TEAP EETF REPORT 2022

Decision XXXIII/5: Continued provision of information on energy efficient and low-global-warming-potential technologies

TEAP

United Nations Environment Programme

44th OEWG
Bangkok, 11-16 July 2022

TEAP Energy Efficiency Task Force 2022

Omar Abdelaziz, co-chair	EGY	Herlin Herlianika	ID
Suely Carvalho, co-chair	BRA	Steven Kujak	USA
Ashley Woodcock, co-chair	UK	Saurabh Kumar	IN
Kofi Agyarko	GH	Tingxun Li	CN
Paulo Altoé	BRA	Richard Lord	USA
Jitendra Bhambure	IN	Petter Neksa	NO
Daniel Colbourne	UK	Tetsuji Okada	JP
Hilde Dhont, Ch 3 lead author	BE	Mohamed Alaa Olama	EGY
Gabrielle Dreyfus, Ch 5 lead author	USA	Roberto Peixoto	BRA
Bassam Elassaad, Ch 2 & 6 lead author	LB	Nihar Shah, Ch 4 lead author	IN
Ray Gluckman, Ch 7 lead author	UK	Rajan Rajendran	USA
Samir Hamed	JOR	Helene Rochat	CH

24 Members; 13 A5, 11 non-A5

Decision XXXIII/5: Continued provision of information on energy efficient and low-global-warming-potential technologies

Requested the Technology and Economic Assessment Panel to prepare a report on energy efficient and lower- global- warming- potential technologies and on measures to enhance and maintain energy efficiency during hydrofluorocarbon transition in equipment for consideration by the Open-ended- Working Group at its forty-fourth meeting, and in the report to:

Overall key messages by Decision sub-paragraphs (1)

a) Update information in the decision XXXI/7 report where relevant, and address additional subsectors not previously covered such as the heat-pump, large commercial refrigeration and larger air-conditioning system sub-sectors

- In all sectors, including the additional sectors specified by this decision, RACHP equipment using low and medium GWP refrigerants with enhanced energy efficiency is ***available*** but not necessarily ***accessible*** in all countries (Chapter 2)

*"**Availability**" is the ability of industry to manufacture products with new technologies with lower-GWP refrigerants and higher efficiency.(impacted by local manufacturing capacity, technological ability, scalability, barriers e.g. IPR etc)*

"Accessibility" *is focussed on the consumer and varies with location within a region, country, or even district within a country (impacted by affordability, supply chain, regulations, servicing capacity etc)* ***EETF 2021***

Overall key messages by Decision sub-paragraphs (2)

b) Assess potential cost savings associated with adoption of lower global warming potential energy efficient technologies in each sector, including for manufacturers and consumers

- The wide range of RACHP equipment and refrigerant options makes it necessary to evaluate material cost impact on a case-by-case basis due to refrigerant characteristics impact on energy efficiency and safety (Chapter 3)

- Cost-benefit analyses can help to maximize benefits to consumers and society from energy efficiency improvement (Chapter 4)

Overall key messages by Decision sub-paragraphs (3)

c) Identify sectors where actions could be taken in the short term to adopt energy efficient technologies while phasing down hydrofluorocarbons; (Chapters 2 and 7)

- Technology developments to improve energy efficiency are proceeding rapidly in all RACHP sectors
- Prioritizing sectors for action is context dependent and will benefit from KIPs data
- Low efficiency high GWP HFC equipment continue to be widely accessible and may delay climate benefits due to the long equipment lifetime

d) Identify options to enhance and maintain energy efficiency in equipment through deploying best practices during installation, servicing, maintenance, refurbishment or repair; (Chapter 6)

- Energy efficient equipment require a higher level of knowledge and training for safe and effective installation and servicing
- Reducing leakage continues to be a service priority even for optimised systems using low-GWP refrigerants with reduced refrigerant charge

Overall key messages by Decision sub paragraphs(3)

e) Provide detailed information on how the benefits of integrating energy efficiency enhancements with the hydrofluorocarbon phase-down measures can be assessed. (Chapters 4, 5, and 7)

- The task force considered measures for integrating energy efficiency enhancements with the HFC phase-down such as:
  - Coordination between National Ozone Units and energy and climate authorities
  - Integration of refrigerant GWP into energy efficiency standards and labelling policies
  - Roadmaps for adopting energy-efficient technologies while phasing down HFCs; these would vary based on national circumstances
  - An illustrative list of enabling standards and policies
  - Measures to avoid dumping of high-GWP/low-EE equipment into A5 parties

Overall key messages by Decision sub paragraphs(4)

e) Provide detailed information on how the benefits of integrating energy efficiency enhancements with the hydrofluorocarbon phase-down measures can be assessed. (Chapters 4, 5, and 7)

- Assessing the benefits may be done through
  - Detailed equipment level modelling for the development of MEPS/investment decisions
  - National and Regional forecasting models evaluating pathways to reduce direct HFC emissions and indirect emissions related to RACHP energy use
- Modelling can be refined through additional data
- Coordinated investment in energy efficiency and refrigerant transition will cost manufacturers and consumers less than if they are made separately

Chapter 1: Introduction

- Urgent need to mitigate climate change (COP-26; IPCC)
- Montreal Protocol
  - already responsible for 25% of climate mitigation through ODS phaseout
  - Potential for 0.3-0.5 °C with HFC phasedown; with potential for more through Energy Efficiency
- The major HFC use worldwide is in the RACHP sector, mostly in comfort cooling and heating
- The ratio of "indirect" energy-related emissions to "direct" refrigerant emissions varies between countries depending on the carbon intensity of power generation, the leakage rate from different applications, and the GWP of the refrigerants
- 2021 EETF Focus: Room AC, Self-Contained Commercial Refrigeration
- 2022 EETF Focus: Update from 2021; and expanded scope to include Heat Pumps, Large Commercial Refrigeration, and Larger Air Conditioning Systems

Chapter 2: Availability of Low and Medium GWP Technologies and Equipment that Maintain or Enhance Energy Efficiency

- RACHP equipment using low and medium GWP refrigerants with enhanced energy efficiency is now available but not necessarily accessible in all countries
- Technology developments are proceeding rapidly
- Early adoption of Kigali Implementation Plans could encourage faster transition to this new generation of RACHP equipment in A5 parties
- Not-In-Kind (NIK) technologies are available (e.g., solar energy driven absorption systems, hybrid evaporative cooling and deep-sea cooling) can offer lower operational lifetime costs (OLC) compared to in-kind systems; currently considered for niche applications but expanding

Heat Pumps with high energy efficiency are available with low/medium GWP refrigerant and can be integrated into building controls

Category	**Heat sink**	**Heating capacity**	**High GWP**	**Medium GWP**		**Low GWP**	
			Options	**Options**	**Regions**	**Options**	**Regions**
Exhaust air	Space heating	< 8 kW	R-410A	HFC-32 R-452B R-454B R-454C	E, EA, A	HC-290	E
Air-to-water	Hot water	< 3 kW				HC-290 R-744	E, EA
	Space heating	3 – 80 kW				HC-290, (HC-1270, HC-600) R-717†	E
Water-to-water	Hot water	< 3 kW				HC-290 R-744 HC-600	E, EA
	Space heating	3 - >100 kW				HC-290, (HC-1270, HC-600) R-717†	E

Definition of High, medium, and low GWP is based on RTOC

A = Australia, E = Europe, EA = East Asia

† *Used with sorption systems*

Heat Pumps with high energy efficiency are available with low/medium GWP refrigerant and can be integrated into building controls

Category	Heat sink	Heating capacity	High GWP	Medium GWP		Low GWP	
			Options	Options	Regions	Options	Regions
Exhaust air	Space heating	< 8 kW	R-410A	HFC-32 R-452B R-454B R-454C	E, EA, A	HC-290	E
Air-to-water	Hot water	< 3 kW				HC-290 R-744	E, EA
	Space heating	3 – 80 kW				HC-290, (HC-1270, HC-600) R-717†	E
Water-to-water	Hot water	< 3 kW				HC-290 R-744 HC-600	E, EA
	Space heating	3 - >100 kW				HC-290, (HC-1270, HC-600) R-717†	E

Several medium/low GWP Options

Definition of High, medium, and low GWP is based on RTOC

A = Australia, E = Europe, EA = East Asia

† *Used with sorption systems*

Large and Medium AC systems

- Are available with comparable energy efficiency for low/medium GWP refrigerants compared to baseline equipment with high GWP
- Are being further optimised for higher efficiency

Split Units 10 kW to 17 kW HC-290 (within charge limits), HFC-32, R-452B, R-454B
Unitary Equipment Packaged & Split 10 - 85 kW HFC-32, R-452B, R-454B (multi-refrigerant circuit)
Unitary Equipment Packaged & Split > 85 to 340 kW HFC-32, R-452B, R-454B (multi-refrigerant circuit)
Unitary Equipment Packaged & Split> 340 kW Exceeding charge limit
Multi Split less than 20 kW and VRF > 20 kW HFC-32 for capacity < 10 kW
Chilled water systems 10 kW to 85 kW HC-290, HFC-32, R-452B , R-454B , HFO-1234ze
Chilled water systems > 85 kW to 340 kW HC-290/HC-1270 with < 100 kg refrigerant charge HFC-32, R-452B, R-454B, R-513, HFO-1234ze
Chilled water system > 340 kW HC-290/HC-1270 with < 100 kg refrigerant charge HFC-32 (Scroll), R-452B, R-454B, R-513A (screw), HFO-1234ze, HFO-1233zd, R-514A (centrifugal)

Large and Medium AC systems

- Are available with comparable energy efficiency for low/medium GWP refrigerants compared to baseline equipment with high GWP
- Are being further optimised for higher efficiency

Split Units 10 kW to 17 kW HC-290 (within charge limits), HFC-32, R-452B, R-454B
Unitary Equipment Packaged & Split 10 - 85 kW HFC-32, R-452B, R-454B (multi-refrigerant circuit)
Unitary Equipment Packaged & Split > 85 to 340 kW HFC-32, R-452B, R-454B (multi-refrigerant circuit)
Unitary Equipment Packaged & Split> 340 kW Exceeding charge limit
Multi Split less than 20 kW and VRF > 20 kW HFC-32 for capacity < 10 kW
Chilled water systems 10 kW to 85 kW HC-290, HFC-32, R-452B , R-454B , HFO-1234ze
Chilled water systems > 85 kW to 340 kW HC-290/HC-1270 with < 100 kg refrigerant charge HFC-32, R-452B, R-454B, R-513, HFO-1234ze
Chilled water system > 340 kW HC-290/HC-1270 with < 100 kg refrigerant charge HFC-32 (Scroll), R-452B, R-454B, R-513A (screw), HFO-1234ze, HFO-1233zd, R-514A (centrifugal)

Several medium/low GWP Options

UN environment
United Nations Environment Programme

Medium and large commercial refrigeration

- Are available with higher energy efficiency for low/medium GWP refrigerants compared to baseline equipment with high GWP
- High energy efficiency is particularly important for equipment that runs all year

Design for energy efficiency

Heat recovery

Click to add text

Improvement in component design

Reducing cooling loads

Optimum control, operation, and maintenance

Room AC and Self-Contained Commercial Refrigeration Equipment (SCCRE)
Update to 2020 EETF Report – a Fast Transition

- Room AC
  - Most countries have adopted seasonal energy efficiency (SEER) as basis for evaluating the performance
  - In some moderate climate countries, most room air conditioners are reversible – enabling heat pump heating in winter
  - Revision of standard IEC603325-2-40 allows for larger A3 charges based on grams/m^2 up to a limit of 988 g, for new equipment meeting additional safety requirements
- SCCRE
  - SCCRE increasingly uses higher efficiency compressors, evaporators, condensers and suction-line heat exchange as well as efficient ancillary components for lower power consumption
  - Many regions have MEPS for this equipment as well as voluntary higher standards for adding value to the consumer

Chapter 3: Cost of Equipment Using Low and Medium GWP Refrigerants whilst Maintaining or Enhancing Energy Efficiency

- The wide range of RACHP equipment and refrigerant options necessitate case-by-case analysis for material cost impact
- The material cost of RACHP equipment related to maintaining or enhancing energy efficiency is influenced by:
  - **Refrigerant thermodynamic** characteristics (e.g., pressure, density, COP, etc.)
  - **Refrigerant safety** characteristics (e.g., flammability, toxicity, pressure)
  - **Material compatibility** (e.g., ammonia requires switch from copper to steel)
- Flammability and/or toxicity may limit the acceptable amount of a refrigerant, and limit the cooling or heating capacity and/or energy efficiency
- Refrigerant charge can be reduced with new technologies such as microchannel heat exchangers, but these can also bring technical and application challenges

Example of **Thermodynamic factors** influencing RACHP material costs

UN environment
United Nations Environment Programme

Examples of **Safety factors** influencing RACHP material costs

Additional hazard	Examples	Mitigation measures
Higher toxicity	R-717	Refrigerant quantity limits, charge minimisation, limited releasable charge, leak detection, ventilation, alarms, increased system tightness, instructions/marking
Flammability	HC-290, HFC-152a, HFC-32	Refrigerant quantity limits, charge minimisation, limited releasable charge, leak detection, airflow/ventilation, alarms, no ignition sources, increased system tightness, instructions/marking
Higher pressure	R-744	Thicker system wall material, additional pressure safety devices, instructions/marking

Chapter 4: Cost Benefit Analysis of Low GWP Technologies and Equipment that Maintain or Enhance Energy Efficiency

- Cost-benefit analyses help to understand the benefits of energy efficiency improvements for consumers, manufacturers and the environment
- Examples of in-depth cost-benefit analyses are conducted in the EU and the USA
- Cost-benefit analyses are increasingly used by A5 parties

Cost-benefit Analysis: Mini-split ACs in India Higher hours of use/higher electricity prices make energy efficiency more valuable

- Technical option analysis

Component	Energy Savings from Base Case[1]	Incremental Manufacturing Cost (Rs)		Retail Price Increase from Base Case (Rs) [2]	
		Baseline	Range (50% lower to 50% higher than baseline)	Baseline	Range
Baseline Compressor (2.8 EER), 1.5 TR Cooling Capacity	-	-		-	
3.0 EER compressor	5.5%	200	100-300	480	240-720
3.2 EER compressor	10.5%	400	200-600	960	480-1440
3.4 EER compressor	15.0%	575	280-860	1,380	690-2070
Alternating Current Compressor variable speed drive	21.0%	3,600	1800-5400	8,640	4320-12960
Direct Current Compressor variable speed drive	23.0%	5,400	2700-8100	12,960	6480-19440
Variable speed drives for fans and compressor	26.0%	6,300	3150-9450	15,120	7560-22680
UA value of both heat exchangers increased by 20%	7.5%	1,470	735-2200	3,528	1760-5290
UA value of both heat exchangers increased by 40%	13.5%	3,240	1620-4860	7,776	3880-11660
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

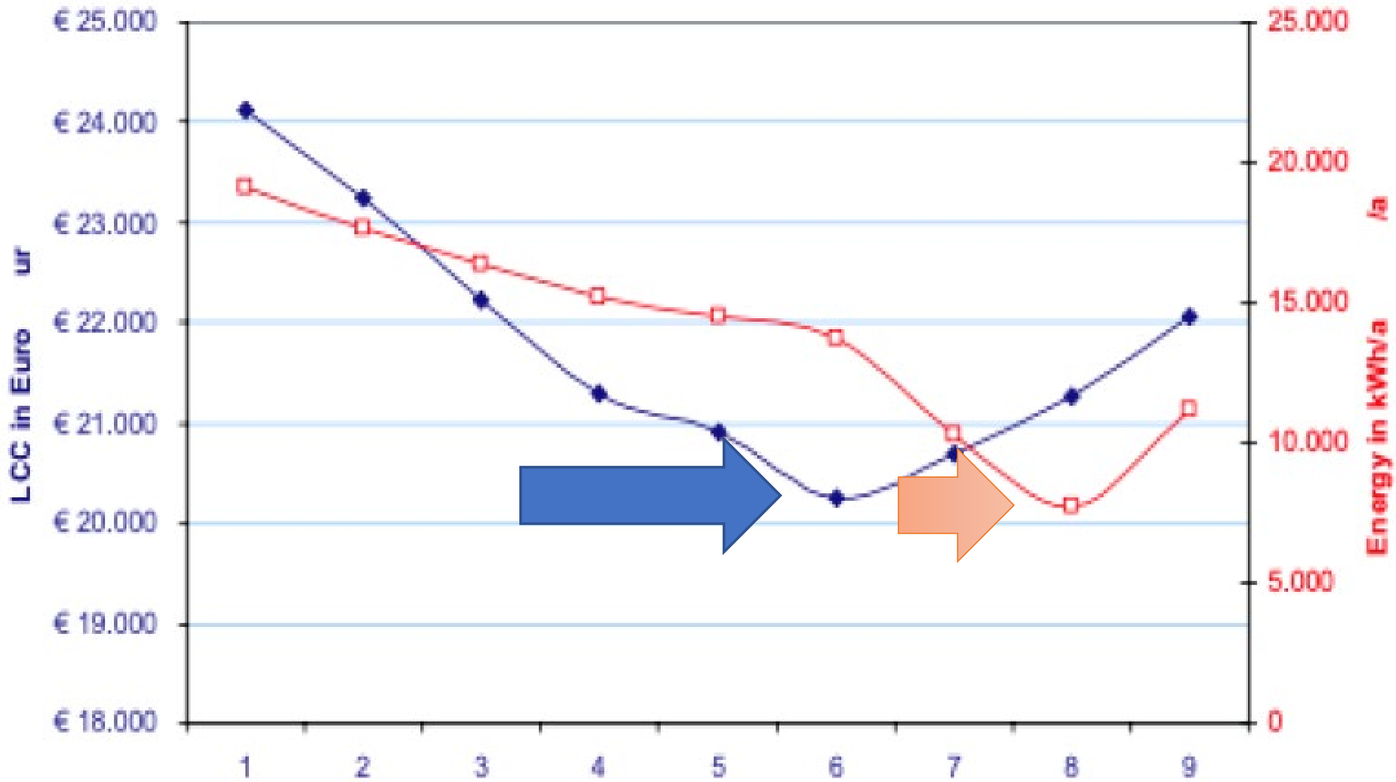
- Cost-benefit Analysis results (from Higher EE equipment)

ISEER (W/W)	Retail price increase required to cover the cost of efficiency improvement (Rs. %)	Bill savings per year for 1000 & 1600 hours of use (Rs.)	Bill savings over lifetime for 1000 & 1600 hours of use (Rs.)	Simple payback period for 1000 & 1600 hours of use (years)
3.5	4900, ~15%	2625 -4200	18300 -29400	1.9-1.2
4	9360, ~27%	3950- 6300	27500-44100	2.4-1.5

UN environment
United Nations Environment Programme

Cost-benefit analysis can help identify the least lifecycle cost option(s):

Highest technically feasible EE level may not be the most cost-effective for consumers



Alternative Design options

UN environment
United Nations Environment Programme

Cost-benefit Analysis: Mini-split ACs in Brazil Higher EE equipment can increase manufacturer revenues

MEPS Level	**EER = 3.23**	**EER = 3.44**	**EER = 3.50**	**EER = 3.98**
Seasonal Performance	3.64	3.77	5.36	6.84
Manufacturing Costs (million R$)	7.7	26.6	43.7	45.7
Capital Conversion Costs (million R$)	16.3	56.2	73.9	86.6
Total Investment needed (million R$)	24.1	82.8	117.6	132.4
Change in industry net present value (million R$)	-18.3	-26.9	243.6	397.7

UN environment
United Nations Environment Programme

Chapter 5: Short Term Roadmap for Adoption of Energy-Efficient Technologies While Phasing Down HFCs

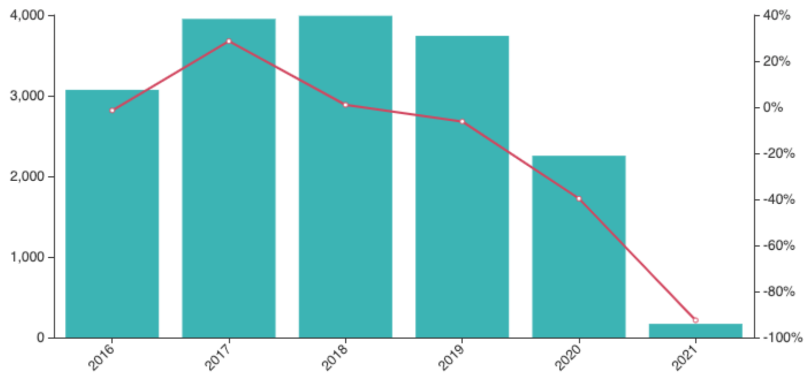
- Measures for adopting energy-efficient technologies while phasing down HFCs will vary based on national circumstances
- National measures can affect technology accessibility
- Adopting enabling policies and standards could support technology transition
- Options include sector-specific and cross-cutting measures:
  - Integrated energy performance standards and labelling with refrigerant requirements
  - Best practice performance metrics and test procedures
  - Enabling building energy and safety standards
  - Support for ongoing service sector training
  - Monitoring, compliance, and enforcement

Chapter 5: Short Term Roadmap for Adoption of Energy-Efficient Technologies While Phasing Down HFCs

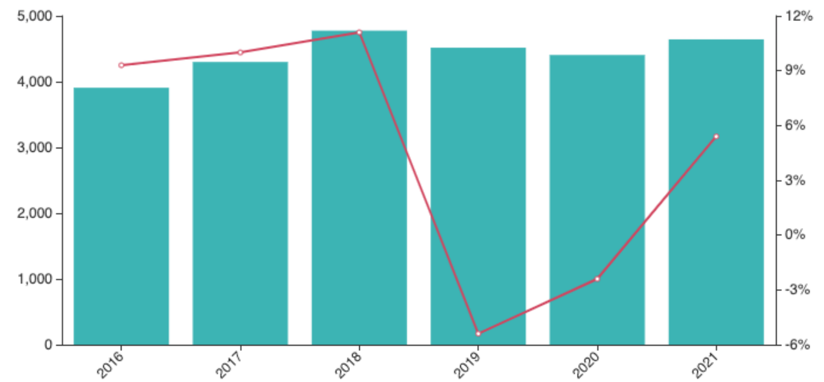
- Coordination between National Ozone Units and national energy and climate authorities could:
  - Support the technology transition, and enable integration of lower GWP HFC requirements into energy efficiency standards and labelling policies
  - Help raise awareness across government institutions and community-based consumer programmes to speed adoption of energy-efficient and low-GWP equipment
  - Increase access to additional financing e.g., through electricity utility efficiency programs and bulk procurement programmes and others
- Many A5 parties do not have the capacity to prescribe and enforce laws to prohibit shipping of obsolete products
- Exporting parties may wish to consider sharing the responsibility with A5 recipient parties to prevent the environmental dumping of obsolete products

An example of policy affecting accessibility

Domestic Sales



Export Sales



- Recently strengthened domestic energy efficiency standards resulted in rapid drop in domestic sales of fixed speed AC low EE/high GWP (left bar chart)
- Domestic high EE/Variable Speed ACs increased (none used HCFC-22)
- Export of Fixed Speed AC to developing country markets with no or low MEPS continue unchanged (right bar chart)

An example of national policy options

- Enhance awareness amongst policy makers and key stakeholders across environment, energy, and climate authorities
- Integrate with relevant national priorities (e.g., climate action plan)
- Strengthen institutional and regulatory framework
- Implement integrated energy and refrigerant performance standards and labelling
- Identify sector-specific barriers and strategies to overcome them
- Link with import policies under HPMP and KIP
- Link green building policies with HPMP and KIP
- Promote public procurement to increase access to desired technologies

Case studies detailed in Annex 9.5

UN environment
United Nations Environment Programme

Chapter 6: Options to Maintain and Enhance Energy Efficiency through Best Practices in installation, servicing, maintenance,

- Design upgrades to meet energy efficiency levels, combined with more flammable refrigerants, require a higher level of knowledge and training for safe and effective installation and servicing
- Greater technical know-how and rigorous service requirements drive higher training, certification, and specialisation
- End-user environmental awareness is increasing, and consequently regular preventive and predictive maintenance is becoming a priority for both operators and service providers
- Energy Efficiency degradation over time is affected by
  - Severity of use and operating conditions
  - Refrigerant leakage - Reducing leakage is a service priority

Role of Technicians in the Synergy between Energy Efficiency and Refrigerant Phase-Down

Technicians are the trusted advisors on decisions to upgrade or replace systems by end users.

Technicians taking the lead in bringing awareness about maintaining EE during service will also drive new higher efficiency products being put on the market.

Including EE in training and technical school curricula ensures sustainability of initiatives undertaken during HPMP and KIP.

Training and certification of technicians on alternative refrigerants for HCFC phase-out, HFC phase-down, and on maintaining EE are convergent and should not conflict each other.

Best Practices

Regional Centres of Excellence advance sustainable development

Competence Standards: ISO 22712 for personnel skill assessment

Codes of refrigerants, certification, training, and enforcement

Cooling Action Plans set goals on EE and service training

Chapter 7: How to Assess the Benefits of Integrating Energy Efficiency Enhancements with the HFC Phase-Down

EETF has reviewed two different types of modelling that provide an understanding of the relative importance of direct versus indirect GHG emissions

- Chapter 4: Detailed equipment level modelling can support specific investment decisions and MEPS and Labels development

- Chapter 7: National or regional forecasting models to assess pathways for:
  - Reduction of "direct" emissions of HFCs
  - Reduction of "indirect" emissions related to RACHP energy use

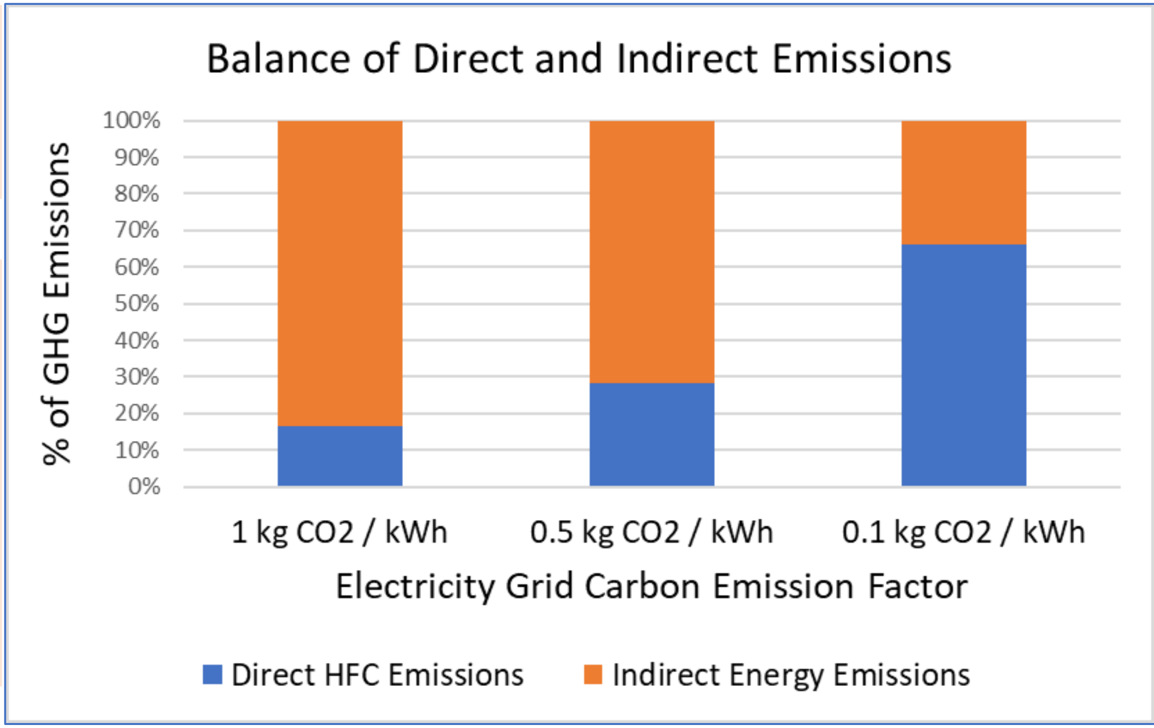
Direct vs. indirect emissions: national impact

Modelling shows significant variations in the relative importance of direct emissions between different countries

Driver:
Electricity generation carbon emissions factor, $kgCO_{2eq}$ per kWh

Key message:

- For countries with high grid factors, reducing energy use has greater impact.
- For countries with low grid factors, reducing HFC emissions has greater impact



Direct vs. indirect emissions: technology impact

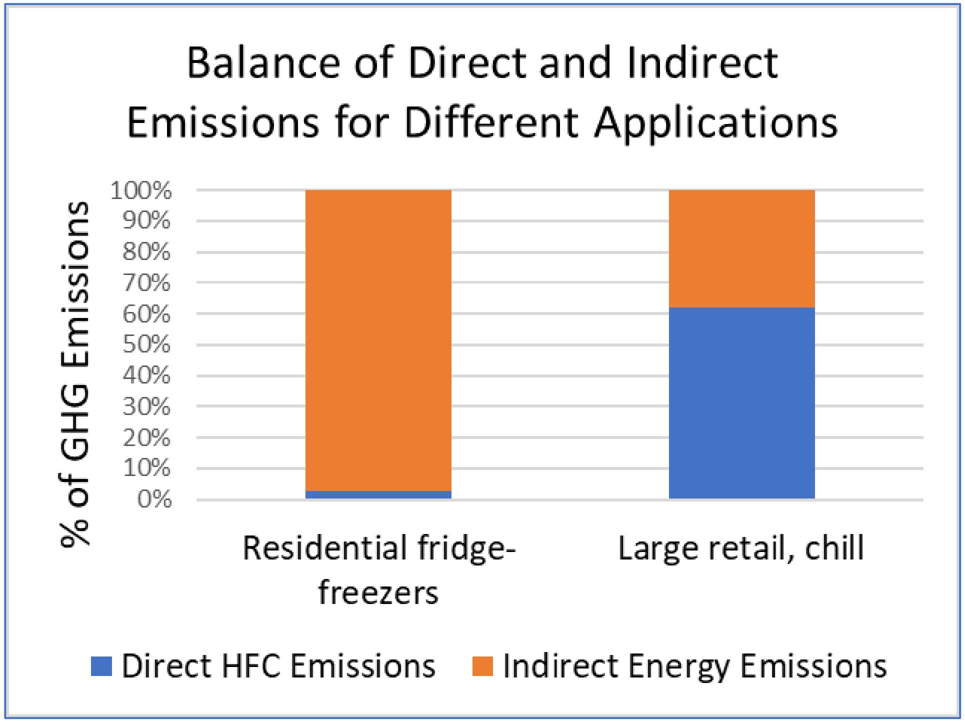
Modelling shows significant variations in the relative importance of direct emissions between different RACHP technologies

Small sealed systems (e.g., residential refrigerators):

- Low leakage, long hours of use
- Energy-related indirect emissions dominant

Large site-built systems (e.g., large supermarkets):

- High leakage
- Refrigerant emissions of great importance

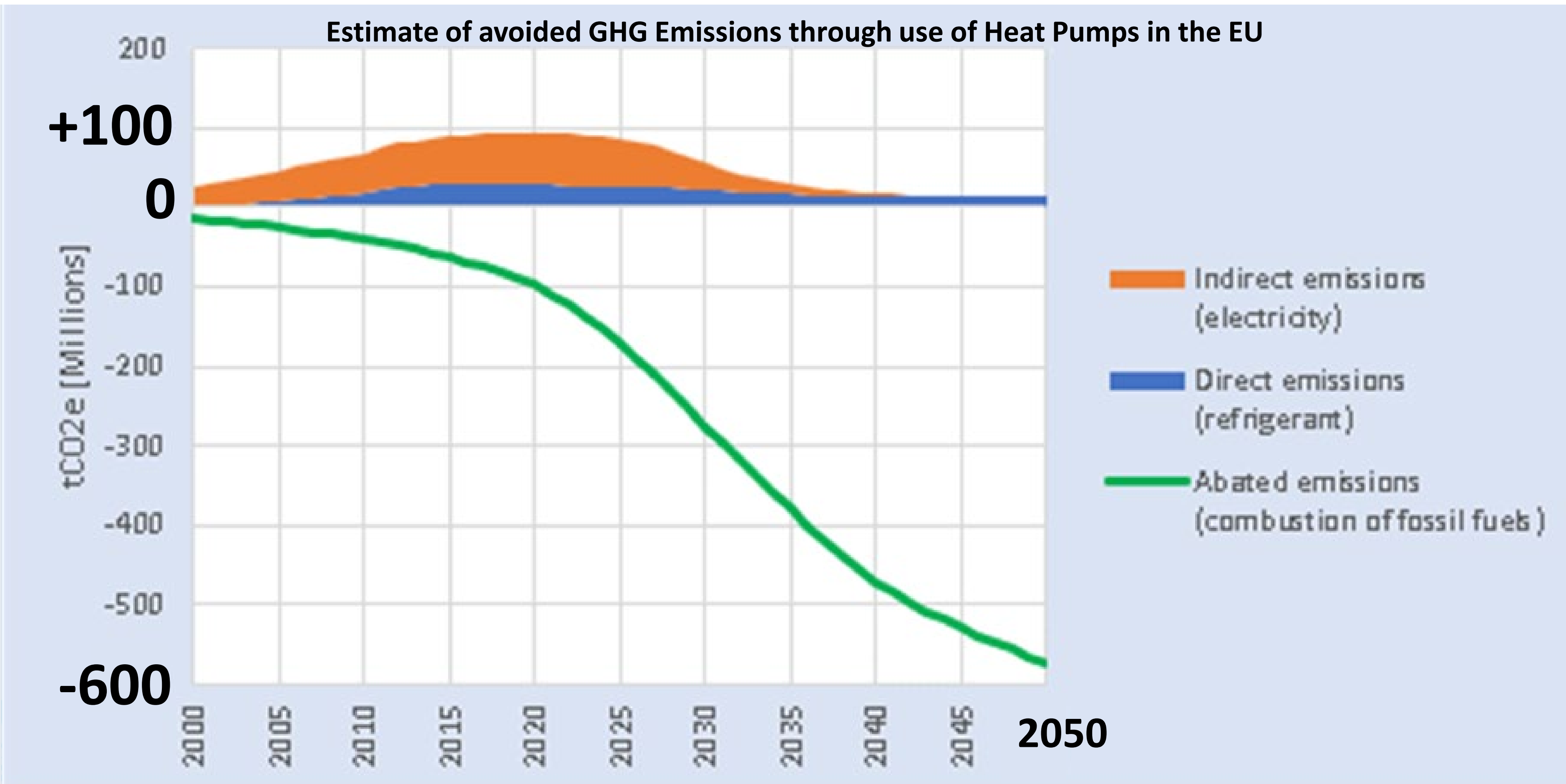


Key message:

The RACHP market is complex and different technologies and applications might need their own dedicated measures.

Deployment of heat pumps in the EU

An EU example shows the significant benefits of replacing fossil-fuel heating with heat pumps in countries with reducing electricity generation carbon factors



Understanding actions for reducing emissions

- Modelling HFC phase-down pathways and energy efficiency improvements is based on making assumptions about a range of actions that can be used to reduce direct or indirect emissions.
- Energy efficiency impact may be enhanced through synergies between MEPS and
  - Reductions in cooling requirements minimization (e.g., building design)
  - Improvements in operational control and maintenance

Key message:

By considering how to reduce both direct and indirect emissions together, in the context of other factors such as building design, the greatest overall emissions reductions can be achieved with lowest cost.

UN environment
United Nations Environment Programme

Overall Conclusions

- In all RACHP sectors covered in this report, equipment using low/medium GWP refrigerants with comparable or enhanced energy efficiency is now available, but not yet always accessible
- Montreal Protocol support for transition to new generation RACHP equipment containing low GWP refrigerants could enable the realisation of the energy efficiency benefits
- Modelling can be a useful tool to evaluate the benefits of integrating energy efficiency enhancements with the HFC phase-down measures