO ACCELERATE EFFICIENT COOLING? NATIONAL COOLING ACTION PLANS ARE KEY

"We need all countries to develop National Cooling Action Plans to deliver efficient and sustainable cooling and bring essential life-preserving services like vaccines and safe food to all people." Antonio Guterres, UN Secretary General , World Ozone Day 2019

Can only improve what you can measure. Drives governance and market signals for investment

Link technological choices in Heating, Ventilation Air Conditioning Refrigeration (HVAC-R) sectors to energy efficiency while phasing-down/out substances controlled by the Montreal Protocol

Harmonizes efforts and policies on cooling across multiple sectors and dimensions and brings together the actors required to take a comprehensive approach & integrate EE in cooling sector

India, China, Rwanda, Trinidad and Tobago, Lebanon, Cuba examples. With support from K-CEP 20+ countries are currently at different stages of NCAP development largely with UNEP & UNDP.

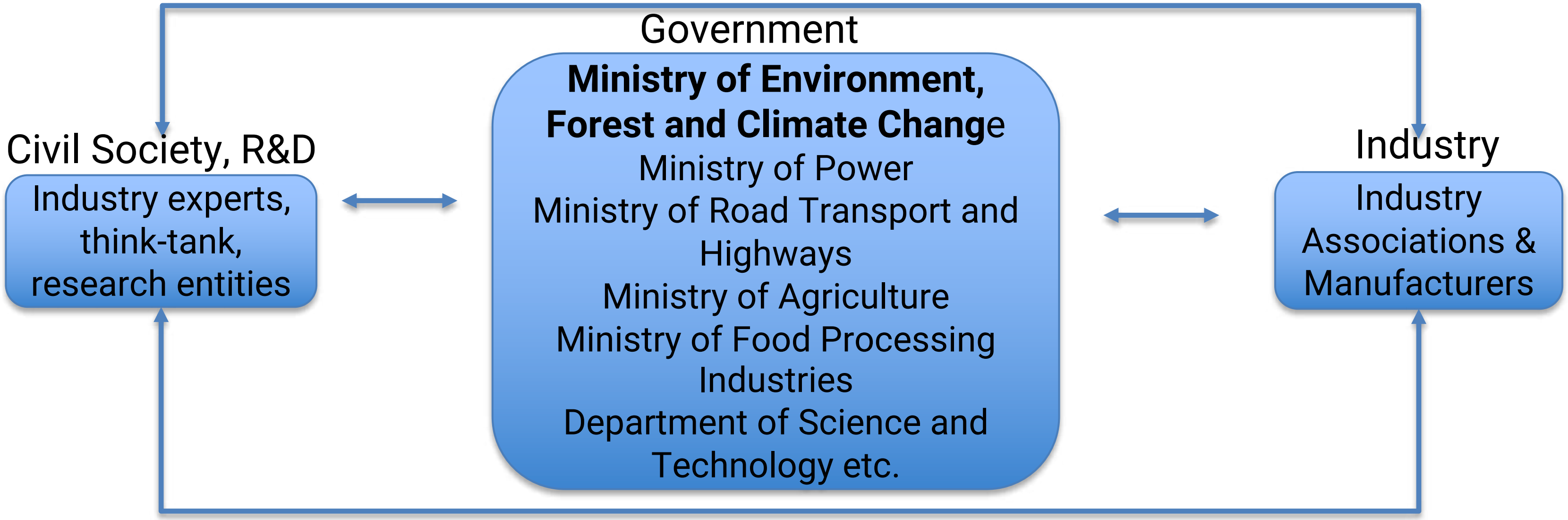
Cool Coalition – K-CEP, Alliance for Energy Efficiency Economy (AEEE), UNESCAP in collaboration with UNEP, UNDP, WBG, EFC, CLASP, SEforALL producing a **model NCAP** for use by any country

Cool Coalition

INDIA EXAMPLE: NCAP DEVELOPMENT PROCESS

- ✓ **Champion and Goal**: MOEFCC Ozone Cell - political will to develop a plan to harmonize EE of HVACR appliances with refrigerant transition pathways for enhanced **climate action and access**

- ✓ **Collaborative multi-stakeholder development framework:** help achieve cross sectoral integration and synthesis of recommendations and targets . Breaking Silo’s



Government

Ministry of Environment, Forest and Climate Change
Ministry of Power
Ministry of Road Transport and Highways
Ministry of Agriculture
Ministry of Food Processing Industries
Department of Science and Technology etc.

Civil Society, R&D

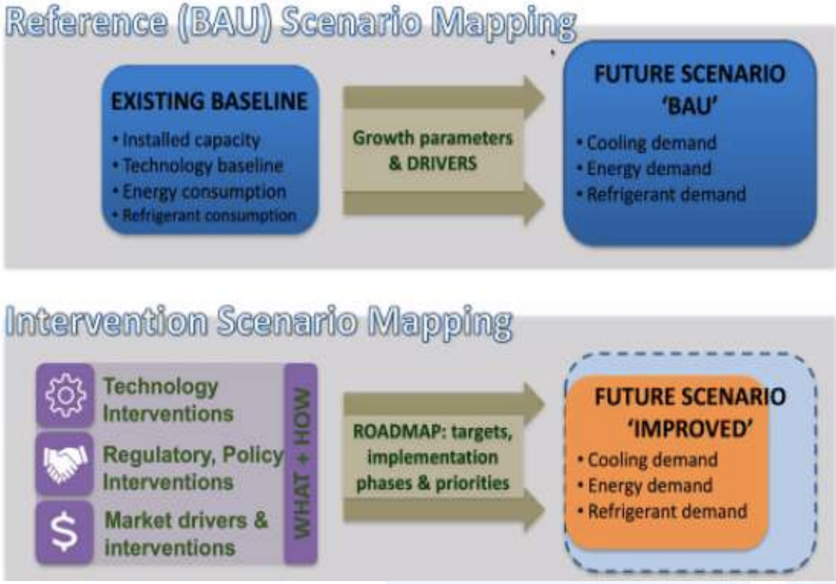
Industry experts, think-tank, research entities

Industry

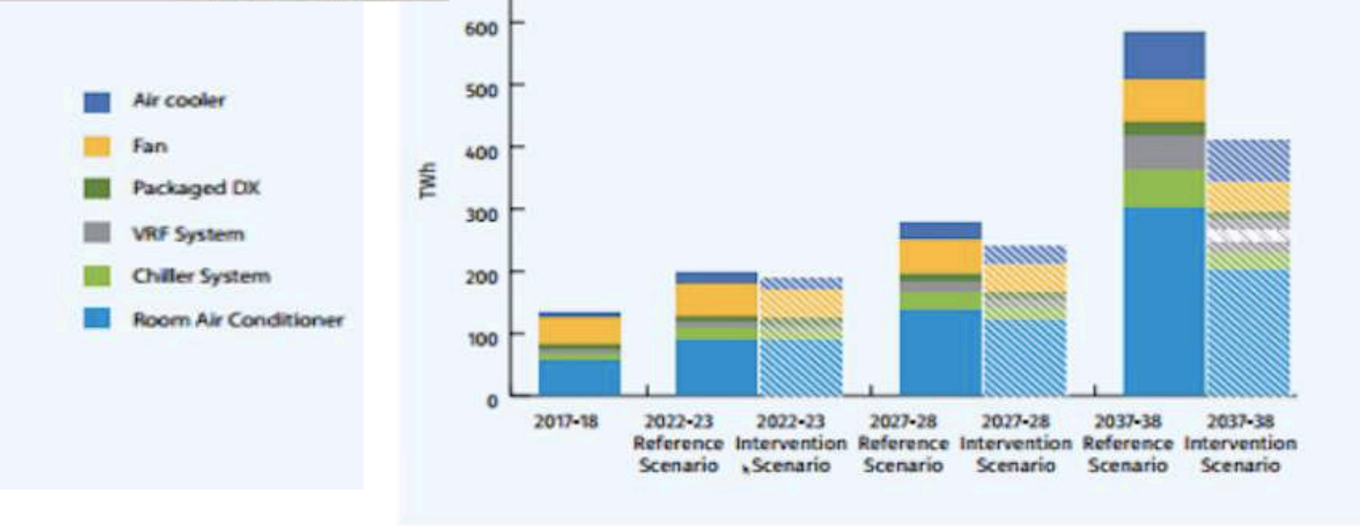
Industry Associations & Manufacturers

- ✓ **Multi-sectoral: Six Thematic Areas Selected for baseline, future, intervention scenario**
  - Space Cooling in Buildings
  - Air-conditioning Technology
  - Cold-Chain & Refrigeration
  - Mobile Air Conditioning
  - Refrigeration and AC servicing sector
  - Refrigerant Demand and Indigenous Production

CASE EXAMPLE OF INDIA



- ✓ Based on existing frameworks and polices and projects to increase chance of success and involve existing stakeholders
- ✓ Look at met and unmet demand
- ✓ Includes all relevant sectors
- ✓ Both active and passive cooling, refrigerant and non-refrigerant technologies, and emerging in-kind technologies
- ✓ Existing SC under MP and WG to monitor and Implement Framework



Source:
Ministry of Environment, Forest & Climate Change (2019). India Cooling Action Plan. New Delhi: Ministry of Environment, Forest & Climate Change.

National Cooling Action Plan Structure

1. Foreword
2. Introduction: Why Cooling Matters, Objectives
3. Space Cooling in Buildings
4. Cold Chain (Agriculture, Dairy Health)
5. Mobile Air Conditioning
6. Process Cooling
7. Access to Cooling Needs Assessment

Demand Assessment:
Baseline; technologies; future growth scenarios (reference & intervention) with associated refrigerant demand and energy use; and suggested interventions.

→ Country driven - each country to decide on priority sectors - not necessary to cover all .

8. Recommendations and Implementation framework: Cross-sectoral integration and synthesis of recommendations and targets. Examples include but not limited to:

- ✓ MEPS and Energy Labels
- ✓ Building Energy Codes, Thermal Comfort St.
- ✓ Service sector upskilling for HVAC prof.
- ✓ User operational efficiency
- ✓ Promotion of low-GWP refrigerants
- ✓ Alternative / not-in kind technologies
- ✓ Training and capacity building, certification
- ✓ NDC enhancement and HPMP updates
- ✓ Recycling and waste management
- ✓ Nature based solutions (cool roofs, greenery)
- ✓ Heat Action Plans/ Urban Cooling Action Plans
- ✓ Access to Cold Chain (off-grid micro cooling)
- ✓ Public Procurement of EE Cooling equipment
- ✓ Funding and financial mechanisms

BEST PRACTICE CAPTURED IN MODEL NCAP

In Collaboration with

- ✓ Governance – champion, multi-stakeholder, HPMP/NOU starting point, monitoring
- ✓ Flexible -- scope and depth adapted to country readiness and priorities
- ✓ Cooling Demand Assessment - Multi-sectoral e.g. Cold Chain
- ✓ Integrate Access - SEforALL Needs Assessment
- ✓ Recommendations – dovetail with ongoing government policies & programs
- ✓ Living Document - review and revise for adjustment to new realities & technologies

Cool Coalition

Thank you!

Contact us:
Lily Riahi, Coordinator, Cool Coalition
lily.riahi@un.org
Sophie Loran, Lead Advocacy and Outreach
Sophie.loran@un.org

www.coolcoalition.org

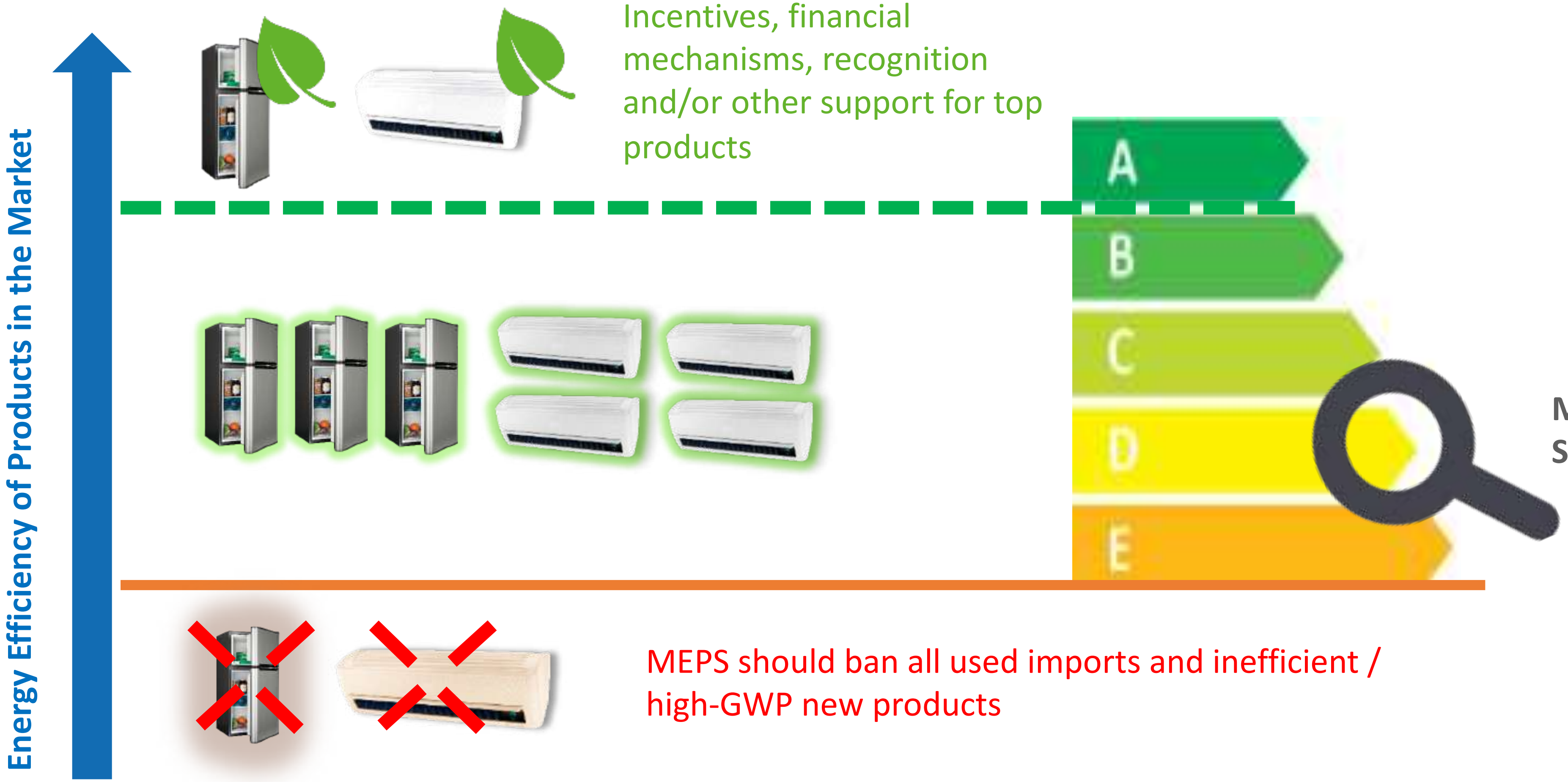
MEPS, LABELS
and supporting policies

Patrick Blake,
Programme Management Officer, United for Efficiency (U4E),
United Nations Environment Programme

MEPS, labels and supporting policies for Energy-Efficient and Climate Friendly Cooling

Patrick Blake
Programme Officer
United Nations Environment Programme

Roles of MEPS & Energy Labels

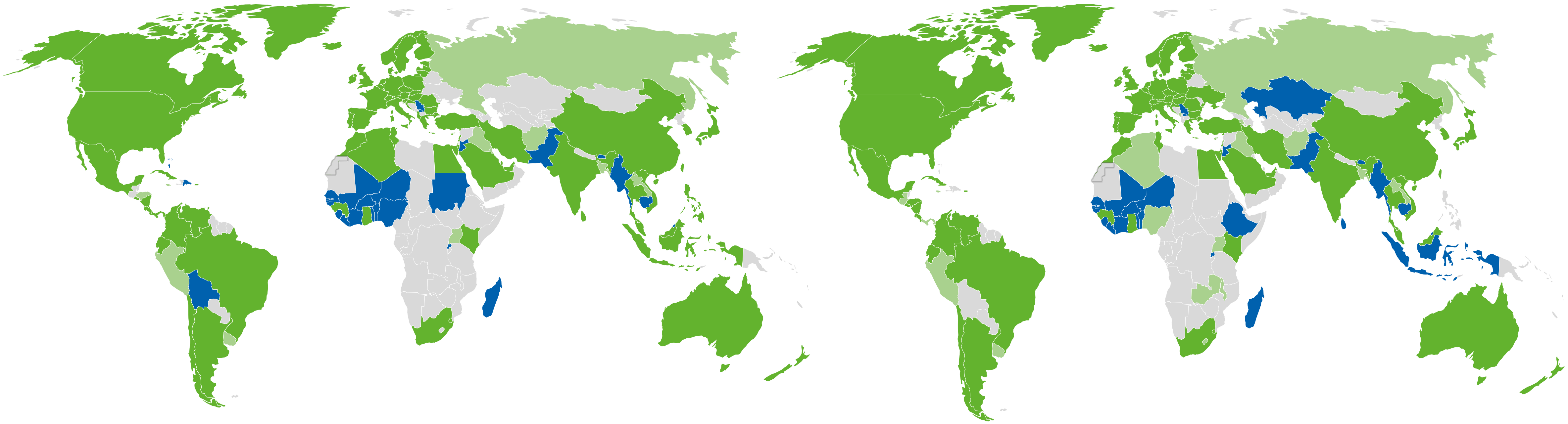


Incentives, financial mechanisms, recognition and/or other support for top products

Market Monitoring and Surveillance

MEPS should ban all used imports and inefficient / high-GWP new products

Policy gaps exist on MEPS and labelling



Room ACs MEPS & Labels Status

Residential Refrigerator MEPS & Labels Status

🟩 **Mandatory**

🟦 **New Development**

▨ **Voluntary**

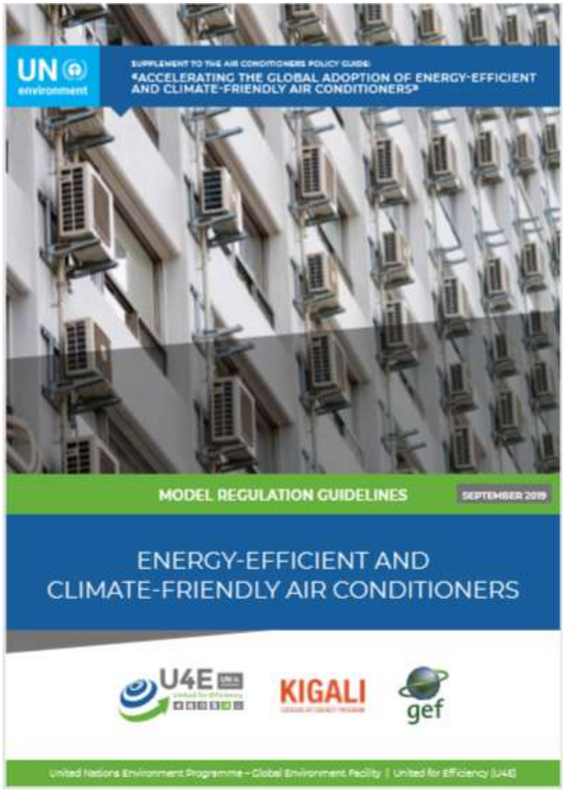
⬜ **No Data Found**

Yet many are:

Out of date, unenforced, circumvented,
Varying in stringency

U4E UN environment programme
United for Efficiency

U4E Model Regulation Guidelines for ACs and Refrigerators



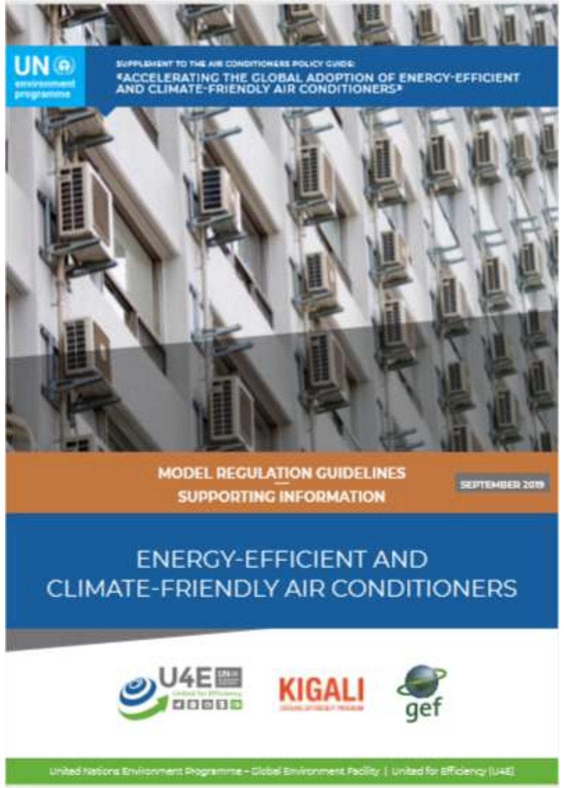
SUPPLEMENT TO THE AIR CONDITIONERS POLICY GUIDE:
"ACCELERATING THE GLOBAL ADOPTION OF ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS"

MODEL REGULATION GUIDELINES

SEPTEMBER 2019

ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS

United Nations Environment Programme – Global Environment Facility | United for Efficiency (U4E)



SUPPLEMENT TO THE AIR CONDITIONERS POLICY GUIDE:
"ACCELERATING THE GLOBAL ADOPTION OF ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS"

MODEL REGULATION GUIDELINES
SUPPORTING INFORMATION

SEPTEMBER 2019

ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS

United Nations Environment Programme – Global Environment Facility | United for Efficiency (U4E)

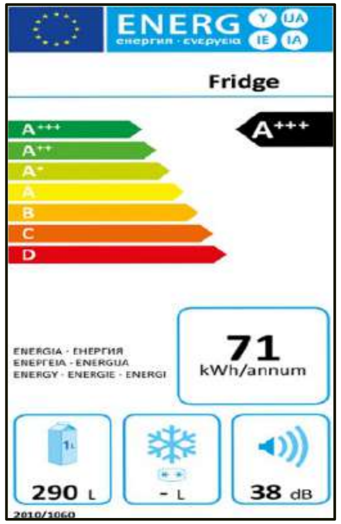
- → intended as guidance to help **inform regulatory authorities and policy makers**
- → sets a **minimum efficiency floor** to prohibit future sales of inefficient products from the market.
- → References global technology and policy trends
- → Deployed in various countries and multiple regions (such as Southeast Asia, Southern Africa and Eastern Africa)

Available in English, Spanish, Chinese, Portuguese, French.
Arabic version upcoming

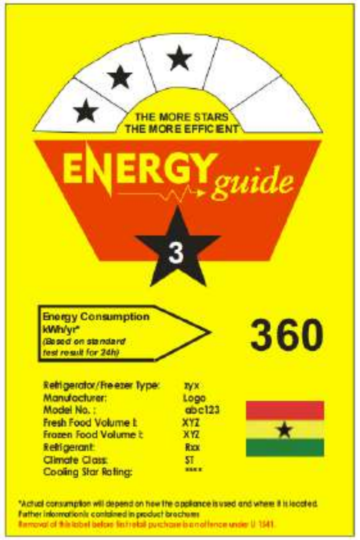
Resources: https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficient-and-climate-friendly-air-conditioners/
https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficient-and-climate-friendly-refrigerating-appliances/

Background on Labels for Energy Efficient Cooling Products

- → Labels assist in overcoming the informational barrier to energy efficiency when consumers are unaware of energy consumption of the products.
- → Labels help “pull” the market to more energy efficient products as a part of an integrated policy approach.
- → Different types of labels can be used (particularly comparative and endorsement labels) along with different options for appearance.
- → Step-by-step guidance for development of labels forthcoming in 2020-Q3.



EU – Comparative Label



Ghana – Comparative Label

Republic of Korea – Comparative Label

US – Voluntary Endorsement Label

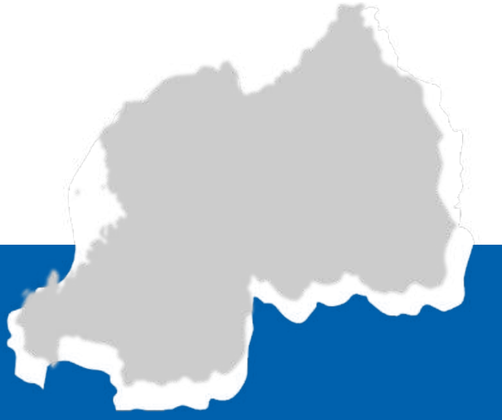
National Project – Rwanda (RCOOL & RCOOL FI)

Main components

- Conduct **Market Assessment**
- Draft a **National Cooling Strategy** and facilitate **MEPS** and **Labels** adoption
- Develop financial mechanisms **- Coolease** (commercial) and **on-utility bill financing** (residential)
- Develop and implement **Communication Campaign**
- Create a **toolkit** on Rwanda's approach and provide **capacity building** in EAC

Recent achievements

- **National Cooling Strategy** adopted by Cabinet – implementation underway
- **Financial mechanisms** near-ready for implementation
- **MEPS** and **Labels** anticipated for entry into force in 2021
- **Communication Campaign** developed and will be launched soon



Q2 2018
–
Q1 2021

Donor: | Partners:

Regional Project – ASEAN - Air Conditioners

Main components

- **Technical documents** recommending adoption of common evaluation method of air conditioners by ASEAN Member States
- Updated ASEAN **Regional Policy Roadmap** on Air Conditioners
- Updated **National Policy Roadmap** on Promotion of Higher Efficiency Room Air Conditioners of ASEAN Member States
- Provide **technical recommendation** on adoption of harmonized evaluation standards.

Recent achievements

- Agreement to project **workplan**
- Convened inception of **Project Steering Committee**, **Policy Working Groups** and **Technical Working Groups** in June 2020

Q2 2020
–
Q4 2021

Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam

Donors:

Partners:

Conclusions

- MEPS and labels are needed to address the large energy use and climate impact of new cooling products;
- Harmonization efforts (including at the regional level) provide benefits to consumers, manufacturers and governments;
- Tools, templates and resources (such as Model Regulations Guidelines, Product Registration Prototype and forthcoming Labelling Guidance) are available for use in project development and implementation;
- Support is available from U4E and its partners to support the development GCF Readiness projects on energy-efficient and climate friendly cooling, such as more focused webinars on specific activities and/or convening regional workshops on development of regional projects.

Thank you!

TRANSFORMING MARKETS TO ENERGY-EFFICIENT PRODUCTS

PHONE

+33 1 44 37 19 86

EMAIL

u4e@unep.org

WEBSITE

united4efficiency.org

Opportunities for EFFICIENCY IMPROVEMENT BY GCF WITH REFRIGERANT TRANSITION under the Montreal Protocol

Ambereen Shaffie

President and Managing Partner, Shaffie Law and Policy

Nihar Shah

Presidential Director, Global Cooling Efficiency Program,

Lawrence Berkeley National Laboratory

Opportunities for Funding Energy Efficiency Improvement by Green Climate Fund with Refrigerant Transition under the Montreal Protocol

Nihar Shah, PhD, PE

Ambereen K. Shaffie, JD, LLM

Lawrence Berkeley National Laboratory

August 5, 2020

Introduction to Lawrence Berkeley National Laboratory

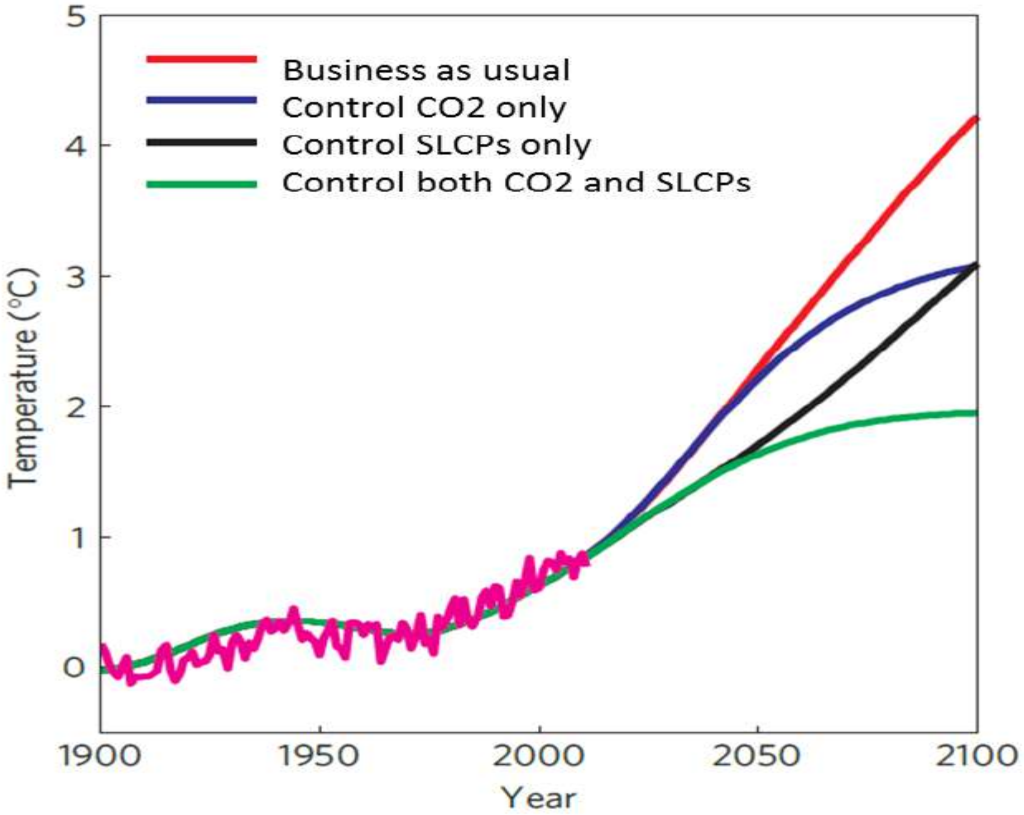
Managed by the University of California for
the United States Department of Energy

BERKELEY LAB
Lawrence Berkeley
National Laboratory

13 — Nobel Prizes
13 — National Medal of Science recipients
4,200 — Employees
200 — Site acreage

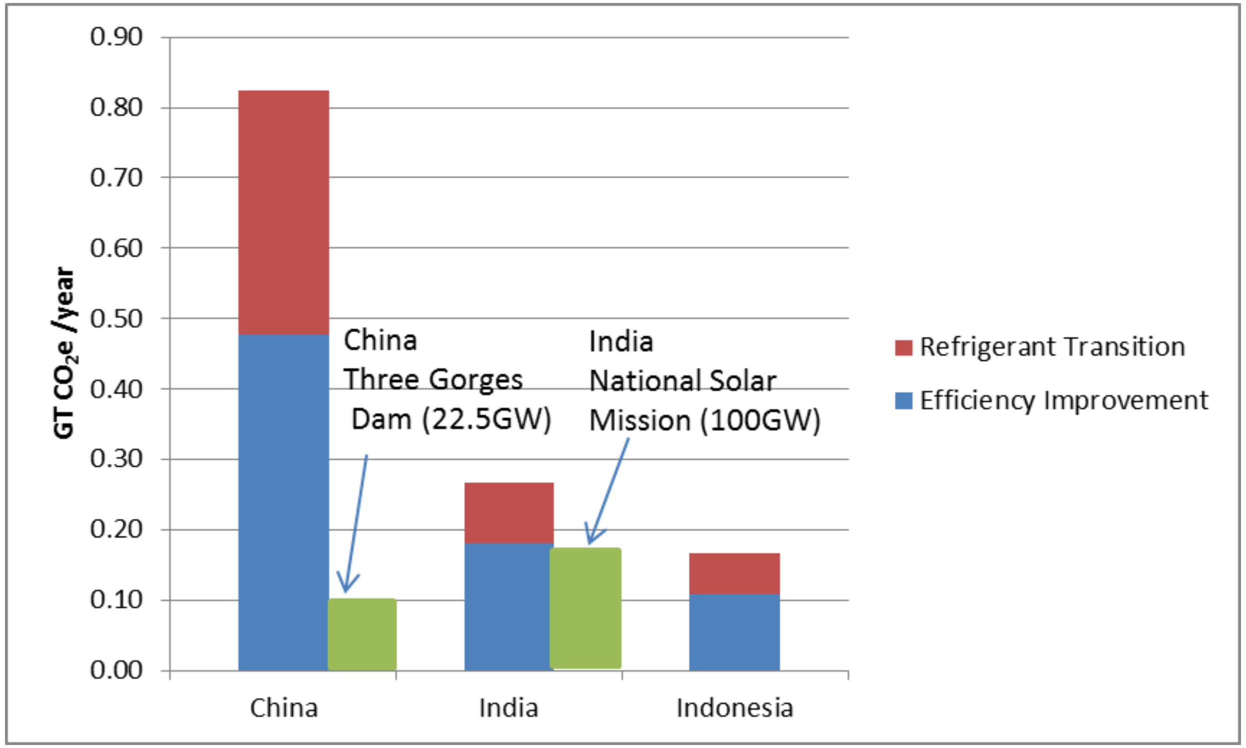
- Dedicated to solving the most pressing scientific problems facing humanity.
- More than two decades of work internationally on clean energy and climate policy, appliances, buildings, transport, industry, air quality.
- Significant focus on energy efficiency, including technical Support to US DOE Appliance Standards Rulemakings.
- Technical support for Kigali Amendment and Montreal Protocol negotiations.
- Technical support for market transformation programs for efficient ACs and refrigerators in various countries including China, India, Brazil, Mexico, Egypt, Indonesia and UNEP United for Efficiency (U4E) "model regulations".
- Technical support for manufacture of superefficient CFC-free refrigerators during previous refrigerant transition

The Opportunity in Cooling



Source: Hu et al, 2013, Nature Climate Change

Both CO2 and refrigerant (HFC) emissions need to be controlled to stay below 2 deg



Source: Shah et al, 2015

Transformation of the AC industry to efficient ACs and low GWP refrigerants in 2030 could provide GHG savings of 0.85 GT/year annually in China, which is equivalent to over (8) Three Gorges dams and over 0.32 GT/year annually in India, roughly twice India's Solar Mission.

Views on Energy Efficiency Finance from the Montreal Protocol

- The Montreal Protocol Parties at the 30th Meeting of the Parties discussed energy efficiency investment, in part responding to the section of the Technical and Economic Assessment Panel (TEAP) EE Task Force report focused on financing
- TEAP EE Task Force Report spoke to need:
  - To "develop appropriate liaison with main funding institutions with shared objectives…enable timely access to funding for MP-related projects" with EE component
  - To "investigate funding architectures that could build on and complement the current, familiar funding mechanisms under the MP"
- Parties echoed this, and added:
  - "Could we identify existing or potential mechanisms that would help MLF coordinate with other financing institutions (measures, approaches, modalities) that could assist us in joining financing flows?"
  - "What are the barriers to funding flows?"
  - "How do we overcome those barriers and unlock funding?"

Why Consider Joint Investment in Energy Efficiency (EE) and Refrigerant Transition (RT)?

- R/AC appliances are often first products targeted for energy efficiency programs and will also undergo refrigerant transition under Kigali Amendment or current Montreal Protocol obligations.
- The MLF already funds the incremental costs of the refrigerant transition for "Article 5" Parties
- Refrigerant transition and efficiency improvement both *require* redesign of appliances and retooling of manufacturing lines (typically).
- Co-funding allows both funders of EE and RT to save money and maximize benefits from investment:
  - For manufacturers by redesigning/retooling for EE and RT together, rather than multiple times
  - For consumers by lowering their energy costs
  - For utilities by reducing overall and peak electricity demand, when producing electricity is often the most costly, and increasing economic benefits from power generation (each W provides more services)

Energy Efficiency and Refrigerant Transition

NOTE: GCF could plan EE investments in cooling by considering MLF approved projects as a starting point followed by some amount of "cost-effective" EE investment by the GCF to avoid deployment of high GWP refrigerants

Energy Efficiency(EE)	Refrigerant Transition(RT)
Standards and labels updated every few years	Sectoral transition over decades
Many different efficiency levels available on any market for any sector	only one or a few refrigerants per sector
"continuous"	"step change"
Various possible funding sources	Transition for A5 Parties Funded by Montreal Protocol

How to Co-ordinate EE and Refrigerant Transition Investments?

- Refrigerant transition has an impact on EE[**]
- “Indirect” climate benefits from EE energy savings are not currently considered in Montreal Protocol project funding
- Not all EE investments are equal, different peak load, climate, energy impacts varying by economy and sector
- Can EE and RT be invested in to the “same”[***] level?
- How to maximize benefit while minimizing costs?
- What level of EE should be targeted?
- How to appropriately allocate costs and benefits to EE and RT?

** This implies that just by changing refrigerant in the same equipment, there will be higher (or lower) efficiency. This needs to be accounted for when planning further EE investment, beyond this level.

*** There could be various views on what “same” might mean, e.g. monetary value or CO_2eq GHG benefit or other metric.

The Joint Investment Framework Tool

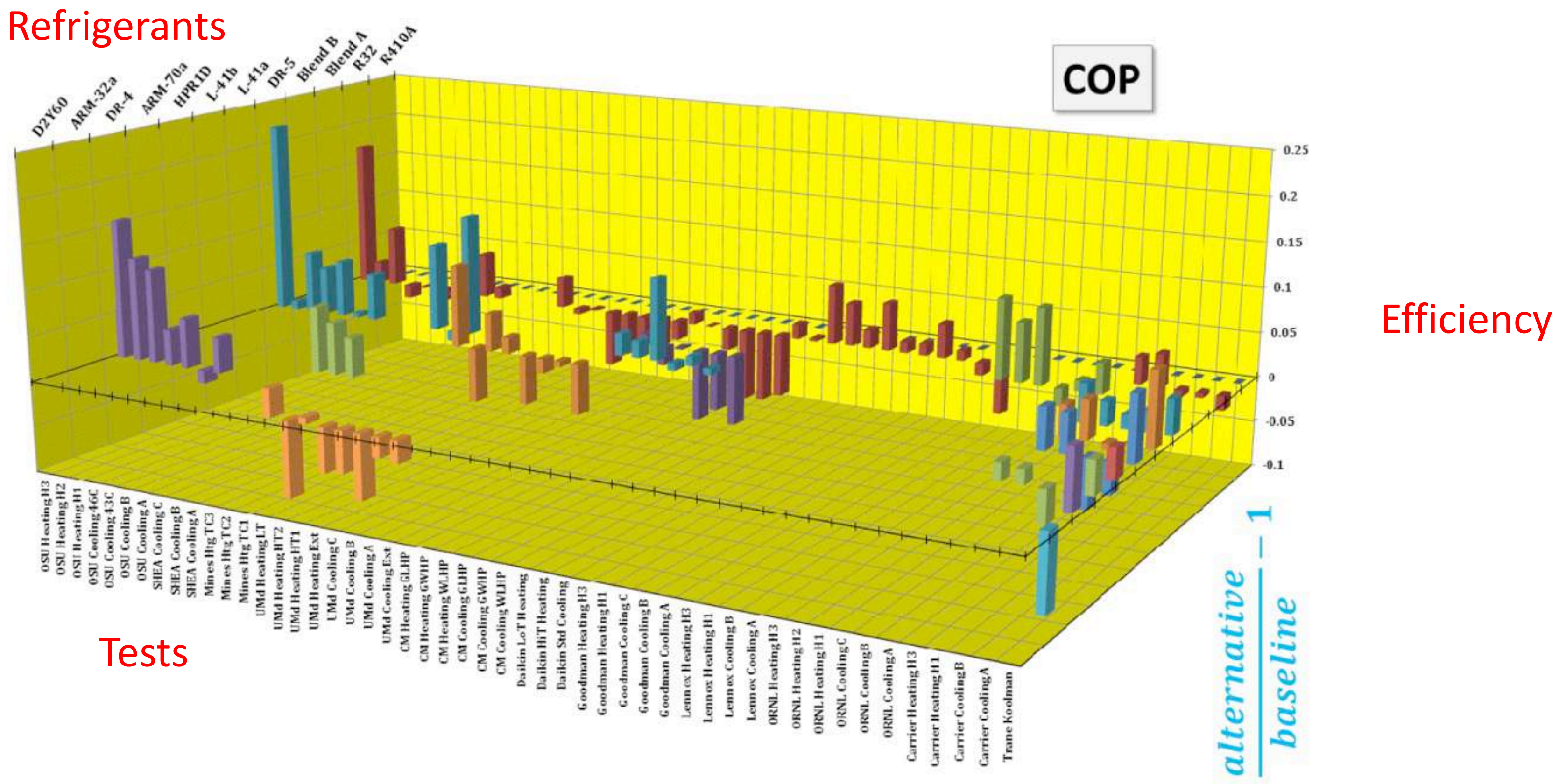
Addressing barriers to co-financing energy efficiency and the refrigerant transition

- Relies on publicly available data on cost of efficiency improvement
- Flexible tool for planning and/or evaluation of energy efficiency projects co-ordinated with refrigerant transition
- Enables the pipeline of projects in the Montreal Protocol to be leveraged for EE improvement

Joint Investment Framework Ingredients

- Cost-effectiveness metrics ($/$CO_2$ equivalent, $ invested/$ saved)
- Metrics such as Total Equivalent Warming Impact (TEWI), to account for direct and indirect climate benefits over the equipment lifetime.
- Incremental costs of refrigerant transition, e.g., those developed and used by the Multilateral Fund to the Montreal Protocol (MLF) and Montreal Protocol's implementing agencies (UNEP, UNIDO, UNDP and World Bank).
- Manufacturing cost versus efficiency curves such as those used by the US DOE's EE standards rulemakings and extended to other countries, e.g., India, China etc. and an understanding of incremental cost categories associated with design options for improving efficiency and switching refrigerant.
- Manufacturer impact analyses such as those developed by Berkeley Lab for the US DOE's EE standards rulemakings to estimate the cost of retooling manufacturing lines for higher efficiency.
- The efficiency and capacity of alternate refrigerants from testing programs

Impact of refrigerant on EE: Example of R410A alternatives

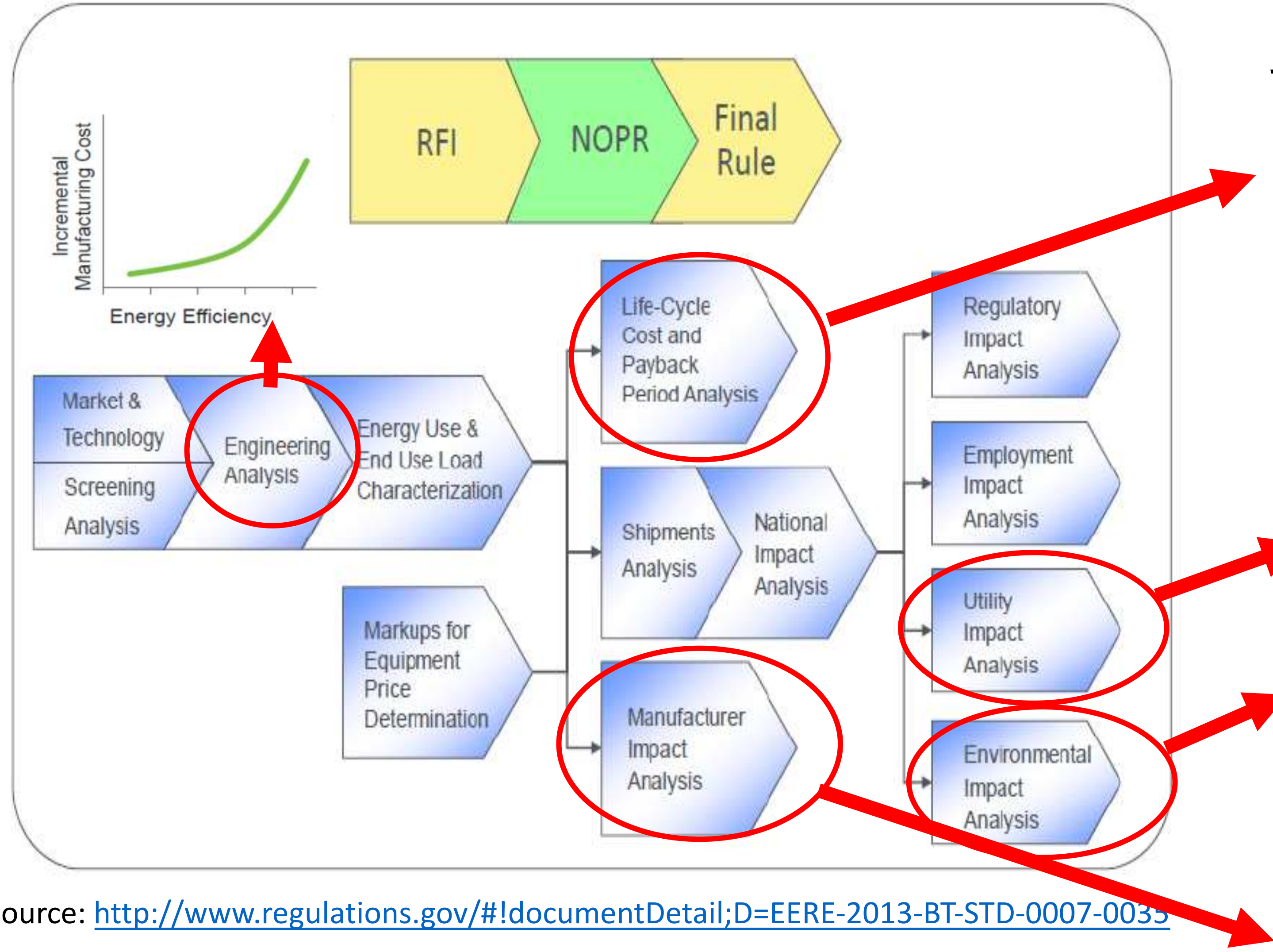


Source: AHRI low-GWP Alternate Refrigerant Evaluation Program (AREP)

Refrigerant impact on EE can be obtained from:

- AHRI Alternate Refrigerant Evaluation Program(AREP)
- ORNL High Ambient Temperature Testing Program
- PRAHA/EGYPRA etc.
- Others

DOE Efficiency Standards Process and JIF cost-effectiveness metrics



JIF
“consumer”
cost effectiveness
metric

JIF
“utility”
cost effectiveness
metric

JIF
“climate”
cost effectiveness
metric

JIF EE
Investment
needed

Source: http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0007-0035

Note: these are publicly available for various equipment types at various levels of efficiency

Cost vs Efficiency Example: mini-split ACs in India and China

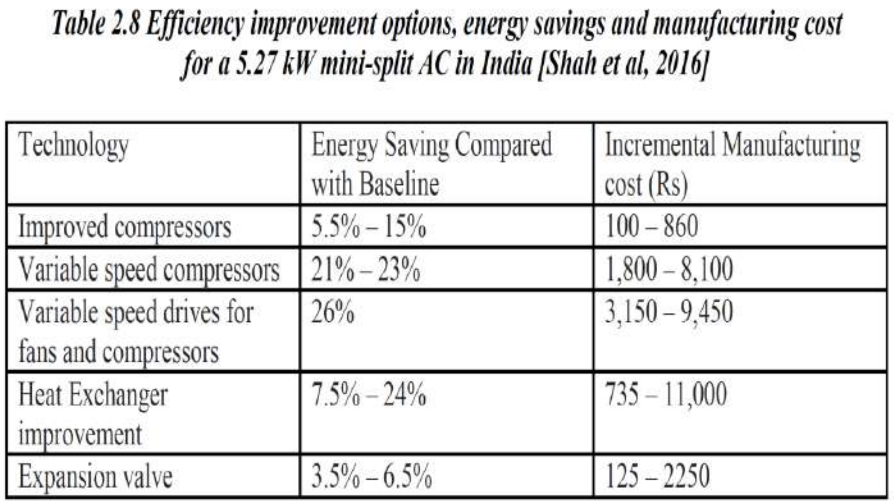
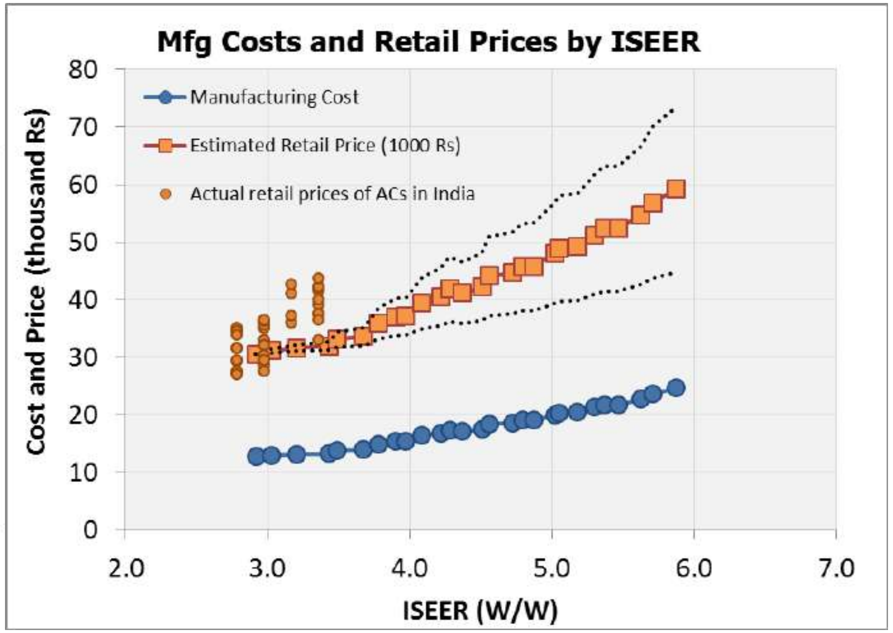


Table 2.8 Efficiency improvement options, energy savings and manufacturing cost for a 5.27 kW mini-split AC in India [Shah et al, 2016]

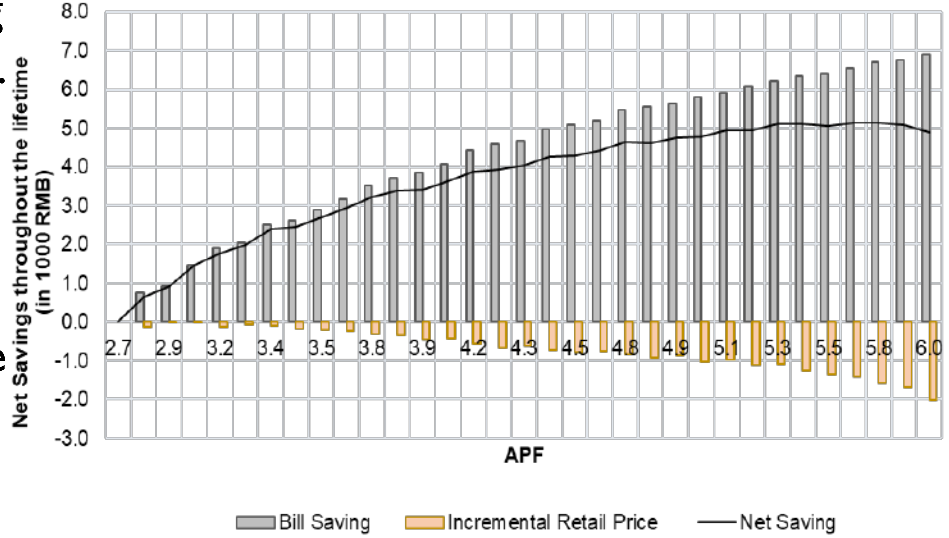
Technology	Energy Saving Compared with Baseline	Incremental Manufacturing cost (Rs)
Improved compressors	5.5% – 15%	100 – 860
Variable speed compressors	21% – 23%	1,800 – 8,100
Variable speed drives for fans and compressors	26%	3,150 – 9,450
Heat Exchanger improvement	7.5% – 24%	735 – 11,000
Expansion valve	3.5% – 6.5%	125 – 2250

Source: Shah et al, 2016



- Retail price estimates based on "bottom-up" engineering analysis were used for designing the EE standard for ACs in India in 2016 and also for designing the specifications for EESL's bulk procurement of ACs in India in 2016-2017.
- Similar data was used to design China's new EE standard for room ACs in March 2020.
- Can be used to design "consumer", "climate/CO2-equivalent" or other type of cost-effectiveness metric.

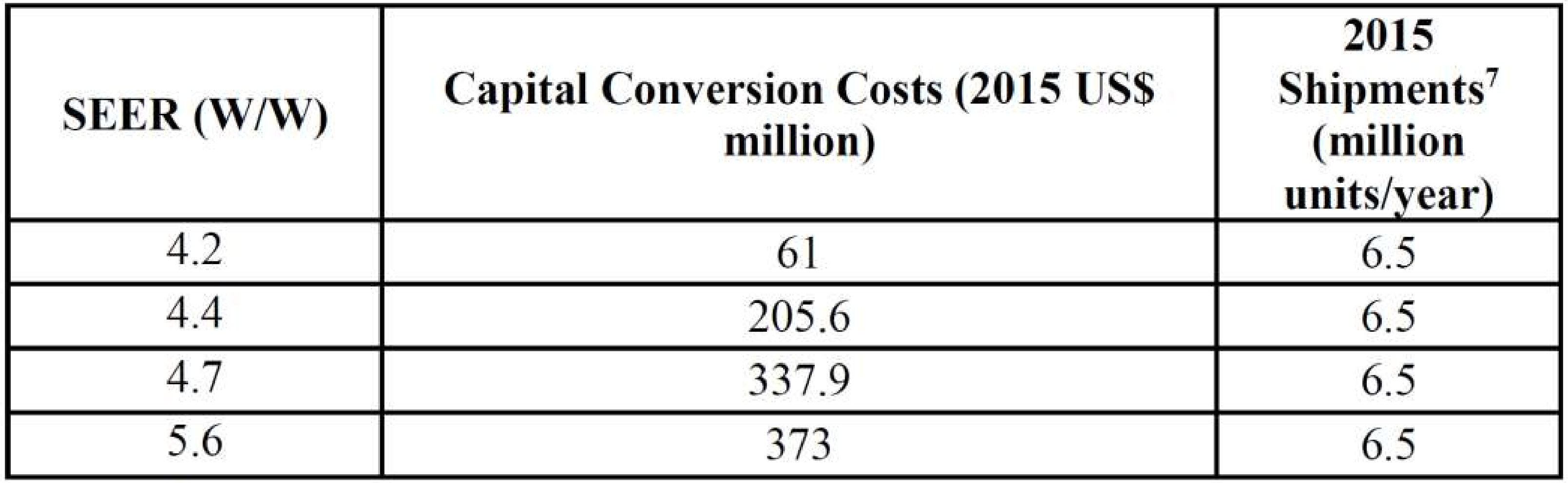
Source: Karali et al, 2019



Joint Investment Framework: Investment Needed

At the "cost-effective" efficiency level identified, use "Manufacturer Impact Analysis" results to calculate EE investment needed:

E.g. "Industry wide" conversion costs for different EE levels in US in 2015, also in Montreal Protocol TEAP EE Task Force report



SEER (W/W)	**Capital Conversion Costs (2015 US$ million)**	**2015 Shipments[7] (million units/year)**
4.2	61	6.5
4.4	205.6	6.5
4.7	337.9	6.5
5.6	373	6.5

Source: DOE 2016

Summary

- Starting from an MLF-approved refrigerant transition project, based on a particular type of EE investor perspective (consumer, climate or utility) interested in co-funding EE we can use this approach to:
  - Identify a corresponding EE "project",
  - a corresponding benefit ($, GW, or CO2 eq)
  - a corresponding "target efficiency level"
  - a corresponding "investment need" or $ amount
- Type of investor and structure of investment might dictate which perspective is most useful in designing energy efficiency investment with refrigerant transition.
- Publicly available data from US DOE, EU Ecodesign program and other EE programs may be useful in designing and planning co-ordinated EE investments in tandem with the refrigerant transition.
- Data can be customized for economy and sector-specific investments adjusting for: labor cost, electricity price, discount rate, refrigerant leakage rate, climate, hours of use, income, carbon intensity etc.

Summary

- Kigali Amendment offers an opportunity to simultaneously improve energy efficiency along with refrigerant transition
- Significant co-benefits: energy security, climate, peak load ~$Billions saved.
- Co-ordination of efficiency improvement along with refrigerant transition would likely lower costs in comparison to separate implementation: Maximize climate benefits.
- Refrigerant transition is "step change" while energy efficiency improvement is "continuous": Start from MLF approved projects
- Refrigerant transition has an impact on energy efficiency that can be accounted for from testing results: Prevent "double-counting" of benefits.
- Cost vs efficiency data is useful in calculating multiple "cost-effective" levels of efficiency improvement: Consumer, climate, utility etc. which could map to different energy efficiency funding levels: allows flexibility in decisionmaking.

Thank you!

Questions, Suggestions?

Nihar Shah, PhD, PE
Presidential Director,
Global Cooling Efficiency Program,
Lawrence Berkeley National Laboratory
nkshah@lbl.gov

Ambereen Shaffie, JD, LLM
Managing Partner,
Shaffie Law and Policy
aks@shaffielaw.com

SCALING-UP GCF PROJECTS

ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

Eduardo Freitas,
Regional Manager, Division
of Country Programming
Green Climate Fund

Brief Introduction on the
READINESS SUPPORT MODALITY

SCALING-UP GCF PROJECTS ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

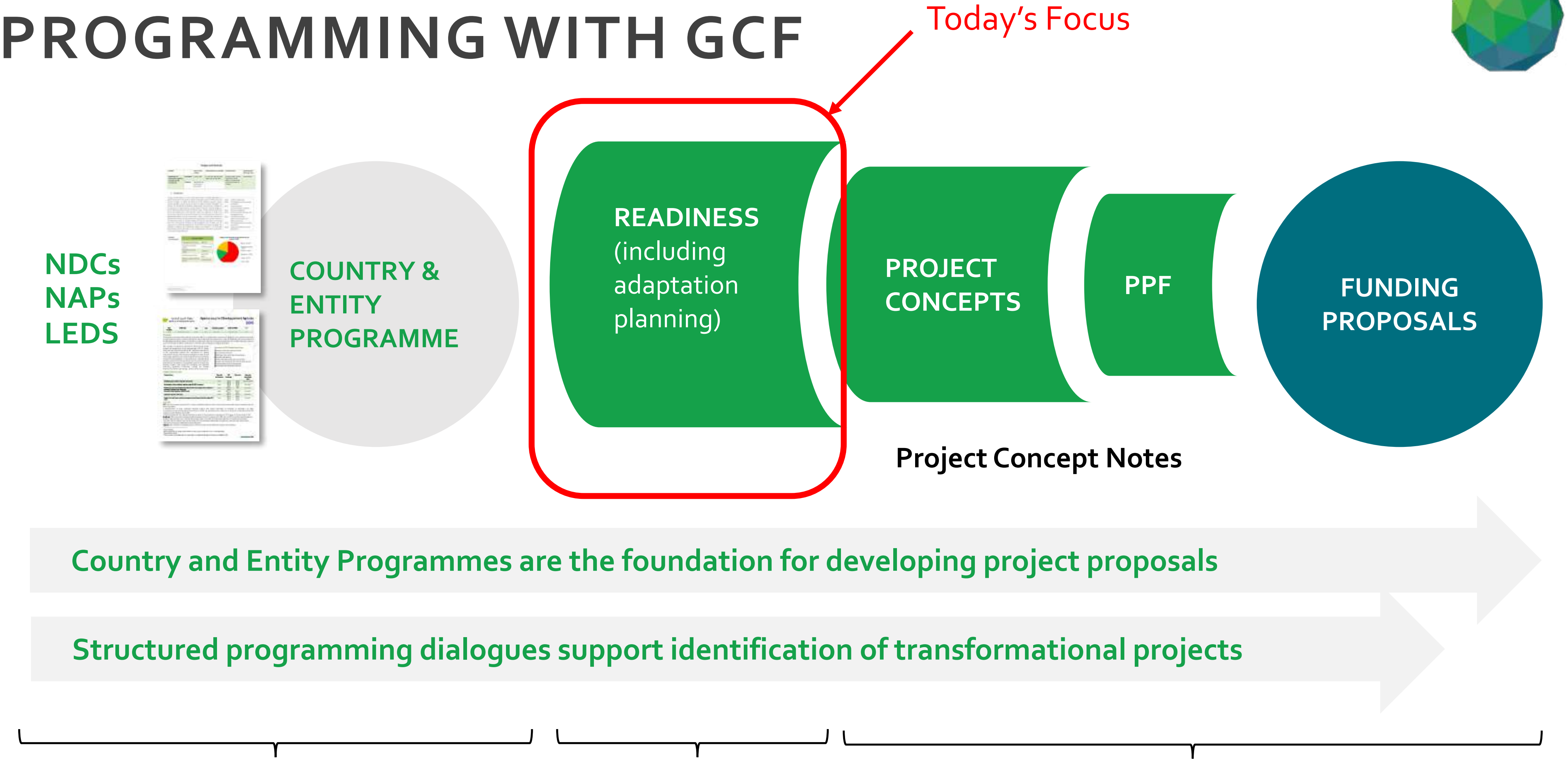
GREEN
CLIMATE
FUND

INTRODUCTION TO GCF READINESS

5 August 2020

Eduardo Freitas, Africa Regional Manager (efreitas@gcfund.org)

PROGRAMMING WITH GCF



Today's Focus

NDCs
NAPs
LEDS

COUNTRY & ENTITY PROGRAMME

READINESS (including adaptation planning)

PROJECT CONCEPTS

PPF

FUNDING PROPOSALS

Project Concept Notes

Country and Entity Programmes are the foundation for developing project proposals

Structured programming dialogues support identification of transformational projects

What sectors, what projects are a priority for the country?

Are there any gaps for identifying or strengthening entities?

Which entity(ies) is the most suitable to deliver the pipeline?

READINESS PROGRAMME (AS OF JUNE 15, 2020)

GLOBAL	381	250 USD million	322	107.7 USD million
	Total number of readiness grants approved	Total value of readiness grants approved	Total number of readiness grants disbursed	Disbursements

USD 1 million cap per country per year

- NDA and DAE strengthening
- Country Programmes and GCF strategic engagement
- Access to climate finance

USD 3 million cap per country

- National adaptation plans (NAP) / adaptation planning processes

WHAT'S NEW IN READINESS?

GREEN CLIMATE FUND

Multi-Year	✓ NDAs can apply for multi-year readiness up to 3M over 3 years ✓ NDAs can still apply for 1-year readiness
Programmatic Focus	✓ NDAs are encouraged to plan strategic use of Readiness resources to address climate finance priorities (i.e. 5-year plan, NDC, NAP, TNC) and complementarity with other efforts
Objective Areas	✓ Objective areas have been expanded and clarified. ✓ This means the outcomes have also changed in the log frame
Template Changes	✓ Baselines, theory of change, capacity assessment/analysis

- ✓ Regional team can help work on co-development prior to review
- ✓ Consult the readiness guidebook for checklists, best practice examples, quality assurance checklist

STEPS OF SUBMITTING A READINESS PROPOSAL

GREEN CLIMATE FUND

Stage I: Proposal Development Phase

- Begin engaging with relevant government agencies to develop concept
- Select Delivery Partner (either be AE or organization that has passed FMCA)
- Engage with GCF Regional Officer to develop the Readiness proposal.

Stage II: Appraisal

- GCF Regional Officer will provide early feedback to NDA and DP
- GCF Regional Officer to determine when proposal is ready for GCF appraisal process
- The Readiness proposal is submitted to the Readiness Working Group (RWG) for endorsement

Stage III: Approval

- RWG can either endorse or not endorse a proposal. In many cases a proposal is endorsed with conditions.
- Once all RWG conditions are fully addressed, the proposal is submitted to the Deputy Executive Director for approval
- Upon approval, GCF will notify the NDA and hand over contracting and implementation to UNOPS

Key Points to remember

- ✓ Work closely with the NDAs – only they can submit proposals
- ✓ Work closely with GCF Regional Officers on development of readiness proposals
- ✓ Start early – on average Readiness proposals can take 6 months from submission to approval
- ✓ Proposal will be counted towards the cap of the year that it was approved by the GCF (not submitted)
- ✓ Route communication through institutional focal point for Delivery Partner

READINESS EXAMPLE

NATIONAL FRAMEWORK FOR LEAPFROGGING TO ENERGY EFFICIENT APPLIANCES AND EQUIPMENT

Example Activities	Interventions under this proposal will support development of: ✓ Mandatory Minimum energy performance standards and labeling schemes for refrigerators and distribution transformers ✓ National policy roadmap and enabling environment for implementation of standards and label for refrigerators and distribution transformers ✓ Appropriate financing mechanisms to accelerate deployment of energy efficient refrigerators and distribution transformers. ✓ A strengthened national capacity to develop standards and labels for other appliances in future.

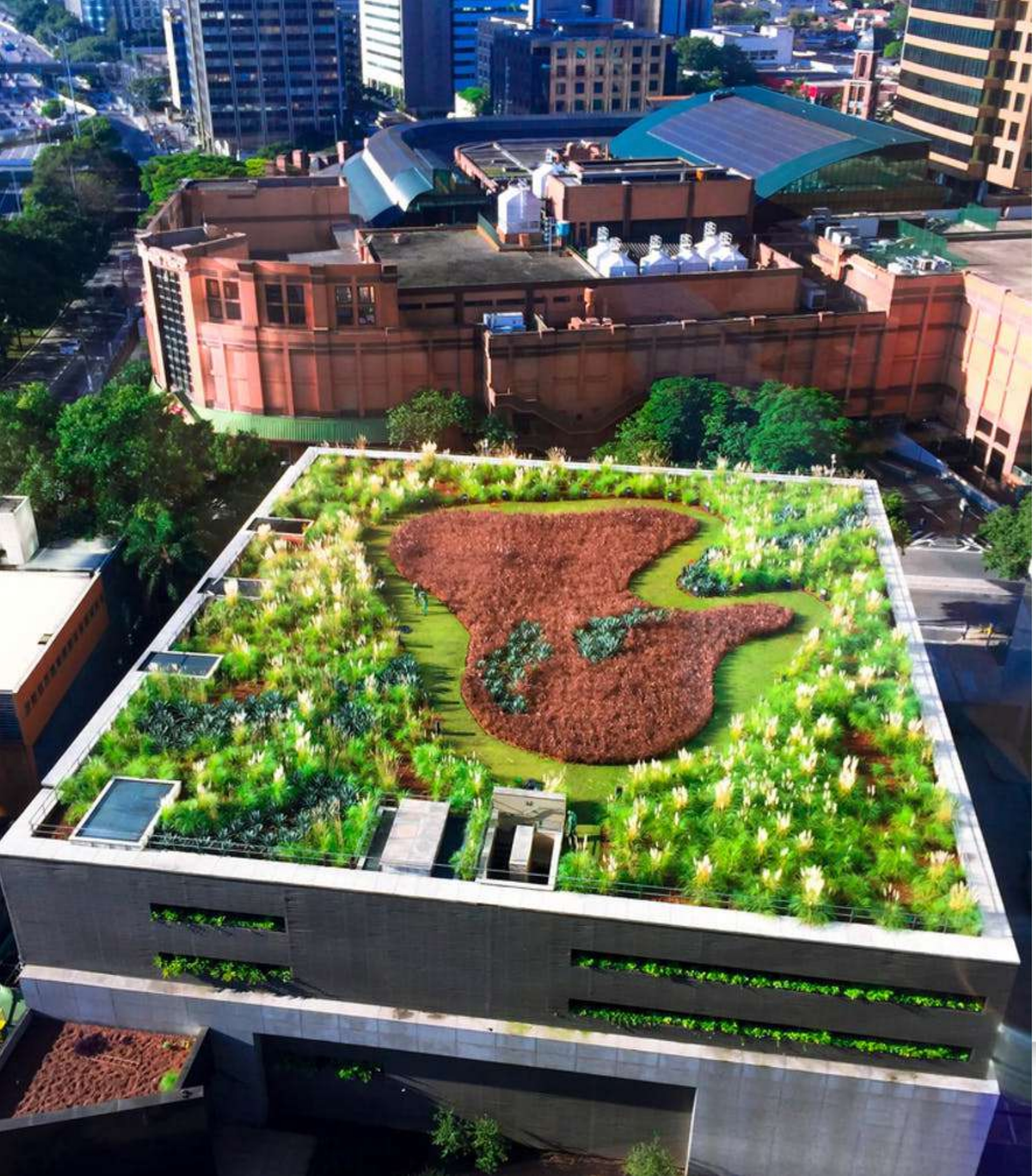
GREEN
CLIMATE
FUND

SCALING-UP GCF PROJECTS ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

QUESTIONS AND ANSWERS

UN environment programme

GREEN CLIMATE FUND



SCALING-UP GCF PROJECTS

ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

CALL TO ACTION / CLOSING

THANK YOU

SCALING-UP GCF PROJECTS ON ENERGY-EFFICIENT AND CLIMATE FRIENDLY COOLING

GREEN CLIMATE FUND

GREEN CLIMATE FUND:

Sabin Basnyat
sbasnyat@gcfund.org

Yunyeong Yang
yyang@gcfund.org

UN environment programme

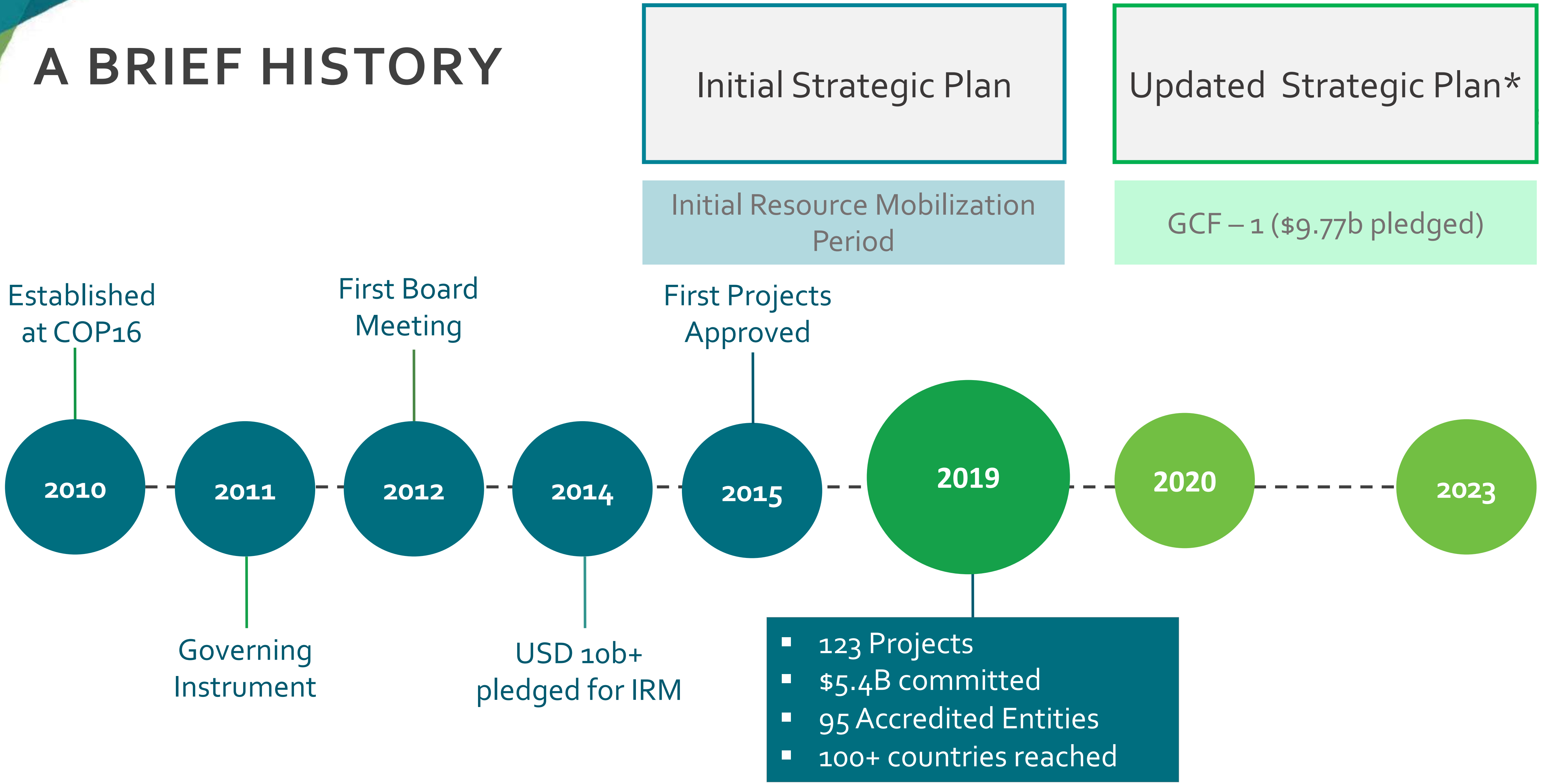
UNITED NATIONS ENVIRONMENT PROGRAMME:

Patrick Blake
patrick.blake@un.org

Sophie Loran
sophie.loran@un.org

Additional Slides

A BRIEF HISTORY



Initial Strategic Plan

Updated Strategic Plan*

Initial Resource Mobilization Period

GCF – 1 ($9.77b pledged)

2010 – Established at COP16

2011 – Governing Instrument

2012 – First Board Meeting

2014 – USD 10b+ pledged for IRM

2015 – First Projects Approved

2019

- 123 Projects
- $5.4B committed
- 95 Accredited Entities
- 100+ countries reached

2020

2023

*Strategic Plan for consultation of the GCF Board

STEPS OF SUBMITTING A READINESS PROPOSAL

GREEN CLIMATE FUND

Stage I: Proposal Development Phase

- Begin engaging with relevant government agencies to develop concept
- Familiarize yourself with GCF Readiness template and Guidebook
- Select Delivery Partner that fits project management needs not necessarily technical needs (Delivery Partner can either be AE or organization that has passed FMCA)
- Engage with GCF Regional Officer to develop proposal.

Stage II: Appraisal

- GCF Regional Officer will provide early feedback to NDA and DP to help strengthen the proposal and to make sure it is in line with GCF policies and practices
- GCF Regional Officer to decide when proposal is ready for appraisal process which consists of an interdivisional review and sent back to the NDA/DP (if needed; potentially multiple rounds)
- After interdivisional review comments are addressed sufficiently, the proposal is submitted to the Readiness Working Group (RWG) for endorsement

Stage III: Approval

- RWG can either endorse or not endorse a proposal. In many cases a proposal is endorsed with conditions. The Regional Officers will work with the NDA and DP to address the RWG conditions.
- Once all RWG conditions are fully addressed, the proposal is submitted to the Deputy Executive Director for approval (final approving authority)
- Upon approval, GCF will notify the NDA officially and hand over contracting and implementation to UNOPS

Key Points to remember

- ✓ Work closely with the NDAs – only they can submit proposals
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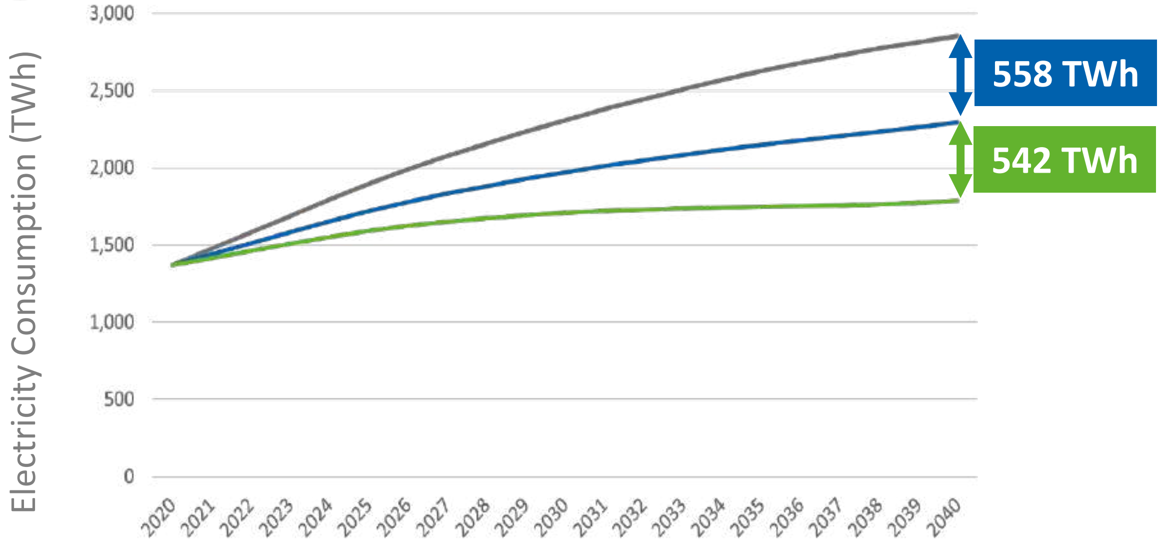
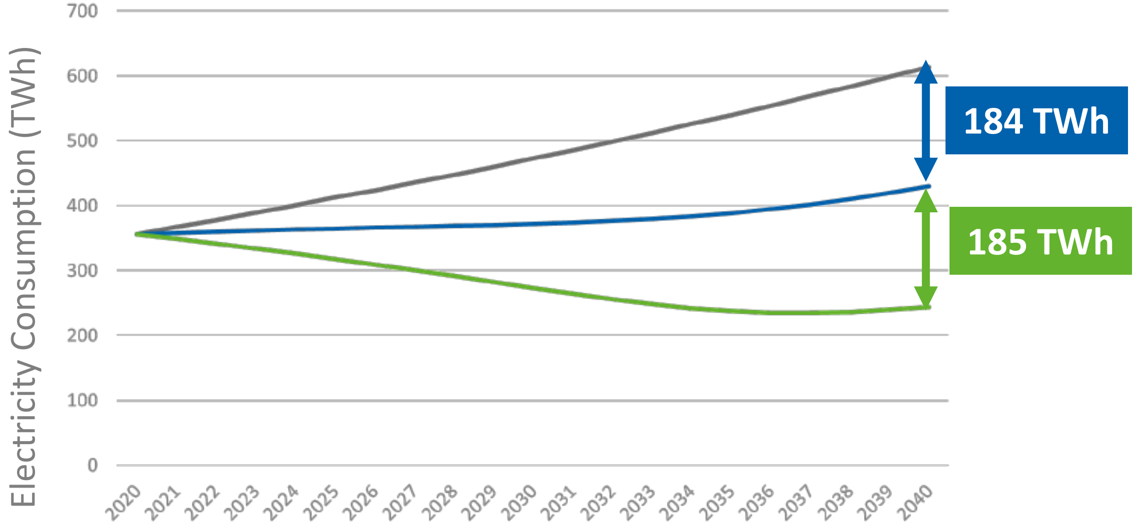
Country Savings Assessments

Savings potential of room ACs and residential refrigerators by 2040*

Room ACs



Residential refrigerators



Electricity consumption growth by 2040		
Business As Usual Scenario (BAU)	108 %	72%
With Minimum Ambition Scenario (MEPS)	68%	21%
With High Ambition Scenario (HEPS)	31%	(31%)

Annual Savings in 2040**		
Electricity Savings (TWh)	558	184
equivalent to:		
Power Stations **[500 MW]**	255	84
Millions of CO_2	516	155
billions of USD in electricity bills	51	17

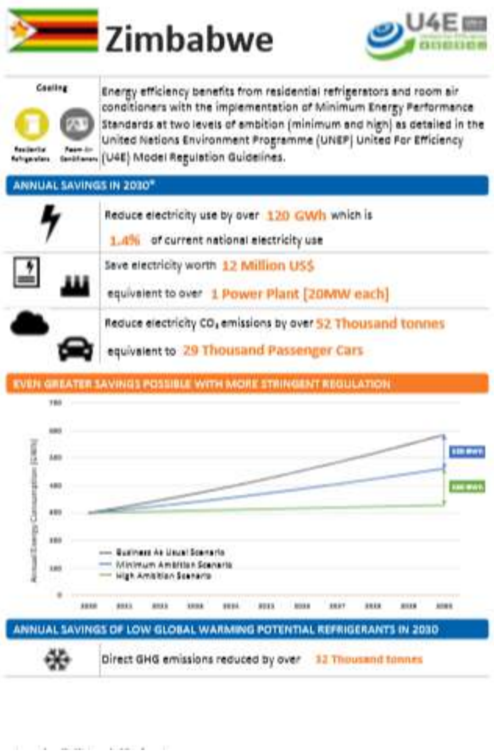
- Business As Usual Scenario
- Minimum Ambition Scenario
- High Ambition Scenario

* Graph refers to the 156 developing countries and emerging economies that had been assessed for the U4E Country Saving Assessments.

Opportunity to leverage U4E’s tools

To support market transformation

156 country assessments



Zimbabwe

Cooling

Residential Refrigerators

Room Air Conditioners

Energy efficiency benefits from residential refrigerators and room air conditioners with the implementation of Minimum Energy Performance Standards at two levels of ambition (minimum and high) as detailed in the United Nations Environment Programme (UNEP) United For Efficiency (U4E) Model Regulation Guidelines.

ANNUAL SAVINGS IN 2030*

Reduce electricity use by over 120 GWh which is 1.4% of current national electricity use

Save electricity worth 12 Million US$ equivalent to over 1 Power Plant (20MW each)

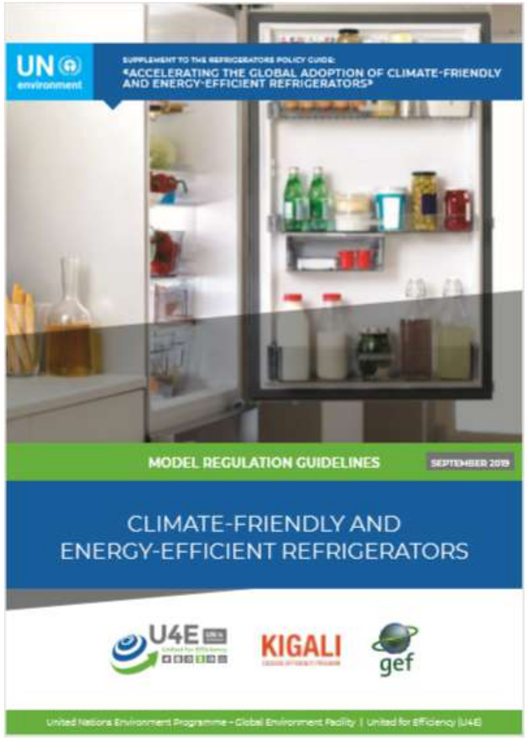
Reduce electricity CO₂ emissions by over 52 Thousand tonnes equivalent to 29 Thousand Passenger Cars

EVEN GREATER SAVINGS POSSIBLE WITH MORE STRINGENT REGULATION

ANNUAL SAVINGS OF LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN 2030

Direct GHG emissions reduced by over 32 Thousand tonnes

Model Regulation Guidelines for ACs and Refrigerators



UN environment

SUPPLEMENT TO THE REFRIGERATORS POLICY GUIDE: "ACCELERATING THE GLOBAL ADOPTION OF CLIMATE-FRIENDLY AND ENERGY-EFFICIENT REFRIGERATORS"

MODEL REGULATION GUIDELINES

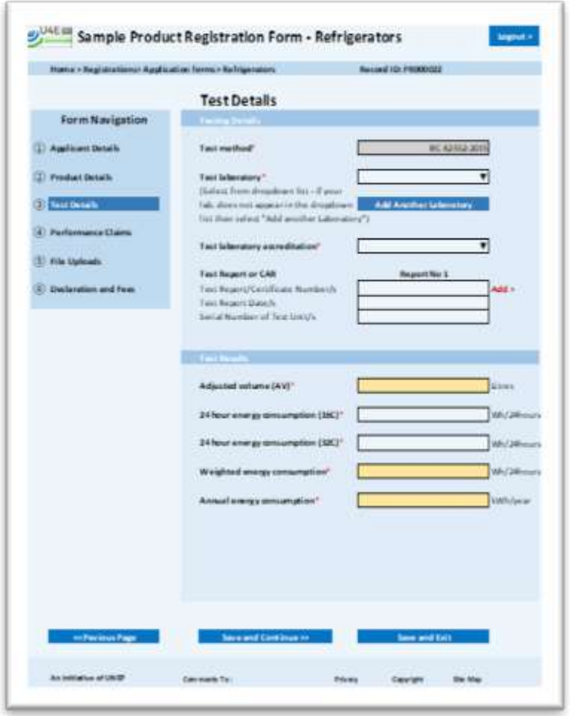
SEPTEMBER 2019

CLIMATE-FRIENDLY AND ENERGY-EFFICIENT REFRIGERATORS

U4E KIGALI gef

United Nations Environment Programme – Global Environment Facility | United for Efficiency (U4E)

Prototype product Registration System and specifications for software development



Sample Product Registration Form - Refrigerators

Test Details

Form Navigation

1. Applicant Details
2. Product Details
3. Test Details
4. Performance Claims
5. File Uploads
6. Declaration and Fees

Test method*

Test laboratory*

Add Another Laboratory

Test laboratory accreditation*

Test Report or CAR

Report No 1

Add >

Adjusted volume (AV)*

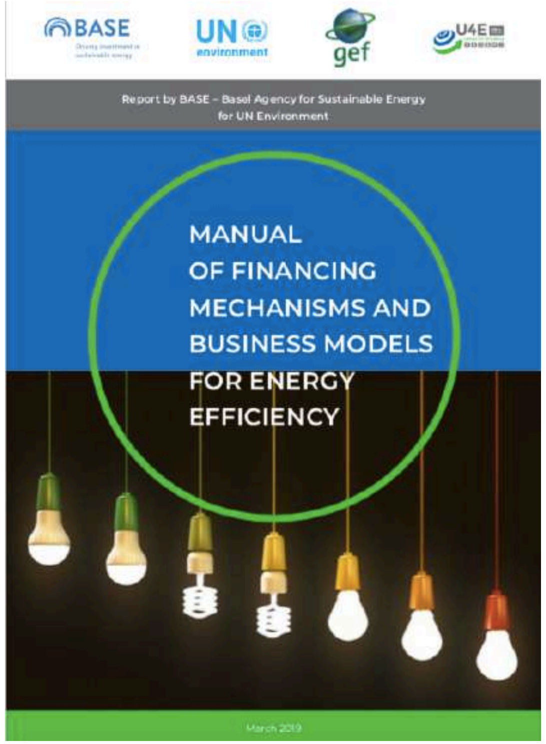
24 hour energy consumption (16C)*

24 hour energy consumption (32C)*

Weighted energy consumption*

Annual energy consumption*

Financial Mechanisms



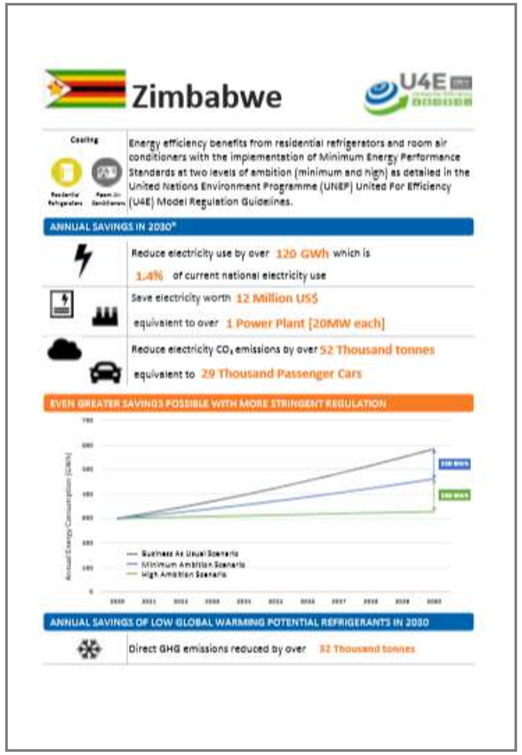
BASE UN environment gef U4E

Report by BASE – Basel Agency for Sustainable Energy for UN Environment

MANUAL OF FINANCING MECHANISMS AND BUSINESS MODELS FOR ENERGY EFFICIENCY

March 2019

Overview of U4E Tools and Guidance


Zimbabwe

Energy efficiency benefits from residential refrigerators and room air conditioners with the implementation of Minimum Energy Performance Standards at two levels of ambition (minimum and high) as detailed in the United Nations Environment Programme (UNEP) United For Efficiency (U4E) Model Regulation Guidelines.

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EVEN GREATER SAVINGS POSSIBLE WITH MORE STRINGENT REGULATION

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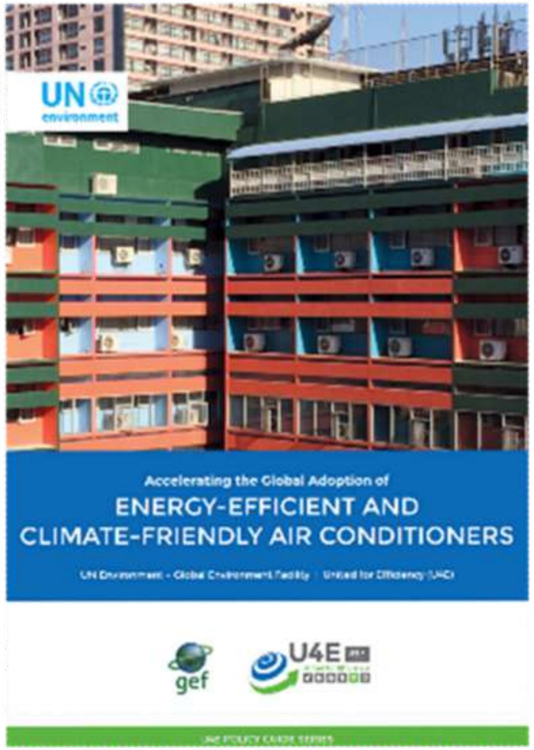
Country Savings Assessments

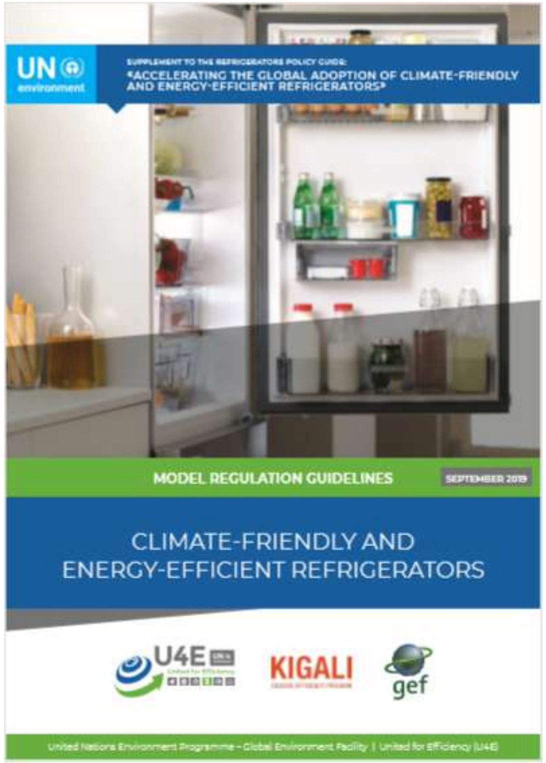

Accelerating the Global Adoption of
ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS

UN Environment – Global Environment Facility | United for Efficiency (U4E)

Policy Guides


PERFORMANCE TESTING OF LIGHTING PRODUCTS

Technical Guidance


SUPPLEMENT TO THE REFRIGERATORS POLICY GUIDE: «ACCELERATING THE GLOBAL ADOPTION OF CLIMATE-FRIENDLY AND ENERGY-EFFICIENT REFRIGERATORS»

MODEL REGULATION GUIDELINES SEPTEMBER 2019

CLIMATE-FRIENDLY AND ENERGY-EFFICIENT REFRIGERATORS

United Nations Environment Programme – Global Environment Facility | United for Efficiency (U4E)

Model Regulations

Why is EE important? Which products should we prioritise?

→

Which integrated policies and interventions should be considered? How have others done it?

→

How to analyze data, test products, enforce regulations?

→

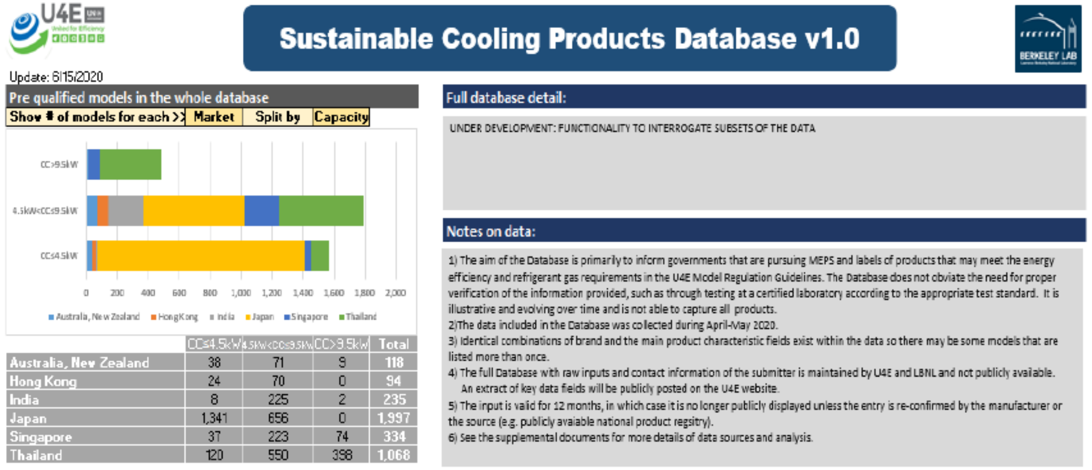
Which scope, performance, safety, testing, etc. are a good starting point for MEPS & labels?

Which products are claimed to meet the Model Regulation Guidelines and where are they available?

How to monitor the market, enhance enforcement, and share information?

How to address higher first costs, risk, access to capital, & other barriers?

Sustainable Cooling Products Database



Sustainable Cooling Products Database v1.0

Update: 6/15/2020

Pre qualified models in the whole database

Show # of models for each >> Market Split by Capacity

	CC≤4.5kW	4.5kW<CC≤9.5kW	CC>9.5kW	Total
Australia, New Zealand	38	71	9	118
Hong Kong	24	70	0	94
India	8	225	2	235
Japan	1,341	656	0	1,997
Singapore	37	223	74	334
Thailand	120	550	398	1,068

Full database detail:

UNDER DEVELOPMENT: FUNCTIONALITY TO INTERROGATE SUBSETS OF THE DATA

Notes on data:

1) The aim of the Database is primarily to inform governments that are pursuing MEPS and labels of products that may meet the energy efficiency and refrigerant gas requirements in the U4E Model Regulation Guidelines. The Database does not obviate the need for proper verification of the information provided, such as through testing at a certified laboratory according to the appropriate test standard. It is illustrative and evolving over time and is not able to capture all products.

2)The data included in the Database was collected during April-May 2020.

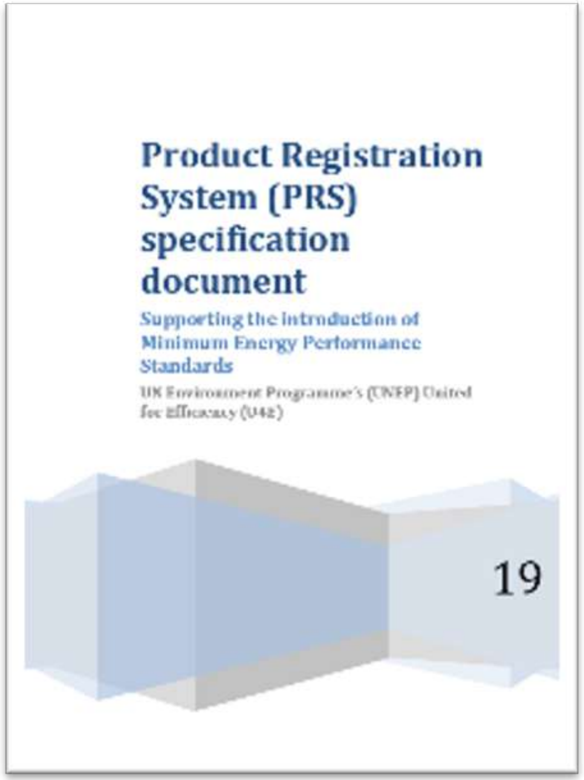
3) Identical combinations of brand and the main product characteristic fields exist within the data so there may be some models that are listed more than once.

4) The full Database with raw inputs and contact information of the submitter is maintained by U4E and LBNL and not publicly available. An extract of key data fields will be publicly posted on the U4E website.

5) The input is valid for 12 months, in which case it is no longer publicly displayed unless the entry is re-confirmed by the manufacturer or the source (e.g. publicly avaiable national product regsitry).

6) See the supplemental documents for more details of data sources and analysis.

Product Registration System



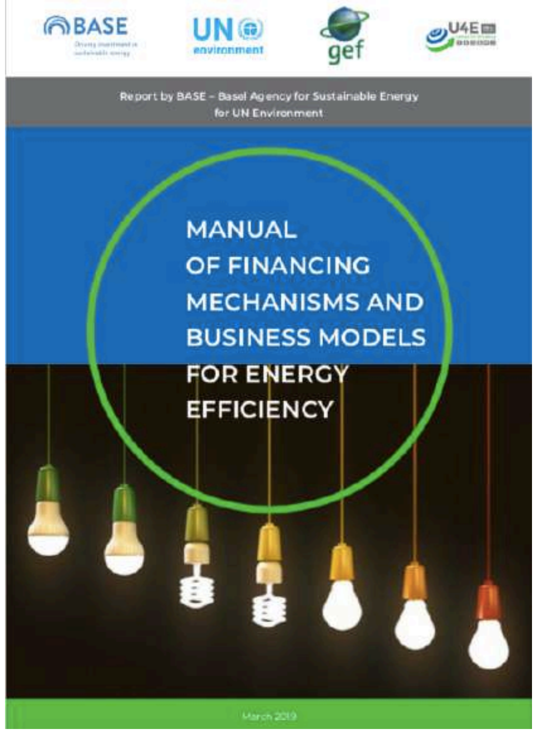
Product Registration System (PRS) specification document

Supporting the Introduction of Minimum Energy Performance Standards

UN Environment Programme's (UNEP) United for Efficiency (U4E)

19

Financial mechanisms



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March 2019

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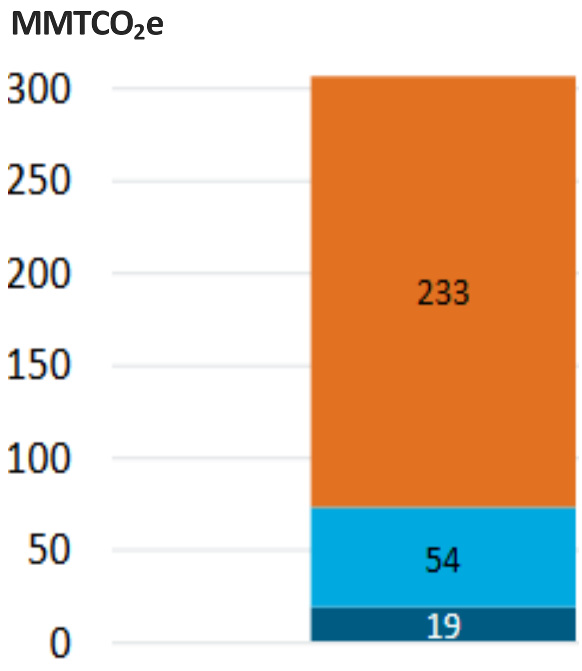
Resource: https://united4efficiency.org/resources/accelerating-global-adoption-energy-efficient-climate-friendly-refrigerators/
https://united4efficiency.org/resources/accelerating-global-adoption-energy-efficient-air-conditioners/

Address energy efficiency and refrigerants together

Indirect Emissions	From burning fossil fuels to generate electricity ✓ Reduce cooling load (shading, insulation) ✓ Select the right-size (capacity) ✓ **Improve energy efficiency** ✓ Improve operations (controls, set points) ✓ Conduct regular maintenance

+

Direct Emissions	From Gases inside ACs and refrigerators that transfer heat ✓ Use lower GWP and non ODS refrigerants ✓ Stop leaks, capture & process f-gasses



Global Residential AC emissions

Source: DOE, USA 2016

🟧 **Indirect**

🟦 **Direct from HCFCs**

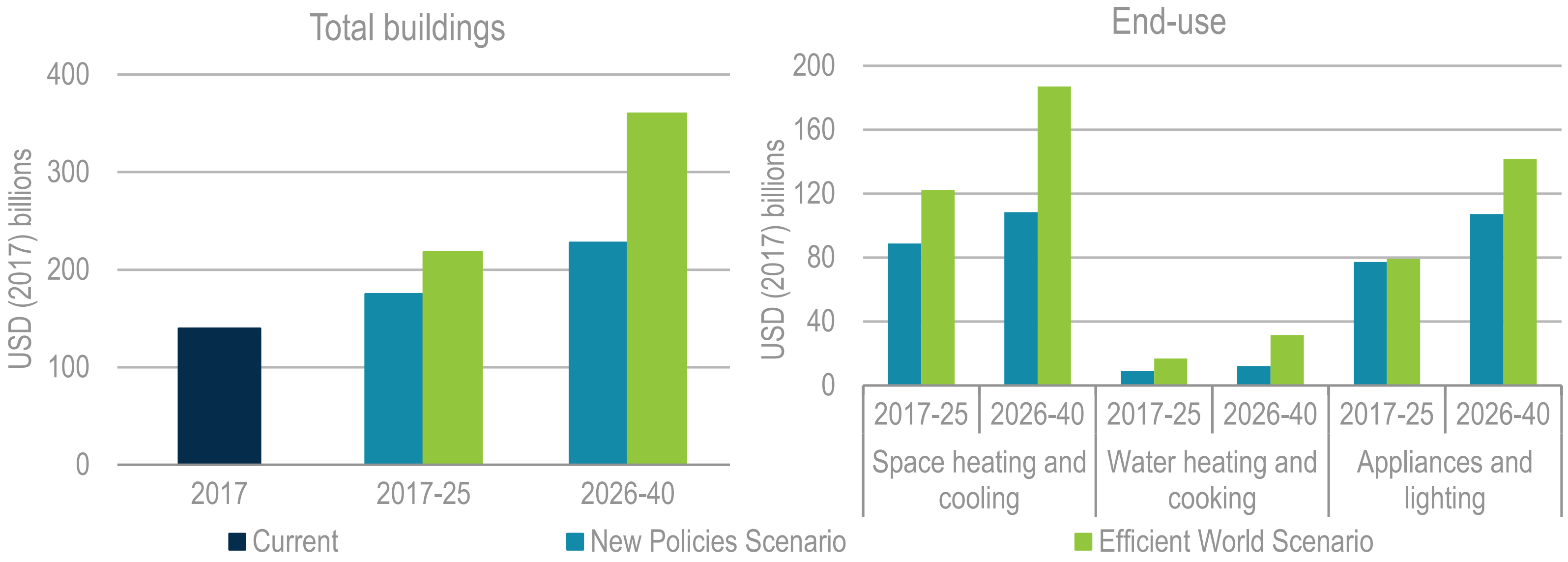
🟦 **Direct from HFCs**

Climate Perspective: CO_2 Equivalent of RT investment

- Calculate CO_2 equivalent of direct and indirect emissions from refrigerant change : R410A →R452B
- GWP: R410A (1924) → R452B (698) (IPCC AR5)
- Efficiency: R452B ~5% better than R410A (AHRI AREP)
- Use metric such as Total Equivalent Warming Impact(TEWI) or LifeCycle Climate Performance(LCCP)
- ~18.4% emissions reduction from total "baseline" emissions going from R410A to R452B for an AC used ~4.4 hrs/day.
- CO_2 Equivalent: ~23% improvement in "equipment efficiency" gives the same ~18.4% emissions reduction in total emissions as the switch from R410A to R452B.

Investment in EE for HVAC expected to grow

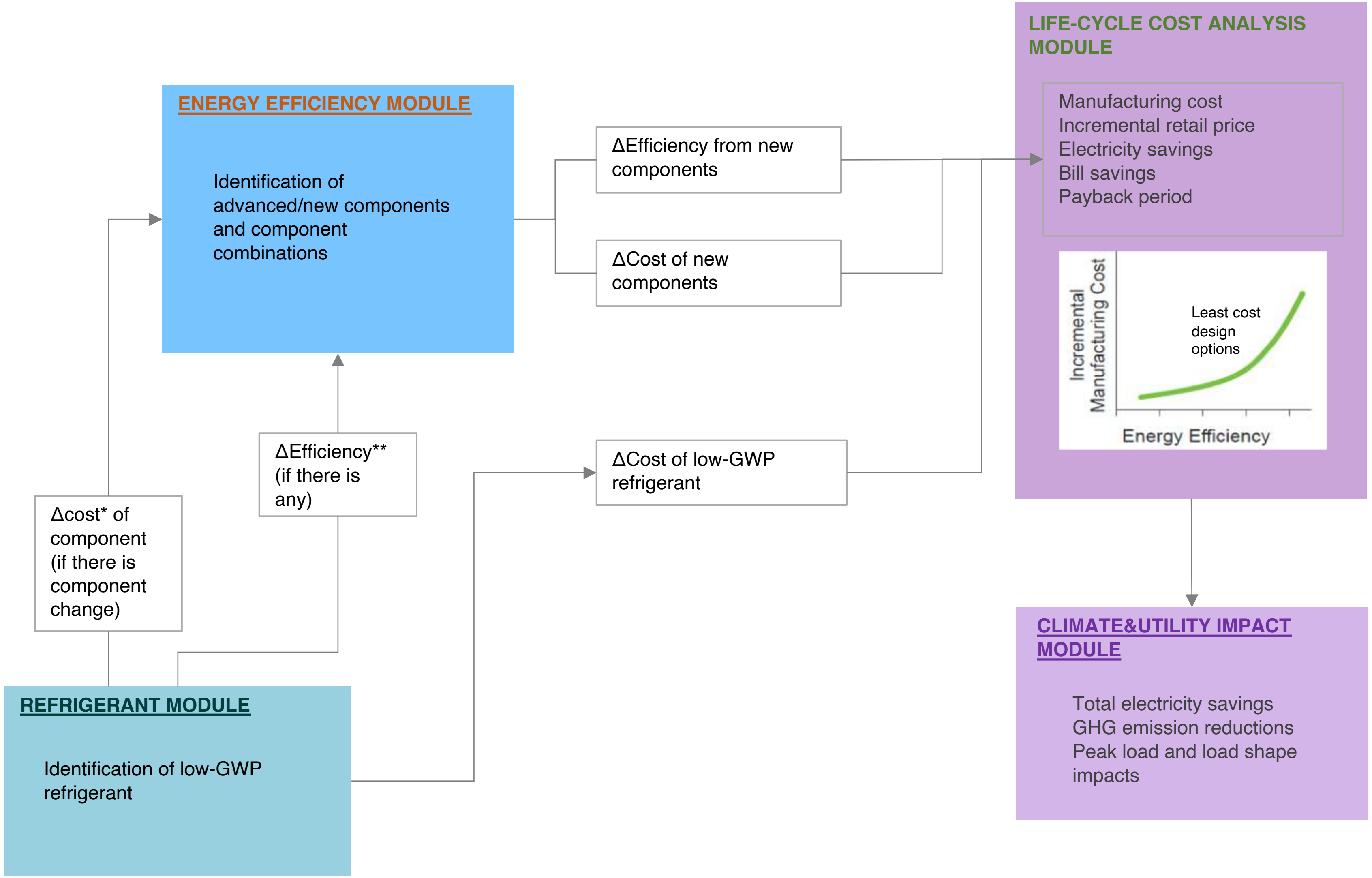
Figure 3.6 Average annual energy efficiency investment in buildings, in total (left) and by end-use (right), 2017-40



Source: EE Marketing Report IEA 2018

- Global government and utility energy efficiency spending is **expected to grow from $25.6 billion in 2017 to $56.1 billion in 2026**. (Source: Navigant, *Market Data: Global Energy Efficiency Spending*, 2017)
- Growth of energy efficiency investment is expected to be **highest in space heating and cooling**: $80-180 billion annually from 2017-2040.

Joint Investment Framework: *Details of the Methodology*



LIFE-CYCLE COST ANALYSIS MODULE

Manufacturing cost
Incremental retail price
Electricity savings
Bill savings
Payback period

ENERGY EFFICIENCY MODULE

Identification of advanced/new components and component combinations

ΔEfficiency from new components

ΔCost of new components

ΔEfficiency** (if there is any)

ΔCost of low-GWP refrigerant

Δcost* of component (if there is component change)

CLIMATE&UTILITY IMPACT MODULE

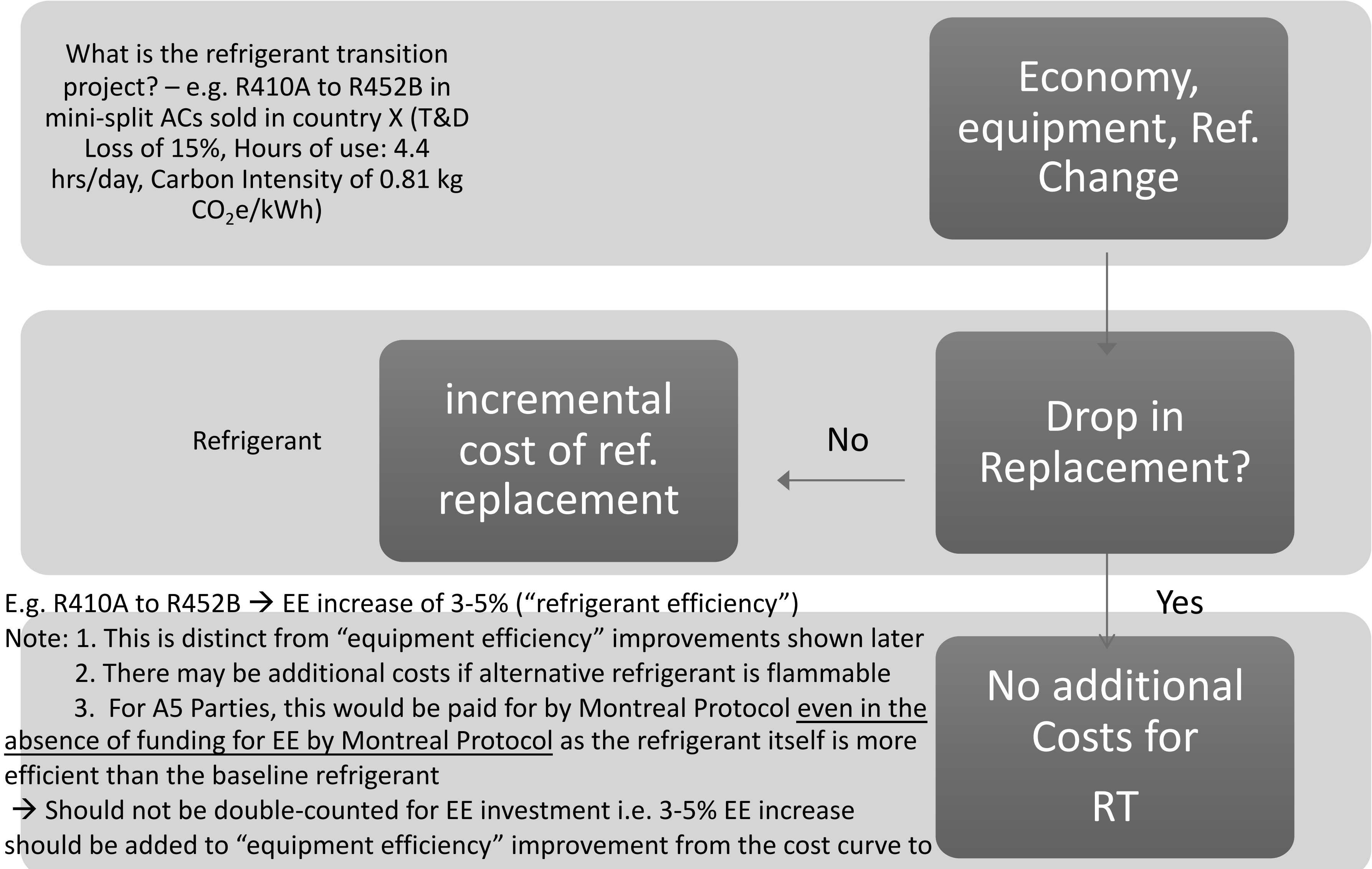
Total electricity savings
GHG emission reductions
Peak load and load shape impacts

REFRIGERANT MODULE

Identification of low-GWP refrigerant

* ΔCost: Incremental cost; ** ΔEfficiency: ± change in efficiency

Joint Investment Framework Decision Tree



What is the refrigerant transition project? – e.g. R410A to R452B in mini-split ACs sold in country X (T&D Loss of 15%, Hours of use: 4.4 hrs/day, Carbon Intensity of 0.81 kg CO_2e/kWh)

Economy, equipment, Ref. Change

Refrigerant

incremental cost of ref. replacement

No

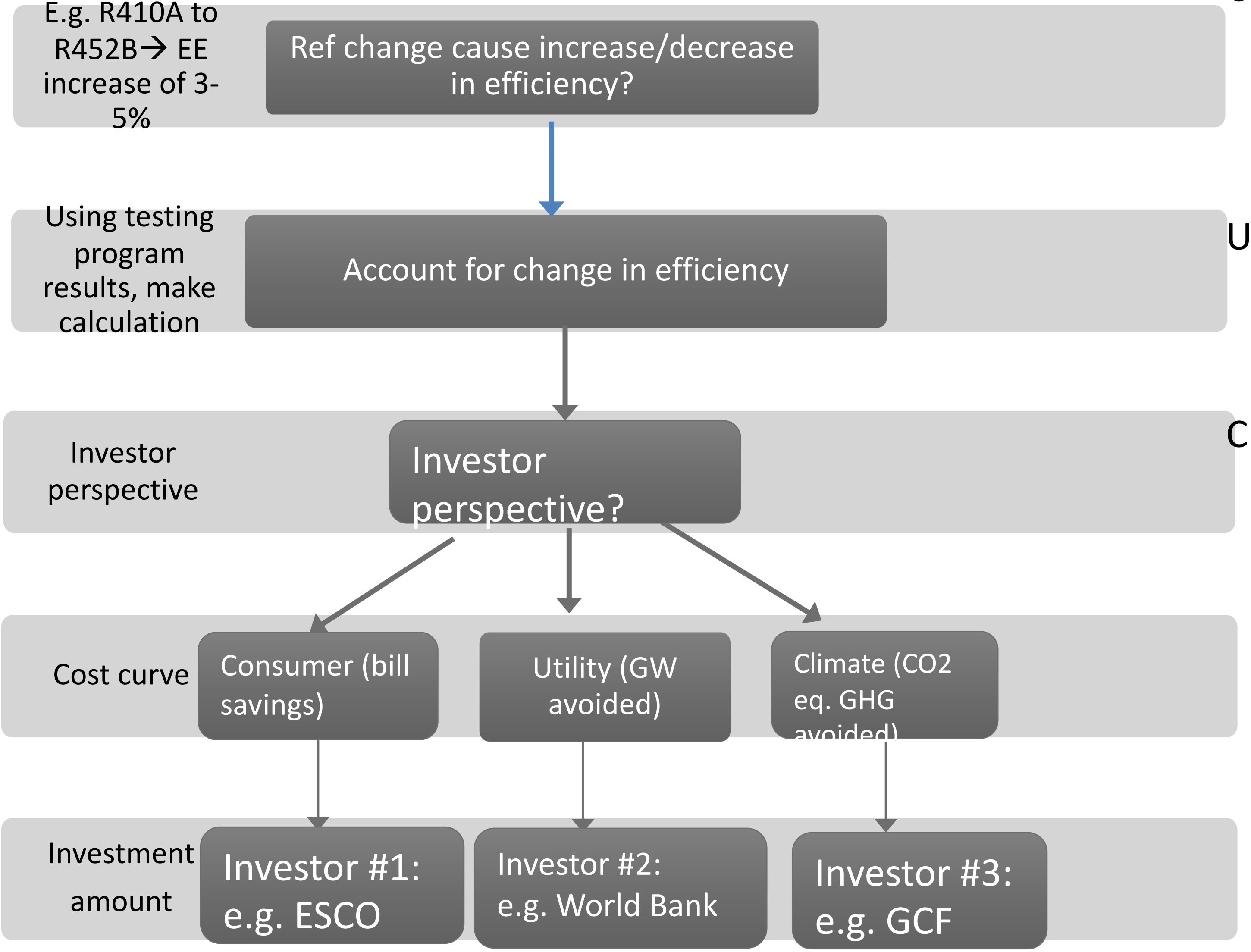
Drop in Replacement?

Yes

No additional Costs for RT

E.g. R410A to R452B → EE increase of 3-5% (“refrigerant efficiency”)
Note: 1. This is distinct from “equipment efficiency” improvements shown later
2. There may be additional costs if alternative refrigerant is flammable
3. For A5 Parties, this would be paid for by Montreal Protocol <u>even in the absence of funding for EE by Montreal Protocol</u> as the refrigerant itself is more efficient than the baseline refrigerant
→ Should not be double-counted for EE investment i.e. 3-5% EE increase should be added to “equipment efficiency” improvement from the cost curve to calculate total EE improvement.

Joint Investment Framework Decision Tree (cont)



E.g. R410A to R452B→ EE increase of 3-5%

Ref change cause increase/decrease in efficiency?

Using testing program results, make calculation

Account for change in efficiency

Investor perspective

Investor perspective?

Cost curve

Consumer (bill savings)

Utility (GW avoided)

Climate (CO2 eq. GHG avoided)

Investment amount

Investor #1: e.g. ESCO

Investor #2: e.g. World Bank

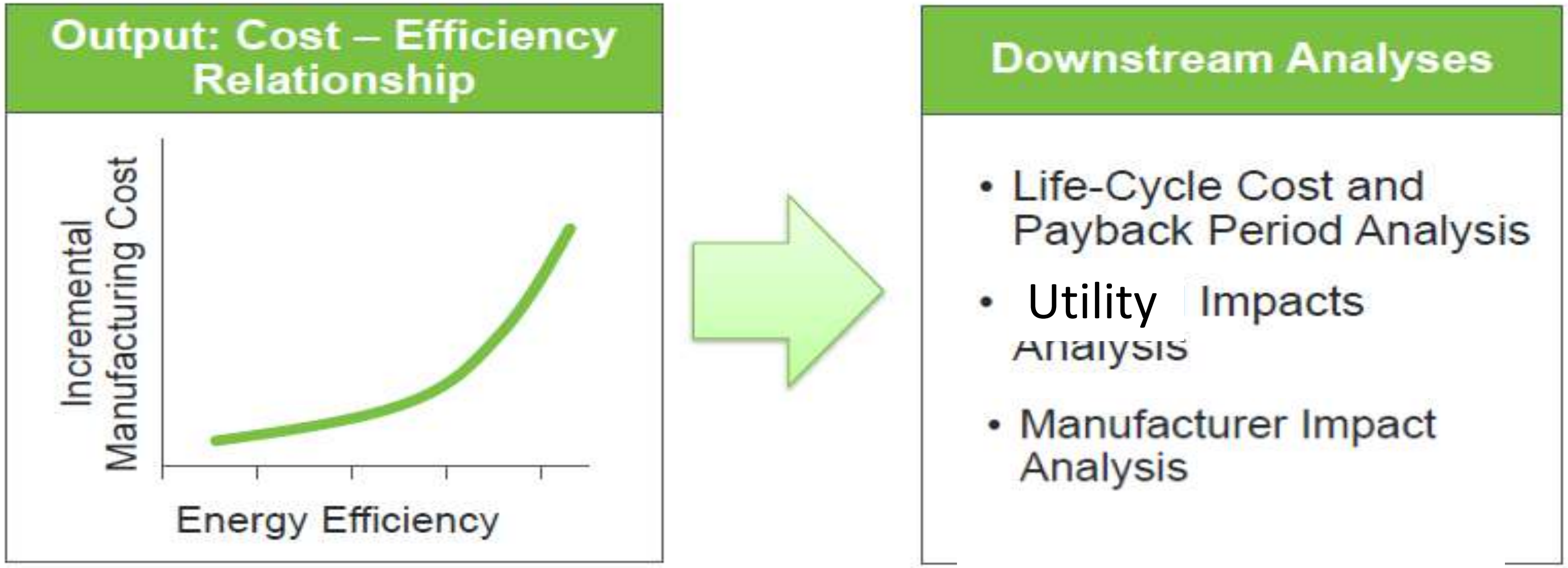
Investor #3: e.g. GCF

Consumer: ~44% efficiency improvement i.e. ~5.2 APF

Utility: ~52% efficiency improvement i.e. ~6.0 APF

Climate or CO2 equivalent: ~23% equipment efficiency improvement + ~5% improvement from refrigerant transition = ~28% efficiency improvement ~4.0 APF

Overview of DOE Rulemaking process (contd.)



Output: Cost – Efficiency Relationship

Downstream Analyses

- Life-Cycle Cost and Payback Period Analysis
- Utility Impacts Analysis
- Manufacturer Impact Analysis

- Similar publicly available cost-efficiency relationships can be useful for various market transformation programs including EE investment projects and EE S&L programs.
- Energy savings estimates are common across economies, but EE metrics and test procedures vary.
- Costs are also largely similar in the globalized market but could vary based on labor, shipping, tax and other conditions and can be customized for different markets.
- Similar curves generated by US DOE and EU Ecodesign for various equipment every 2-3 years

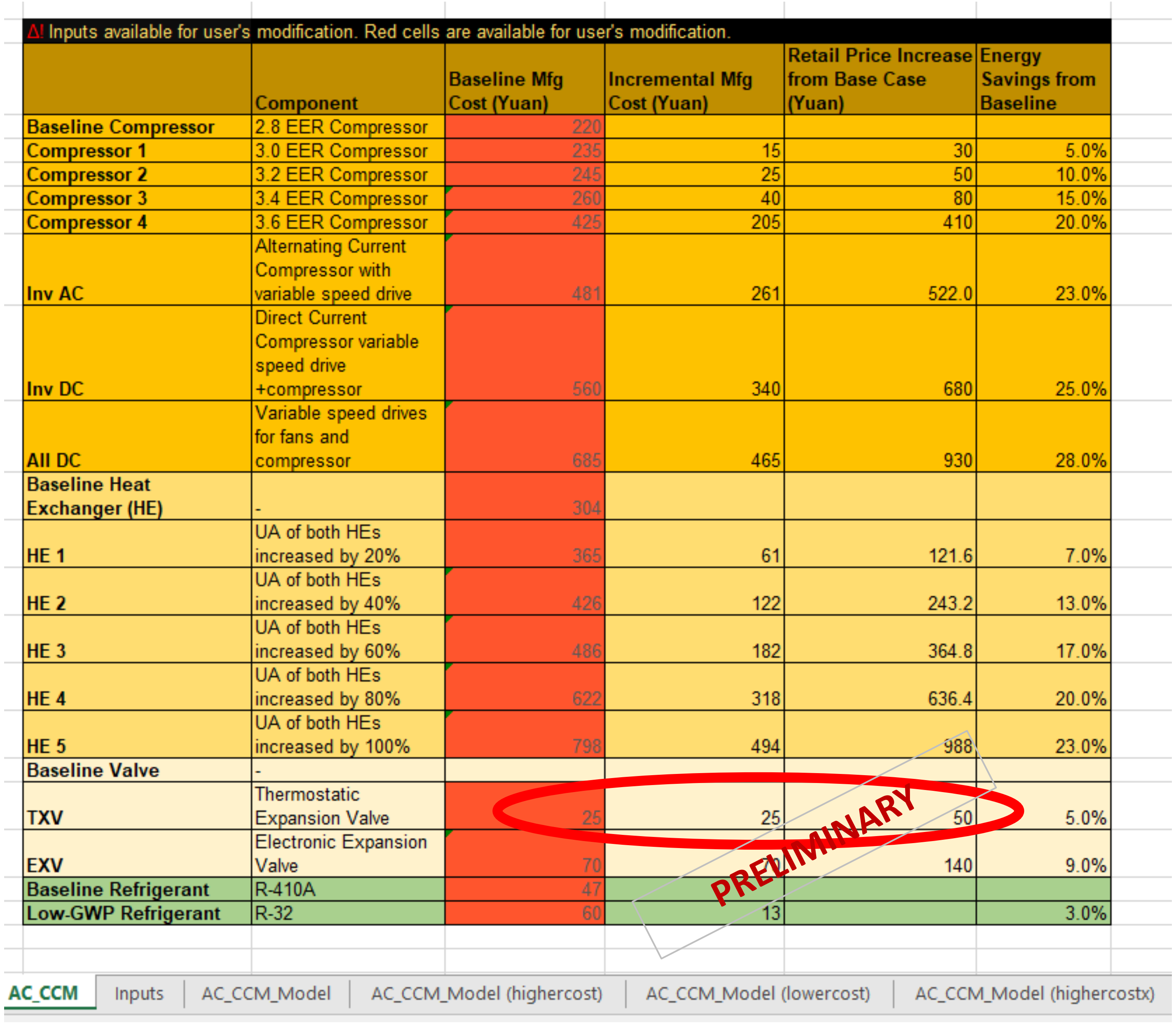
Source: http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0007-0035

"Types" of efficiency improvement

		Explanation	Factors	Magnitude
A	Refrigerant	Alternate Low-GWP refrigerants being considered are more efficient		~5%
B	Replacement	New equipment is more efficient than old equipment	• decline in performance over the life • Current standards are more stringent • Current technology is more efficient	~10-50%
C	Market Transformation (e.g. standards, labeling, incentives, awards etc.)	Best performing equipment on the market are 40-50% more efficient than average	• Best available technology is significantly more efficient • Variable speed drives	~20-40%
Total			1-(0.95x0.7x0.7)	>50%

Only A and C should be considered as B will continue to happen
A: "refrigerant efficiency" and C: "equipment efficiency"

Joint Investment Framework: Structure and data

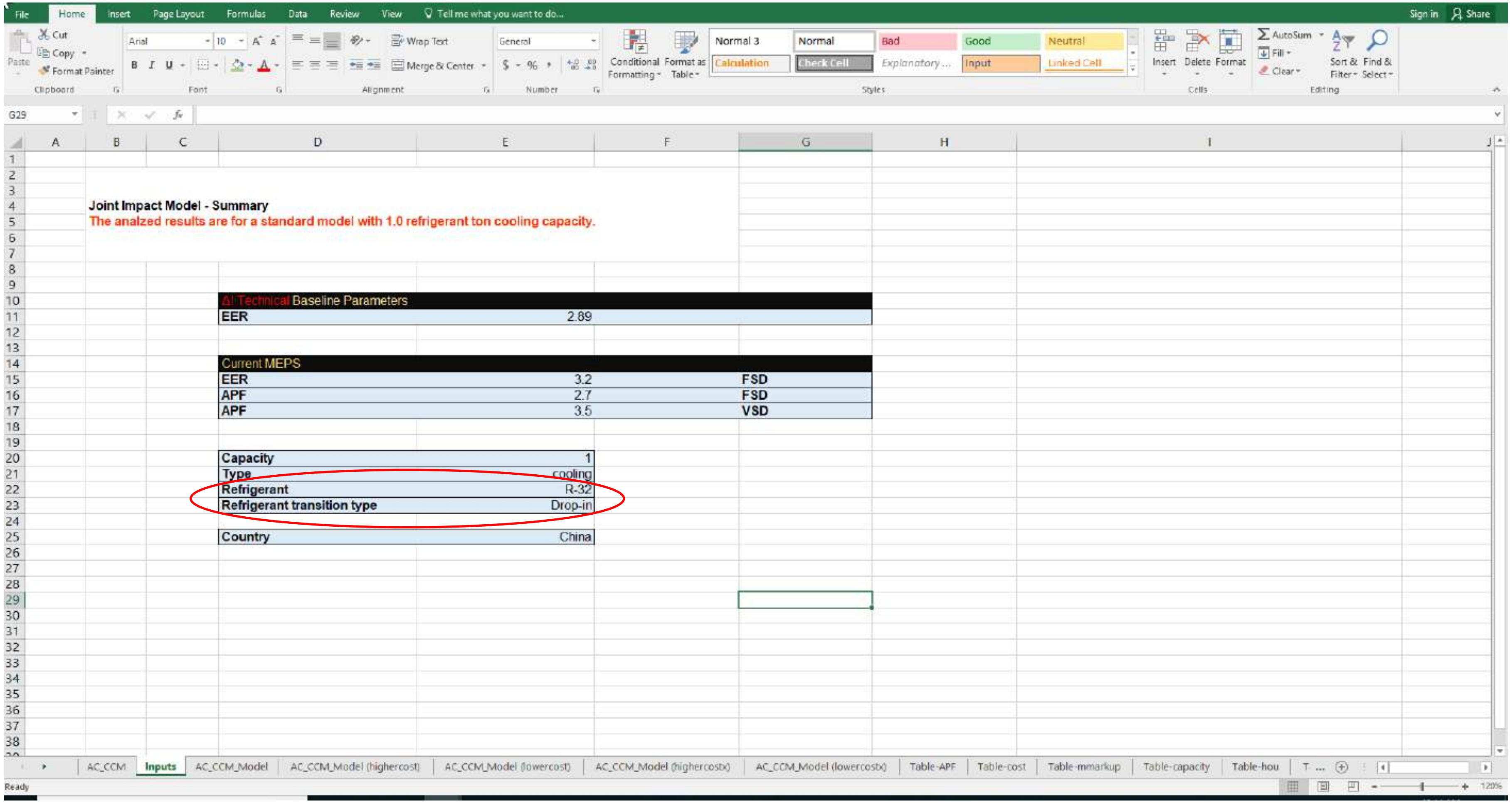


Δ! Inputs available for user's modification. Red cells are available for user's modification.

	Component	Baseline Mfg Cost (Yuan)	Incremental Mfg Cost (Yuan)	Retail Price Increase from Base Case (Yuan)	Energy Savings from Baseline
Baseline Compressor	2.8 EER Compressor	220			
Compressor 1	3.0 EER Compressor	235	15	30	5.0%
Compressor 2	3.2 EER Compressor	245	25	50	10.0%
Compressor 3	3.4 EER Compressor	260	40	80	15.0%
Compressor 4	3.6 EER Compressor	425	205	410	20.0%
Inv AC	Alternating Current Compressor with variable speed drive	481	261	522.0	23.0%
Inv DC	Direct Current Compressor variable speed drive +compressor	560	340	680	25.0%
All DC	Variable speed drives for fans and compressor	685	465	930	28.0%
Baseline Heat Exchanger (HE)	-	304			
HE 1	UA of both HEs increased by 20%	365	61	121.6	7.0%
HE 2	UA of both HEs increased by 40%	426	122	243.2	13.0%
HE 3	UA of both HEs increased by 60%	486	182	364.8	17.0%
HE 4	UA of both HEs increased by 80%	622	318	636.4	20.0%
HE 5	UA of both HEs increased by 100%	798	494	988	23.0%
Baseline Valve	-				
TXV	Thermostatic Expansion Valve	25	25	50	5.0%
EXV	Electronic Expansion Valve	70	70	140	9.0%
Baseline Refrigerant	R-410A	47			
Low-GWP Refrigerant	R-32	60	13		3.0%

PRELIMINARY

Joint Investment Framework: Structure and Data



Joint Impact Model - Summary

The analzed results are for a standard model with 1.0 refrigerant ton cooling capacity.

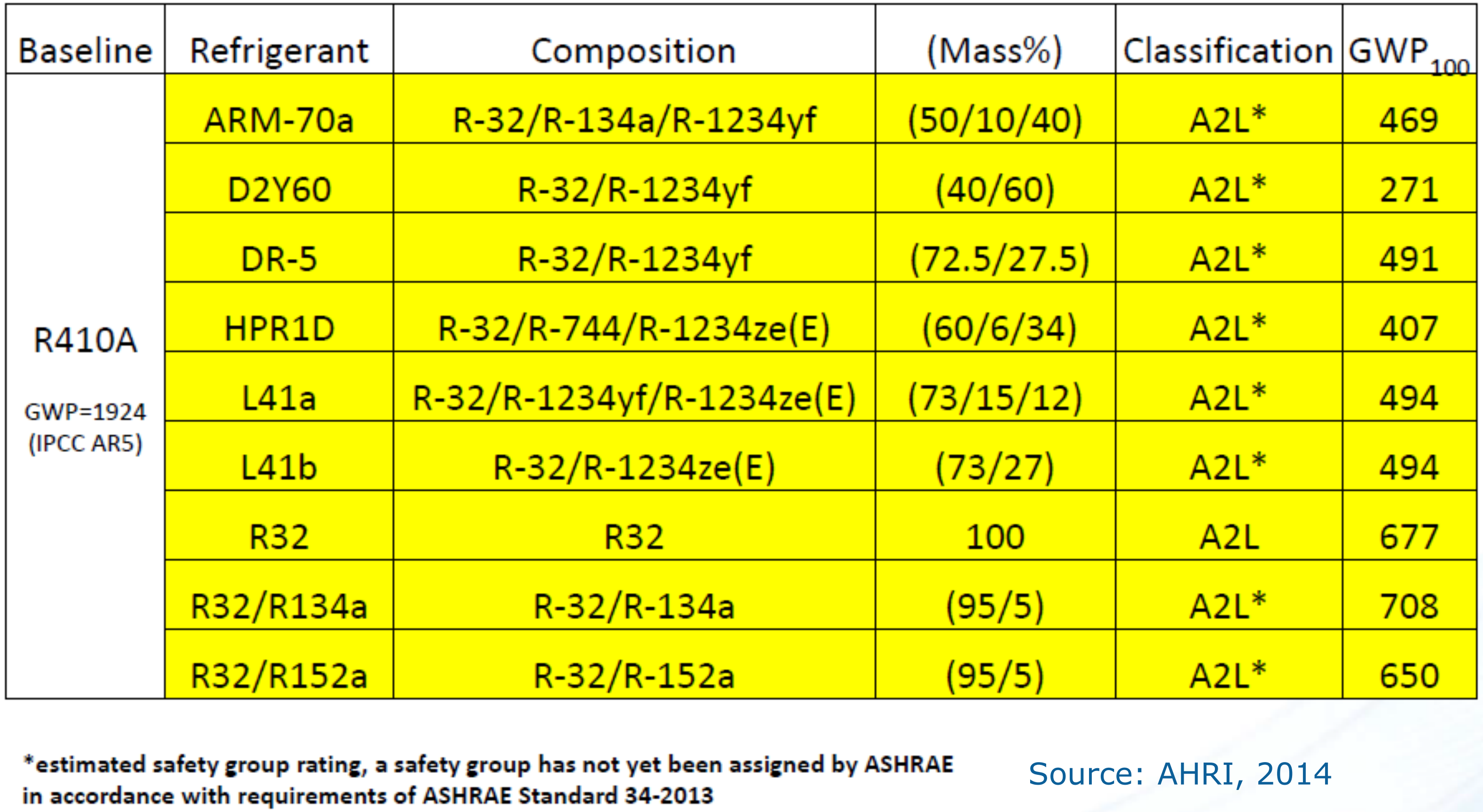
∆! Technical Baseline Parameters	
EER	2.89

Current MEPS		
EER	3.2	**FSD**
APF	2.7	**FSD**
APF	3.5	**VSD**

Capacity	1
Type	cooling
Refrigerant	R-32
Refrigerant transition type	Drop-in

Country	China

AHRI Low-GWP Alternate Refrigerant Evaluation Program (AREP) Phase 1(2012-2014) R410A alternatives



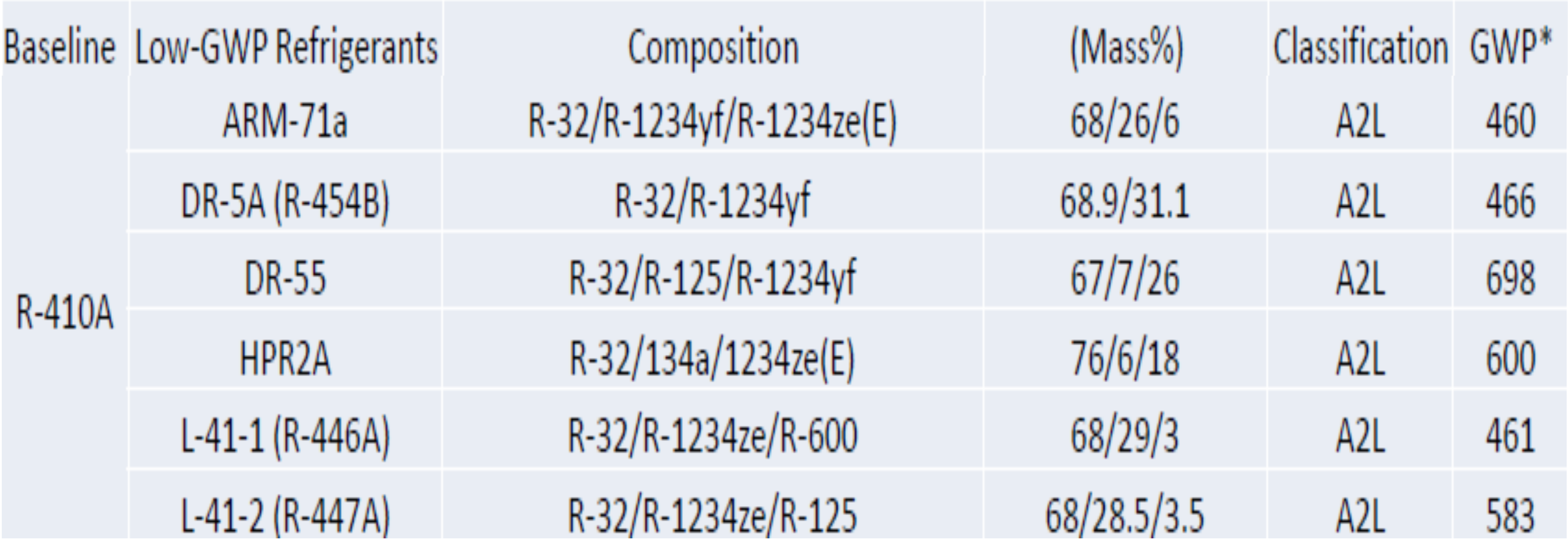
Baseline	Refrigerant	Composition	(Mass%)	Classification	GWP_{100}
R410A GWP=1924 (IPCC AR5)	ARM-70a	R-32/R-134a/R-1234yf	(50/10/40)	A2L*	469
	D2Y60	R-32/R-1234yf	(40/60)	A2L*	271
	DR-5	R-32/R-1234yf	(72.5/27.5)	A2L*	491
	HPR1D	R-32/R-744/R-1234ze(E)	(60/6/34)	A2L*	407
	L41a	R-32/R-1234yf/R-1234ze(E)	(73/15/12)	A2L*	494
	L41b	R-32/R-1234ze(E)	(73/27)	A2L*	494
	R32	R32	100	A2L	677
	R32/R134a	R-32/R-134a	(95/5)	A2L*	708
	R32/R152a	R-32/R-152a	(95/5)	A2L*	650

*estimated safety group rating, a safety group has not yet been assigned by ASHRAE in accordance with requirements of ASHRAE Standard 34-2013

Source: AHRI, 2014

- **Voluntary co-operative research and testing program to identify suitable alternatives to high-GWP refrigerants.**
- **Standard reporting format for candidate refrigerants strongly desired by industry.**

AHRI Low-GWP Alternate Refrigerant Evaluation Program (AREP) Phase 2 (2015-2016) R410A alternatives

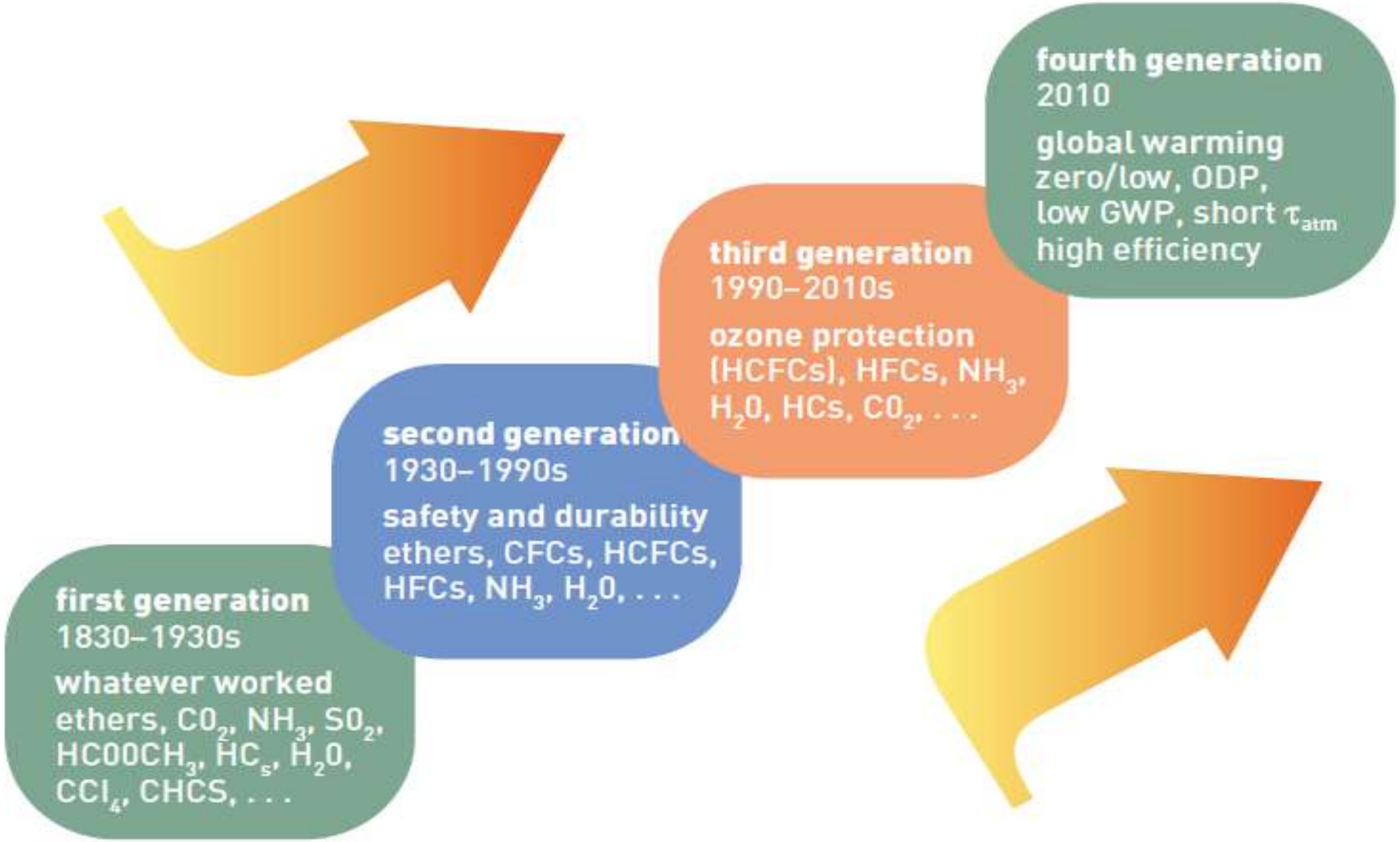


Baseline	Low-GWP Refrigerants	Composition	(Mass%)	Classification	GWP*
R-410A	ARM-71a	R-32/R-1234yf/R-1234ze(E)	68/26/6	A2L	460
	DR-5A (R-454B)	R-32/R-1234yf	68.9/31.1	A2L	466
	DR-55	R-32/R-125/R-1234yf	67/7/26	A2L	698
	HPR2A	R-32/134a/1234ze(E)	76/6/18	A2L	600
	L-41-1 (R-446A)	R-32/R-1234ze/R-600	68/29/3	A2L	461
	L-41-2 (R-447A)	R-32/R-1234ze/R-125	68/28.5/3.5	A2L	583

Source: AHRI, 2016

- Voluntary co-operative research and testing program to identify suitable alternatives to high-GWP refrigerants.
- Lowest GWP >450.
- Note: all refrigerant blends use R32.
- Overall *performance of refrigerant* should be judged not just on GWP but also on overall efficiency using a metric such as Total Equivalent Warming Impact(TEWI) that can account for both direct and indirect climate benefits.

Evolution of Refrigerant Use



fourth generation
2010
global warming
zero/low, ODP,
low GWP, short τ_{atm}
high efficiency

third generation
1990–2010s
ozone protection
(HCFCs), HFCs, NH_3,
H_2O, HCs, CO_2, . . .

second generation
1930–1990s
safety and durability
ethers, CFCs, HCFCs,
HFCs, NH_3, H_2O, . . .

first generation
1830–1930s
whatever worked
ethers, CO_2, NH_3, SO_2,
$HCOOCH_3$, HC_s, H_2O,
CCl_4, CHCS, . . .

Source: Adapted from Calm, *International Journal of Refrigeration*, 2008,
http://www.sciencedirect.com/science/article/pii/S0140700708000261

Global AC Market and refrigerant alternatives

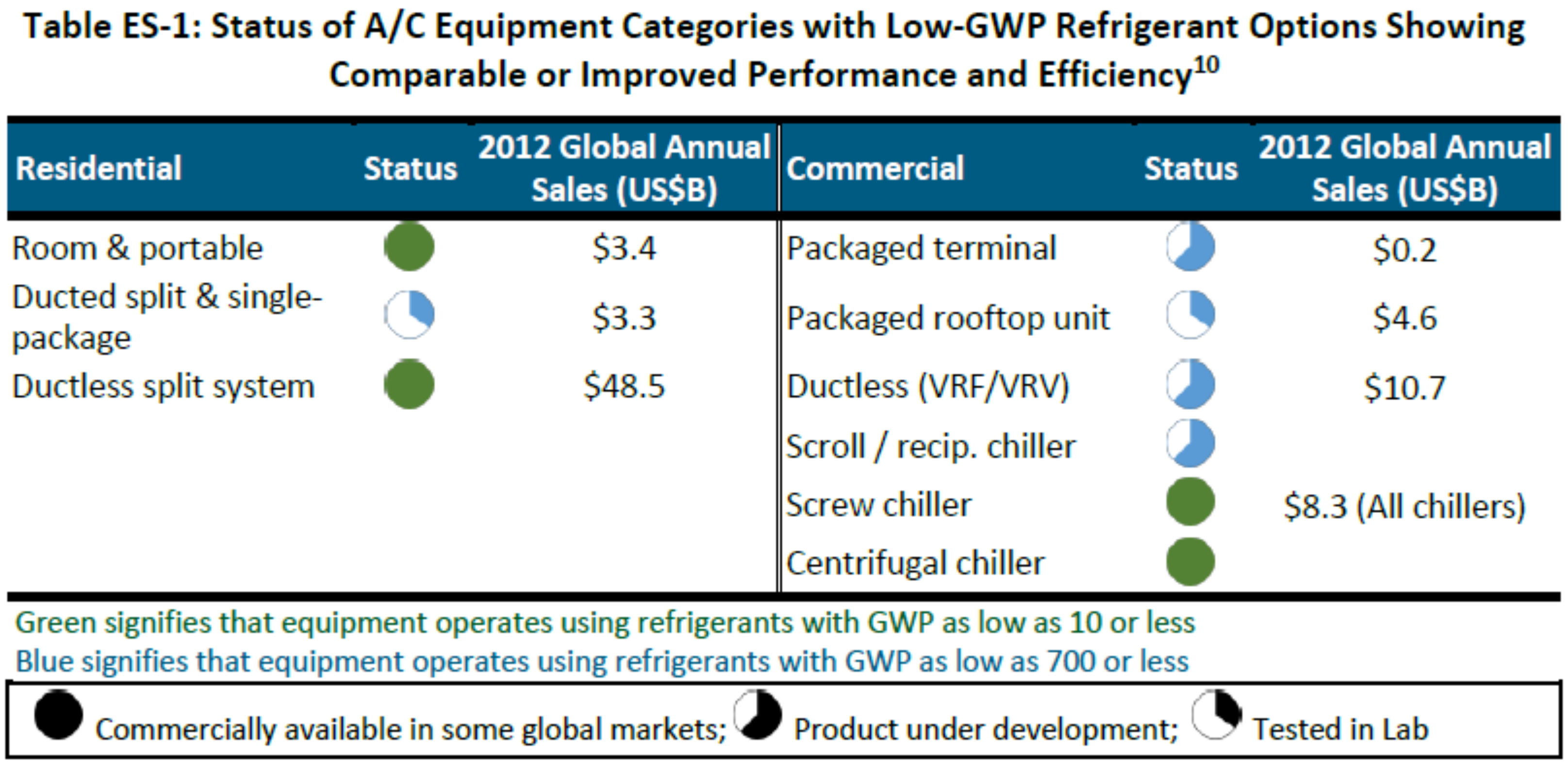


Table ES-1: Status of A/C Equipment Categories with Low-GWP Refrigerant Options Showing Comparable or Improved Performance and Efficiency[10]

Residential	Status	2012 Global Annual Sales (US$B)	Commercial	Status	2012 Global Annual Sales (US$B)
Room & portable	●	$3.4	Packaged terminal	◕	$0.2
Ducted split & single-package	◔	$3.3	Packaged rooftop unit	◔	$4.6
Ductless split system	●	$48.5	Ductless (VRF/VRV)	◕	$10.7
			Scroll / recip. chiller	◕	$8.3 (All chillers)
			Screw chiller	●	
			Centrifugal chiller	●	

Green signifies that equipment operates using refrigerants with GWP as low as 10 or less
Blue signifies that equipment operates using refrigerants with GWP as low as 700 or less

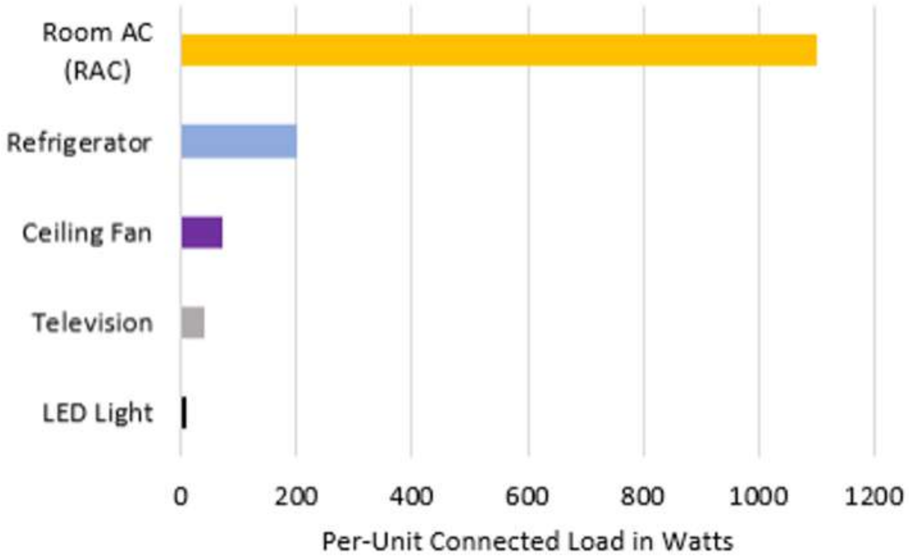
● Commercially available in some global markets; ◕ Product under development; ◔ Tested in Lab

Source: DOE,"Future of Airconditioning for Buildings" , 2016

- The industry has developed alternative technologies for many categories and is in the process of developing further alternatives.

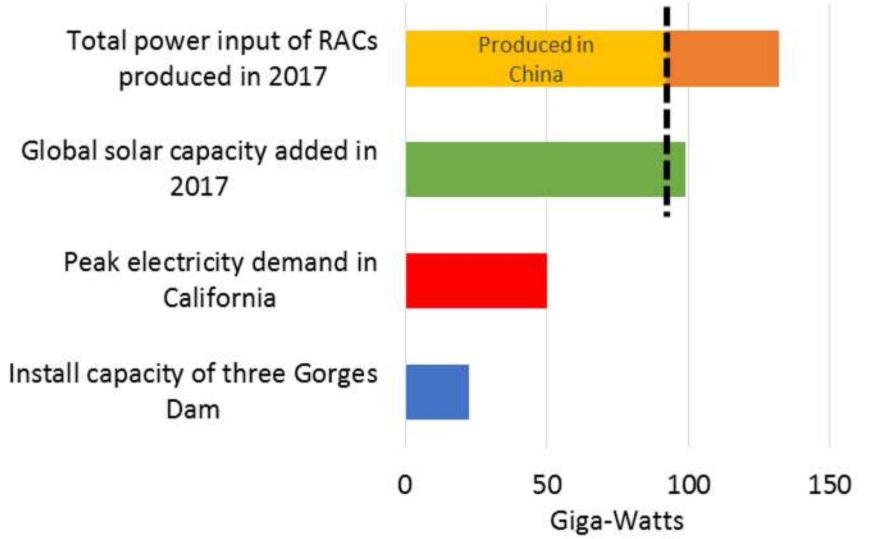
Size of Cooling Opportunity: Room ACs

- China is estimated to produce about 84 million room air-conditioners (RACs) in 2017, accounting for about 70% of the total RAC production worldwide (120 million units).
- Total load added by ACs in China is comparable to total solar capacity added in 2017 (100GW).



Source: Shah et al 2019 (forthcoming)

Per-unit connected load of an RAC and other end-uses



Source: Shah et al 2019 (forthcoming)

Total power input from RACs produced in 2017 and selected comparable electricity demand and generation capacity 2017

Nihar Shah, PhD, PE

- Presidential Director, Cooling Efficiency Research Program
- Co-Leader, Emerging Economies Research Program, Lawrence Berkeley National Laboratory
- Chair of UN Environment, United for Efficiency (U4E) Air Conditioner Task Force
- Member of the Energy Efficiency Task Force for the Technical and Economic Assessment Panel (TEAP) of the Montreal Protocol
- Member of Technical Advisory Committee to Kigali Cooling Efficiency Program (K-CEP)
- Member of Technical Review Committee of the Global Cooling Prize

Principal Investigator for:

- “Benefits of Leapfrogging” study that first quantified the benefits of energy efficiency of room ACs in tandem with the HFC Phasedown under the Kigali Amendment
- Kigali Cooling Efficiency Program: AC standards and complementary policies in Brazil, China, Egypt, Mexico and collaboration with UN Environment on Rwanda and the Caribbean on room ACs and refrigerators
- Kigali Cooling Efficiency Program: UN Environment United for Efficiency (U4E) Air Conditioner “model regulations” presented to 147 countries in 2019 and 2020.
- Revision of China’s energy efficiency standards for mini-split ACs and VRF ACs in 2020 and 2021.
- Revision of India’s mini-split AC standard with India’s Bureau of Energy Efficiency: 2015-2016
- Co-authored LBNL memo to EESL on bulk procurement program for ACs in India in 2016

Research featured in: New York Times, Washington Post, Economist, Forbes Magazine, NPR

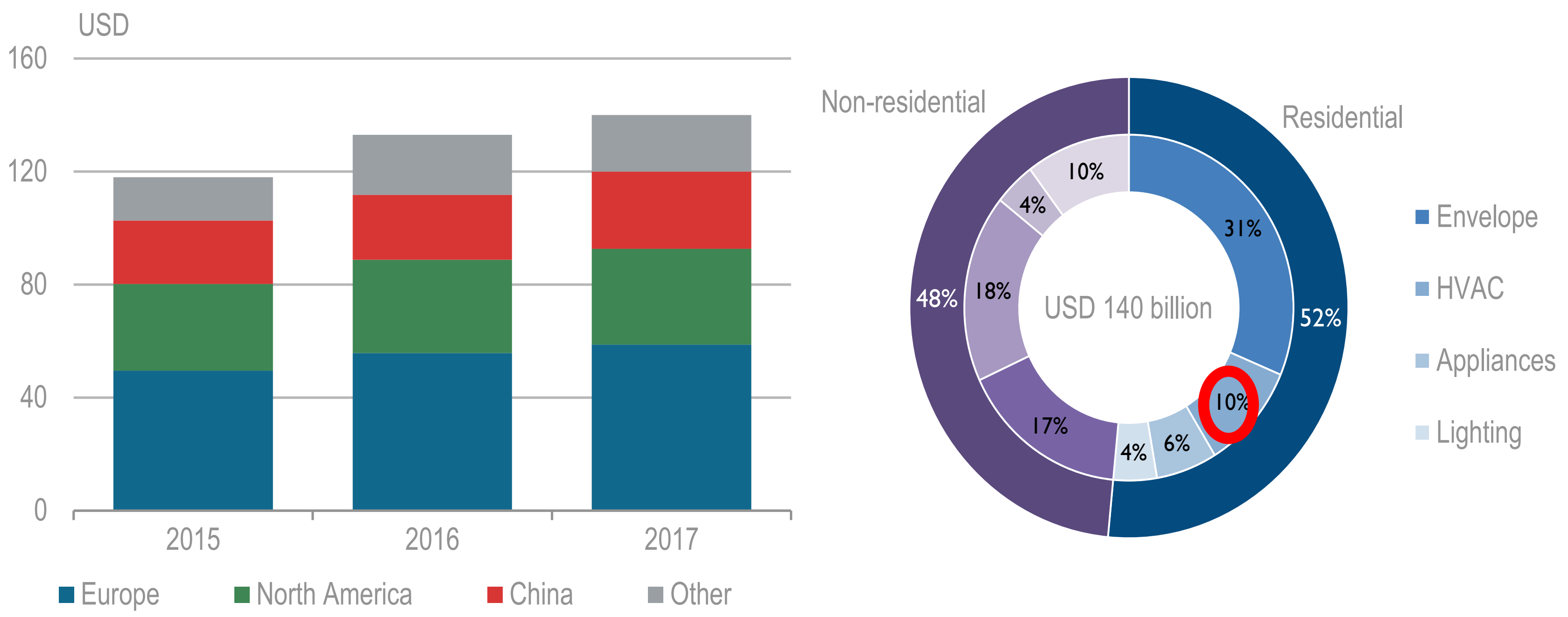
Ambereen Shaffie, J.D., LLM

- Climate, energy and environment lawyer with expertise in cooling efficiency programs and policies; multilateral negotiations, energy efficiency, energy policy, short-lived climate pollutants, environmental policy and project management in developing countries, litigation
- Juris Doctorate
- LL.M. in International and Comparative Law
- Montreal Protocol expert; Played key role in the multilateral negotiations leading to global adoption of the Kigali Amendment and Paris Agreement
- Co-managing projects focused on fast-start implementation of the Kigali Amendment and Paris Agreement in multiple countries: *e.g.* Egypt; Indonesia
- Advising public and private stakeholders to achieve national commitments, including governments, technical experts, private sector leaders, policymakers, NGO’s and industry leaders to form partnerships

Ms. Shaffie is the President and Managing Partner of Shaffie Law and Policy (link is external), based in the Washington, DC Metropolitan area. She practices environmental law and policy, most recently focused on enabling the implementation of environmental policies, including the Kigali Amendment to the Montreal Protocol.

II. Key Observations: Global Energy Efficiency Investment by region and sector

Figure 3.5 Buildings incremental investment by region, 2015-17 (left) and by sector and end-use (right)



Note: Total energy efficiency spending is the expenditure on products and services that deliver energy efficiency in a building. Incremental energy efficiency investment is additional cost compared with a baseline or business-as-usual expenditure.

Source: EE Marketing Report IEA 2018

~$14 Billion annually of energy efficiency investment from 2015-2017 was spent on HVAC

While a majority was spent in the EU and North America, ~$40-60 billion was spent in the rest of the world with ~10% spent on HVAC.