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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL
Ninety-sixth Meeting
Montreal, 26-30 May 2025
Items 9(c) and (d) of the provisional agenda[1]

PROJECT PROPOSALS: EGYPT

This document consists of the comments and recommendation of the Secretariat on the following project proposals:

Phase-out

• HCFC phase-out management plan (stage II, fifth tranche)	UNIDO, UNDP, UNEP and the Government of Germany	Blanket approval

Phase-down

• Kigali HFC implementation plan (stage I, first tranche)	UNIDO and UNDP	Individual consideration

[1] UNEP/OzL.Pro/ExCom/96/1

PROJECT EVALUATION SHEET – MULTI-YEAR PROJECTS

Egypt

(I) PROJECT TITLE	**AGENCY**	**MEETING APPROVED**	**CONTROL MEASURE**
HCFC phase-out plan (stage II)	UNIDO (lead), UNDP, UNEP, Government of Germany	79th (revised at 84th)	67.5% phase-out by 2025

(II) LATEST ARTICLE 7 DATA (Annex C, Group I)	Year: 2023	236.65 ODP tonnes

(III) LATEST COUNTRY PROGRAMME SECTORAL DATA (ODP tonnes)									**Year: 2024**
Chemical	Aerosol	Foam	Fire-fighting	Refrigeration		Solvent	Process agent	Lab use	Total sector consumption
				Manufacturing	Servicing				
HCFC-22					215.09				215.09
HCFC-123									0.00
HCFC-141b									0.00

(IV) CONSUMPTION DATA (ODP tonnes)			
2009–2010 baseline:	386.30	Starting point for sustained aggregate reductions:	484.61
CONSUMPTION ELIGIBLE FOR FUNDING			
Already approved:	386.41	Remaining:	98.20

(V) ENDORSED BUSINESS PLAN		**2025**	**2026**	**2027**	**Total**
UNIDO	ODS phase-out (ODP tonnes)	18.8	0.00	0.00	18.8
	Funding (US $)	2,070,000	0	0	2,070,000
UNEP	ODS phase-out (ODP tonnes)	1.0	0.00	0.00	1.0
	Funding (US $)	1,611	0	0	1,611

(VI) PROJECT DATA			2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
Montreal Protocol consumption limits (ODP tonnes)			347.64	347.64	347.64	251.08	251.08	251.08	251.08	251.08	125.54	n/a
Maximum allowable consumption (ODP tonnes)			347.64	289.70	289.70	251.08	251.08	251.08	241.08*	241.08*	115.54*	n/a
Funding agreed in principle (US $)	UNIDO	Project costs	3,356,641	0	4,668,214	0	4,664,196	0	4,039,413	0	195,000	16,923,464
		Support costs	234,965	0	326,775	0	326,494	0	282,759	0	13,650	1,184,643
	UNDP	Project costs	1,042,352	0	1,836,750	0	816,620	0	0	0	0	3,695,722
		Support costs	72,965	0	128,573	0	57,163	0	0	0	0	258,701
	UNEP	Project costs	230,000	0	279,500	0	260,000	0	180,000	0	105,500	1,055,000
		Support costs	27,480	0	33,394	0	31,064	0	21,506	0	12,605	126,049
	Germany	Project costs	0	0	207,300	0	0	0	0	0	0	207,300
		Support costs	0	0	26,949	0	0	0	0	0	0	26,949
Funds approved by ExCom (US $)		Project costs	4,628,993	0	6,991,764	0	5,740,816	0	0	2,480,298**	0	19,841,871
		Support costs	335,410	0	515,691	0	414,721	0	0	182,527**	0	1,448,349
Total funds recommended for approval at this meeting (US $)		Project costs									2,039,615***	2,039,615
		Support costs									147,993***	147,993

* Maximum allowable total consumption of Annex C, Group I substances were reduced by 10 ODP tonnes upon approval at the 84th meeting of a domestic air-conditioning sector plan as part of stage II.
**Approved, noting that UNIDO, on behalf of the Government, would submit the request for the remaining US $1,739,115, plus agency support costs of US $121,738, at the same meeting the country submits stage I of its Kigali HFC implementation plan or at the 96th meeting, whichever comes earlier.
*** Recommended at the present meeting including the remaining amount for the fifth and final tranche and the deferred amount from the fourth tranche

Secretariat's recommendation:	Blanket approval

PROJECT DESCRIPTION

1. On behalf of the Government of Egypt, UNIDO as the lead implementing agency has submitted a request for funding for the fifth and final tranche of stage II of the HCFC phase-out management plan (HPMP) at a total cost of US $2,187,608 consisting of US $1,934,115, plus agency support costs of US $135,388, for UNIDO and US $105,500, plus agency support costs of US $12,605, for UNEP.[2] The submission includes a progress report on the implementation of the fourth tranche, the verification report on HCFC consumption for 2024, and the tranche implementation plan for 2025 to 2026.

Report on HCFC consumption

2. The Government of Egypt reported under the country programme (CP) implementation report a consumption of 215.09 ODP tonnes of HCFCs in 2024, which is 44 per cent below the country's HCFC baseline for compliance. The Article 7 data for 2024 has not been reported yet. The 2020-2024 HCFC consumption is shown in table 1.

Table 1. HCFC consumption in Egypt (2020-2024 Article 7 data)

HCFC	2020	2021	2022	2023	2024*	Baseline
Metric tonnes (mt)						
HCFC-22	4,481.91	3,759.59	3,244.76	4,302.55	3,910.80	4,367.16
HCFC-123	0.00	7.75	2.50	0.00	0.00	5.25
HCFC-124	0.00	0.34	0.00	0.54	0.00	0.00
HCFC-141b	0.00	0.00	0.00	0.00	0.00	1,178.26
HCFC-142b	52.93	34.13	18.37	0.00	0.00	251.69
Total (mt)	**4,534.84**	**3,801.81**	**3,265.63**	**4,303.09**	**3,910.80**	**5,802.36**
HCFC-141b in imported pre-blended polyols*	0.00	0.00	0.00	0.00	0.00	894.00**
ODP tonnes						
HCFC-22	246.51	206.78	178.46	236.64	215.09	240.19
HCFC-123	0.00	0.16	0.05	0.00	0.00	0.11
HCFC-124	0.00	0.01	0.00	0.01	0.00	0.00
HCFC-141b	0.00	0.00	0.00	0.00	0.00	129.61
HCFC-142b	3.44	2.22	1.19	0.00	0.00	16.36
Total (ODP tonnes)	**249.95**	**209.16**	**179.71**	**236.65**	**215.09**	**386.27**
HCFC-141b in imported pre-blended polyols*	0.00	0.00	0.00	0.00	0.00	98.34**

* Country programme (CP) data
** Average consumption between 2007 and 2009

3. As reported to the 94th meeting, HCFC-22, which is used exclusively to service refrigeration and air-conditioning (RAC) equipment, increased in 2023 due to stockpiling by refrigerant suppliers given expected increases in the price of HCFC-22 and the anticipated reduction in quotas in 2025.[3] The overall reduction in HCFC-22 since 2020 has been attributed to the project to convert five enterprises in residential air-conditioning (AC) manufacturing to HFC-32 and the project to phase-out HCFC-142b in the manufacture of extruded polystyrene (XPS) foam, which was used as a co-blowing agent with HCFC-22. The latter was phased out, in line with the 1 January 2023 ban on the use of HCFCs in the manufacture of XPS foam. Small quantities of HCFC-123 and HCFC-124 are used intermittently to service RAC equipment.

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[2] As per the letter of 1 February 2025 from the Ministry of Environment of Egypt to UNIDO.
[3] UNEP/OzL.Pro/ExCom/94/33

Country programme implementation report

4. The Government of Egypt reported HCFC sector consumption data under the 2023 country programme (CP) implementation report that is consistent with the data reported under Article 7 of the Montreal Protocol.

Verification report

5. The verification report confirmed that the Government was implementing a licensing and quota system for HCFC imports and exports and that the total consumption of HCFCs reported under the CP report for 2024 was correct (as shown in table 1 above). The verification concluded that Egypt has been in compliance with the 2024 maximum allowable consumption specified in the Agreement between the country and the Executive Committee. The report also suggested that climate change and higher than average temperatures in Egypt during 2024 contributed to higher servicing needs in older AC units; that this was expected to be rectified in 2025 as older equipment would be exchanged for new equipment based on HFC-32; and that the launching and operation of the first refrigerant reclamation centre in Egypt had increased the quantities of reclaimed refrigerants.

Progress report on the implementation of the fourth tranche of stage II of the HCFC phase-out management plan

Legal framework

6. The HCFC licensing and quota system (except for HCFC-141b in imported pre-blended polyols) came into force in 2013. The import of HCFC-141b contained in pre-blended polyols was banned on 1 January 2018; imports of HCFC-141b on 1 January 2020; and imports of R-406A and the import and manufacture of HCFC-22-based equipment on 1 January 2023. The import ban of HCFC-141b in pre-blended polyols is implemented through the cooperation between the Egyptian Environmental Affairs Agency (EEAA) and Customs Authority, whereby the customs authority checks all imports under the general Harmonized System (HS) code for polyols with the assistance of the National Ozone unit (NOU). An Ozone Committee decision on 16 April 2024 prohibits the issuance of approvals or industrial licenses for new manufacturing lines of residential AC based on R-410A. The decision was made jointly by the General Authority for Industrial Development, the Ministry of Trade and Industry, and the Central Department for Environmental Impact Assessment in the Ministry of Environment.

7. In January 2024, Egypt issued Ministerial Decree 502/2023 adopting standard ES3795/2023 for seasonal energy efficiency regulation for room and ducted air conditioners and unifying the requirements for both fixed-speed and inverter AC. The Egyptian Organization for Standardization and Quality (EOS) issued a standard for the certification of technicians on good practices, including the handling of flammable refrigerants, in the installation and after-sales sectors of RAC equipment operating with non-ODS and low-global-warming-potential (GWP) refrigerants (standard number 8938/2024).

8. A national certification scheme is being developed in collaboration with key stakeholders, including vocational training institutions, technical education bodies, EOS, and national experts. The NOU and a national committee will support the Ministry of Labor in updating the existing certification framework for RAC technicians.

Manufacturing sector

Extruded Polystyrene (XPS) and polyurethane (PU) foam manufacturing sectors

9. The conversions in this sector were completed[4] in line with the 1 January 2023 ban implemented by the country. The memoranda of understanding (MOUs) were finalized, and two enterprises have received their incremental operating costs (IOCs), while Modern Plastics and Chem-foam received these only in part with the remaining amount to be completely disbursed by fall 2025.

10. The PU foam manufacturing sector conversions to cyclopentane are completed.[5] Agreements had not been reached with two enterprises: Siltal, which is already manufacturing with cyclopentane and Bahgat, which has stopped manufacturing.

Residential air-conditioning manufacturing

11. Stage II included the conversion of five residential AC manufacturing enterprises (El Araby, Fresh, Miraco, Power, and Unionaire) (with a total consumption of 1,189.78 mt of HCFC-22) to HFC-32 and, should the enterprises so decide once the technology became available, R-454B (decision 84/72(b)). At the 94th meeting, members expressed concern that there had been no manufacturing of HFC-32-based residential AC units at the enterprises converted and noted the absence of regulatory measures that might help ensure the sustained uptake of that technology in the market and requested further information on regulatory measures which would be introduced. Also at the 94th meeting, based on comments from the Secretariat, UNIDO had agreed to defer the request for the remaining funding allocated for the residential AC manufacturing sector under the fourth tranche for the agreed IOCs for the two enterprises that had not yet signed IOC contracts (i.e., Miraco and Power) until the submission of stage I of the Kigali HFC implementation plan (KIP).

12. Technical specifications, which would also be applicable to R-454B when possible, were finalized, a supplier was selected, equipment was received, and installation, commissioning, and training were completed for El Araby, Fresh, Power, and Unionaire. In response to the requirements and specifications outlined in decision 84/72, Unionaire had committed to only manufacturing HFC-32-based residential AC units for the local market by 1 January 2025, Power by 31 December 2025, and El Araby and Fresh had committed to doing so by 31 December 2026.

13. UNIDO and Miraco finalized and signed the contract for the conversion of the enterprise. Miraco decided to convert their manufacturing lines to HFC-32 only for residential AC and opted out of R-454B. The enterprise submitted a letter of intent addressing decision 84/72, equipment has been received and installed, and commissioning and training have been completed. An independent expert was recruited for the safety audit, which will be completed by May 2025. The contract for IOCs has been prepared, which requires the enterprise to only manufacture HFC-32-based residential AC units for the local market by 31 December 2026; at the time of finalization of the present document the contract was in the signature process.

Commercial air-conditioning manufacturing

14. Stage II included technical assistance for three enterprises (EGAT, Volta, and Delta Construction and Manufacturing (DCM)) that manufacture central AC equipment for light commercial and residential use (below approximately 144,000 BTU/h (12 tonnes of refrigeration (TR)) to low-GWP alternatives and for larger capacity systems to a combination of low-GWP alternatives and indirect evaporative cooling

[4] In enterprises CMB, Isutech, Chema-Foam, and Modern Plastics to phase out 24.3 mt of HCFC-141b (2.67 ODP tonnes) and 599.0 mt of HCFC-22 (65.89 ODP tonnes).

[5] Involving the enterprises Bahgat, Electrostar, Fresh, Kiriazi, Ocean, Siltal, Star, TopMaker, Tredco, as well as Everest and 28 other small and medium sized enterprises to phase out 586.72 mt of HCFC-141b (64.539 ODP tonnes)

(IEC), resulting in a hybrid IEC-direct expansion unit (IEC-H). At the 88th meeting, it was agreed that three additional enterprises would be added to the project at no additional cost to the Multilateral Fund (Tiba Engineering Industries, Misr Engineering and Industries, and Miraco-Carrier).[6]

15. At the 94th meeting, UNIDO submitted a report on the outcome of the technical assistance that, inter alia, demonstrated that the performance of the IEC-H exceeded that of the direct expansion systems. Testing of prototypes was undertaken in two climate zones representative of Cairo, the Nile delta, and the eastern coast region in summer. In addition, UNIDO reported that four enterprises (DCM, Volta, Tiba Engineering Industries, and Misr Engineering and Industries) were offering IEC-H units as part of their regular manufacturing.

16. Since the 94th meeting, additional tests were conducted in a climate zone with the highest dry-bulb ambient temperatures and lowest humidity, comparing direct expansion (DX) units using HFC-32 refrigerant and IEC-H systems for four manufacturers. As reflected in the addendum to the report submitted to the 94th meeting that is appended to the present document,[7] those tests showed energy savings of 40-50 per cent for the IEC-H systems, demonstrating the benefits of the technology. The enterprises are offering IEC-H units using HFC-32. Three enterprises have submitted final reports (DCM, Misr Engineering Industries, and Tiba), and payments have been disbursed to all six enterprises. The project outputs were shared during the 14th International Conference of Sustainable Construction and Nanotechnology and were presented during a special event on environmental issues and heating, ventilation, and air-conditioning (HVAC). Side events were also organized during the 35th Meeting of the Parties and the 28th United Nations Climate Change Conference.

Refrigeration servicing sector

17. During the implementation of the fourth tranche, the equipment to upgrade four RAC training centres under the Ministry of Education and Technical Education, two RAC training centres under the Ministry of Manpower, and one RAC training centre and one centre of excellence under the Ministry of Trade and Industry was delivered. The distribution of 167 previously procured recovery tool kits is ongoing and 25 sets will be delivered by the end of April.

18. The guidebook on good servicing practices for training curricula was finalized. A total of 355 technicians working in industry and small workshops employing one or two technicians and consuming two to three cylinders of refrigerants per month were trained and received participation certifications. Two training sessions for a total of 31 assessors (including 3 women) were held in the centre of excellence. The assessors will be responsible for testing technicians applying to be certified in RAC servicing using flammable refrigerants. The pilot technician certification programme was launched through a contract to certify after-sales technicians and a total of 61 technicians were certified (including 6 women).

19. The first of two reclamations centres was established and became operational and as of March 2025 a total of 80 mt of refrigerant recovered and reused, and 7 mt of refrigerant had been reclaimed. The distribution of two hundred sets of equipment (e.g., recovery machines, vacuum pump and gauge, high-accuracy pressure gauges, cylinders, thermometer) that had been previously procured to support the reclamation centre was ongoing. The second reclamation centre has been selected and the contract signed; equipment for the centre is expected to be procured and delivered, and the centre’s permit, finalized by December 2025.

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[6] The participation of these additional enterprises would be at no additional cost to the Multilateral Fund, and no funding would be provided directly to the enterprises under this technical assistance activity; their participation will facilitate the uptake of the low-GWP technology in the market, thus contributing to the sustainability of the activity.

[7] As reflected in paragraph 170 of document UNEP/OzL.Pro/ExCom/94/67, Report of the 94th meeting.

Project implementation and monitoring

20. The project management unit (PMU) coordinates and monitors implementation of the HPMP, including visiting beneficiaries and stakeholders, organizing workshops and meetings, and preparation of relevant reports. Disbursements under the PMU for the fourth tranche total US $49,000 (of the allocated US $180,000), including staff and operational costs (US $20,454), consultants (US $8,963), support to the residential AC manufacturing conversion (US $4,583), and contingency (US $15,000).

Level of fund disbursement

21. As of March 2025, of the US $19,841,871 approved so far, US $15,350,374 had been disbursed (US $11,890,003 for UNIDO, US $769,300 for UNEP, US $2,483,771 for UNDP, and US $207,300 for the Government of Germany), as shown in table 2. The balance of US $4,491,497 will be disbursed during 2025 and 2026.

Table 2. Financial report of stage II of the HPMP for Egypt (US $)

Tranche		UNIDO	UNEP	UNDP	GIZ	Total	Disbursement rate (%)
First	Approved	3,356,641	230,000	1,042,352	0	4,628,993	95
	Disbursed	3,117,186	229,800	1,035,119	0	4,382,104	
Second	Approved	4,668,214	279,500	1,836,750	207,300	6,991,764	87
	Disbursed	4,152,912	279,500	1,448,333	207,300	6,088,045	
Third	Approved	4,664,196	260,000	816,620	0	5,740,816	61
	Disbursed	3,234,799	260,000	320	0	3,495,119	
Fourth	Approved	2,300,298	180,000	0	0	2,480,298	56
	Disbursed	1,385,107	0	0	0	1,385,107	
Total	**Approved**	**14,989,349**	**949,500**	**3,695,722**	**207,300**	**19,841,871**	**77**
	Disbursed	**11,890,003**	**769,300**	**2,483,771**	**207,300**	**15,350,374**	
	Balance	**3,099,346**	**180,200**	**1,211,951**	**0**	**4,491,497**	

Implementation plan for the fifth and final tranche of stage II of the HCFC phase-out management plan

22. The following activities will be implemented between June 2025 and December 2026:

(a) Residential AC manufacturing: Completion of the conversion of the five residential AC manufacturing enterprises (provision of IOCs to Miraco and Power) (UNIDO) (US $1,739,115);

(b) Policy and awareness: Continue enforcement of the regulatory network and work to update national codes; outreach on the recovery and recycling network in the servicing sector through vocational and technical institutions and publication of outreach material; four awareness-raising workshops for 200 participants on the updated codes and standards related to refrigerant containment and leakage prevention (UNEP) (US $35,500 and funds from previous tranche);

(c) Control and enforcement: Five workshops to train 250 staff from consumer protection, supply investigation, and industrial control agencies and related stakeholders on the planned quick-response (QR) code for the refrigerant cylinder tracking system; five workshops for 100 staff from the customs authority and other organizations involved in the export and import of controlled substances (UNEP) (US $30,000 and funds from previous tranche); procurement of 15 refrigerant identifiers for customs training and refrigerant surveillance programs (UNIDO) (funds from previous tranche);

(d) Refrigeration and servicing: Training and certification of 345 technicians from large and intermediate workshops in good servicing practices for RAC equipment (UNEP) (US $20,000 and funds from previous tranche); ten on-site training workshops for a total of 150 to 200 technicians on good servicing practices for small workshops employing one or two technicians and consuming two to three cylinders; complete the provision of portable service tool kits for field teams and tools for the after-sales centres of five residential AC manufacturers (UNIDO) (US $20,000 and funds from previous tranche);

(e) Recovery and reclamation: Establishment of the second reclamation centre and continued support for the first one, established under the previous tranche and complete the provision of the 200 additional recovery tools kits to service shops with certified technicians (UNIDO) (US $50,000 and funds from previous tranche);

(f) Project monitoring: At a total cost of US $145,000 for management of the certification and training activities including national and international consultants, regional meetings and an exchange programme (UNEP) (US $20,000 and funds from previous tranche) and monitoring and support for all activities of the HPMP and support for the implementation of the manufacturing investment projects including consultancy services, monitoring and evaluation of implementation, travel, development and submission of verification and tranche reports (UNIDO US $125,000 and funds from previous tranche).

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

Report on HCFC consumption

23. While noting with appreciation that the country's consumption in 2024 was below that specified in the Agreement between the country and the Executive Committee, the Secretariat noted that in 2025 the country will need to reduce approximately 100 ODP tonnes of HCFC-22 in order to remain in compliance with its Agreement with the Executive Committee. UNIDO expressed confidence that the country will be able to do so and noted that the country's 2025 quota had been issued in line with the 2025 target, which is 53.5 per cent of the country's 2024 consumption.

Progress report on the implementation of the fourth tranche of stage II of the HCFC phase-out management plan

Legal framework

24. The Government of Egypt has already issued HCFC import quotas for 2025 at 115.00 ODP tonnes, which is lower than the Montreal Protocol control targets and in accordance with the target set for the year in the HPMP Agreement.

Manufacturing sector

25. UNIDO provided additional information on the status of the conversions to HFC-32 at the residential AC manufacturing enterprises. The R-410A-related manufacturing data from 2020 to 2024 of the five enterprises is shown in table 3 below. As reported to the 94th meeting, in 2023 the enterprises had manufactured 110 HFC-32-based residential AC units; in 2024, that had increased substantially to 244,166 HFC-32-based units (consuming 169.70 mt of HFC-32). As of March 2025, approximately 10 per cent of the manufacturing at Power and El Araby, 30 per cent of the manufacturing at Fresh, and 100 per cent of the manufacturing at Unionaire was based on HFC-32. At the time of finalization of the present document, UNIDO was discussing the decommissioning of R-410A charging stations with Unionaire. UNIDO has

issued partial payments of incremental capital costs (ICC) and of the IOCs based on a year of operation with the new refrigerant, taking into consideration the enterprises' eligible consumption.

Table 3. Consumption of R-410A and R-410A-based residential AC units manufactured by El Araby, Fresh, Miraco, Power, and Unionaire

Year	R-410A consumption (mt)	R-410 residential AC units
2020	716.92	828,632
2021	1,229.29	1,175,896
2022	1,407.25	1,269,675
2023	1,105.53	986,823
2024	1,212.28	1,063,735

26. While manufacturing with the agreed alternative at the five enterprises took longer than expected, since 2023 this manufacturing has rapidly accelerated. All enterprises will cease manufacturing R-410A-based units for the local market by 31 December 2026. As described in paragraphs 40 to 155 of the present document, the country has submitted stage I of the Kigali HFC implementation plan (KIP) to the present meeting. The submitted project includes the conversion of the remaining residential AC manufacturing enterprises using R-410A in the country, and the implementation of a ban on the import and manufacture of R-410A-based residential AC units to ensure the sustainability of the conversion.

Refrigeration servicing sector

27. The Secretariat noted with appreciation that UNIDO had undertaken efforts to address the delay in the procurement and delivery of 15 refrigerant identifiers for customs and import agents, which had been delayed due to the ongoing global supply chain issues for this equipment, by identifying a supplier that will initially provide five identifiers, with the additional identifiers to be procured subsequently.

28. A number of planned activities in the servicing sector have either not yet been initiated or are still under implementation, including:

(a) Five workshops to train 75 customs officials and related stakeholders on controlling the import and export of controlled substances have not yet been undertaken;

(b) While the pilot technician certification programme was launched, and 61 technicians certified, a total of 500 technicians are planned to be certified under the project;

(c) Training of a further 375 technicians in good servicing practices for RAC equipment has not yet been undertaken;

(d) The regulatory and institutional tools to enforce the RAC technician certification programme are still being designed;

(e) An assessment of equipment needs for the AC after-sales service network was completed, with the procurement of portable service tool kits for field teams, but the support tools for after-sales centres has not yet been completed;

(f) The refrigerant containment and leakage prevention programme was implemented, focusing on large RAC equipment; however, the pilot inspection and certification of one or two buildings, initially expected by December 2024, is now expected by December 2026;

(g) The development of the refrigerant tracking system based on QR codes for refrigerant cylinders has been initiated but not yet completed and QR codes for refrigerant cylinders are expected to be mandatory by 31 December 2026;

(h) Five awareness-raising workshops for 60 customs stakeholders on the QR code-refrigerant tracking system have not yet been undertaken;

(i) The update of local codes and standards to support the refrigerant containment and leakage prevention programme and the four awareness-raising workshops to enforce the updated codes have not yet been undertaken; and

(j) The development of policies and measures to ensure the sustainability of the conversion in the commercial AC manufacturing sector is still ongoing.

29. UNIDO confirmed that the planned activities would be completed by the date of completion of the project. In light of activities that still needed to be initiated or completed, the Secretariat requested that stage III of the HPMP that is expected to be submitted to the 97th meeting include a detailed report on the progress of implementing the remaining activities under stage II.

Level of fund disbursement

30. UNEP clarified that while its disbursement under the fourth tranche was zero, it expected to disburse approximately US $36,000 by July 2025 based on activities already undertaken once the small-scale funding agreement with the Government is finalized. The Secretariat urged UNEP to finalize that agreement, and that of the fifth and final tranche, once approved, as soon as possible so that the country can benefit from UNEP's assistance.

<u>Gender policy implementation</u>

31. During the implementation of the fourth tranche, the participation of women in meetings and training activities was tracked. In the residential AC project, engineers at two beneficiaries (El Araby and Fresh) were women. As a result of the gender mainstreaming promotional activities, three women participated in the training for trainers. Three women received certificates of appreciation from the Minister of Environment, Minister of Manpower, and the Minister of Social Solidarity during a celebration ceremony for their efforts in facilitating cooperation between these authorities and the NOU. During the implementation of the fifth tranche, a draft policy will be prepared on gender mainstreaming, and specific courses will be organized for technical women in the RAC sector.

<u>Completion of stage II of the HCFC phase-out management plan</u>

32. UNIDO has confirmed that stage II for Egypt will be completed on 31 December 2026 as established in paragraph 14 of the Agreement.

<u>Sustainability of the HCFC phase-out and assessment of risks</u>

33. UNIDO assessed that the risk to the sustainability of the conversion from HCFC-22 in residential AC is low, as evidenced by the acceptance of HFC-32 technology in both the local and global market. UNIDO further noted that the availability of HFC-32-based inverter compressors will further enhance the sustainability of the conversion. The Secretariat concurs with UNIDO's assessment and further noted that the sustainability of the conversion and the uptake of HFC-32 will be enhanced by the activities planned under the KIP, which will ensure the phase-out of R-410A-based manufacturing in residential AC, through a ban on the import and manufacture of R-410A-based residential AC units. These activities will help ensure that the five enterprises that proactively converted early, even before the country had ratified the Kigali

Amendment, are competing on an even playing field. The Secretariat further noted with appreciation that the Government plans to submit to the 97th meeting, a project under decision 94/60 to improve the energy efficiency of, inter alia, residential AC units manufactured by the five enterprises under the HPMP and the enterprises participating in the KIP. The Secretariat encouraged the Government to submit such a project, noting that it would further enhance the sustainability of the conversions to the agreed alternative, and further assist the enterprises included in the HPMP. In that regard, UNIDO confirmed that the five enterprises assisted under the HPMP understand that they will be subject to the 1 January 2029 ban on the manufacture of R-410A-based residential AC units to be implemented under the KIP, at which point they would no longer be able to manufacture R-410A-based residential AC units for export.

34. At the 79th meeting, it was noted that the sustainability of the conversion in the commercial AC manufacturing sector was a concern due to the use of high-GWP HFCs on the market in package units, central units, and chillers, including HFC-134a and R-410A. Accordingly, it was agreed that the Government, through UNIDO, would report on the implementation of policies and measures to ensure the sustainability of the conversion through the tranche implementation progress report of stage II of the HPMP until the successful uptake in the market of the alternatives.[8] The technical assistance provided to the sector has demonstrated the substantial improvement in energy efficiency that can be achieved through the IEC-H technology, which should help with the market uptake of that technology. Four enterprises (DCM, Volta, Tiba Engineering Industries, and Misr Engineering and Industries) are offering IEC-H units as part of their regular manufacturing, and two enterprises were still considering their options. The development and implementation of policies and measures to help enable the market uptake of low-GWP, energy-efficient IEC-H units would further sustain the conversion and the uptake of the technology in the market.

35. The reclamation centres established in the country should be able to offer reclaimed HCFC-22 to the market as its price rises with the phase-out. The brands, prices, and distribution channels of refrigerants reclaimed by the existing and new reclamation centres need to further be supported by the NOU. Continued training and implementation of the RAC technician certification programme will help reduce HCFC-22 servicing demand.

Conclusion

36. The country is in compliance with its Agreement with the Executive Committee. The conversions in the XPS and PU foam manufacturing sectors are complete, and the Government has implemented a number of bans to sustain the HCFC phase-out. The level of disbursement of the fourth tranche is 56 per cent, and 77 per cent of the funds approved to date. At the 94th meeting, the Executive Committee decided not to approve all the funding under the fourth tranche, as at that time it was not clear how the sustainability of the conversion of the residential AC manufacturing enterprises to HFC-32 would be assured given manufacturing by other enterprises of residential AC equipment with R-410A. As further described in paragraph 25 above, Egypt has proposed, under the stage I of its KIP, a comprehensive plan to convert the remaining residential AC manufacturing enterprises in the country to HFC-32, and to ban, by 1 January 2029, the import and manufacture of residential AC equipment with R-410A.

RECOMMENDATION

37. The Fund Secretariat recommends that the Executive Committee:

(a) Note the progress report on the implementation of the fourth tranche of stage II of the HCFC phase-out management plan (HPMP) for Egypt; and

[8] Paragraph 50(b) of document UNEP/OzL.Pro/ExCom/79/32.

(b) Request the Government of Egypt, through UNIDO as lead implementing agency, to include, when submitting the request for stage III of the HPMP, a detailed report on the progress of implementing the remaining activities under stage II;

(c) Request the Government of Egypt, UNIDO, UNDP, UNEP and the Government of Germany to submit the project completion report to the first meeting of the Executive Committee in 2027; and

38. The Fund Secretariat further recommends blanket approval of the fifth and final tranche of stage II of the HPMP for Egypt and the corresponding 2025-2026 tranche implementation plan at the funding levels shown in the table below.

	Project title	**Project funding (US $)**	**Support costs (US $)**	**Implementing agency**
(a)	HCFC phase-out management plan (stage II, fifth tranche)	1,934,115	135,388	UNIDO
(b)	HCFC phase-out management plan (stage II, fifth, tranche)	105,500	12,605	UNEP

PROJECT EVALUATION SHEET – MULTI-YEAR PROJECTS

Egypt

PROJECT TITLE	AGENCY
Kigali HFC implementation plan (stage I)	UNIDO (lead), UNDP

LATEST ARTICLE 7 DATA (Annex F)	Year: 2023	7,686.28 mt	14,890,881 CO_2-eq tonnes

SECTORAL HFC CONSUMPTION DATA (CO_2-eq tonnes) AND ACTIVITIES									
	Aerosol	Foam	Fire-fighting	Air-conditioning and refrigeration				Solvent	Other
				Manufacturing			Servicing		
				Refrigeration	AC	Other			
Latest CP report (2024)	260,632	197,184	1,595,494	1,080,564	3,345,441	0	10,754,212	0	0
KIP stage I activities as agreed (Y/N)	N	Y	N	Y	Y	N	Y	N	N

AVERAGE 2020–2022 HFC CONSUMPTION IN SERVICING*	4,390.29 mt	9,345,372 CO_2-eq tonnes

* Including consumption to service firefighting equipment

BASELINE CONSUMPTION DATA (CO_2-eq tonnes)	2020	2021	2022	Average 2020-2022
HFC annual consumption	12,498,835	12,840,128	14,317,946	13,218,970
HCFC baseline (65%)				6,071,380
HFC baseline				19,290,350

HFC CONSUMPTION ELIGIBLE FOR FUNDING	
Starting point for sustained aggregate reductions	TBD
Previously approved HFC phase-down investment projects	No
Aggregate reductions from previously approved projects (CO_2-eq tonnes)	n/a

PROJECT DATA AS AGREED			2025*	2026	2027	2028	2029	2030	Total
Consumption (CO_2-eq tonnes)	Montreal Protocol limits		19,290,350	19,290,350	19,290,350	19,290,350	17,361,315	17,361,315	n/a
	Maximum allowable		19,290,350	19,290,350	18,500,000	18,000,000	16,387,179	15,046,473	n/a
	Reductions from baseline (%)		0	0	4.1	6.7	15.0	22.0	n/a
Amounts recommended in principle (US $)	UNIDO	Project costs	9,081,787	0	3,545,129	0	1,648,115	0	14,275,031
		Support costs	635,725	0	248,159	0	115,368	0	999,252
	UNDP	Project costs	1,704,688	0	1,047,100	0	170,779	0	2,922,567
		Support costs	119,328	0	73,297	0	11,955	0	204,580
	Total project costs		10,786,475	0	4,592,229	0	1,818,894	0	17,197,598
	Total support costs		755,053	0	321,456	0	127,323	0	1,203,832
	Total funds		11,541,528	0	4,913,685	0	1,946,217	0	18,401,430

* Recommended for approval at the present meeting

Reduction from remaining consumption eligible for funding in stage I (CO_2-eq tonnes)	5,795,458*

* Including 35,850 CO_2-eq tonnes of HFCs contained in imported pre-blended polyols

Secretariat's recommendation:	Individual consideration

PROJECT DESCRIPTION

39. The present document contains the following sections:

I. Summary of the proposal as submitted

II. Background: Status of implementation of the HCFC phase-out management plan

III. HFC consumption overview: HFC consumption levels, trends, and consumption by sector

IV. Stage I of the Kigali HFC implementation plan, as submitted: Regulatory framework, phase-down strategy, total stage cost, and implementation plan for the first tranche

V. Secretariat's comments, including the agreed cost of activities

VI. Recommendation

I. Summary of the proposal as submitted

40. On behalf of the Government of Egypt, UNIDO as the lead implementing agency has submitted a request for stage I of the Kigali HFC implementation plan (KIP), at a total cost of US $29,817,042, consisting of US $22,197,232, plus agency support costs of US $1,553,806 for UNIDO and US $5,669,162, plus agency support costs of US $396,841 for UNDP, as originally submitted.[9]

41. The implementation of stage I of the KIP will assist the Government of Egypt in reducing its HFC consumption by 21.40 per cent of its baseline by 1 January 2029, in advance of the Montreal Protocol control schedule.

42. The first tranche of stage I of the KIP being requested at this meeting amounts to US $17,392,844 consisting of US $12,707,775, plus agency support costs of US $889,544 for UNIDO and US $3,547,220, plus agency support costs of US $248,305 for UNDP, as originally submitted, for the period of June 2025 to December 2027.

II. Background

Status of implementation of the HCFC phase-out management plan

43. Table 1 presents information on the HCFC phase-out management plan (HPMP) in Egypt as of February 2025.

Table 1. HPMP implementation status for Egypt

	Stage I	**Stage II**
Meetings when HPMP was approved/updated	65th	79th/84th
Reduction from baseline	25% by 2018	67.5% by 2025
Total project cost (US $)	8,502,815	21,881,486
Date of completion (actual/planned)	1 December 2019	31 December 2026

[9] As per the letter of 22 January 2025 from the Ministry of Environment of Egypt to UNIDO.

Status of implementation of previous HFC-related activities

44. Table 2 presents an overview of activities implemented in Egypt in the context of the Kigali Amendment that have been funded by the Multilateral Fund.

Table 2. Previously approved HFC-related activities in Egypt

Approval meeting	Project title	Implementing agency	Cost (US $)	Date of completion
81st	Enabling activities for HFC phase-down	UNIDO/UNEP	250,000	June 2022
93rd	Energy efficiency pilot project in the refrigeration and air-conditioning (RAC) sector in Egypt to maintain and/or enhance the energy efficiency of replacement technologies and equipment in the context of HFC phase-down	UNIDO	285,000	Ongoing

III. HFC consumption overview

HFC consumption levels

45. Egypt only imports HFCs for use in the manufacturing and servicing sectors. The most consumed substances in 2024 were HFC-134a (37.8 per cent of total HFC consumption in CO_2-equivalent (CO_2-eq) tonnes), R-410A (34.3 per cent), R-404A (15.4 per cent), and HFC-227ea (9.4 per cent), while other HFCs accounted for 3.1 per cent of the overall consumption. Table 1 presents the country's HFC consumption as reported to the Ozone Secretariat under Article 7 of the Montreal Protocol and the country's HFC baseline.

Table 3.HFC consumption (2020–2024 Article 7 data) and baseline in Egypt

HFC	GWP	2020	2021	2022	2023	2024*
Metric tonnes (mt)						
HFC-134a	1,430	3,109.95	2,836.53	2,797.31	3,673.87	4,556.45
HFC-152a	124	275.45	454.66	429.90	227.00	281.22
HFC-227ea	3,220	539.55	429.94	460.20	502.41	500.50
HFC-245fa	1,030	22.53	67.62	115.61	64.00	116.50
HFC-365mfc	794	30.45	33.06	34.80	0.00	33.00
R-404A	3,922	720.60	621.96	607.22	669.47	677.88
R-410A	2,088	1,501.90	2,114.50	2,844.18	2,415.15	2,832.64
Others	n/a	132.48	226.29	226.51	134.38	222.16
Total (mt)		**6,332.90**	**6,784.57**	**7,515.73**	**7,686.28**	**9,220.34**
HFC-245fa in pre-blended polyol*	1,030	21.42	23.78	31.86	27.37	29.00
HFC-365mfc in pre-blended polyol*	794	0.00	0.00	0.00	0.00	21.00
CO_2-eq tonnes						
HFC-134a	1,430	4,447,229	4,056,238	4,000,162	5,253,638	6,515,716
HFC-152a	124	34,156	56,378	53,308	28,148	34,871
HFC-227ea	3,220	1,737,351	1,384,407	1,481,844	1,617,773	1,611,610
HFC-245fa	1,030	23,204	69,653	119,075	65,920	119,995
HFC-365mfc	794	24,177	26,250	27,631	0	26,202
R-404A	3,922	2,825,905	2,439,086	2,381,262	2,625,377	2,658,374
R-410A	2,088	3,135,216	4,414,019	5,937,217	5,041,627	5,913,136
Others**	n/a	271,598	394,098	317,447	258,398	353,623
Total (CO_2-eq tonnes)		**12,498,835**	**12,840,128**	**14,317,946**	**14,890,881**	**17,233,528**
HFC-245fa in pre-blended polyol*	1,030	22,062	24,493	32,816	28,191	29,870
HFC-365mfc in pre-blended polyol*	794	0	0	0	0	16,674
HFC baseline calculation (CO_2-eq tonnes)						
HFC average consumption in 2020–2022						13,218,970
HCFC baseline (65%)						6,071,380
HFC baseline						**19,290,350**

* Country programme data

** Including HFC-32, HFC-125, HFC-143a, HFC-236fa, HFC-23, R-406A, R-407C, R-407F, R-408A, R-417A, R-507A, and R-508B

Country programme implementation report

46. The sectoral HFC consumption data provided by the Government of Egypt in its country programme (CP) implementation report for 2023 is consistent with the data reported under Article 7 of the Montreal Protocol.

HFC consumption trends

47. The consumption of HFCs in Egypt has been increasing each year since 2020, with substantial increases in 2022 and in 2024. In 2022, consumption grew by approximately 11.5 per cent in CO_2-eq-tonnes primarily given increased use of R-410A in air-conditioning (AC). In 2023, consumption increased modestly given increased consumption of three of the most commonly used HFCs/blends (HFC-134a, HFC-227ea, and R-404A) and decreases in some HFCs. In 2024, consumption increased by 16 per cent in CO_2-eq tonnes, driven in part by a recovery from the 2023 currency devaluation. While increases in consumption of HFC-134a and R-410A accounted for a substantial proportion of the 2024 increase, there were also increases in the other seven most commonly imported HFCs in the country,[10] and a substantial increase in consumption of HFC-32 in line with the conversion of five residential AC manufacturing enterprises to that technology under the HPMP. The average consumption of each refrigerant in the three baseline years shows that that HFC-134a, and R-410A constitute 73 per cent in mt and 66 per cent in CO_2-eq tonnes of the HFC consumption in Egypt. Prior to 2024, importers were pre-informing the National Ozone Unit (NOU) of imports related to all substances, including, HFCs in anticipation of the new measure, which enabled the NOU to calculate the consumption of HFCs for the reporting years.

HFC consumption by sector

48. HFCs are consumed in the servicing sector (59 per cent of consumption in terms of CO_2-eq tonnes), in various manufacturing subsectors (29 per cent), and in firefighting (12 per cent). In manufacturing, the largest percentage of HFCs is the manufacture of residential and commercial AC equipment, which amounted to 20 per cent of the total consumption in baseline years in CO_2-eq tonnes,[11] followed by the manufacture of domestic refrigeration equipment (4 per cent), the manufacture of metered-dose inhalers (MDIs) (1.3 per cent), the manufacture of commercial and transport refrigeration (1 per cent each), polyurethane (PU) foam (almost 1 per cent), and the manufacture of mobile air-conditioning (MAC) and extruded polystyrene (XPS) foam (less than 1 per cent each).

49. HFCs for servicing are mainly consumed in the refrigeration subsector (37 per cent in mt and 39 per cent in CO_2-eq tonnes of total HFC consumption in baseline years)[12], followed by the AC subsector (14 per cent in mt and 15 per cent in CO2-eq tonnes),[13] and the MAC subsector (7 per cent in mt and 5 per cent in CO2-eq tonnes), as shown in tables 4 and 5.

[10] HFC-134a (24 per cent), HFC-152a (24 per cent), HFC-245fa (82 per cent), HFC-23 (5 per cent), R-404A (1 per cent), R-407C (32 per cent), R-410A (17 per cent), R-417A (6 per cent), and R-507A (3 per cent).

[11] These two sector are combined in the CP data and the survey of consumption in preparation of the KIP was not able to identify all enterprises using HFCs in manufacturing commercial AC, however indicated that all reported R-410A is in the residential AC sector.

[12] Due to discrepancies in the data a further breakdown is not shown but the refrigeration servicing subsector consists of the following in rough percentages of the total HFC consumption: commercial (34 per cent in CO_2-eq tonnes), industrial (15 per cent), domestic (11 per cent), and transport (7 per cent).

[13] The AC servicing subsector consists of the following in rough percentages of the total HFC consumption: residential (25 per cent) and commercial (less than 1 per cent).

Table 4. HFC consumption in Egypt by sector in mt (2020-2022)[14]

Sector	HFC-32	HFC-134a	HFC-152a	HFC-227ea	HFC-245fa	HFC365mfc	R-404A	R-407C	R-410A	Other	Total	Share of total (%)
Manufacturing sectors												
Domestic refrigeration	0.00	409.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	409.44	6
Commercial refrigeration	0.00	31.79	0.00	0.00	0.00	0.00	5.24	0.45	0.00	0.00	37.48	1
Transport refrigeration	0.00	37.51	0.00	0.00	0.00	0.00	8.51	45.55	0.00	0.00	91.58	1
Residential and commercial AC	3.35	41.71	0.00	0.00	0.00	0.00	0.00	1.18	1250.67	0.00	1,255.19	18
MAC	0.00	41.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.71	1
PU foam	0.00	0.00	0.00	4.90	68.59	32.77	0.00	0.00	0.00	0.00	106.25	2
XPS foam	0.00	0.00	386.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	386.67	6
Aerosol	0.00	118.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	118.98	2
Subtotal for manufacturing	***3.35***	***639.43***	***386.67***	***4.90***	***68.59***	***32.77***	***13.75***	***47.18***	***1250.67***	***0.00***	***2,447.29***	***36***
Refrigeration and AC servicing												
Refrigeration subsectors	0.00	1816.11	0.00	0.00	0.00	0.00	636.18	39.33	0.00	11.81	2,503.43	37
AC subsectors	12.92	18.63	0.00	0.00	0.00	0.00	0.00	38.00	897.39	2.69	969.64	14
MAC	0.00	440.39	0.00	0.00	0.00	0.00	0.00	0.00	5.47	0.00	445.86	7
Subtotal for servicing	***12.92***	***2275.14***	***0.00***	***0.00***	***0.00***	***0.00***	***636.18***	***77.33***	***902.86***	***14.50***	***3,918.93***	***57***
Other sectors												
Firefighting	0.00	0.00	0.00	471.67	0.00	0.00	0.00	0.00	0.00	0.32	471.98	7
Other	5.41	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.12	15.90	0
Subtotal for other sectors	***5.41***	***0.37***	***0.00***	***471.67***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***10.44***	***487.88***	***7***
Total	**21.67**	**2,914.94**	**386.67**	**476.56**	**68.59**	**32.77**	**649.93**	**124.51**	**2,153.53**	**24.94**	**6,854.10**	**100**

* An average consumption in the foam sector of 25.69 mt of HFC-245a in imported pre-blended polyols was also reported in the CP data.

[14] Data in this table for the commercial and residential AC, firefighting, and ‘other’ sectors is from the CP report while other sectors are taken form the survey. The data aligns with the CP in most sectors except for the servicing sector where there is a difference of 0.62 mt from the CP report.

Table 5. HFC consumption in Egypt by sector in CO_2-eq tonnes (2020-2022)[15]

Sector	HFC-32	HFC-134a	HFC-152a	HFC-227ea	HFC-245fa	HFC-365mfc	R-404A	R-407C	R-410A	Other*	Total	Share of total (%)
Manufacturing sectors												
Domestic refrigeration	0	585,499	0	0	0	0	0	0	0	0	585,499	4
Commercial refrigeration	0	45,465	0	0	0	0	20,542	793	0	0	66,800	1
Transport refrigeration	0	53,643	0	0	0	0	33,382	80,807	0	0	167,832	1
Residential and commercial AC	2,258	0	0	0	0	0	0	2,084	2,610,767	0	2,615,109	20
MAC	0	59,641	0	0	0	0	0	0	0	0	59,641	0
PU foam*	0	0	0	15,767	70,644	26,019	0	0	0	0	112,431	1
XPS foam	0	0	47,947	0	0	0	0	0	0	0	47,947	0
Aerosol	0	170,137	0	0	0	0	0	0	0	0	170,137	1
Subtotal for manufacturing	***2,258***	***914,385***	***47,947***	***15,767***	***70,644***	***26,019***	***53,922***	***83,684***	***2,610,767***	***0***	***3,825,393***	***29***
Refrigeration and AC servicing												
Refrigeration subsectors	0	2,597,040	0	0	0	0	2,494,840	69,767	0	8,184	5,202,265	39
AC subsectors	8,721	26,645	0	0	0	0	0	67,406	1,873,306	6,320	1,982,398	15
MAC	0	629,761	0	0	0	0	0	0	11,412	0	641,173	5
Subtotal for servicing	***8,721***	***3,253,446***	***0***	***0***	***0***	***0***	***2,494,840***	***137,174***	***1,884,718***	***14,504***	***7,825,836***	***59***
Other sectors												
Firefighting	0	0	0	1,518,767	0	0	0	0	0	3,113	1,521,880	12
Other	3,650	529	0	0	0	0	0	0	0	41,921	46,099	0
Subtotal for other sectors	***3,650***	***529***	***0***	***1,518,767***	***0***	***0***	***0***	***0***	***0***	***45,034***	***1,567,979***	***12***
Total	**14,628**	**4,168,360**	**47,947**	**1,534,534**	**70,644**	**26,019**	**2,548,762**	**220,858**	**4,495,485**	**59,537**	**13,219,208**	**100**

* An average consumption in the foam sector of 26,457 CO_2-eq tonnes of HFC-245a in imported pre-blended polyols was also reported in the CP data.

[15] Data in this table for the commercial and residential AC, firefighting, and 'other' sectors is from the CP report while other sectors are taken form the survey. The data aligns with the CP in most sectors except for the servicing sector where there is a difference of 2,343 CO_2-eq tonnes from the CP report.

Manufacturing sectors

50. In Egypt, manufacturing sectors using HFCs include enterprises manufacturing domestic and commercial refrigeration and residential and commercial AC equipment, PU foam, XPS foam, and aerosols to produce MDIs.

Polyurethane foam manufacturing sector

51. Under the HPMP eight enterprises manufacturing PU foam in the domestic refrigeration sector were assisted to convert from HCFC-141b to cyclopentane. However, several small and medium-sized enterprises (SMEs) in the sector were already using HFC-245fa pure and in imported pre-blended polyols as a blowing agent before the implementation of the conversion project, and one enterprise manufacturing water heaters was using HFC-365mfc blended with HFC-227ea as a blowing agent. The HFC consumption in this sector would be addressed in stage I of the KIP.

Extruded polystyrene foam manufacturing sector

52. In Egypt there are two companies, using HFC-152a to manufacture discontinuous panels for construction. This manufacturing sector amounts to 6 per cent of the total HFC consumption in the country in terms of mt but only 0.4 in terms of CO_2-eq tonnes. HFC-152a is used only in the XPS sector and it is proposed to be addressed during stage I after which a ban would be implemented by 2028.

Domestic refrigeration manufacturing sector

53. There are six enterprises with HFC-134a consumption greater than 15 mt, five enterprises with consumption between 15 mt and 1.5 mt, and four enterprises with consumption less than 1.5 mt that manufacture domestic refrigerators. Enterprises with consumption less than 1.5 mt charge equipment on site and will be referred to as very-small enterprises (VSEs) though some of these enterprises also manufacture other RAC products.[16] Consumption in this sector has been targeted for phase out during stage I of the KIP. HFC-134a is the dominant refrigerant consumed in this sector; however, there is some manufacturing of domestic refrigeration equipment using R-600a; R-600a-based domestic refrigerators are also imported into the country.

Commercial refrigeration manufacturing sector

54. In the commercial refrigeration manufacturing sector, one manufacturer, six SMEs and four VSEs manufacture stand-alone commercial refrigeration equipment. HFC-134a is the primary HFC used in the sector (roughly 85 per cent); R-404A and R-407C are the other HFCs used by these enterprises. Consumption in this sector would be targeted in stage I of the KIP.

Transport refrigeration manufacturing sector

55. Three enterprises were identified in the manufacturing and installation of refrigerated transport (two SMEs and one VSE). These enterprises use primarily R-404A and R-407C as well as some HFC-134a. This manufacturing sector will be addressed in a future stage.

[16] In the present document, manufacturing enterprises with consumption above 15 mt will be referred to as "manufacturers," with consumption between 1.5 and 15 mt as SMEs, and below 1.5 mt as VSEs.

Residential air-conditioning manufacturing sector

56. Under stage II of the HPMP, five enterprises[17] were supported to convert from HCFC-22 to HFC-32 or R-454B.[18] At the 84th meeting, it was noted that all the enterprises except one manufactured both HCFC-22- and R-410A-based units on their manufacturing lines. At the 88th meeting it was agreed that the enterprises would implement a phase-out of R-410A-based units manufactured for the local market by 2028[19] in order to ensure the successful introduction of HFC-32. By 2024, the manufacturing of HFC-32 based-units in these enterprises accounted for 0.04 per cent of the units produced between 1 January 2023 and 13 March 2024. UNIDO noted that of the three enterprises had signed contracts to meet the timeline for the full phase-out of R-410A-based units for the local market, which would be replaced by HFC-32 technology by 1 January 2025, or 31 December 2026. At the 94th meeting in 2024, it was also clarified that the five enterprises being converted did not comprise the entire residential AC manufacturing sector and that several other enterprises in this sector were manufacturing products based on R-410A. Following this, the Executive Committee decided that the fourth tranche, which would include funding for the two residential AC manufacturing enterprises that had not yet signed contracts for incremental operating costs (IOCs) of the HPMP could be submitted at the same meeting as the KIP.[20] In 2024, a substantial increase in HFC-32 consumption can be attributed to the manufacturing with HFC-32 in these enterprises.

57. During the KIP preparation, four manufacturers, one SME and one VSE were identified in the residential AC manufacturing sector that had not been part of the conversion projects under the HPMP, which manufacture R-410A-based units and are eligible under the HFC phase-down. While there was no growth in HFC consumption among these enterprises in 2020, the consumption has grown steadily since 2021, particularly in 2021 and in 2024, with a 21 per cent and 57 per cent growth respectively. While two of the enterprises consumed less than 15 mt of HFCs from 2019 to 2021 and thus would have been considered as SMEs, by 2023 four enterprises, and by 2024 all five enterprises were consuming more than 15 mt of R-410A. All of the R-410A consumption in the country has been attributed to these 11 enterprises in residential AC (those assisted under HPMP and those identified under the KIP). This sector would be addressed during stage I of the KIP to ensure the sustainability of the conversions under the HPMP.

Commercial AC manufacturing sector

58. Six enterprises in the commercial AC manufacturing sector received technical assistance under the HPMP to convert to low-GWP HFCs and four of these as well as a seventh enterprise, which was not included the project, were reported to have begun manufacturing indirect evaporative cooling (IEC) units. While the survey did not identify the number of enterprises using HFCs in this sector some consumption of R-407C may be attributed to this sector. A demonstration project has been proposed in the commercial AC sector during stage I of the KIP.

Mobile air-conditioning (MAC) manufacturing sector

59. During project preparation, 12 enterprises were identified in the MAC manufacturing sector, some of which have joint foreign ownership. This manufacturing sector relies on HFC-134a and consumes less than 1 per cent of the total HFC consumption in the country in terms of CO_2-eq tonnes. This consumption will be targeted in a future stage.

[17] El-Araby, Fresh, Miraco, Power, and Unionaire
[18] Should the enterprises so decide once the technology became available (decision 84/72(b)).
[19] With three intermediate targets: 25 per cent of products offered to local market by 2025, 50 per cent of products offered to local market by 2026; and 75 per cent of products offered to local market by 2027 (decision 88/70(a)(ii)a.).
[20] Decision 94/35(c)(i)

Aerosol and solvents

60. HFCs are used as propellant in MDIs in Egypt and this consumption has been increasing annually.[21] There is otherwise no consumption of HFCs in industrial solvents in the country. The manufacturing sector for MDIs in Egypt uses only HFC-134a while HFC-227ea is found only in imported pre-charged MDIs. Low-GWP alternatives such as HFC-152a and HFO-1234ze are not currently used in Egypt. This sector will be addressed in a future stage.

Refrigeration and air-conditioning servicing sector

61. There are approximately 100,000 technicians (of which women comprise approximately 5 per cent) and 24,000 workshops consuming HFCs in Egypt. Among these, 75,000 technicians (including 3,000 women) are specialized in AC, while 25,000 technicians (including 2,000 women) are specialized in refrigeration. Approximately 35 per cent of the workforce is employed in formal workshops that adhere to industry standards and regulations, and the remaining 65 per cent work in informal workshops with limited regulatory oversight. The number of technicians working in the MAC servicing sector is estimated at 20,000 (with less than 5 per cent estimated to be women technicians).

62. RAC technical education and vocational training in Egypt are distributed among three main entities: the Ministry of Education and Technical Education, which oversees 285 technical schools with RAC departments staffed by 2,965 teachers specializing in RAC education; the Ministry of Manpower, which manages 27 vocational training centres specifically focused on RAC; and the Productivity and Vocational Training Department (PVTD) under the Ministry of Industry, which oversees several RAC training centres. Under the HPMP, 21 training centres were upgraded and three master training centres and one centre of excellence were established, trainers were trained, and the training curriculum was updated and introduced. One reclamation centre was established, and another is planned and underway.

63. In 2024, a national guideline for the certification of technicians was issued with the Egyptian Standard number 8938/2024 by the Egyptian Organization for Standards. The guideline is based on good practices for RAC equipment operating with low-GWP refrigerants, including the safe handling of flammable refrigerants in the installation and servicing sectors. Efforts to update the national certification for RAC technicians to align with this standard have commenced, involving collaboration between the NOU, the vocational training departments of the Ministry of Manpower and Ministry of Industry, and the Egyptian Organization for Standards.

Domestic, commercial, industrial and transport refrigeration servicing

64. The refrigeration servicing subsectors using HFCs in Egypt include domestic, commercial, industrial and transport refrigeration. The consumption attributed to servicing in the refrigeration subsectors during baseline years from the survey was approximately 37 per cent in mt and 39 per cent in CO_2-eq tonnes making this the highest HFC consuming sector. HFC-134A is the primary HFC used in refrigeration servicing followed by R-404A, and R-407C and with some limited use of R-407F, R-507A, and R-508A.

Residential and commercial air-conditioning servicing

65. The AC servicing subsectors using HFCs in Egypt include residential and commercial AC. The consumption attributed to servicing in the AC subsectors during baseline years from the survey was approximately 13.75 per cent in mt and 14.6 per cent in terms of CO_2-eq tonnes. R-410A is the primary

[21] This consumption in MDI manufacturing had been reported under solvents by the country instead of under aerosol in the CP report. Accordingly, the country will submit revised CP data.

HFC used in residential AC followed by HFC-32. Other HFCs attributed to the AC sector include some HFC-134a (roughly 1 per cent of the use for this substance) and R-417A.

Mobile air-conditioning servicing

66. The MAC servicing sector relies on HFC-134a and amounts to 5 per cent of the total HFC consumption in the country in terms of CO_2-eq tonnes. This sector was nor previously addressed under the HPMP and some servicing sector activities under stage I of the KIP will target this sector.

Firefighting

67. All firefighting systems are imported to Egypt but are filled and serviced in the country; there is no manufacturing in this sector. During the preparation survey, 14 specialized suppliers of firefighting systems were identified and 16 service providers. HFCs comprise 75 per cent of the market for firefighting systems and some of the alternatives used in this sector include nitrogen, CO_2, dry chemicals, water, water mist, and hydrofluoroethers (HFEs) although the latter are under assessment for environmental impact. HFC-227ea is the primary HFC used in servicing firefighting, with some limited use of HFC-236fa. The consumption of HFCs in firefighting amounts to 12 per cent of the total HFC consumption in the country in terms of CO_2-eq tonnes.

Local installation and assembly subsector

68. The proposal, as submitted, referred to enterprises in several manufacturing sectors with consumption of less than 1.5 mt as "installers." However, these enterprises charge equipment on site and as such do not fall under the category of installer as defined in documents UNEP/OzL.Pro/ExCom/92/49 and Corr.1. In the servicing sector survey, 62.15 mt (243,727 CO_2-eq tonnes) was estimated to be in this sector during baseline years; however, a more detailed analysis of this sector was not available.

Manufacturing of blends

69. In 2021, a total of 39.89 mt of HFC blends were manufactured in the country (7.44 mt of R-404A and 32.45 mt of R-410A). Such blending was not reported in any of the other years in the 2020 to 2024 period.

IV. Stage I of the Kigali HFC implementation plan as submitted

Institutional, policy and regulatory framework

70. Egypt ratified the Kigali amendment on 22 August 2023. The licensing and quota system in Egypt has been updated to include HFCs and quotas were issued for 2024. HFCs and other ODS are regulated and controlled through the National Ozone Committee (NOC), which oversees the HPMP and KIP implementation as well as managing the issuance of quotas; the Customs office, which monitors and controls the import and export of controlled substances; and the Customer Protection Agency, which has set in place mechanisms to monitor and deter illegal trade in the marketplace. In 2024, a NOC decision prohibited the issuance of industrial licenses for new manufacturing lines of residential AC based on R-410A. Egypt has also prioritized reducing energy consumption and improving energy efficiency in the country and to that end a decree from the Minister of Environment in 2023 added a representative from the Ministry of Electricity and Power to the NOC.

Phase-down strategy for stage I of the Kigali HFC implementation plan

Overarching strategy

71. Egypt's overarching strategy is based on achieving the compliance requirement for 2029 through the servicing sector activities while using the investment projects to further reduce the country's future needs by converting enterprises in the priority sectors.

Proposed reductions

72. The Government of Egypt forecasted HFC consumption in a business-as-usual scenario (BAU) using an annual growth of 4.3 per cent. The projection is calculated based on the estimated 2024 consumption and projections by Egypt's Ministry of Economy of GDP growth of 4 per cent and a 1.3 per cent population growth for the fiscal year 2024-2025. In this BAU scenario, the growth of HFC consumption is expected to exceed the control level by 2028, as shown in table 6.

Table 6. HFC consumption forecast under the unconstrained scenario, Montreal Protocol limits, and proposed HFC reductions under stage I (CO_2-eq tonnes)

	2025	2026	2027	2028	2029
HFC consumption forecast at an annual growth rate of 4.3 %	17,093,331	17,828,344	18,594,963	19,394,546	20,228,512
Montreal Protocol HFC consumption limits	19,290,350	19,290,350	19,290,350	19,290,350	17,361,315
HFC consumption levels proposed under the KIP	19,290,350	19,290,350	19,290,350	19,290,350	15,161,919*
Proposed reductions from the HFC consumption baseline (%)	freeze	freeze	freeze	freeze	21.40

* Based on the original calculation of the reduction in CO_2-eq tonnes in the submission. The reduction in CO_2-eq tonnes from the original proposal was corrected during project review as shown in table 27.

Proposed activities

73. Stage I includes investment projects in the PU and XPS foam manufacturing sectors, the domestic and commercial refrigeration manufacturing sectors and the residential AC manufacturing sector, as well as non-investment projects in the servicing sector including regulatory and capacity building projects, communications and outreach, and sectoral projects in the residential AC, commercial AC, MDI sector, MAC, RAC, and firefighting sectors, as originally submitted.

Foam manufacturing sectors - UNDP

74. Egypt has proposed conversions in the PU and XPS foam sectors which will be implemented by UNDP. The total requested for the two sectors is US $4,131,206 consisting of US $1,560,431 for PU foam, US $2,195,211 for XPS foam, and a 10 per cent project management cost of US $375,564. This will be discussed by sector below.

I. Polyurethane foam manufacturing sector

75. An investment project is proposed in the PU foam manufacturing sector in one enterprise, El Araby (founded in 2008), to phase out 37.67 mt (41,797 CO_2-eq tonnes)[22] of HFC-365mfc/227ea[23] in the

[22]As submitted, this was based on the 2020-2022 average submitted in the CP data.

[23] 32.77 mt (26,019 CO_2-eq tonnes) of HFC-365mfc and 4.90 mt (15,778 CO_2-eq tonnes) of HFC-227ea. The commonly available blend of HFC-365mfc and HFC-227ea has a composition of 93 per cent and 7 per cent, respectively, of those HFCs. The formulation used by El Araby has a higher percentage content of HFC-227ea given the high temperatures prevalent in Egypt and to better control the endothermic foaming process.

manufacturing of water heaters[24] through conversion to cyclopentane and an umbrella project for 30 SMEs and VSEs to phase out 68.59 mt of HFC-245fa (pure) and 25.68 mt of HFC-245fa contained in imported pre-blended polyols through conversions to cyclopentane. The consumption in the sector is as shown in table 7 below.

Table 7. Consumption of HFC-365mfc/227ea, HFC-245fa pure and contained in pre-blended polyols in PU foam manufacturers for 2020-2024

Enterprise	Substance	2020	2021	2022	2023	2024	Average 2020-2022
Mt							
El Araby	HFC-365mfc/227ea	66.11	68.81	121.83	71.76	77.50	85.58*
30 SMEs and VSEs	HFC-245fa	22.53	67.62	115.61	64.00	116.50	68.59
30 SMEs and VSEs	HFC-245fa contained in pre-blended polyols	21.42	23.78	31.86	27.37	29.00	25.68

* The enterprise level consumption is different from the CP data, which was initially attributed to the enterprise using stockpiles at a level higher than the imports and the data reported in the CP.

76. Funding was requested for two high-pressure injection foaming machines (US $240,000) and for encapsulation, CP tank, piping and electrical adaptations (US $47,200), a safety audit, trials and commissioning (US $40,000), technical assistance (US $50,000), and contingencies of 5 per cent (US $18,860); resulting in a cost of US $396,060 in ICCs. The IOCs were calculated at minus US $27,687; those savings were subtracted from the ICCs for a total project cost of US $368,373. The costs for the umbrella project were calculated based on the cost-effectiveness threshold for HCFCs in the foam sector of 9.78 US $/kg for the phase-out of HFC-245fa pure and contained in imported pre-blended polyols amounting to 94.28 mt (97,108 CO_2-eq tonnes), for a total of US $922,058 and an additional US $270,000 is requested for technical support to three system houses participating in the formulation development and supplying the SMEs/VSEs, for project management, technology development, trials, testing and training. Table 8 shows the reductions, requested amounts, and cost effectiveness (CE) in terms of US $/kg and US $/$CO_2$-eq tonnes.

Table 8. Reductions, requested funding and CE for investment project in PU foam in Egypt

Enterprise	Substance	Phase out		Requested funding (US $)	CE	
		mt	CO_2-eq tonnes		US $/kg	US $/$CO_2$-eq tonne
El Araby	HFC-365mfc	32.77	26,019	368,373	9.78	8.81
	HFC-227ea	4.90	15,778			
Umbrella project for SMEs/VSEs	HFC-245fa	68.59	70,648	670,810	9.78	9.50
	HFC-245fa in imported pre-blended polyol	25.69	26,461	251,248	9.78	9.50
Technical assistance to system houses		n/a	n/a	270,000	n/a	n/a
Total for PU foam sector		**131.95**	**138,905**	**1,560,431**	**11.83**	**11.23**

II. Extruded polystyrene foam manufacturing sector

77. An investment project is proposed in the XPS foam manufacturing sector in two enterprises, Egypt Foam Co. (founded in 2019) and Al Alamiya for Insulation Co. (began manufacturing in 2019), to phase out 386.67 mt (47,947 CO_2-eq tonnes)[25] of HFC-152a used in the sector as a blowing agent in the

[24] El Araby was assisted in stage I of the HPMP to phase-out the use of HCFC-141b in its manufacturing of foam in domestic refrigeration to cyclopentane.

[25] As submitted, this was based on the 2020-2022 average submitted in the CP data.

manufacturing of XPS foams and replace it with CO_2. Table 9 below shows the consumption in the two enterprises and the sector.[26]

Table 9. HFC-152a consumption in XPS foam manufacturers in mt and CO_2-eq tonnes (2020-2024)

Enterprise	2020	2021	2022	2023	2024	Average 2020-2022
Mt						
Egypt Foam Co.	90	103	95	85	93	96.00
Al Alamiya	100	114	112	115	147	108.67
Other	85.45	237.66	222.9	27	41.22	182.00
Sector total	**275.45**	**454.66**	**429.9**	**227**	**281.22**	**386.67**
CO_2-eq tonnes						
Egypt Foam Co.	11,160	12,772	11,780	10,540	11,532	11,904
Al Alamiya for Insulation Co.	12,400	14,136	13,888	14,260	18,228	13,475
Other	10,596	29,470	27,640	3,348	5,111	22,568
Sector total	**34,156**	**56,378**	**53,308**	**28,148**	**34,871**	**47,947**

78. ICCs requested include retrofitting of the extruder at Egypt Foam (US $516,000) and of the extruder at Al Alamiya (US $633,620) as the current systems are too sensitive and for each enterprise, technical assistance (US $50,000); DME tank, including installation and certification (US $85,000); single head blowing agent pump (US $60,000); retrofit of plumbing (US $60,000); exhaust/ventilation retrofit (US $60,000), gas sensor system (US $30,000), manufacturing trials and safety audit (US $65,000), and 10 per cent contingencies. IOCs of US $0.57/kg are requested due to the higher cost of technology for a total of US $54,720 for Egypt Foam Co. and US $61,940 for Al Alamiya for Insulation Co. based on their respective average 2020-2022 consumption. The total requested for Egypt Foam Co. is US $1,029,320 and US $1,165,891 for Al Alamiya, as shown in table 10.

Table 10. Phase out, requested funding and CE for investment project in XPS foam in Egypt

XPS foam sector	Phase out		Requested funding (US $)	CE	
	mt	CO_2-eq tonnes		US $/kg	US $/$CO_2$-eq tonne
Egypt Foam Co.	96.00	11,904	1,029,320	10.72	86.47
Al Alamiya	108.67	13,475	1,165,891	10.73	86.52
Other	182.00	22,568	n/a	n/a	n/a
Total	**386.67**	**47,947**	**2,195,211**	**5.68**	**45.78**

Domestic and commercial refrigeration and residential AC manufacturing sectors - UNIDO

79. Egypt has proposed conversion projects for manufacturers, SMEs, and VSEs in the domestic refrigeration, commercial refrigeration, and residential AC sectors. These will be implemented through UNIDO and will be discussed by sector below. The total requested for the three sectors is US $15,735,232 consisting of US $9,215,527 for domestic refrigeration, US $1,366,823 for commercial refrigeration, US $3,722,407 for residential AC, and a 10 per cent project management cost of US $1,430,476 for the phase out of 613.44 mt of HFCs[27] or 993,926 CO_2-eq tonnes.

[26] While the consumption of the two enterprises does not equal the consumption of HFC-152a reported in the CP report, the Government has committed to phasing out the entire consumption of HFC-152a as per the CP report of which all is attributed to this sector.

[27] HFC-134a-422.04 mt/603,518 CO_2-eq tonnes; R-404A-11.15 mt/14,318 CO_2-eq tonnes; R-407A-0.55 mt/976 CO_2-eq tonnes; and R-410A-179.70 mt/375,114 CO_2-eq tonnes.

I. Domestic refrigeration manufacturing sector

80. Six enterprises manufacturing domestic refrigeration units would phase-out 345.59 mt[28] (494,197 CO_2-eq tonnes) of HFC-134a through conversion projects in five enterprises[29] with a total of 22 manufacturing lines. Five SMEs would phase-out 17.38 mt (24,858 CO_2-eq tonnes) of HFC-134a in five manufacturing lines, and four VSEs enterprises would phase-out 2.85 mt (4,069 CO_2-eq tonnes) of HFC-134a in four manufacturing lines. All enterprises would convert to R-600a phasing out a total of 365.82 mt (523,124 CO_2-eq tonnes) of HFC-134a in 31 manufacturing lines in domestic refrigeration. Table 11 below provides an overview of the enterprises in this sector.

Table 11. Enterprises in domestic refrigeration, units manufactured, manufacturing lines and consumption

Enterprise	Year established	Manufacturing lines		Units (2023)	Consumption (2023)		Sectors for proposed conversion in KIP or covered in previous HPMP stage
		HFC-134a	HC-600a		mt	CO_2-eq tonnes	
Manufacturer							
Electrostar	1986	3	1	321,072	48.96	70,014	PU foam HPMP stage II
Alaska	1978	5	0	230,000	49.00	70,070	
Kiriazi	1986	6	1	244,238	38.82	55,518	Residential AC KIP; PU foam HPMP stage I; PU foam HPMP stage II
Fresh	2012	6	0	1,751,000	158.50	226,655	PU foam HPMP stage I; PU foam and residential AC under HPMP stage II
El Araby	2001	3*		296,331	39.30	56,204	PU foam KIP; PU foam HPMP stage I; residential AC HPMP stage II
Unionaire	2013	2	0	100,038	11.00	15,736	Residential AC HPMP stage II
Subtotal manufactures	***n/a***	***22***	***5***	***2,942,679***	***345.58***	***494,197***	***n/a***
SMEs							
Alradwan International	2008	1	0	33,000	3.24	4,633	Commercial refrigeration KIP
Minlo	2005	1		120,000	4.74	6,774	
Akwarj	2014	1	0	29,000	3.00	4,290	
Mas Electric	2018	1	0	21,000	2.10	3,003	
Trust for Ind.	2017	1	0	21,100	4.31	6,158	Commercial refrigeration KIP
Subtotal SMEs	***n/a***	***5***	***0***	***224,100***	***17.38***	***24,858***	***n/a***
VSEs							
Tredco for Engineering Industries	1989	1	3	13,300	1.40	1,995	PU foam HPMP stage II
Eastern Engineering Enterprises	1996	1		10,000	0.90	1,287	

[28] Conversion project as submitted was based on 2023 consumption, which for some enterprises was subsequently updated.
[29] Funding to convert one enterprise that had already installed equipment to enable the manufacturing of R-600a-based domestic refrigerators was not requested notwithstanding that the enterprise also continued to manufacture HFC-134a-based domestic refrigerators.

Enterprise	Year established	Manufacturing lines		Units (2023)	Consumption (2023)		Sectors for proposed conversion in KIP or covered in previous HPMP stage
		HFC-134a	HC-600a		mt	CO_2-eq tonnes	
Elsaeedy Electrical Appliances	2018	1		10,000	0.34	486	
Tiba	2010	1		680	2.11	301	Residential AC KIP; Commercial AC HPMP stage II
Subtotal VSEs	***n/a***	***4***	***3***	***33,980***	***2.85***	***4,069***	***n/a***
Total for sector	**n/a**	**31**	**8**	**3,200,759**	**365.81**	**523,124**	**n/a**

* El Araby has three factories with one line each producing HFC-134a and R-600a on the same line. Accordingly, no funding was requested to convert the enterprise.

81. The ICCs for the conversion of domestic refrigeration manufacturers include helium-related equipment, R-600a-related equipment, an ultrasonic welding machine, safety equipment and retrofits/ upgrades, assembly line adaptations and spare parts; as well as installation, prototype development and testing, training, safety certification, and contingencies. The total ICCs for manufacturing enterprises in this sector amounts to US $6,999,685. The details of the calculated ICCs are presented in table 12.

Table 12. ICCs for conversion project in manufacturers in the domestic refrigeration sector

Enterprise	Electrostar		Alaska		Kiriazi		Fresh		Unionaire	
Items	**Qty**	**US $**	**Qty**	**US $**	**Qty**	**US $**	**Qty**	**US $**	**Qty**	**US $**
Helium leak detection system (charging unit; detector and calibrator; and recovery unit)	3	215,550	1	71,850	1	71,850	6	431,100	2	143,700
R-600a supply system, (charging machine, pump, and leak detectors	3	231,450	5	385,750	6	462,900	6	462,900	2	154,300
Ultrasonic welding machine	3	90,000	5	150,000	6	180,000	6	180,000	2	60,000
Safety infrastructure (ventilation; safety control and gas monitoring; antistatic flooring)	3	188,100	5	313,500	6	376,200	6	376,200	2	125,400
Assembly line adaptation	3	27,000	5	45,000	6	54,000	6	54,000	2	18,000
Spare parts	3	36,000	5	60,000	6	72,000	6	72,000	2	24,000
Subtotal equipment	***n/a***	***788,100***	***n/a***	***1,026,100***	***n/a***	***1,216,950***	***n/a***	***1,576,200***	***n/a***	***525,400***
Installation, delivery, prototype development, testing and training	3	146,100	5	243,500	6	292,200	6	292,200	2	97,400
Safety audit and certification	3	60,000	5	100,000	6	120,000	6	120,000	2	40,000
Contingencies on equipment (6.4 to 7.3 per cent)	n/a	57,300	n/a	66,760	n/a	78,675	n/a	114,600	n/a	38,200
Total ICCs	**n/a**	**1,051,500**	**n/a**	**1,436,360**	**n/a**	**1,707,825**	**n/a**	**2,103,000**	**n/a**	**701,000**

82. For domestic refrigeration, an IOC of US $5.75/kg was used as per the threshold agreed under decision 95/86(a). Table 13 shows the IOCs, the total project cost, and the cost-effectiveness as proposed for domestic refrigeration manufacturers.

Table 13. IOC, ICC, requested funding, and cost-effectiveness for manufacturers in domestic refrigeration

Enterprise	No. of lines	Consumption (2023)		Requested funding			CE	
		kg	CO_2-eq tonnes	IOC (US $)	ICC (US $)	Total (US $)	US $/kg	US $/$CO_2$-eq tonne
Electrostar	3	48,961	70,014	281,526	1,051,500	1,333,026	27.23	19.04
Alaska	5	49,000	70,070	281,750	1,436,360	1,718,110	35.06	24.52
Kiriazi	6	38,824	55,518	223,238	1,707,825	1,931,063	49.74	34.78
Fresh	6	158,500	226,655	911,375	2,103,000	3,014,375	19.02	13.30
Unionaire	2	11,004	15,736	63,273	701,000	764,273	69.45	48.57
El Araby*	3	39,304	56,204	n/a	n/a	n/a	n/a	n/a
Total	**25**	**345,584**	**494,197**	**1,761,162**	**6,999,685**	**8,760,847**	**25.35**	**17.73**

* Baseline equipment already includes R-600a-based equipment and enterprise already manufactures some R-600a domestic refrigerators

83. The total estimated funding required for the conversion of the five SMEs in the domestic refrigeration manufacturing sector is US $2,476,020; however, based on decision 95/86(d)(i), the amount requested of US $315,732 was calculated at US $18.16/kg (32 per cent above the cost-effectiveness threshold of US $13.76 for manufacturers in domestic refrigeration for SMEs with HFC consumption of 15 metric tonnes or less), and the cost-effectiveness in terms of CO_2-eq tonnes is 12.70 US $/$CO_2$-eq tonne per project. The details of the calculated costs and the requested amounts are presented in table 14.

Table 14. Calculated costs, requested funding, and cost effectiveness for SMEs in domestic refrigeration with consumption of less than 15 mt

Enterprise	No. of lines	Consumption (2023)		Calculated costs			Requested funding (US $)
		kg	CO_2-eq tonnes	ICC (US $)	IOC (US $)	Total (US $)	
Alradwan International	1	3,240	4,633	350,500	106,590	457,090	58,849
Minlo	1	4,737	6,774	350,500	387,600	738,100	86,039
Akwarj	1	3,000	4,290	350,500	93,670	444,170	54,490
Mas Electric	1	2,100	3,003	350,500	67,830	418,330	38,143
Trust for Ind.	1	4,306	6,158	350,500	67,830	418,330	78,211
Total	**5**	**17,383**	**24,858**	**1,752,500**	**723,520**	**2,476,020**	**315,732**

84. The four VSEs have a consumption of less than 1.5 mt and the requested funding for these has been based on a cost-effectiveness of US $34.40/kg (based on decision 95/86(e) where enterprises with consumption of less than 1.5 metric tonnes could receive funding of up to 2.5 times the agreed cost-effectiveness threshold specified for manufacturers); however, a minimum of US $30,000 per enterprise is requested. The details of the calculated costs and the requested amounts are presented in table 15.

Table 15. Requested funding and cost-effectiveness for VSEs in domestic refrigeration with consumption of less than 1.5 mt

Enterprise	No. of lines	Consumption 2023		Requested IOC	CE	
		kg	CO_2-eq tonnes	CE US $34.40/kg and min of US $30,000	US $/kg	US $/$CO_2$-eq tonnes
Tredco	1	1,395	1,995	47,988	34.40	24.05
Eastern Engineering Enterprises	1	900	1,287	30,960	34.40	24.06
Elsaeedy Electrical Appliances	1	340	486	30,000	88.24	61.73
Tiba	1	211	301	30,000	142.31	99.67
Total	**4**	**2,846**	**4,069**	**138,948**	**48.82**	**34.15**

II. Commercial refrigeration manufacturing sector

85. As submitted, one enterprise, Miraco, is considered as a manufacturer and would phase out a total of 21.50 mt (30,745 CO_2-eq tonnes) of HFC-134a and 8.50 mt (3,922 CO_2-eq tonnes) of R-404A in one

manufacturing line. Six SMEs would phase-out 33.10 mt (47,336 CO_2-eq tonnes) of HFC-134a in nine manufacturing lines and 2.36 mt (9,255 CO_2-eq tonnes) of R-404A in one manufacturing line, and four VSEs would phase out 1.62 mt (2,313 CO_2-eq tonnes) of HFC-134a, 0.29 mt (1,141 CO_2-eq tonnes) of R-404A, and 0.55 mt (976 CO_2-eq tonnes) of R-407A in four manufacturing lines. All enterprises would convert to R-290 or an HFO blend such as R-452B and in total would phase out 67.92 mt (95,688 CO_2-eq tonnes) in 14 manufacturing lines, as shown in table 16 below.

Table 16. Enterprises in commercial refrigeration, units manufactured, manufacturing lines and 2023 consumption

Enterprise	Year established	HFC(s)	No. of lines	Units (2023)	Consumption (2023)		Sectors for proposed conversion in KIP or covered in previous HPMP stage
					mt	CO_2-eq tonnes	
Manufacturer							
Miraco*	1995	HFC-134a	1	4,300	21.50	30,745	Residential and commercial AC under HPMP stage II
		R-404A		1,700	8.50	3,922	
Subtotal manufacturer	***n/a***	***n/a***	***1***	***6,000***	***30.00***	***34,667***	***n/a***
SMEs							
Alradwan International	2008	HFC-134a	1	65,000	13.00	18,590	Domestic refrigeration KIP
Trust for Ind.	2017	HFC-134a	1	14,650	4.33	6,188	Domestic refrigeration KIP
Everest Egypt Industrial**	2003	HFC-134a	1	35,349	9.50	13,587	PU foam HPMP stage II
ICEBERG	2019	HFC-134a	1	2,500	1.07	1,530	
		R-404A		1,385	2.36	9,255	
Egyptian Gulf Co.	2006	HFC-134a	2	7,890	2.68	3,837	
Makka for refrigerators	2006	HFC-134a	3	21,000	2.52	3,604	
Subtotal SMEs	***n/a***	***n/a***	***9***	***147,774***	***35.46***	***56,591***	***n/a***
VSEs							
Ratomag	1975	HFC-134a	1	169	0.18	255	
		R-404A		40	0.04	165	
DRIC	1988	HFC-134a	1	3,333	1.00	1,430	
		R-407A		28	0.55	976	
MOG	1961	HFC-134a	1	1,070	0.30	428	PU foam HPMP stage I
		R-404A		830	0.25	976	
Masria	1985	HFC-134a	1	1,550	0.14	200	
Subtotal VSEs	***n/a***	***n/a***	***4***	***7,020***	***2.46***	***4,430***	***n/a***
Total	**n/a**	**n/a**	**14**	**160,795**	**67.92**	**95,688**	**n/a**

*As submitted, Miraco had 30 mt of HFC consumption. This consumption was subsequently revised to a total of 7 mt and manufacturing 6,000 units in 2023, and an average consumption in 2020-2022 of 5.5 mt with average manufacturing of 5,533 units.
** Everest Egypt Industrial also manufactures R-290-based bottle coolers and is a United Arab Emirates-owned enterprise.

86. The ICCs for the conversion of one manufacturer to R-290 are similar to those in the domestic refrigeration sector described in paragraph 78 above but with R-290 related equipment. The total ICCs for the manufacturing enterprise in this sector amounts to US $350,500. The details of the calculated ICCs are presented in table 17.

Table 17. ICCs for conversion project in one manufacturer in the commercial refrigeration sector

Enterprise	**Miraco**	
Items	**Quantity**	**US $**
Helium leak detection system	1	71,850

Enterprise	Miraco	
Items	**Quantity**	**US $**
R-290 related supply system, charging machines and leak detectors	1	77,150
Ultrasonic welding machine (US $30,000)	1	30,000
Safety related infrastructure	1	62,700
Assembly line adaptation	1	9,000
Spare parts	1	12,000
Subtotal	***n/a***	***262,700***
Installation, delivery, prototype development, testing and training	1	48,700
Safety audit and certification	1	20,000
Contingencies on equipment (6.4 to 7.3 per cent)		19,100
Total ICCs	**n/a**	**350,500**

87. For the commercial refrigeration manufacturer, the requested IOC was calculated at US $3.00/kg. Table 18 shows the IOC, total project cost, and the cost-effectiveness as proposed for the commercial refrigeration manufacturer.

Table 18. IOC, ICC, requested funding, and cost-effectiveness for commercial refrigeration manufacturer

Enterprise	No. of lines	Consumption (2023)		Requested funding			CE	
		kg	CO_2-eq tonnes	IOC (US $)	ICC (US $)	Total (US $)	US $/kg	US $/$CO_2$-eq tonne
Miraco	1	30,000	34,667	90,000	350,500	440,500	14.68	12.71

88. The total funding calculated for the conversion of the six SMEs in the commercial refrigeration manufacturing sector is US $2,197,263, with no ICCs calculated for the enterprise Trust for Ind. and with separate IOCs calculated for the conversion of HFC-134a and R-404A for ICEBERG. However, based on decision 95/86(d)(i), the amount requested was calculated at US $21.78/kg (32 per cent above the CE threshold of US $16.50 for manufacturers in commercial refrigeration for SMEs with HFC consumption of 15 metric tonnes or less), and the CE in terms of CO_2-eq tonnes is 15.23 US $/$CO_2$-eq tonne for each enterprise with only HFC-134a to convert and US $6.93/$CO_2$-eq tonne for ICEBERG for the conversion of both HFC-134a and R-404A. The details of the calculated costs and the requested amounts are presented in table 19.

Table 19. Calculated costs, requested funding, and cost-effectiveness for SMEs in commercial refrigeration with consumption of less than 15 mt

Enterprise	No. of lines	Consumption (2023)		Calculated costs			Requested funding (US $)
		kg	CO_2-eq tonnes	ICC (US $)	IOC (US $)	Total (US $)	
Alradwan International	1	13,000	18,590	350,500	227,500	578,000	283,140
Trust for Ind.	1	4,328	6,188	0	51,275	51,275	94,264
Everest Egypt industrial	1	9,502	13,587	350,500	51,275	401,775	206,954
ICEBERG	1	3,430	10,785	350,500	13,598*	364,098	74,705
Egyptian Gulf Co.	2	2,683	3,837	350,500	27,615	378,115	58,436
Makka for refrigerators	3	2,520	3,604	350,500	73,500	424,000	54,886
Total	**5**	**35,463**	**56,591**	**1,752,500**	**444,763**	**2,197,263**	**772,385**

* The calculated IOCs were US $8,750 for HFC-134a and US $4,848 for R-404A.

89. The four VSEs have a consumption of less than 1.5 mt, and the requested funding for these has been based on a cost-effectiveness of US $41.25/kg (based on decision 95/86(e) where enterprises with consumption of less than 1.5 metric tonnes could receive funding of up to 2.5 times the agreed CE threshold specified for manufacturers) or US $30,000, whichever is lower. The details of the calculated costs and the requested amounts are presented in table 20.

Table 20. Requested funding and cost effectiveness for VSEs in commercial refrigeration with consumption of less than 1.5 mt

Enterprise	No. of lines	Consumption 2023		Requested funding (US $)	CE	
		kg	CO_2-eq tonnes		US $/kg	US $/$CO_2$-eq tonnes
Ratomag	1	220	420	30,000	136.26	71.43
DRIC	1	1,550	2,406	63,938	41.25	26.57
MOG	1	549	1,404	30,000	54.64	21.37
Masria	1	140	200	30,000	214.29	150.00
Total	**4**	**2,459**	**4,430**	**153,938**	**62.60**	**34.75**

III. *Residential air-conditioning manufacturing sector*

90. Four manufacturers in the residential AC sector would phase-out 169.25 mt (353,320 CO_2-eq tonnes)[30] of R-410A through conversions of six manufacturing lines, one SME would phase-out 9.95 mt (20,779 CO_2-eq tonnes) and one VSE would phase-out 0.49 mt (1,015 CO_2-eq tonnes) of R-410A in 1 manufacturing line each. All enterprises would convert to HFC-32, phasing out a total of 179.70 mt (375,114 CO_2-eq tonnes) of R-410A in eight manufacturing lines in residential AC. Table 21 below provides an overview of the enterprises in this sector.

Table 21. Enterprises in residential AC, units manufactured, manufacturing lines and 2023 consumption

Enterprise	Year established	No. of lines	Units manufactured (2023)	Consumption 2023	
				mt	CO_2-eq tonnes
Manufacturer					
Kiriazi*	2017	1	39,440	41.40	86,431
Raya Electric	2019	1	30,738	27.66	57,749
Free Air	2016	3	62,650	64.55	134,754
Tiba**	2010	1	24,697	35.63	74,386
Subtotal manufactures	***n/a***	***6***	***157,525***	***169.25***	***353,320***
SME					
Elteriak	2018	1	10,000	9.95	20,779
Subtotal SMEs	**n/a**	**1**	**10,000**	**9.95**	**20,779**
VSE					
Helwan Industries	?	1	400	0.49	1,015
Subtotal VSE	**n/a**	**1**	**400**	**0.49**	**1,015**
Total	**n/a**	**8**	**167,925**	**179.70**	**375,114**

* Sectors for proposed conversion in KIP or covered in previous HPMP stage: Domestic refrigeration KIP and PU foam HPMP stage II

** For Tiba due to reduced volume in 2023, not experience by other manufacturers, the consumption and manufacturing in baseline years was used instead of the 2023.

91. The ICCs for the conversions of residential AC manufacturers include charging and recovery-related equipment, leak detection equipment, an ultrasonic welding machine, safety related equipment, assembly line adaptations and spare parts for which the quantity is based on the number of manufacturing lines. In addition, the ICCs include installation, delivery, training, consultants, safety certification and contingencies. The total ICCs for manufacturing enterprises in this sector amount to US $2,489,800. The details of the calculated ICCs are presented in table 22.

Table 22. ICCs for conversion project in manufacturers in the residential AC sector

Enterprise	Kiriazi	Raya Electric	Free Air	Tiba
Number of lines	1	1	3	1

[30] Conversion project as submitted was based on 2023 consumption.

Enterprise	Kiriazi	Raya Electric	Free Air	Tiba
Charging and recovery: charging machine, refrigerant supply pumps, and recovery machine	92,000	92,000	276,000	92,000
Leak detection: Industrial leak detector, including calibration, and hand-held leak-detector for HC	17,000	17,000	51,000	17,000
Ultrasonic welding machine	30,000	30,000	90,000	30,000
Safet related: ventilation; safety control and gas monitoring system for charging area; antistatic floor charging area; ventilation for storage area; antistatic floor storage area	93,700	93,700	255,100	93,700
Assembly line adaptation and run test area	89,000	89,000	267,000	89,000
Spare parts	20,000	20,000	60,000	20,000
Subtotal	***341,700***	***341,700***	***999,100***	***341,700***
Installation, delivery, training and consultants	33,700	33,700	101,100	33,700
Safety certification	20,000	20,000	60,000	20,000
Contingencies on equipment (7.0 to 7.2 per cent)	23,900	23,900	71,700	23,900
Total ICCs	**419,300**	**419,300**	**1,231,900**	**419,300**

92. For residential AC IOCs based on manufacturing at US $6.5/unit rather than based on refrigerant consumption of US $7.60/kg as per decision 95/86(a). This is requested as the manufacturing in this sector is more relevant to the number of lines, which must all be converted to ensure successful migration away from R-410A. Table 23 shows the IOC as well as the total project cost and the cost-effectiveness as proposed for residential AC manufacturers.

Table 23. IOC, ICC, requested funding, and cost-effectiveness for residential AC manufacturers

Enterprise	No. of lines	Units manufactured (2023)	Consumption (2023)		Requested funding			CE	
			kg	CO_2-eq tonnes	IOC (US $)	ICC (US $)	Total (US $)	US $/kg	US $/$CO_2$-eq tonnes
Kiriazi	1	39,440	41,404	86,431	256,360	419,300	675,660	16.32	7.82
Raya Electric	1	30,738	27,664	57,749	199,797	419,300	619,097	22.38	10.72
Free Air	3	62,650	64,553	134,754	407,225	1,231,900	1,639,125	25.39	12.16
Tiba	1	24,697*	31,321	65,383	160,531	419,300	579,831	16.27	7.79
Total	**6**	**157,525**	**169,255**	**353,320**	**1,023,913**	**2,489,800**	**3,513,713**	**20.76**	**9.94**

* For Tiba the average manufacturing from 2020-2021, shown in this table, was used in the calculation. The IOCs for the enterprises was calculated using the 2023 manufacturing.

93. The requested funding to convert one SME in the residential AC manufacturing sector is US $178,694 based on cost-effectiveness threshold of US $17.95/kg (32 per cent above the cost-effectiveness threshold of US $13.60, based on decision 95/86(d)(i)), the amount requested was calculated at, as presented in table 24.

Table 24. Calculated costs, requested funding, and cost-effectiveness for SMEs in residential AC with consumption of less than 15 mt

Enterprise	No. of lines	Consumption 2023		Calculated costs			Requested funding (US $)
		kg	CO_2-eq tonnes	ICC (US $)	IOC (US $)	Total (US $)	
Elteriak	1	9,954	20,779	419,300	65,000	484,300	178,694
Total	**1**	**9,954**	**20,779**	**419,300**	**65,000**	**484,300**	**178,694**

94. The total funding calculated for the conversion of one VSE in the residential AC manufacturing sector is US $30,000 with based on a cost-effectiveness of US $34.00/kg (based on decision 95/86(e) where enterprises with consumption of less than 1.5 metric tonnes could receive funding of up to 2.5 times the

agreed cost-effectiveness threshold specified for manufacturers) and using a minimum of US $30,000. The details of the calculated costs and the requested amounts are presented in table 25.

Table 25. Calculated costs, requested funding, and cost-effectiveness for VSEs in residential AC with consumption of 1.5 mt or less

Enterprise	No. of lines	Units manufactured (2023)	Consumption 2023		Requested IOC	CE	
			kg	CO_2-eq tonnes	US $34.00/kg and min of US $30,000	US $/kg	US $/$CO_2$-eq tonnes
Helwan Industries	1	400	486	1,015	30,000	61.73	29.57
Total	**1**	**400**	**486**	**1,015**	**30,000**	**61.73**	**29.57**

Non-investment activities in the servicing and other sectors

95. Non-investment activities in the servicing, MDI and firefighting sectors are proposed for implementation under stage I and the first tranche and their cost breakdown are presented in table 26.

Table 26. Non-investment activities in the servicing, MDI and firefighting sectors and their costs in stage I and the first tranche of the KIP for Egypt as submitted

Component	Activity	Agency	Cost (US $)	
			Stage	First tranche
1. Regulatory framework and control mechanism	Strengthening the HFC policy and regulatory framework: • Review and update the policy and regulatory framework for HFC phase-down; • Updating labour competency standards, development/updating of safety standards for natural refrigerants, and other codes and standards; • Stakeholder meetings/workshops/dissemination activities on regulatory adjustments; • Training for relevant governmental institutions on legal and regulatory measures; • Development of a RAC sector circular economy model; • Study on the economic impact of subsidy or tax measures in the residential RAC sector; and • Creating a registry of medium and large end users and a process for updating it.	UNDP	250,000	125,000
	Training programme on updated HFC control policies and regulations: • Six training courses for customs/border control officers; three training sessions for importers; designing/updating training materials including a border control handbook; • Developing an application to assist customs officers in control and enforcement of regulations and an electronic-based training programme; • Purchase of 10 refrigerant identifiers and a new gas Chromatograph for customs central laboratory; and • Review and update of licensing and quota system procedures including accounting for control of quotas in CO_2-eq tonnes.		322,000	88,700
	Gender equality programme: • Recruiting a specialist and study RAC sector gender equality including identification of barriers and key action areas, and developing an action plan for gender equality; and • Promotional activities to encourage participation of women in implementation, including six workshops for 50 to 80 stakeholders each and the development of promotional materials.		156,000	78,000

Component	Activity	Agency	Cost (US $)	
			Stage	First tranche
	Subtotal regulatory framework and control mechanism	*UNDP*	*728,000*	*291,700*
2. Capacity building of technicians	Review/update of standards, guidelines and RAC curriculum: • Review/update codes of practices covering all sectors and newer technologies; • Developing a standard and guidelines for MAC servicing and translation of materials for dissemination; • Conducting awareness campaigns and workshops for stakeholders, including staff from training institutions, national associations, trainers, regulators, and recycling centre operators; and • Updating the MAC training curriculum ensuring links to nationally adopted standards.	UNIDO	80,000	80,000
	Extending technician certification to the MAC sector: • Establishing committee with technical experts and national stakeholders to prepare new certification based on the updated MAC curriculum; • Creating a database of potential MAC service technician for certification; • 23 sensitization workshops across the country to promote MAC certification; and • Training of 100 assessors for MAC certification.		250,000	95,000
	Provision of tools to 900 MAC and RAC workshops:[31] • Survey to identify MAC and RAC workshops and needs and purchase and delivery of equipment		2,295,000	510,000
	Establish five training centres for MAC and establish/upgrade five RAC training centres for five regions: [32] • Study and consultation with MAC manufacturers to identify centres and needs; • Procuring tools and engaging a safety expert; and • Linking established centres with other outreach activities.		1,000,000	418,000
	Training and testing of 1,000 MAC and 1,000 RAC technicians: • Three-day training sessions through centres of excellence and training institutes on good practices, brazing competency, and safe use of flammable refrigerants and preparation for certification testing.		400,000	160,000
	After-sales training of 1,250 technicians at major brand RAC and MAC service centres: • In-depth instruction in diagnostics and troubleshooting, using appropriate tools and techniques, safety and industry standards.		250,000	10,0000
	Subtotal capacity building of technicians	*UNIDO*	*4,275,000*	*1,363,000*
3. Outreach and communica-tion	Campaigns in various sectors (MDI, MAC, RAC) to raise awareness on phase-down and on energy efficiency and sustainable cooling: • Producing outreach materials, biannual round tables, four targeted workshops, and online engagement.	UNIDO	400,000	160,000

[31] Including provision of equipment and tools such as recovery unit for HFCs, various hoses, filter, refrigerant cylinders, electronic scale, vacuum pump, electronic leak detector, screwdriver set, flaring and swaging tools, Allen key set, tube cutter.

[32] Including didactic training modules (three per centre), recovery units, vacuum pumps, refrigerant identifiers, lockring sets, leak detectors, four-valve manifold gauges, and servicing tools. Other expenses would cover safety assessment and safety upgrades/preparations (e.g. alarm system, forced ventilation system, smoke and leak detectors and explosion proof electrical connections).

Component	Activity	Agency	Cost (US $)	
			Stage	First tranche
	Campaigns to promote activities in the foam sectors, and raise awareness of regulatory changes: • Producing outreach materials, targeted workshops and multimedia engagement.	UNDP	180,000	65,000
	Subtotal outreach and communications	*UNIDO*	*400,000*	*160,000*
		UNDP	*180,000*	*65,000*
4. Sectoral projects (a) residential AC	Demonstration project for R-290-based heat pump in residential AC: • Designing project/process for selection of beneficiaries; • Launching incentive for enterprises to offer consumers up to 200 units; • Providing of technical assistance on installation and preventative maintenance, and providing one R-290-based unit for each training centre; and • Monitoring and report on results from the programme.	UNIDO	140,000	15,000
	Demonstration project for two not-in-kind (NIK)[33] direct-indirect evaporative cooling (D-IEC) technologies[34] for residential split applications: • Manufacturing prototype D-IEC units of 5 to 7.5 kW capacity; • Testing in an accredited laboratory for energy efficiency and other features,[35] and comparison to individual split units of the same capacities; • Financial analysis and preparation of materials comparing the net present value of the prototype units with other individual split units; and • Final report and dissemination of results, including workshops and visits to the installations.	UNIDO	125,000	45,000
	Demonstration project of three NIK packaged chilled water systems replacing multi split units • Manufacturing prototype chilled water systems of 10 to 17.5 kW capacity; • Testing in an accredited laboratory for energy efficiency and other features, and comparison to multi split unit of the same capacities; • Financial analysis, and preparation of materials comparing the net present value of the prototype units with other multi split units; and • Final report and dissemination of results, including workshops and visits to the installations.	UNIDO	135,000	55,000
Sectoral projects	Demonstration project for NIK deep sea cooling[36] technology in commercial AC:	UNIDO	360,000	40,000

[33] The term of not-in-kind (NIK) cooling technologies refers to any alternative cooling systems other than vapor compression cooling systems.

[34] Direct-indirect evaporative cooling: First uses indirect evaporative cooling to pre-cool the air without adding moisture. The pre-cooled air then undergoes direct evaporative cooling, further reducing its temperature. The combination maximizes cooling efficiency while controlling humidity levels, making it suitable for a wide range of applications.

[35] Parameters to be tested include energy efficiency, refrigeration capacity, indoor dry bulb temperature, and outdoor dry bulb and wet bulb temperature of the system at Egypt's testing conditions.

[36] Deep sea cooling technologies leverages the naturally cold temperatures found in deep waters to provide cooling for buildings and industrial processes. This method can significantly reduce energy consumption and greenhouse gas emissions compared to conventional air-conditioning systems.

Component	Activity	Agency	Cost (US $)	
			Stage	First tranche
(b) Commercial AC	• Hiring a consultant to determine the viability of district cooling using deep sea cooling technology in two new developments; • Data collection using a remote operated vehicle in deep layers of the Gulf of Aqaba; • Identifying a beneficiary to replace one chiller with a proposed capacity of 350 kW at a hotel with the demonstration technology; • Measuring the performance of existing chiller for six months and of the replacement technology for six months; and • Final report and dissemination of results, including workshops, a study tour to existing installations in Egypt and visits to the installations.			
4. Sectoral projects (c) MAC and RAC sectors	Study tour, local market acceptance and risk assessments for the MAC sector, and study tour for the RAC sector: • Study tour to research and development centres and labs working on low-GWP MAC technologies, including R-744 and R-290 to enable stakeholders to access these technologies for adoption in their manufacturing facilities. • Survey of local market acceptance for natural refrigerants in the MAC sector and a risk assessment to complement the tour in raising interest within the MAC industry in moving directly to natural refrigerants, and workshops to disseminate results; and • Study tour to observe the low-GWP RAC alternatives being used, promoting their adoption, and regulations that have assisted countries to remain in compliance and HFC phase-down targets.	UNIDO	150,000	60,000
4. Sectoral projects (d) MDI sector	Study tour for the MDI sector and research project: • Study tour to research and development centres and laboratories specializing in low-GWP propellant technologies, including HFO-1234ze(E) and R-290, to provide stakeholders with access to cutting-edge innovations suitable for integration into MDI manufacturing; and • Building a prototype based on these technologies and field tests, conducting a market feasibility study covering barriers to introduction and environmental benefits, and workshop to disseminate results.	UNIDO	160,000	60,000
4. Sectoral projects (e) firefighting sector	Technical assistance and monitoring the use of HFCs as fire extinguishing agents: • Developing an inventory of enterprises that import, sell, use, install and refill HFC-based fire control equipment and flood systems; • Promotion and development/printing of booklet on best practices in maintaining and recharging portable fire extinguishers; • Coordinating a working group to develop technical capacity on customs codes to control the trade of cylinders used in the firefighting sector; • Conducting two study tours for industry representatives to organizations which have experience in HFC-free extinguishers; • Demonstration of applications and assessments of reaction time and damage reduction;	UNDP	520,000	162,000

Component	Activity	Agency	Cost (US $)	
			Stage	First tranche
	• Establishing a training and examination centre that is compatible with international standards on fire protection and safe handling of fluorinated gases and their recovery, that can be accredited by a vocational qualification institution; and • Developing informative material for applicators and users.			
4. Sectoral projects (f) refrigerated transport sector	Technical assistance to the refrigerated transport subsector: • Identification all stakeholders in the subsector, the technologies and the applications (container trucks, small trucks, reefers, or marine refrigeration) use consumption trends, and readiness for alternative technologies; and an assessment of the after-sales servicing capabilities; • Workshops for SMEs and installers on new technologies, reducing leakage through design and proper tools; • Technical assistance provided through individual visits arranged with stakeholders.	UNIDO	255,000	102,000
	Subtotal sectoral projects	UNIDO	*1,325,000*	*377,000*
		UNDP	*520,000*	*162,000*
Total servicing sector activities*			**7,428,000**	**2,418,700**
Subtotal for UNIDO			**6,000,000**	**1,900,000**
Subtotal for UNDP			**1,428,000**	**518,700**

* Excluding project monitoring discussed in paragraph 96 and shown in table 27 below.

Project implementation, coordination and monitoring

96. Project monitoring and implementation activities will be implemented through the NOU which will be responsible for data collection, monitoring, and the preparation of reports, while the project management unit (PMU) will be responsible for project implementation and supporting the NOU. UNDP will coordinate with the NOU and PMU for the foam sector investment projects and its non-investment activities, while UNIDO will coordinate monitoring and implementation for the investment projects in the RAC sectors and its non-investment activities as outlined in table 26 above. The cost of monitoring and implementation in investment and non-investment activities is outline in table 27 below.

Total cost of stage I of the Kigali HFC implementation plan

97. The total budget for stage I has been proposed at US $27,866,395. The costs of activities in the refrigeration servicing sector have been proposed at US $7,428,000 in line with decision 92/37. The proposed components and cost of stage I of the KIP are summarized in table 27.

Table 27. Proposed cost of activities to be implemented in stage I of the KIP for Egypt (US $)

Sector	Substances	Phase out		Requested funding (US $)	CE (US $/kg)	Agency
		mt	CO_2-eq tonnes			
PU Foam	HFC-365mfc/HFC-227ea, HFC-245fa, HFC-245fa in pre- blended polyols	131.95	138,905	1,560,431	11.83	UNDP
XPS	HFC-152	386.67	47,947	2,195,211	5.68	UNDP
Subtotal investment project in the foam sectors		*518.62*	*186,852*	*3,755,642*	*7.24*	*UNDP*
Subtotal project management for the foam investment project		*n/a*	*n/a*	*375,564*	*n/a*	*UNDP*
Domestic refrigeration	HFC-134a	365.82	523,124	9,215,527	25.19	UNIDO
Commercial refrigeration	HFC-134a, R-404A, R-407A	67.92	95,688	1,366,823	20.12	UNIDO
Residential AC	R-410A	179.70	375,114	3,722,407	20.72	UNIDO

Subtotal investment project in the RAC manufacturing sector		*613.44*	*993,926*	*14,304,757*	*23.32*	*UNIDO*
Subtotal project management for RAC investment project		n/a	n/a	1,430,476	n/a	UNIDO
Servicing sector	n/a	1,456.47	3,068,017	6,000,000	5.10	UNIDO
				1,428,000		UNDP
Project management for servicing sector	n/a	n/a	n/a	462,000	n/a	UNIDO
				109,956		UNDP
Grand Total	**n/a**	**2,558.53**	**4,248,795**	**27,866,395**	**10.77**	**n/a**

<u>Implementation plan for the first tranche</u>

98. The first funding tranche of stage I of the KIP was submitted at a total amount of US $17,392,844 (including US $2,418,700 for activities in the service sector as shown in table 26 above), to be implemented between June 2025 and December 2027. Detailed information on the activities to be implemented under the first tranche, including adjustments and level of funds agreed are presented in paragraph 145 below and in annex II to the present document.

SECRETARIAT'S COMMENTS AND RECOMMENDATION

V. Comments

<u>Overarching strategy</u>

99. In line with decision 92/44, the Government of Egypt has expressed strong commitment to supporting reductions in HFC consumption in advance of Montreal Protocol targets.[37]

100. In 2023, the Central Bank of Egypt devalued the Egyptian Pound, which resulted in a loss of approximately 40 per cent of its value relative to the US dollar, which in turn limited imports of HFCs relative to the increased market demand. Consumption in 2024 increased by 16 per cent in CO_2-eq tonnes, driven in part by a recovery from the 2023 currency devaluation. Notwithstanding that increase, consumption in 2024 remained 10.7 per cent below the country's HFC baseline.

Eligibility of HFCs contained in imported pre-blended polyols

101. Egypt is the first country to include in its KIP a project to phase out the use of both HFCs pure and contained in pre-blended polyols.[38] In order to sustainably phase out the consumption of the former, the country must also be able to address the latter. The Executive Committee is considering, at the present meeting under agenda item 10(c), an additional analysis of the issue of HFCs contained in imported pre-blended polyols in the PU foam sector in Article 5 countries (decision 95/88(b)). Notwithstanding that the Executive Committee has not yet decided whether it would fund the phase-out of HFCs contained in imported pre-blended polyols, the Secretariat has reviewed the PU foam manufacturing project in Egypt in line with the approach proposed by the Secretariat in document UNEP/OzL.Pro/ExCom/96/59. In particular, eligible costs were determined on the basis of consumption of HFCs sold domestically for use by the PU foam enterprises from 2022 to 2024. In its discussions with UNIDO and UNDP, the Secretariat emphasized that its recommendation on the inclusion of the PU foam manufacturing conversion project was subject to a decision the Executive Committee may take under agenda item 10(c).

102. The Secretariat notes that the stage I proposal for Egypt included the amount and type of HFCs imported in pre-blended polyols for the years 2022 to 2024; the list of 32 PU foam enterprises established

[37] As per the letter of 22 January 2025 from the Ministry of Environment of Egypt to UNIDO.
[38] Previously, the Executive Committee decided that projects to phase out HFCs contained in imported pre-blended polyols in the PU foam sector would be subject to the decision taken by the Committee on whether it would fund the phase-out of HFCs contained in imported pre-blended polyols.

prior to 1 January 2020 that used imported polyol systems, including the amount and type of HFCs contained therein; a plan for the complete phase-out of the use of HFCs contained in imported pre-blended polyols; and a commitment from the country to put in place, by the time the last foam manufacturing plant has been converted to a non-HFC technology, regulations or policies banning the import and the use of HFCs, both pure and contained in pre-blended polyols, in the PU foam sector. In addition, the Secretariat notes that the prioritization of the PU foam manufacturing sector by the country is in line with decision 95/86(g), and that enterprises participating in the project would convert exclusively to low-GWP alternatives.

Institutional, policy and regulatory framework

HFC licensing and quota system

103. In line with decision 87/50(g), UNIDO has confirmed that Egypt has an established and enforceable system of licensing and quotas for monitoring HFC imports/exports in place. Quotas for 2025 have been set at the level of the baseline at 19,290,350 CO_2-eq tonnes. Quotas are allocated to importers based on prior years' consumption, with 10 per cent of the national quota reserved for new importers.

Technical and cost-related issues

PU foam manufacturing sector

104. In clarifying the difference between the use of HFCs reported by the PU foam manufacturing enterprises and that submitted under the CP report, UNDP explained that the enterprises may have inadvertently included flame retardants and other additives in their reported use. Accordingly, it was agreed to assess the project and costs using the data from the CP report for sectoral use, in line with decisions 34/18 and 41/16, and as shown in table 28 below.

Table 28. Consumption of HFCs pure and contained in imported pre-blended polyols in the PU foam manufacturing sector[*]

HFC	2020	2021	2022	2023	2024	Average 2022-2024
HFC-227ea	4.55	4.94	5.20	5.16	0.00	3.45
HFC-245fa	22.53	67.62	115.61	64.00	116.50	98.70
HFC-365mfc	30.45	33.06	34.80	0.00	33.00	22.60
HFC-245fa in imported pre-blended polyol	21.42	23.78	31.86	27.37	29.00	29.41
HFC-365mfc in imported pre-blended polyol	0.00	0.00	0.00	0.00	21.00	7.00
Sector total	**78.95**	**129.40**	**187.47**	**96.53**	**199.50**	**161.17**

[*] As reported in the country's CP reports

105. Regarding the project to convert the PU foam manufacturing line for water heaters at El Araby, the Secretariat noted that due to an inadvertent error, the IOCs requested were calculated per kilogram of PU foam system rather than per kilogram of blowing agent. Correcting that calculation results in overall savings from the implementation of the conversion given the lower price of cyclopentane (US $3/kg) relative to that of the HFC-365mfc/HFC-227ea blend (US $12/kg). In addition, the Secretariat noted that the enterprise's two high-pressure foaming machines could continue to be used with cyclopentane, though encapsulation would be required to do so safely.

106. Notwithstanding that there would be savings in the longer term if the enterprise switched from using HFC-365mfc/HFC-227ea to cyclopentane, the enterprise has to date chosen not to do so. Some investments are needed to enable the enterprise's conversion to cyclopentane, a flammable blowing agent. The Secretariat therefore considered that it would be meaningful to provide assistance to enable the timely

conversion of the enterprise that, in turn, would enable the Government to implement by 1 January 2028 a ban on the import of HFC-365mfc and HFC-245fa pure and contained in imported pre-blended polyols. Accordingly, on an exceptional basis, and without setting a precedent, it was agreed not to consider the incremental operating savings and for the Secretariat to recommend a total of US $101,420 to enable the enterprise to convert to cyclopentane, based on: US $10,000 for technical assistance, trials, and commissioning, noting that the enterprise had already received assistance under the HPMP to convert to cyclopentane in its PU foam manufacturing for domestic refrigerators; US $30,200 for encapsulation of the foaming machines, a cyclopentane storage tank and piping; US $25,000 for ventilation and a gas sensing system; US $17,000 for electrical adaptations; US $10,000 for a safety audit; and a 10 per cent contingency (US $9,220) on those costs. The conversion of El Araby, based on the 2022-2024 average consumption, will result in the phase out of 22.60 mt of HFC-365mfc, 3.45 mt of HFC-227ea, and 7.00 mt of HFC-365mfc contained in imported pre-blended polyols.

107. Regarding the project to convert the 31 SMEs consuming HFC-245fa pure and contained in pre-blended polyols, the Secretariat noted that the price of HFC-245fa is US $10/kg, that of HFO-1233zd is US $17/kg, and that of methyl formate is US $6/kg. If SMEs convert to methyl formate, there would be incremental operating savings, while if SMEs decided to convert to HFO-1233zd there would be IOCs. The Secretariat considers that the SMEs would benefit from assistance to enable their conversions to low-GWP alternatives. Accordingly, on an exceptional basis, and without setting a precedent, and recalling that the eligible systems houses in Egypt had already been provided assistance under the HPMP to enable them to provide downstream users with low-GWP systems, it was agreed the Secretariat would recommend:

(a) US $124,000 for the systems houses to assist 31 downstream SMEs, based on US $1,000 and US $3,000 per downstream user for project management and trials, testing and training, respectively; and

(b) US $192,169 for IOCs for SMEs based on average 2022-2024 imports of HFC-245fa pure and contained in imported pre-blended polyols (128.11 mt) and, on an exceptional basis and without setting a precedent, based on the price of HFO-1233zd, while noting that during implementation the SMEs would have flexibility to select the most appropriate low-GWP blowing agent for their use.

108. On that basis, the total agreed cost to convert the 31 SMEs to methyl formate or HFO-1233zd is US $316,169 and will result in the phase-out of 98.70 mt of HFC-245fa (101,663 CO_2-eq tonnes) and 29.41 mt of HFC-245fa contained in imported pre-blended polyols (30,292 CO_2-eq tonnes). UNDP confirmed that none of the SMEs had received assistance under the HPMP. If during implementation any SME were found to be not eligible, this would be reported to the Executive Committee in line with paragraph 7(c) of the draft Agreement for stage I of the KIP, and the funding associated with its conversion would be returned to the Multilateral Fund, in line with paragraph 7(d) of the draft Agreement.

109. In order to ensure the sustainability of the phase-out, the Government will by 1 January 2028 implement a ban on the import of HFC-245fa and HFC-365mfc, pure and contained in imported pre-blended polyols, and prohibit the use of HFCs in the manufacture of PU foam. HFC-227ea, which is not a foam blowing agent and is added to HFC-365mfc to reduce flammability, will not be banned as it will continue to be used in the firefighting sector.

XPS foam manufacturing sector

110. Although the XPS manufacturing sector would contribute only a minor portion of the phase-out to be achieved, its inclusion under stage I of the KIP is consistent with the flexibility provided to Article 5 countries in decision 95/86(g) and paragraph 13 of decision XXVIII/2, which specified that Article 5 countries would have flexibility to prioritize HFCs, define sectors, select technologies and alternatives, and

elaborate and implement their strategies to meet agreed HFC obligations, on the basis of their specific needs and national circumstances, following a country-driven approach.

111. In reviewing the baseline equipment of each enterprise, the Secretariat noted that a retrofit of Al Alamiya's extruder was not necessary as the extruder was compatible with CO_2 and dimethyl ether (DME); and that the extruder at Egypt Foam Co. was from 2005 and likely approaching the end of its useful life. To better understand the cost of retrofitting the extruder, the Secretariat requested a quote from a supplier of XPS foam manufacturing lines. The freight-on-board price of an entirely new XPS foam manufacturing line compatible with CO_2 and DME is US $569,500, which includes an automatic feeding and mixing system; the primary extruder with hydraulic screen exchanger; blowing agent metering system; secondary single screw extruder and static mixer; slot die with temperature controller; board calibrator and first haul-off system; cooling rack, trimming machine; second haul-off system; online length cutting system; driving roller; horizontal pushing and edge trimming machine; and control system. The price of the primary extruder, blowing agent metering system, and secondary single screw extruder is US $238,000. In addition, the Secretariat noted that HFC-152a was flammable and the enterprises would already have an exhaust and ventilation system to operate safely.

112. Based on the adjustments noted above for the extruder at Al Alamiya and the exhaust and ventilation system for each enterprise; the agreed costs in the original submission include (per enterprise, a DME tank, blowing agent pump and plumbing (US $165,000); gas sensor system (US $30,000), and safety audit (US $15,000)), and US $50,000 per enterprise for both technical assistance and trials, as well as, in line with decision 18/25, 50 per cent of the funding requested to retrofit the extruder at Egypt Foam Co. (i.e., US $258,000); and 10 per cent contingencies, resulting in agreed ICCs of US $286,000 and US $569,800 for Al Alamiya and Egypt Foam Co., respectively.

113. The price of HFC-152a (US $3.24/kg), of CO_2 (US $3.83/kg), and DME (US $2.00/kg), and a blowing agent mixture of 2/3 CO_2 and 1/3 DME, results in incremental operating savings of US $0.01/kg. Based on the 2023 consumption, this results in incremental operating savings of US $1,599 and US $1,182 for Al Alamiya and Egypt Foam Company, respectively.

114. Imports of HFC-152a in 2020-2024 are substantially larger than the consumption reported by the two enterprises. UNDP confirmed there were no additional XPS foam manufacturing enterprises consuming HFC-152a in the country, nor was there use of HFC-152a in glass manufacturing or in the aerosol sector. Accordingly, the Government would prohibit the import of HFC-152a by 1 January 2028 to ensure the sustainability of the conversion.

115. Based on the above, including taking into account the small operating savings, the total agreed incremental costs for the conversion of Al Alamiya is US $284,402 to phase out 115 mt of HFC-152a, and of Egypt Foam Co. is US $568,619 to phase out 85 mt of HFC-152a. The 2023 imports of HFC-152a were 227 mt. Accordingly, the remaining 27 mt of HFC-152a would be deducted from the country's remaining consumption eligible for funding.

Domestic refrigeration manufacturing sector

116. Regarding the proposed IOCs for the manufacturers, the Secretariat noted that the lower price of R-600a (US $4.74/kg) relative to that of HFC-134a (US $6.43/kg) reported by the country, and the reduction in refrigerant charge when converting from HFC-134a to R-600a, would result in savings. In addition, information from industry experts indicates that global manufacturing of R-600a-based compressors for domestic refrigerators exceeds that of HFC-134a-based compressors and the price of such compressors are generally lower, though there may be variations in the relative price of the two compressor types based on the local supply chain and other factors. There is a local compressor manufacturer in the

country that has capacity to serve part of the local domestic refrigeration manufacturing industry[39] and that may be able to provide HFC-134a-based compressors at a competitive price relative to imported R-600a-based compressors. Moreover, some time may be required to establish a supply chain for R-600a-based compressors, which would result in costs that are initially higher relative to those from HFC-134a-based compressors. Accordingly, and considering the cost of safety-related adjustments needed for the conversion to R-600a, it was agreed to set IOCs to zero.

117. The Secretariat and UNIDO had detailed discussions on the ICCs to convert the five large-sized manufacturing enterprises, resulting in the following agreed adjustments:

(a) As submitted, the proposal envisioned using cylinders to store R-600a in the charging area, which personnel would switch out as needed. Given the capacity of the manufacturing lines, the volume of R-600a needed, and the potential risks associated with switching out cylinders filled with R-600a, the Secretariat instead proposed using an isotank with the associated piping, pump, and safety features for US $130,000 per enterprise; except for the enterprise Fresh for which two isotanks, piping and associated safety features were recommended given the higher manufacturing capacity of the enterprise;

(b) As the enterprise Fresh has substantially higher consumption, manufactures more models, and has two factories with a total of six manufacturing lines, increased funding for the safety audits, training, and protype and testing, accordingly;

(c) The cost for a high-capacity R-600a charging machine was increased to US $72,000, in line with the prevailing market price. The costs of industrial and handheld hydrocarbon leak detectors were adjusted to US $12,000 and US $1,000 per unit, respectively, and the ultrasonic welding machine to US $25,000 per unit. The cost of safety infrastructure was reduced to US $20,900 per line, and the contingency costs were adjusted to 10 per cent of the cost of capital equipment;

(d) Based on the baseline equipment at the enterprises, the number of ultrasonic welding machines for Fresh was reduced to five; industrial leak detectors were excluded for Fresh and Unionaire, given that the baseline equipment was already capable of detecting R-600a; the funding for the helium leak detection system for Alaska and for HC leak detectors for Fresh and Unionaire was removed given that these enterprises already had such equipment; and the cost of spare parts was excluded as this was a regular ongoing operating expense for the enterprises.

118. Based on the above adjustments, and in line with the cost-effectiveness threshold specified in decision 95/86(a), the agreed incremental cost to convert the five large-sized domestic refrigerator manufacturers is US $4,157,495, as summarized in table 29 below.

Table 29. 2023 consumption and agreed incremental costs for the five large-sized domestic refrigerator manufacturers

Particulars	Electrostar	Alasaka	Kiriazi	Fresh	Unionaire	Total
Consumption (mt)	48.96	49.00	49.97*	158.50	11.00	**317.43**
Agreed cost (US $)	673,703	674,240	687,601	1,970,536	151,415	4,157,494

* Consumption of the enterprise corrected during the project review process.

[39] The Executive Committee considered but did not approve a project to convert the compressor manufacturer from HFC-134a to R-600a at the 87th meeting. A project for to enhance the energy efficiency of compressors manufactured by the enterprise in the context of the HFC phase-down is expected to be submitted to the 97th or 98th meeting pursuant to decision 95/87.

119. The Secretariat and UNIDO also had detailed discussions on the conversion of El Araby, a 100 per cent locally owned enterprise with domestic refrigeration manufacturing lines established before 1 January 2020, for which funding had not been requested. The enterprise already has the equipment needed to manufacture R-600a-based domestic refrigerators and, therefore, is not eligible for capital costs. However, in 2020, 88 per cent of the refrigerators manufactured by the enterprise were HFC-134a-based and 76 per cent in 2023. Noting that over three-quarters of the enterprise's manufacturing was still HFC-134a based, the Secretariat considered it meaningful to recommend US $50,000 for technical assistance to enable the enterprise to finalize its conversion to R-600a in line with the timeline of the other enterprises assisted under the project, i.e., 1 January 2028.

120. Further to discussions, the incremental cost to convert SMEs consuming between 1.5 mt to 15 mt per year was agreed at US $78,300 per enterprise based on the cost for product redesign, prototype development and testing; modification of refrigerant supply and charging systems; R-600a leak detectors; safety infrastructure and assembly line modifications; inspection, commissioning and safety training; technical assistance; product certification; and contingency. Similarly, the incremental cost to convert enterprises consuming 1.5 mt or less per year was agreed at US $31,150 per enterprise based on the above elements and taking into account the smaller manufacturing volumes.

121. Although enterprises in domestic refrigeration are not included in the definition of SMEs provided in decision 95/86(c), the Secretariat considered that smaller enterprises in domestic refrigeration manufacturing would face similar financial and technical constraints in their HFC phase-down as SMEs in commercial RAC manufacturing. Accordingly, the Secretariat proposed to use the same definition for SMEs in domestic refrigeration as specified in paragraph (c) of decision 95/86, and to use as a guideline the additional funding for SMEs specified in paragraphs (d)(i) and (e) of the same decision. Regarding the latter, UNIDO confirmed that the project included all the remaining enterprises in the sector and that it was understood that Egypt would submit no further requests for funding from the Multilateral Fund for any enterprise in the domestic refrigeration manufacturing sector.

122. Of the nine enterprises with an HFC consumption of less than 15 mt per year, Alradwan International, Minlo, Tredco Engineering Industries and Tiba were not considered as SMEs in line with decision 95/86(c) based on the total consumption at the enterprise or the volume of equipment manufactured. Accordingly, the incremental cost for those enterprises was agreed based on the lower of US $78,300 and a cost effectiveness of US $13.76/kg. For SMEs with consumption above 1.5 mt (i.e., Akwarj, Mas Electric and Trust for Ind.), the incremental cost was agreed based on the lower of US $78,300 and a cost effectiveness of US $18.16/kg and based on the lower of US $31,150 and US $34.40/kg for SMEs with consumption of 1.5 mt and below (Eastern Engineering Enterprises and Elsaeedy Electrical Appliances).

123. Based on the above, the total agreed funding for the projects in domestic refrigeration is US $4,552,856 as summarized in table 30 below.

Table 30. Agreed funding for the domestic refrigeration manufacturing sector

Particulars	No.	Consumption (mt)	Agreed funding (US $)	CE (US $/kg)
Large enterprises (> 15 mt)	5	317.43	4,157,494	13.10
El Araby	1	39.30	50,000	1.27
Enterprises with consumption between 1.5 mt and 15 mt	5	17.38	280,607	16.14
Enterprises with consumption of 1.5 mt or less	4	2.85	64,755	22.75
Total	**15**	**376.97**	**4,552,856**	**12.08**

Commercial refrigeration manufacturing sector

124. The Secretariat sought to better understand whether Miraco manufactured or assembled condensing units, and how the sustainability of the conversion would be ensured, as Miraco was the only enterprise manufacturing condensing units participating in the project and other enterprises could continue to assemble and install HFC-based condensing units after Miraco's conversion. Subsequent to a discussion with UNIDO and given the challenges in ensuring the sustainability of the conversion, it was agreed to remove the conversion of the enterprise from the project.

125. The Secretariat and UNIDO had detailed discussions regarding the conversion of the enterprises manufacturing standalone commercial refrigeration equipment. While the price of HFC-134a (US $6.43/kg) and R-290 (US $6.40/kg) are comparable, the reduction in the refrigerant charge would lead to operating savings. In contrast, the price of R-290-based compressors is higher than that of HFC-134a-based compressors, resulting in agreed IOCs of US $5.50/kg, in line with decision 95/86(a).

126. Of the six enterprises submitted as SMEs with HFC consumption between 15 mt and 1.5 mt per year, in line with decision 23/14, Everest is ineligible as the enterprise is United Arab Emirates-owned. In line with decision 95/96(c)(i), Alradwan is not considered a SME given that the entirety of its HFC consumption is more than 15 mt. ICCs for Alradwan were agreed at US $82,496 given the higher manufacturing capacity of the enterprise. For the remaining enterprises, the ICCs were agreed at US $65,120 per enterprise based on product redesign, prototype development and testing; modification of refrigerant supply and charging systems; safety infrastructure; technical assistance; safety-related training; product certification and safety verification; and 10 per cent contingency. The agreed costs to convert the six enterprises were based on the lower of the agreed ICCs and IOCs, and the applicable cost-effectiveness threshold, which is US $16.50/kg for Alradwan and US $21.78/kg for the remaining SMEs, resulting in agreed costs of US $430,947 to convert the six enterprises, as summarized in table 31 below.

127. For the four enterprises with HFC consumption of 1.5 or less per year, ICCs were agreed at US $25,300 per enterprise. The agreed costs to convert each enterprise were determined based on the lower of the agreed ICCs and IOCs, and the applicable cost-effectiveness threshold. Notwithstanding that the Executive Committee specified a cost-effectiveness threshold for commercial refrigeration that encompasses standalone commercial refrigeration equipment but is not exclusive to it, the Secretariat noted and UNIDO confirmed that the project included all the remaining enterprises manufacturing HFC-based standalone commercial refrigeration equipment and that the Government of Egypt would submit no further requests for funding from the Multilateral Fund for any enterprise manufacturing such equipment. Accordingly, the Secretariat proposed to use the higher cost-effectiveness threshold provided under decision 95/86(e) for the enterprises consuming 1.5 mt or less of HFCs. In that regard, UNIDO confirmed that the enterprise DRIC consumed more than 1.5 mt and, therefore, the applicable threshold for the enterprise is US $21.78/kg, while for the remaining three enterprises the applicable cost-effectiveness threshold is US $41.25/kg, resulting in agreed costs of US $72,255 to convert the four enterprises, as summarized in table 31 below.

128. Based on the above, the total agreed funding for the projects in commercial refrigeration is US $502,202 as summarized in table 31 below.

Table 31. Agreed funding for commercial refrigeration manufacturers

Particulars	No.	Consumption (mt)	Agreed funding (US $)	CE (US $/kg)
Enterprises with consumption between 1.5 mt and 15 mt	6	35.46*	430,947	12.15
Enterprises with consumption of 1.5 mt or less**	4	2.46	71,255	28.97
Total	**10**	**37.92**	**502,202**	**13.24**

* Includes 9.50 mt of HFC-134a at Everest, an ineligible enterprise.
** Includes DRIC that has consumption of 1.55 mt

Residential AC manufacturing

129. The Secretariat recalled the commitment made by the Government under the HPMP to inter alia ensure full control of R-410A- and R-407C-based residential AC equipment, imported or placed in the local market (decision 84/72(e)(i)b) and to secure the uptake of the HFC-32 by the local market (decision 84/72(e)(i)b); and the commitment of the five enterprises participating in the stage II of the HPMP to inter alia actively to participate in efforts to promote the market acceptance of the residential AC equipment based on the agreed technology (decision 84/72(e)(iv)). In addition, the Secretariat recalled the commitment made at the 94th meeting by the enterprises assisted under the HPMP that signed IOC contracts to meet a timeline for full manufacturing for the local market with HFC-32 technology by 1 January 2025 or 31 December 2026. In light of those commitments, and the continued progress by the five enterprises that had converted to HFC-32 under the HPMP as described in paragraphs 25 to 26 of the present document, the Secretariat considered the conversion of enterprises manufacturing with R-410A that had not been assisted under the HPMP to be critical to the sustainable conversion of the residential AC manufacturing sector in the country.

130. On that basis, the Secretariat and UNIDO had detailed discussions on the proposed conversion to HFC-32 of the remaining enterprises manufacturing residential AC units with R-410A in the country, including the eligible costs, the policy measures to ensure sustainability of the conversion, and the associated deductions in HFC consumption eligible for funding. Those issues will be discussed in turn.

131. Information from industry experts indicates that the price of HFC-32-based compressors has changed substantially in the last five years. Global manufacturing of HFC-32-based compressors for residential ACs now exceeds that of R-410A-based compressors. As manufacturing volume, and hence economies-of-scale, are a primary driver of compressor cost, the global price of HFC-32-based compressors is now comparable to or lower than that of R-410A-based compressors, though there may be some variations in the relative price of the two compressor types based on the local supply chain and other factors. The lower price of HFC-32 (US $3.56/kg) relative to that of R-410A (US $7.51/kg), and the expected 10 per cent reduction in charge when converting from R-410A to HFC-32, would lead to operating savings. However, given the need for enterprises to establish their supply chains for HFC-32-based compressors, which may result in costs that are initially higher relative to that of R-410A-based compressors, and minor safety-related adjustments needed for the conversion to HFC-32, it was agreed to set IOCs to zero.

132. The Secretariat and UNIDO had detailed discussions on the ICCs to convert the five of the six enterprises (i.e., Kiriazi, Raya Electric, Free Air, Tiba, and Elteriak) resulting in the following agreed adjustments:

(a) In line with past precedent projects, for all enterprises: price of an ultrasonic welding machine of US $25,000; price of a recovery station for HFC-32 including cylinder for repair area of US $2,750; price of an industrial leak detector capable of detecting HFC-32 of US $12,000; and safety-related measures (including ventilation, gas monitoring system, antistatic floor, etc.) of US $62,700 per line. A 10 per cent contingency is added to those costs;

(b) Adjusted the equipment provided to the enterprises based on whether they already had baseline equipment capable of handling HFC-32, resulting in one industrial leak detector provided to each enterprise except Raya Electric, which already had three such detectors; and if baseline equipment had been purchased after the 1 January 2020 cut-off date for eligible capacity (i.e., supply pump at Free Air);

(c) For those enterprises that did not have a recovery station or handheld leak detectors in their baseline equipment, on an exceptional basis, to provide 50 per cent of the costs for such equipment as it is required for good and good practice; and

(d) On an exceptional basis, to provide an additional US $25,000 per enterprise for those enterprises consuming more than 20 mt for additional safety measures, including a supply line for external refrigerant storage, shut-off valves, and other safety measures.

133. The Secretariat sought to better understand the status of manufacturing at Helwan Industries. The enterprise is associated with the Ministry of Military Production, has not manufactured R-410A-based residential AC units regularly over the last few years, and has a factory manufacturing R-600a-based domestic refrigerators. As reflected by its limited R-410A consumption of the enterprise, the enterprise imported a small number of complete knockdown kits that it charged in its factory. On that basis, it was agreed that UNIDO would provide technical assistance to the enterprise in line with the cost-effectiveness threshold specified under decision 95/86 (i.e., US $6,610). Notwithstanding the limited consumption by Helwan, as well as by Eletriak, it was agreed not to consider those enterprises as SMEs given other manufacturing undertaken by those enterprises. It was nonetheless agreed that Helwan would be able to take advantage of the technical assistance to be provided under the dedicated technical assistance programme for SMEs proposed by the Secretariat for the domestic and commercial refrigeration manufacturing sector, further discussed in paragraph 139 below.

134. Based on the adjustments described in paragraph 129 and 133 above, the enterprises' 2023 consumption, and the cost-effectiveness threshold specified in decision 95/86, the agreed incremental costs to convert the six enterprises amounts to US $1,948,235 as summarized in table 32 below.

Table 32. R-410A consumption and agreed costs to convert six manufacturers of residential AC units

	Kiriazi	**Raya Electric**	**Free Air**	**Tiba**	**Eletriak**	**Helwan**	**Total**
Consumption (mt)	41.40	27.66	64.55	19.69	9.95	0.49	**163.75**
Agreed cost (US $)	361,168	348,086	829,296	267,719	135,374	6,610	**1,948,253**

135. While the residential AC manufacturing enterprises participating under the HPMP ceased manufacturing with R-410A for the local market by 1 January 2025 (Unionaire), 31 December 2025 (Power) or will do so by 31 December 2026 (El Araby, Fresh, and Miraco), the enterprises participating under stage I of the KIP will need additional time to complete their conversion. Accordingly, it was agreed that the six enterprises participating in the KIP will cease manufacturing R-410A-based residential AC units by 1 January 2028. In order to ensure the sustainability of the conversion of sector to HFC-32, the Government will ban the manufacture and import of R-410A-based residential AC units by 1 January 2029.

136. UNIDO noted an Article 5-owned multinational enterprise established a new R-410A residential manufacturing line in 2024. Subsequently, the Ozone Committee took decision #2 of 2024 that prohibits the issuance of approvals or industrial licenses for new manufacturing lines of residential AC based on R-410A. The newly established will convert to HFC-32 by 1 January 2029 with its own resources.

137. As reflected in paragraph 25 of the present document, consumption of R-410A by the five enterprises assisted under the HPMP increased from 716.92 mt in 2020 to 1,407.25 mt in 2022 and then decreased to 1,212.28 mt by 2024. Given the inclusion of that consumption in the baseline years, the conversion from R-410A to HFC-32 by the five residential AC manufacturers assisted under the HPMP should be considered in determining the deductions in remaining HFC consumption eligible for funding from stage I of the KIP. Noting that the country was proposing to phase-down its consumption in advance of the Montreal Protocol targets, and in line with decision 92/44, and on an exceptional basis; and recalling that the enterprises assisted under the HPMP had committed to manufacture HFC-32-based residential AC units for the domestic market but could continue to manufacture R-410A-based residential AC units for export, and that the entire consumption of the enterprises was being phased out without additional assistance from the Multilateral Fund under the stage I of the KIP, it was agreed to only consider the 2020 R-410A consumption of the enterprises assisted under the HPMP when assessing the deductions from remaining consumption eligible for funding (i.e., 716.92 mt, or 1,496,571 CO_2-eq tonnes).

138. At the 95th meeting, the Executive Committee approved funding for the preparation of a project to be submitted under decision 94/60 to inter alia enhance the energy efficiency of residential AC equipment manufactured by enterprises in Egypt as part of their HFC phase-down (decision 95/35). The Secretariat noted with appreciation that the Government intended to submit such a project to the 97th meeting. While IOCs for the conversion from R-410A to HFC-32 were zero, the approval of a project under decision 94/60 would allow additional funding to be provided to the enterprises to improve the energy efficiency of the equipment they manufacture as part of their HFC phase-down. In addition, to ensure the sustainability of a project submitted under decision 94/60 to the 97th meeting, the Secretariat recommends that irrespective of decision 84/72(e)(iii), El Araby, Fresh, Miraco, Power, and Unionaire would be eligible for a project to improve the energy efficiency of residential AC equipment the enterprises manufacture under decision 94/60, subject to the criteria of decision 94/60.

Non-investment activities in the servicing and other sectors

139. Following detailed discussions between the Secretariat and UNIDO, the following adjustments were to the proposed activities were agreed:

(a) Given the large number of RAC and MAC technicians in the country (estimated at 100,000 and 20,000, respectively), to increase the number of MAC and RAC technicians from 1,000 to 1,600 each, and increased the funding accordingly;

(b) Replaced the study tour, local market acceptance and risk assessments for the MAC sector, and study tour for the RAC sector, and the study tour for the MDI sector and research project, for which US $310,000 had been requested, with preparatory technical stakeholder consultation on technology trends, including market acceptance and risk assessment in MAC, large RAC equipment, data centres, and MDI, with an agreed funding of US $150,000;

(c) In the technical assistance for the firefighting sector, UNIDO confirmed that telecommunication and computer rooms, energy buildings, libraries and archives and oil and gas sectors are the main HFC consumers in fire suppression, and that inert gases, CO_2 systems, FK-5-1-12, powder systems and water mist systems can be considered as alternatives. Accordingly, the two demonstration projects will test the performance of several alternatives under different conditions. The parameters measured include speed of reaction, damage of materials, percentage of damage by the fire, possible risks to human lives, and other parameters. On that basis, and in line with precedent projects, the costs were adjusted to US $515,000 after removing the study tours, and increasing the number of workshops to nine;

(d) Noting that the risk to the sustainable conversion to low-GWP alternatives is higher for SMEs than for larger enterprises, that have more technical and financial capacity to enable their conversion, included a dedicated technical assistance programme to assist the SMEs and mitigate that risk at a cost of US $68,400;

(e) Noting the limited information on SMEs in transport refrigeration, and that the project involved the provision of tools to enterprises in the sector, where the beneficiaries and tools required could only be determined during implementation, based on the recommendations of the national consultant that will be hired for this purpose, to adjust the funding to US $205,000; and

(f) In light of the adjustments above, increased the funding for awareness and outreach activities for assessment of alternatives in MDIs, MAC, and RAC sectors, and other activities to promote sustainable cooling to US $595,000.

140. The funding of activities in the firefighting sectors are to be considered on a case-by-case basis. Noting that the activities proposed are like those in the refrigeration servicing sector, it was agreed to fund them together with the servicing sector at US $5.10/kg. The reductions from HFC consumption eligible for funding were therefore based on the average GWP of the servicing sector and firefighting. Accordingly, based on the cost of activities in the servicing sector (including firefighting), agreed at US $7,576,400, reductions from the remaining HFC consumption eligible for funding in the servicing sector amount to 3,162,252 CO_2-eq tonnes, as summarized in table 33.[40]

Table 33. Reductions in remaining HFC consumption eligible for funding in the servicing* sector

Average HFC consumption in the servicing sector in baseline years*	mt	4,390.29
	CO_2-eq tonnes	9,345,372
Agreed funding	US $	7,576,400
Agreed cost-effectiveness threshold	US $/kg	5.10
Reductions from the remaining HFC consumption in the sector*	mt	1,485.57
	CO_2-eq tonnes	3,162,252

* Including consumption to service firefighting equipment.

Project management unit

141. Funding for the project management unit (PMU) was agreed at US $1,347,277 consisting of US $1,118,320 for UNIDO that will cover implementation and project monitoring of the conversion projects in the RAC manufacturing sectors (US $595,281) and UNIDO-led activities in the service sector (US $523,039); and US $228,957 for UNDP which will cover implementation and project monitoring of the conversion projects in the foam sectors (US $108,002) and UNDP-led activities in the service sector (US $120,955).

Total project cost

142. At the total cost of US $17,197,598, stage I of the KIP for Egypt will result in a reduction of 5,795,458 CO_2-eq tonnes from the country's HFC consumption eligible for funding, including 35,850 CO_2-eq tonnes of HFCs contained in imported pre-blended polyols and 1,496,571 CO_2-eq tonnes associated with the conversion of the five residential AC manufacturing enterprises assisted under the stage II of the HPMP, as summarized in table 34 below.

Table 34. Agreed cost of activities to be implemented during stage I of the KIP in Egypt

Sector	**Substances**	**Phase out**		**Agreed funding (US $)**	**CE (US $/kg)**	**Agency**
		mt	**CO_2-eq tonnes**			
PU foam	HFC-365mfc, HFC-227ea	26.05	29,066	101,420	3.07	UNDP
	HFC-365mfc pre-blended	7.00	5,558			
	HFC-245fa	98.70	101,663	316,169	2.47	
	HFC-245fa pre-blended	29.41	30,292			
XPS foam	HFC-152a	227.00	28,148	853,021	3.76	UNDP
Subtotal investment project in the foam sectors		*388.16*	*194,727*	*1,270,610*	*3.27*	*UNDP*
PMU for the foam investment project		*n/a*	*n/a*	*108,002*	*n/a*	*UNDP*
Domestic refrigeration	HFC-134a	376.97	539,066	4,552,856	12.08	UNIDO
Commercial refrigeration	HFC-134a, R-404A, R-407C	*37.92	61,023	502,202	13.24	UNIDO
Residential AC	R-410A	163.75	341,819	1,948,253	11.90	UNIDO
	R-410A from the HPMP **	716.92	1,496,571	0	n/a	n/a
Subtotal investment project in the RAC manufacturing sector		*1,295.56*	*2,438,478*	*7,003,311*	***5.41*	*UNIDO*
PMU for RAC investment project		*n/a*	*n/a*	*595,281*	*n/a*	*UNIDO*
Servicing sector	Various	1,206.55	2,568,318	6,153,400	5.10	UNIDO

[40] Calculated in line with the methodology presented in annex I of document UNEP/OzL.Pro/ExCom/92/46

Sector	Substances	Phase out		Agreed funding (US $)	CE (US $/kg)	Agency
		mt	**CO_2-eq tonnes**			
		279.02	593,934	1,423,000		UNDP
Subtotal servicing sector activities		*1,485.57*	*3,162,253*	*7,576,400*	*5.10*	*n/a*
PMU for servicing sector		*n/a*	*n/a*	*523,039*	*n/a*	*UNIDO*
				120,955		*UNDP*
Subtotal all projects (without PMU)		***3,169.29***	***5,795,458***	***15,850,320***	**5.00**	***n/a***
Subtotal all PMU		***n/a***	***n/a***	***1,347,277***	***n/a***	***n/a***
Grand total (including phase out from 5 residential AC enterprises from HPMP)**		**3,169.29**	**5,795,458*****	**17,197,598**	**5.43**	**n/a**

* Including ineligible consumption of 9.50 mt (13,588 CO2-eq tonnes) of HFC-134a associated with Everest
** The associated phase out of R-410 from the conversion projects in residential AC under the HPMP amount to 716.92 mt (1,496,571CO_2-eq tonnes)
*** Including 35,850 CO_2-eq tonnes of HFCs contained in imported pre-blended polyols

143. The total deductions from the country's remaining consumption eligible for funding are 5,795,458 CO_2-eq tonnes, including 1,496,571 CO_2-eq tonnes associated with the conversion of the five residential AC manufacturing enterprises converting to HFC-32 under the HPMP. The phase-down of those five enterprises, and of the six enterprises converting to HFC-32 in stage I of the KIP, are expected to lead to the phase in of 535,004 CO_2-eq tonnes of HFC-32. Accounting for that phase-in and excluding the phase-out of 35,850 CO_2-eq tonnes of HFCs contained in imported pre-blended polyols, results in net reductions in consumption of 5,224,604 CO_2-eq tonnes. In considering an appropriate final target, the Secretariat noted the increase in consumption in 2024, which reflected the continuing needs of the country for cooling, and that some time may be needed for the activities planned under the KIP to be implemented and affect market demand. On that basis, it was agreed to set the final target for the stage I of the KIP to 15,046,473 CO_2-eq tonnes, a midpoint between the originally proposed target (15,471,223 CO_2-eq tonnes) and that calculated based on the reductions in consumption above (14,065,746 CO_2-eq tonnes). To ensure that the Government had sufficient time to meet that final target, it was agreed to extend the stage I of the KIP to 2030.

144. Stage I of the KIP will be implemented in three tranches. Notwithstanding that decision 95/49(c) specifies that the first tranche of stage I should constitute not more than 60 per cent of the total funding for stage I, on an exceptional basis the first tranche was agreed at 62.7 per cent of total funding for stage I given the need to provide the ICCs for the manufacturing conversions, which constitute the majority (over 80 per cent) of the funding needed for activities in the tranche.

Implementation plan for the first tranche of the Kigali HFC implementation plan

145. Based on the changes described above in paragraphs 104 to 142, UNIDO and UNDP agreed to a revised plan of action for the first tranche that includes the removal of the demonstration project in residential heat pumps, the addition of the dedicated technical assistance programme for SMEs in manufacturing conversion activities, stakeholder consultations on technology trends in the MAC sector and large commercial refrigeration sector, adjustments to the tranche distribution, and revised costs and targets for several activities. The costs of the revised first tranche activities amount to US $10,786,475 and are presented annex II to the present document.

Exemption for high-ambient temperature parties

146. Egypt will not be availing itself of the high ambient exemption as was advised by the letter sent from the NOU to the Ozone Secretariat on 24 October 2024.

Co-financing

147. Sources of co-financing identified in this project included the costs borne by SMEs in the RAC manufacturing sectors to cover the difference between the calculated cost of the conversion and the amount requested for the conversion projects; costs covered by AC distributors participating in the demonstration

project to recover retired units, recover refrigerant and ensure proper disposal; possible co-financing from participants in the demonstration project for residential split units; costs borne by the manufacturers of MDIs to contribute to the development and testing of prototypes; co-financing from participants in the demonstration of chilled water systems; and in-kind services provided by training centres which will contribute the use of their premises and staff for KIP related activities.

2025–2027 business plan of the Multilateral Fund

148. UNIDO and UNDP are requesting US $17,197,598, plus agency support costs, for the implementation of stage I of the KIP for Egypt. The total value of US $16,455,213, including agency support costs, requested for the period of 2025-2027, is US $10,425,357 above the amount in the business plan.

Gender policy implementation

149. In line with decisions 84/92(d), 90/48(c) and 92/40(b), Egypt has incorporated a discussion of the gender policy of the Multilateral Fund into its KIP implementation plan, which includes a study to identify barriers to equitable participation in the project and RAC sector, development of an action plan and design of workshops and materials; as well as to delivery of trainings, workshops and promotional activities. The NOU has prepared a draft outline for a policy to promote gender equality that includes improving reporting and monitoring systems to track and record gender issues, including specific measurable targets and the mandatory gender indicator and outcomes have been included with the project submission

Sustainability of the HFC phase-down and assessment of risks

150. The sustainability of the phase-out in the PU and XPS foam manufacturing sectors will be sustained by the implementation of a ban the import of HFC-245fa and HFC-365mfc pure and contained in imported pre-blended polyols, a ban or prohibition on the import of HFC-152a, and a ban or prohibition on the manufacture of HFC-based PU and XPS foam. The phase-out in the domestic refrigeration and standalone commercial refrigeration manufacturing sectors, and the phase-down in the residential AC manufacturing sector, will be sustained by the 1 January 2029 ban on the manufacture and import of the relevant HFC-based equipment. The enterprises participating in the project will complete their conversion one year in advance of the ban, and would have to compete with imports and, in the case of the residential AC manufacturing sector, one ineligible enterprise that will convert using its own resources. The Secretariat considers the risk to the sustainability of the phase-down due to this one-year difference between the completion of the conversions and implementation of the ban to be low given that overwhelming majority of the market will have converted by 1 January 2028. In the residential AC manufacturing sector, the majority of the country's local manufacturing for the domestic market will have fully converted to HFC-32 by 31 December 2026 given the conversion of the five residential AC manufacturing enterprises under the stage II of the HPMP.

151. It is likely that SMEs participating in the conversion projects will face a greater challenge in implementing their conversion than large enterprises given their limited financial and technical capacity. To address this and mitigate the risk to the sustainability of their conversion, the stage I of the KIP includes a dedicated technical assistance programme. The training and capacity-building activities in the servicing sector, including strengthening the capacity of RAC technicians to safely handle flammable refrigerants, as well as the implementation of the licensing and quota system, which is aligned to the HFC phase-down schedule, will further mitigate the risk to the sustainability of the country's phase-down.

Impact on the climate

152. The activities proposed, including the conversion of domestic refrigeration manufacturing sector to R-600a, the stand-alone commercial refrigeration equipment to R-290, the residential AC manufacturing

sector to HFC-32, and the PU and XPS foam manufacturing sectors to low-GWP alternatives, and efforts to promote low-GWP alternatives, refrigerant recovery and reuse, indicate that the implementation of stage I of the KIP will reduce refrigerant emissions into the atmosphere, resulting in climate benefits. A calculation of the impact on the climate of the activities in the KIP indicates that by 2030, Egypt will have reduced its emissions by approximately 4,243,877 CO_2-eq tonnes of HFCs, calculated as the difference between HFC baseline for compliance and the 2030 target, assuming that all consumed HFCs would eventually have been emitted.

Draft Agreement

153. A draft Agreement between the Government of Egypt and the Executive Committee for stage I of the KIP is contained in annex I to the present document. The Executive Committee is considering the issue of HFCs contained in pre-blended polyols in the PU foam sector in Article 5 countries under agenda item 10(c) of the present meeting. Should a decision on this matter be adopted, the Committee may decide whether to include a relevant clause in the Agreement.

Coordination of activities in the servicing sector under HCFC phase-out and HFC phase-down plans

154. The activities in the manufacturing and servicing sectors are complementary to the approved activities under stage II of the HPMP, for which the final tranche will be implemented simultaneously with stage I of the KIP until December 2026. Stage III of the HPMP, which is expected to be submitted to the 96th meeting, is being planned in alignment with activities under stage I of the KIP. The coordination of activities will be assessed as part of the review of stage III of the HPMP when it is submitted.

VI. Recommendation

155. The Executive Committee may wish to consider:

(a) Approving, in principle, stage I of the Kigali HFC implementation plan (KIP) for Egypt for the period 2025–2030 to reduce HFC consumption by 22 per cent of the country’s baseline, in the amount of US $18,401,430, consisting of US $14,275,031, plus agency support costs of US $999,252, for UNIDO and US $2,922,567, plus agency support costs of US $204,580, for UNDP;

(b) Noting:

(i) That the Government of Egypt will establish its starting point for sustained aggregate reductions in HFC consumption based on guidance provided by the Executive Committee;

(ii) That once the Executive Committee provides the guidance referred to in subparagraph (b)(i), reductions from the country’s remaining HFC consumption eligible for funding will be determined in line with this guidance;

(iii) That the reductions from the country’s remaining HFC consumption eligible for funding referred to in subparagraph (b)(ii) above will be deducted from the starting point referred to in subparagraph (b)(i);

(iv) That the reductions from the country’s remaining HFC consumption eligible for funding referred to in subparagraph (b)(ii) include 35,850 carbon dioxide-equivalent tonnes of HFCs contained in imported pre-blended polyols;

(v) That, on an exceptional basis, an additional reduction of 1,496,571 carbon dioxide-equivalent tonnes would be deducted from the starting point based on the 2020 R-410A consumption of the five enterprises manufacturing residential air-conditioning units that were converting to HFC-32 under the country's stage II of the HCFC phase-out management plan (HPMP) (i.e., El Araby, Fresh, Miraco, Power, and Unionaire);

(vi) That irrespective of decision 84/72(e)(iii), the five enterprises referred to in subparagraph (v) above would be eligible for a project to improve the energy efficiency of residential air-conditioning units they manufacture under decision 94/60, subject to the criteria of decision 94/60;

(c) Further noting the commitment of the Government of Egypt:

(i) To ban or otherwise prohibit the import of HFC-245fa and HFC-365mfc pure and contained in imported pre-blended polyols and to also ban or otherwise prohibit these substances in the manufacture of HFC-based polyurethane foam manufacturing by 1 January 2028;

(ii) To ban or otherwise prohibit the import of HFC-152a and HFC-based extruded polystyrene foam manufacturing by 1 January 2028;

(iii) To ban or otherwise prohibit the import and manufacture of HFC-based domestic refrigerators by 1 January 2029, noting that the enterprises for which funding was being provided to convert under the stage I of the KIP would cease manufacturing HFC-134a domestic refrigerators by 1 January 2028;

(iv) To ban or otherwise prohibit the import and manufacture of HFC-based standalone commercial refrigeration equipment by 1 January 2029; and

(v) To ban or otherwise prohibit the import and manufacture of R-410A-based residential AC units by 1 January 2029, noting that the enterprises for which funding was being provided to convert under the stage I of the KIP would cease manufacturing R-410A-based residential AC units by 1 January 2028;

(d) Approving the draft Agreement between the Government of Egypt and the Executive Committee for the reduction in consumption of HFCs in accordance with stage I of the KIP, contained in annex I to the present document; and

(e) Approving the first tranche of stage I of the KIP for Egypt and the corresponding tranche implementation plan, in the amount of US $ 11,541,528, consisting of US $9,081,787, plus agency support costs of US $635,725, for UNIDO and US $1,704,688, plus agency support costs of US $119,328, for UNDP.

Annex I

DRAFT AGREEMENT BETWEEN THE GOVERNMENT OF THE ARAB REPBULIC OF EGYPT AND THE EXECUTIVE COMMITTEE OF THE MULTILATERAL FUND FOR THE REDUCTION IN CONSUMPTION OF HYDROFLUOROCARBONS IN ACCORDANCE WITH STAGE I OF THE KIGALI HFC IMPLEMENTATION PLAN

(Period:2025-2030)

Purpose

1. This Agreement represents the understanding of the Government of the Arab Republic of Egypt ("the Country") and the Executive Committee with respect to the reduction of controlled use of Annex F substances set out in Appendix 1-A ("The Substances") to a sustained level of 15,046,473 CO_2-equivalent (CO_2-eq) tonnes by 1 January 2030 in compliance with the Montreal Protocol schedule and the terms of this Agreement.

2. The Country agrees to meet the annual consumption limits of Annex F substances as set out in row 1.2 of Appendix 2-A ("The Targets, and Funding") in this Agreement as well as in the Montreal Protocol reduction schedule for Annex F substances mentioned in Appendix 1-A. The Country accepts that, by its acceptance of this Agreement and performance by the Executive Committee of its funding obligations described in paragraph 3, it is precluded from applying for or receiving further funding from the Multilateral Fund in respect to any consumption of Annex F substances that exceeds the level defined in row 1.2 of Appendix 2-A as the final reduction step under this Agreement for Annex F substances specified in Appendix 1-A, and in respect to any consumption of Annex F substances that exceeds the level[s] defined in row[s] 4.1.3 [and 4.2.3] (remaining consumption eligible for funding).

3. Subject to compliance by the Country with its obligations set out in this Agreement, the Executive Committee agrees, in principle, to provide the funding set out in row 3.1 of Appendix 2-A to the Country. The Executive Committee will, in principle, provide this funding at the Executive Committee meetings specified in Appendix 3-A ("Funding Approval Schedule").

4. The Country agrees to implement this Agreement in accordance with stage I of the Kigali HFC implementation plan ("the Plan") as approved. In accordance with subparagraph 5(b) of this Agreement, the Country will accept independent verification of the achievement of the annual consumption limits of Annex F substances set out in row 1.2 of Appendix 2-A of this Agreement. The aforementioned verification will be commissioned by the relevant bilateral or implementing agency.

Conditions for funding release

5. The Executive Committee will only provide the Funding, in accordance with the Funding Approval Schedule, when the Country satisfies the following conditions at least 10 weeks in advance of the applicable Executive Committee meeting set out in the Funding Approval Schedule:

   (a) That the Country has met the Targets set out in row 1.2 of Appendix 2-A for all relevant years. Relevant years are all years since the year in which this Agreement was approved. Years for which there are no due country programme implementation reports at the date of the Executive Committee meeting at which the funding request is being presented are exempted;

   (b) That the meeting of these Targets has been independently verified for all relevant years, unless the Executive Committee decided that such verification would not be required;

(c) That the Country had submitted a Tranche Implementation Report in accordance with Appendix 4-A ("Format of Tranche Implementation Reports and Plans") covering each previous calendar year; that it had achieved a significant level of implementation of activities initiated with previously approved tranches; and that the rate of disbursement of funding available from the previously approved tranche was more than 20 per cent; and

(d) That the Country has submitted a Tranche Implementation Plan in accordance with Appendix 4-A covering each calendar year until and including the year for which the Funding Approval Schedule foresees the submission of the next tranche or, in case of the final tranche, until completion of all activities foreseen.

Monitoring

6. The Country will ensure that it conducts accurate monitoring of its activities under this Agreement. The institutions set out in Appendix 5-A ("Monitoring Institutions and Roles") will monitor and report on implementation of the activities in the previous Tranche Implementation Plans in accordance with their roles and responsibilities set out in the same appendix.

Flexibility in the reallocation of funds

7. The Executive Committee agrees that the Country may have the flexibility to reallocate part or all approved funds, according to the evolving circumstances, to achieve the smoothest reduction of consumption and phase-down of Annex F substances specified in Appendix 1-A, in accordance with the following considerations:

(a) Reallocations categorized as major changes must be documented in advance, either in a Tranche Implementation Plan as foreseen in subparagraph 5(d) above, or as a revision to an existing Tranche Implementation Plan to be submitted 10 weeks prior to any meeting of the Executive Committee, for its approval. Major changes would relate to:

(i) Issues potentially concerning the rules and policies of the Multilateral Fund;

(ii) Changes that would modify any clause of this Agreement;

(iii) Changes in the annual levels of funding allocated to the individual bilateral or implementing agencies for the different tranches;

(iv) Provision of funding for activities not included in the current endorsed Tranche Implementation Plan, or removal of an activity in the Tranche Implementation Plan, with a cost greater than 30 per cent of the total cost of the last approved tranche;

(v) Changes in alternative technologies, on the understanding that any submission for such a request would identify the associated incremental costs, the potential impact on the climate, and any differences in CO_2-eq tonnes to be phased down if applicable, as well as confirm that the Country agrees that potential savings related to the change of technology would accordingly decrease the overall funding level under this Agreement;

(b) Reallocations not categorized as major changes may be incorporated into the approved Tranche Implementation Plan, under implementation at the time, and reported to the Executive Committee in the subsequent Tranche Implementation Report;

(c) Any enterprise included in the Plan that would be found to be ineligible under the policies of the Multilateral Fund (i.e., due to foreign ownership or establishment after the applicable cut off date) would not receive financial assistance. This information would be reported as part of the Tranche Implementation Plan; and

(d) Any remaining funds held by the bilateral or implementing agencies or the Country under the Plan will be returned to the Multilateral Fund upon completion of the last tranche foreseen under this Agreement.

8. Specific attention will be paid to the execution of activities in the refrigeration servicing sector included in the Plan, in particular that the Country may use the flexibility available under this Agreement to address specific needs that might arise during project implementation.

Bilateral and implementing agencies

9. The Country agrees to assume overall responsibility for the management and implementation of this Agreement and of all activities undertaken by it or on its behalf to fulfil the obligations under this Agreement. UNIDO has agreed to be the lead implementing agency (the "Lead IA") and UNDP has agreed to be the cooperating implementing agency/agencies (the "Cooperating IA[s]") under the lead of the Lead IA in respect of the Country's activities under this Agreement. The Country agrees to evaluations, which might be carried out under the monitoring and evaluation work programmes of the Multilateral Fund or under the evaluation programme of the Lead IA and/or Cooperating IA taking part in this Agreement.

10. The Lead IA will be responsible for ensuring coordinated planning, implementation and reporting of all activities under this Agreement, including but not limited to the independent verification as per subparagraph 5(b). The Cooperating IA will support the Lead IA by implementing the Plan under the overall coordination of the Lead IA. The roles of the Lead IA and Cooperating IA are contained in Appendix 6-A and Appendix 6-B, respectively. The Executive Committee agrees, in principle, to provide the Lead IA and the Cooperating IA with the fees set out in rows 2.2 and 2.4 of Appendix 2-A.

Non-compliance with the Targets in the Agreement

11. Should the Country, for any reason, not meet the Targets for the elimination of Annex F substances set out in row 1.2 of Appendix 2-A or otherwise does not comply with this Agreement, then the Country agrees that it will not be entitled to the Funding in accordance with the Funding Approval Schedule. At the discretion of the Executive Committee, funding will be reinstated according to a revised Funding Approval Schedule determined by the Executive Committee after the Country has demonstrated that it has satisfied all its obligations that were due to be met prior to receipt of the next tranche of funding under the Funding Approval Schedule. The Country acknowledges that the Executive Committee may reduce the amount of the Funding by the amount set out in Appendix 7-A ("Reductions in Funding for Failure to Comply") in respect of each CO_2-eq kg of reductions in consumption not achieved in any one year. The Executive Committee will discuss each specific case in which the Country did not comply with this Agreement and take related decisions. Once decisions are taken, the specific case of non-compliance with this Agreement will not be an impediment for the provision of funding for future tranches as per paragraph 5 above.

12. The Funding of this Agreement will not be modified on the basis of any future Executive Committee decisions that may affect the funding of any other consumption sector projects or any other related activities in the Country.

13. The Country will comply with any reasonable request of the Executive Committee, the Lead IA and the Cooperating IA to facilitate implementation of this Agreement. In particular, it will provide the Lead IA and the Cooperating IA with access to the information necessary to verify compliance with this Agreement.

Date of completion

14. The completion of the Plan and the associated Agreement will take place at the end of the year following the last year for which a maximum allowable total consumption level has been specified in Appendix 2-A. Should at that time there still be activities that are outstanding, and which were foreseen in the last Tranche Implementation Plan and its subsequent revisions as per subparagraph 5(d) and paragraph 7, the completion of the Plan will be delayed until the end of the year following the implementation of the remaining activities. The reporting requirements as per subparagraphs 1(a), 1(b), and 1(d) of Appendix 4-A will continue until the time of the completion of the Plan unless otherwise specified by the Executive Committee.

Validity

15. All conditions set out in this Agreement are undertaken solely within the context of the Montreal Protocol and as specified in this Agreement. All terms used in this Agreement have the meaning ascribed to them in the Montreal Protocol unless otherwise defined herein.

16. This Agreement may be modified or terminated only by mutual written agreement of the Country and the Executive Committee of the Multilateral Fund.

APPENDICES

APPENDIX 1-A: THE SUBSTANCES

Substances	Starting point for aggregate reductions in consumption
To be determined	

APPENDIX 2-A: THE TARGETS, AND FUNDING

Row	Particulars		2025	2026	2027	2028	2029	2030	Total
1.1	Montreal Protocol reduction schedule of Annex F substances	%	freeze	freeze	freeze	freeze	10	10	n/a
		CO_2-eq tonnes	19,290,350	19,290,350	19,290,350	19,290,350	17,361,315	17,361,315	n/a
1.2	Maximum allowable total consumption of Annex F substances	Reduction in %	0	0	4.1	6.7	15.0	22.0	n/a
		CO_2-eq tonnes	19,290,350	19,290,350	18,500,000	18,000,000	16,387,179	15,046,473	n/a
2.1	Lead IA (UNIDO) agreed funding (US $)		9,081,787	0	3,545,129	0	1,648,115	0	14,275,031
2.2	Support costs for Lead IA (US $)		635,725	0	248,159	0	115,368	0	999,252
2.3	Cooperating IA (UNDP) agreed funding (US $)		1,704,688	0	1,047,100	0	170,779	0	2,922,567
2.4	Support costs for Cooperating IA (US $)		119,328	0	73,297	0	11,955	0	204,580
3.1	Total agreed funding (US $)		10,786,475	0	4,592,229	0	1,818,894	0	17,197,598
3.2	Total support costs (US $)		755,053	0	321,456	0	127,323	0	1,203,832
3.3	Total agreed costs (US $)		11,541,528	0	4,913,685	0	1,946,217	0	18,401,430

Row	Particulars	2025	2026	2027	2028	2029	2030	Total
4.		To be determined						

APPENDIX 3-A: FUNDING APPROVAL SCHEDULE

1. Funding for the future tranches will be considered for approval at the first meeting of the year specified in Appendix 2-A.

APPENDIX 4-A: FORMAT OF THE TRANCHE IMPLEMENTATION REPORTS AND PLANS

1. The submission of the Tranche Implementation Report and Plans for each tranche request will consist of four parts:

(a) A narrative report, with data provided by tranche, describing the progress achieved since the previous report, reflecting the situation of the Country in regard to phase-down of Annex F substances, how the different activities contribute to it, and how they relate to each other, including, where applicable, activities related to energy efficiency approved in the context of HFC phase-down pursuant to decision 91/65. The report should include the amount of Annex F substances consumption reduced as a direct result of the implementation of activities, by substance, the alternative technology used and the related phase in of alternatives, to allow the Secretariat to inform the Executive Committee on the resulting change in climate relevant emissions. The report should also include quantitative information on the activities implemented and further highlight the successes, experiences, and challenges related to the different activities included in the Plan, reflecting any changes in the circumstances in the Country, and providing other relevant information. The report should also include information on and justification for any changes vis-à-vis the previously submitted Tranche Implementation Plan(s), such as delays, use of flexibility for the reallocation of funds during implementation of a tranche as provided for in paragraph 7 of this Agreement, or other changes;

(b) An independent verification report on the Plan's results and the consumption of Annex F substances, as per subparagraph 5(b) of the Agreement. If not decided otherwise by the Executive Committee, such a verification of consumption data must be provided with each tranche request, covering all relevant years for which a verification report has not yet been acknowledged by the Committee, as specified in subparagraph 5(a) of the Agreement;

(c) A written description of the activities to be undertaken during the period covered by the requested tranche including quantitative information, highlighting implementation milestones, the time of completion and the interdependence of the activities, and taking into account experiences made and progress achieved in the implementation of earlier tranches; the data in the Plan will be provided by calendar year. The description should include a reference to the overall Plan and progress achieved, as well as any possible changes to the overall Plan that are foreseen. The description should also specify and explain in detail such changes to the overall Plan. This description of future activities can be submitted as a part of the same document as the narrative report under subparagraph 1(a) above; and

(d) An Executive Summary of about five paragraphs, summarizing the information contained in subparagraphs 1(a) to 1(c) above.

APPENDIX 5-A: MONITORING INSTITUTIONS AND ROLES

1. All the monitoring activities will be coordinated and managed through the National Ozone Unit (NOU). The Country will ensure that it conducts accurate monitoring of the activities under this Agreement. The institutions set out in Appendix 6-A and 6-B (Roles of Lead and Cooperating Implementing Agencies) will monitor and report on the implementation of the activities in accordance with their roles and responsibilities set out in the same Appendices.

2. The NOU is an integral part of the Ministry of State for Environmental Affairs, under the direct responsibility of the Egyptian Environmental Affairs Agency (EEAA). The NOU will continue to have general responsibility for the implementation of the activities under the present Agreement. To assist the NOU in these responsibilities, the Project Management Unit is established within the NOU and under its direct supervision.

3. The Project Management Unit (PMU) oversees the day-to-day implementation of projects, training programmes, technical assistance, and awareness-raising activities included in the approved Plan to ensure the long-term sustainability of the impact of those activities on the reduction of HFC consumption and use. The PMU will be in continuous contact with stakeholders and other market actors to monitor trends and ensure compliance with the strategy and plan put in place.

4. The Directorate General for the Control of Exports and Imports and the Customs Department, through a protocol that was signed with the National Ozone Committee, have a particularly prominent role in the monitoring of HFC imports and the prevention of illegal trade, Customs records are used as a crosschecking reference in all the monitoring programmes for the different projects within the KIP.

5. The monitoring process will be managed by the NOU in close cooperation with relevant authorities with the assistance of the Lead IA and the Cooperating IA. The NOU will be responsible for monitoring the sustainability of the consumption reduction targets achieved through this Agreement.

6. The consumption of the controlled substances will be monitored and determined based on official import and export data recorded by relevant Government departments. The NOU shall compile and report on an annual basis, on or before the relevant due dates, on consumption of the substances to be submitted to the Ozone Secretariat and on the progress of implementation of the Plan to be submitted to the Multilateral Fund Secretariat.

APPENDIX 6-A: ROLE OF THE LEAD IMPLEMENTING AGENCY

1. The Lead IA will be responsible for a range of activities, including at least the following:

   (a) Ensuring performance and financial verification in accordance with this Agreement and with its specific internal procedures and requirements as set out in the Country's Plan;

   (b) Assisting the Country in the preparation of the Tranche Implementation Reports and Plans as per Appendix 4-A;

   (c) Providing independent verification to the Executive Committee that the Targets have been met and associated tranche activities have been completed as indicated in the Tranche Implementation Plan, consistent with Appendix 4-A;

   (d) Ensuring that the experiences and progress are reflected in the updates to the overall Plan and in the future Tranche Implementation Plans, consistent with subparagraph 1(c) of Appendix 4-A;

(e) Fulfilling the reporting requirements of the Tranche Implementation Reports and Plans and of the overall Plan as specified in Appendix 4-A for submission to the Executive Committee including the activities implemented by the Cooperating IA;

(f) In the event that the last funding tranche is requested one or more years prior to the last year for which a consumption target had been established, annual Tranche Implementation Reports and, where applicable, verification reports on the current stage of the Plan should be submitted until all activities foreseen had been completed and HFC consumption targets had been met;

(g) Ensuring that appropriate independent technical experts carry out the technical reviews;

(h) Carrying out the required supervision missions;

(i) Ensuring the presence of an operating mechanism to allow for an effective and transparent implementation of the Tranche Implementation Plan and accurate data reporting;

(j) Coordinating the activities of the Cooperating IA and ensuring the appropriate sequence of activities;

(k) In case of reductions in funding for failure to comply in accordance with paragraph 11 of the Agreement, to determine, in consultation with the Country and the Cooperating IA, the allocation of the reductions to the different budget items and to the funding of the Lead IA and the Cooperating IA;

(l) Ensuring that disbursements made to the Country are based on the use of the indicators;

(m) Providing assistance with the policy, management and technical support when required;

(n) Reaching consensus with the Cooperating IA[s] on any planning, coordination and reporting arrangements required to facilitate the implementation of the Plan; and

(o) Timely releasing funds to the Country/participating enterprises for completing the activities related to the project.

2. After consultation with the Country and taking into account any views expressed, the Lead IA will select and mandate an independent entity to carry out the verification of the Plan's results and of the consumption of Annex F substances mentioned in Appendix 1-A, as per subparagraph 5(b) of the Agreement and subparagraph 1(b) of Appendix 4-A.

APPENDIX 6-B: ROLE OF THE COOPERATING IMPLEMENTING AGENCIES

1. The Cooperating IA[s] will be responsible for a range of activities. These activities are specified in the Plan, including at least the following:

(a) Providing assistance for policy development when required;

(b) Assisting the Country in the implementation and assessment of the activities funded by the Cooperating IA[s], and referring to the Lead IA to ensure a coordinated sequence of activities;

(c) Providing reports to the Lead IA on these activities, for inclusion in the consolidated reports as per Appendix 4-A; and

(d) Reaching consensus with the Lead IA on any planning, coordination and reporting arrangements required to facilitate the implementation of the Plan.

APPENDIX 7-A: REDUCTIONS IN FUNDING FOR FAILURE TO COMPLY WITH THE TARGETS IN THE AGREEMENT

1. In accordance with paragraph 11 of the Agreement, the amount of funding provided may be reduced by US $5.93 per CO_2-eq tonne of consumption beyond the level defined in row 1.2 of Appendix 2-A for each year in which the Target specified in row 1.2 of Appendix 2-A has not been met, on the understanding that the maximum funding reduction would not exceed the funding level of the tranche being requested. Additional measures might be considered in cases where non-compliance extends for two consecutive years. Where the country has failed to comply with the Agreement due to illegal trade, the reduction in funding would not be applied if the illegally traded controlled substances are seized and subsequently confiscated, destroyed, exported, or returned to the country of origin.

Annex II

Details of the implementation plan for the first tranche of the KIP for Egypt

Component	Activity	Agency	Cost US$
Manufacturing activities			
Foam sectors	PU foam El Araby conversion	UNDP	101,420
	PU foam group project (SMEs)		124,000
	XPS foam conversion		853,021
	Subtotal first tranche investment projects for foam sectors		*1,078,441*
	Project management for investment projects for foam sectors		*91,667*
RAC manufacturing sectors	Domestic refrigeration	UNIDO	4,502,856
	El Araby domestic refrigeration		50,000
	Commercial refrigeration		502,202
	Residential AC		1,948,253
	Subtotal first tranche for investment projects for RAC manufacturing sectors		*7,003,310*
	Project management for investment projects for RAC manufacturing sectors		*595,281*
Servicing sector activities			
1. Regulatory framework and control mechanism	Strengthening the HFC policy and regulatory framework: • Consultancy to review and update policy and regulatory framework • Consultancy to strengthen national capacities • Updating labour competency standard • Development of a RAC sector circular economy model • Economic impact study on incentives and accelerated process • National registry system of medium and large installations	UNDP	125,000
	Training programme on updated HFC control policies and regulations: • International consultancy to design/update training materials • Training courses for customs/border control officers • Training courses for importers and brokers • Purchase of 10 refrigerant identifiers for customs • Review and update licensing and quota system procedures		88,700
	Gender mainstreaming programme: • Recruiting a gender specialist and identification of barriers and priorities for women in the RAC sector • Development of promotional materials and promotion of gender equity and application of gender policies • Workshops for 50 to 80 stakeholders each		62,000
	Subtotal regulatory framework and control mechanism	*UNDP*	*275,700*
2. Capacity building of technicians	Review/update of standards, guidelines and RAC curriculum: • Review/update codes of practices covering all sectors and newer technologies; • Developing standards and guidelines for MAC servicing and translation of materials for dissemination; • Conducting awareness campaigns and workshops for stakeholders, including staff from training institutions, national associations, trainers, regulators, and recycling centre operators; and • Updating the MAC training curriculum ensuring links to nationally adopted standards.	UNIDO	80,000
	Extending technician certification to the MAC sector: • Establishing committee with technical experts and national stakeholders to prepare new certification scheme • Creating a database of potential MAC service technician for certification • Training of 50 assessors for MAC certification.		95,000
	Provision of tools to 900 MAC and RAC workshops: • Survey to identify MAC and RAC workshops, identify needs and		255,000

Component	Activity	Agency	Cost US$
	purchase and delivery of equipment to 100 workshops in first tranche		
	Training and testing of 1,000 MAC and 1,000 RAC technicians: • Three-day training sessions through centres of excellence and training institutes on good practices for 725 MAC and 725 RAC technicians in first tranche.		290,000
	After-sales training of 1,250 technicians at major brand RAC and MAC service centres: • In-depth instruction in diagnostics and troubleshooting, using appropriate tools and techniques, safety and industry standards for 500 trainees in first tranche		100,000
	Subtotal capacity building of technicians	*UNIDO*	*820,000*
3. Outreach and communication	Campaigns in various sectors (MDI, MAC, RAC) raise awareness on phase-down and on energy efficiency and sustainable cooling: • Producing outreach materials, biannual round tables, four targeted workshops, and online engagement	UNIDO	230,000
	Campaigns to promote activities in the foam sectors, and raise awareness of regulatory changes: • Producing outreach materials, targeted workshops and multimedia engagement	UNDP	65,000
	Subtotal outreach and communications	*UNIDO*	*230,000*
		UNDP	*65,000*
4. Sectoral projects (a) residential AC	Demonstration project for two not-in-kind (NIK)[41] direct-indirect evaporative cooling (D-IEC) technologies[42] for residential split applications: • Consulting services to set up the project, advise the participants on the technology and guiding them through the R&D and production phases • Manufacturing prototype D-IEC units of 5 to 7.5 kW capacity	UNIDO	45,000
	Demonstration project of three NIK packaged chilled water systems replacing multi split units • Consulting services to set up the project, advise the participants on the technology and guiding them through the R&D and production phases • Manufacturing two prototypes chilled water systems of 10 to 17.5 kW capacity	UNIDO	55,000
Sectoral projects (b) Commercial AC	Demonstration project for NIK deep sea cooling[43] technology in commercial AC: • Hiring a consultant to determine the viability of district cooling using deep sea cooling technology in two new developments • Data collection using a remote operated vehicle in deep layers of the Gulf of Aqaba	UNIDO	40,000
	Subtotal sectoral projects	*UNIDO*	*190,000*
5. Technical assistance (a) RAC sector	Dedicated technical assistance programme for SMEs in manufacturing conversions • Provision of technical assistance and support towards the conversion of SMEs across the assisted manufacturing sectors	UNIDO	25,000

[41] The term of not-in-kind (NIK) cooling technologies refers to any alternative cooling systems other than vapor compression cooling systems.
[42] Direct-indirect evaporative cooling: First uses indirect evaporative cooling to pre-cool the air without adding moisture. The pre-cooled air then undergoes direct evaporative cooling, further reducing its temperature. The combination maximizes cooling efficiency while controlling humidity levels, making it suitable for a wide range of applications.
[43] Deep sea cooling technologies leverages the naturally cold temperatures found in deep waters to provide cooling for buildings and industrial processes. This method can substantially reduce energy consumption and greenhouse gas emissions compared to conventional air-conditioning systems.

Component	Activity	Agency	Cost US$
5. Technical assistance (b) firefighting sector	Technical assistance and monitoring the use of HFCs as fire extinguishing agents: • Developing an inventory of enterprises that import, sell, use, install and refill HFC-based fire control equipment and flood systems; • Promotion and development/printing of booklet on best practices in maintaining and recharging portable fire extinguishers; • Coordinating a working group to develop technical capacity on customs codes to control the trade of cylinders used in the firefighting sector; • Begin work to establishing a training and examination centre	UNDP	152,000
4. Technical assistance (c) refrigerated transport sector	Technical assistance to the refrigerated transport subsector: • Identification all stakeholders in the subsector, the technologies and the applications (container trucks, small trucks, reefers, or marine refrigeration) use consumption trends, and readiness for alternative technologies; and an assessment of the after-sales servicing capabilities • Workshops for SMEs and installers on new technologies, reducing leakage through design and proper tools • Technical assistance provided through individual visits arranged with stakeholders	UNIDO	102,000
	Subtotal technical assistance	*UNIDO*	*127,000*
		UNDP	*152,000*
	Subtotal UNIDO first tranche servicing sector activities		1,367,000
	Subtotal UNDP first tranche servicing sector activities		492,700
	Subtotal first tranche servicing sector activities		1,859,700
	Project management for first tranche	*UNIDO*	116,195
		UNDP	41,880
Total for UNIDO first tranche			**9,081,787**
Total for UNDP first tranche			**1,704,688**
Grand total			**10,786,475**

Transformation of Commercial Air Conditioning Companies
HCFC Phase-out Management Plan (HPMP) EGYPT (Stage II), UNIDO ID: 140400

DIRECT/INDIRECT EVAPORATIVE COOLING

Year: 2024
Climatic Zone: 8

Project supported by:

MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNITED NATIONS ENVIRONMENT PROGRAMME

EUROPEAN INDUSTRY ASSOCIATION EUROVENT

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Disclaimer

While the information contained herein is believed to be accurate, it is of necessity presented in a summary and general fashion. The decision to implement one of the options presented in this document requires careful consideration of a wide range of situation-specific parameters, many of which may not be addressed by this document. Responsibility for this decision and all its resulting impacts rests exclusively with the individual or entity choosing to implement the option. UNIDO, UNEP, their consultants and the reviewers and their employees do not make any warranty or representation, either expressed or implied, with respect to the accuracy, completeness or utility of this document; nor do they assume any liability for events resulting from the use of, or reliance upon, any information, material or procedure described herein, including but not limited to any claims regarding health, safety, environmental effects, efficacy, performance, or cost made by the source of information.

Acknowledgment

We would like to acknowledge the assistance given by the governmental sectors and the National Ozone Unit Officers of Egypt and the Housing & Building National Research Center (HBRC) for their support in the implementation of the project and their assistance in facilitating communication with different stakeholders.

We also acknowledge the International Technical Review Team "EUROPEAN INDUSTRY ASSOCIATION EUROVENT" that assist the project team in reviewing the process, results and report of the project.

Acknowledgement also goes particularly to HBRC for providing the testing yard, facilities (Electrical feeding, water supply … etc.) and other logistic facilities at their installation in Toshky.

The project team also acknowledges the OEM manufacturers who built the IEC-H prototypes and DX systems to be tested at the location.

- Delta Construction & Manufacturing DCM
- TIBA Engineering Industries Co.
- VOLTA EGYPT
- SS Air Technology

Acknowledgement also goes to the team's technicians, technical assistance staff and drivers which assisted in the project successful completion in this remote location.

Project Team

This Project is contracted between the United Nations Industrial Development Organization "UNIDO" and Housing & Building National Research Center “HBRC”. Whereas, UNIDO has been designated by the **Multilateral Fund for the Implementation of the Montreal Protocol** as Implementing Agency; and has agreed to provide assistance to the Egyptian Government in carrying out the project entitled “HCFC Phase-Out Management Plan (HPMP) Egypt (Stage II)”.

The National Ozone Unit – Ministry of Environment, Egypt: The ministry team provided guidance and direction and participated at project meetings and discussions. The project is funded by the HCFC Phase- out Management Plan (HPMP) of Egypt.

The Project Management: UNIDO and UN Environment provided overall management and coordination of the project, established the link with the technology providers, and oversaw the development of the report of the project. The Project was managed by Mr. Ole Nielsen, Dr. Iino Fukuya, Dr. Yunrui Zhou, Program Officer – UNIDO and Eng. Ayman El-Talouny, International Partnership Coordinator, Ozone Action Program – UN Environment. The Coordination Consultant, Eng. Ahmed El-Korashy provided logistical support and coordination for the project.

EUROVENT (European Industry Association): Due to the absence of local testing standard or guidelines for IEC applications, the service of an International Advisory Partner was needed to offer recommendations, testing reference and quality review of the testing process.

The Project general Manager and Technical Consultant and writer of the report, Dr. Alaa Olama advised OEMs during prototype design and construction. Devised testing methodology and testing TOR, consulted with OEMs to provide technical solutions for problems as they arose wrote the report and provided analysis of data.

HBRC organized testing including testing results in both climatic zones, tabulated and created the excel sheets including figures, drawings and review and edit of the report

The project personnel provided by the HBRC are as follows:

Name	Project Function	Gender
Prof. Sayed Shebl Mohamed	Team Leader	Male
Eng. Sally Aladdin Ali	Expert Testing Engineer	Female
Eng. Aya Mohamed Zaki	Expert Testing Engineer	Female
Eng. Mariam Sayed Shebl	Expert Architecture Photographer	Female
Mrs. Elham Eid Said	Secretarial Work	Female
Mr. Mohamed Hassan Ahmed	Secretarial Work	Male
Mr. Farid Rashed Ibrahim	Specialized Testing Technician	Male
Mr. Ahmed Maher Mohamed	Specialized Testing Technician	Male
Mr. AbuElHagag Abbas Mohamed	Specialized Testing Technician	Male
Mr. Qassem Gad	Specialized Testing Technician	Male
Eng. Ahmed Ezzat Mahmoud	Specialized IT Assistant	Male
Mr. Mohamed Ibrahim Abdel Moiety	Driver	Male

Executive Summary:

This project is contracted to support the Egyptian Government in implementing the "HCFC Phase-Out Management Plan (HPMP) Egypt (Stage II)." As part of the project requirements, each Original Equipment Manufacturer (OEM) was tasked with independently developing custom-built prototypes of Direct/Indirect Evaporative Cooling Hybrid Air Conditioners (IEC-H) and a central Direct Expansion (DX) unit. These units were then tested and compared under real operating conditions in three of Egypt's eight climatic zones (CZ).

The 2022 final report presented test results from CZ 2 and CZ 5. This current report provides the performance results from CZ 8, Egypt's hottest and driest climatic zone.

The testing included a 24-hour performance comparison between a full fresh air IEC-H unit and the DX unit. Key parameters assessed included dry bulb and wet bulb temperatures exiting the IEC-H and DX units, Energy Efficiency Ratios (EERs), and the refrigeration capacities of each unit. Each OEM's IEC-H and DX units were tested simultaneously over the 24-hour period to ensure consistent comparative data.

All OEM results indicated that their IEC-H units achieved better Energy Efficiency Ratios (EER) compared to their respective DX units in the CZ 8 testing conditions. The highest and lowest EERs across all OEMs are highlighted below. This report on CZ 8 demonstrates that the IEC-H system outperforms the DX system thermodynamically, as it consistently achieves higher EERs.

Although the air discharge of both units for each OEM were the same, compressor capacity for each OEM varied considerably. OEMs used different capacity compressor in their IEC-H units compared to their respective DX unit tested. The tests showed that the capacity of the IEC-H unit when compared to the capacity of the respective DX unit also varied considerably. For a certain OEM, for some it was higher and for others inferior. The report breaks new ground for NIK air conditioning technologies and provides an alternative full fresh air system for air conditioning application that exceeds the efficiency of existing DX systems.

This report marks a significant advancement for NIK air conditioning technology by presenting an alternative full fresh air system that surpasses the efficiency of traditional DX systems. Although the final reports for CZ 2 & 5 (2022) and this report for CZ 8 (2024) provide a solid foundation for developing guidelines for a direct/indirect evaporative cooling code in Egypt, the report recommends further research. Specifically, it suggests deriving a mathematical model to predict EERs and refrigeration capacities for IEC-H prototypes across Egypt's remaining five climatic zones. the technical analysis of the results are included in the report issued by the technical consultant of the project.

Chapter 1: Tabulation formats for compiling and presenting the results of the project for the prototypes of four OEMs in Climatic Zone 8

1.1. The layout of the testing yard

The Housing and Building National Research Center (HBRC) has undertaken extensive preparations to establish a fully equipped testing yard in Climatic Zone 8, specifically in Aswan-Toshky. This location was chosen for its unique climatic conditions, providing a suitable environment for testing the Direct/Indirect Evaporative Cooling Hybrid (IEC-H) prototypes and Direct Expansion (DX) units. Below is a summary of the key preparations completed to ensure the site is fully operational and secure:

I. Infrastructure Setup:

- Testing Yard: Essential yard for running out the tests was arranged and coordinate with the Ministry of Water Resources & Irrigation to include both IEC-H and DX units in the same run.
- Electrical Cables, Electrical Panel and Water Supply: Essential site infrastructure was established, including electrical panel and cables and water piping systems. The water supply setup was coordinated through contracts with the Ministry of Water Resources & Irrigation to ensure adequate water availability for testing.
- Power Stability: Due to high summer energy demands in the region, a generator was rented to maintain stable power for the operation of the IEC-H prototypes and DX units. The generator, which required heavy equipment for transport, was essential to compensate for power instability during peak summer loads.

II. Security and Access:

- Safety Gate: A secure gate was installed at the testing yard to control access and ensure the safety of personnel and equipment.
- Road Preparation: Roads leading to the testing site were prepared to facilitate smooth access for equipment and personnel transport.

III. Logistics and Support:

- Weather Station Setup: The technical team installed a weather station at the site to monitor and log climate conditions essential for the testing data.
- Water Pipelines and Pump Purchase: water pipelines and pump was acquired to supply the IEC-H units with the necessary water feed.

IV. Transportation and Accommodation:

- HBRC arranged hotel accommodations in Abu Simbel for team members, and vehicles were rented to transport the team between the hotel and testing site daily.
- Four on-site rooms were prepared to house technicians and drivers from HBRC and the OEMs.
- Forklifts were rented to unload and move the tested prototypes and units within the

testing yard.

V. Continuous Communication:

HBRC ensured consistent communication with OEMs throughout the testing phase to coordinate the secure arrival of personnel and equipment. Additionally, HBRC facilitated OEM members' local transportation by liaising with car rental agencies. HBRC supported OEMs with accommodation and flight reservations through the HBRC Relationship Department.

VI. Coordination and Site Inspections:

Prior to the testing phase, HBRC conducted three site inspections to ensure all arrangements were in place. One of these visits included the HBRC Chairman, Chairman Deputy, and the Project Team Leader to oversee the setup and ensure readiness.

Through these efforts, HBRC has established a well-prepared testing yard in Aswan-Toshky, fully equipped to support comprehensive testing in Egypt's Climatic Zone 8.

VII. Location of the Testing Yard

The testing yard was set up in Climatic Zone 8, located in Aswan-Toshky (latitude: 22°49' 02" N, longitude: 31°28' 16" E, altitude: 196.07 meters above sea level) as in Figure (1). The tests were conducted under this region's extreme climatic conditions, which are characterized by high temperatures and low humidity.

The layout and equipment setup for the testing yard included the following components and arrangements, as illustrated in Figure (2): Schematic diagram:

VIII. Tested Units:

- IEC Hybrid Unit: A Direct/Indirect Evaporative Cooling Hybrid (IEC-H) prototype.
- DX Unit: A Direct Expansion (DX) unit configured to match the airflow rate of the IEC-H unit.

Both the IEC-H prototype and DX unit were configured to operate with a low Global Warming Potential (GWP) refrigerant, R-32, and were set up for full fresh air intake, maintaining the same airflow rate for accurate comparison. Each OEM's equipment was tested simultaneously over a continuous 24-hour period, with data recorded every hour.
The IEC-Hybrid prototype and DX Unit were positioned parallel, with both units set to intake fresh air from the same ambient source to ensure consistency in air conditions. Each unit was equipped with air ducts to facilitate controlled air discharge.

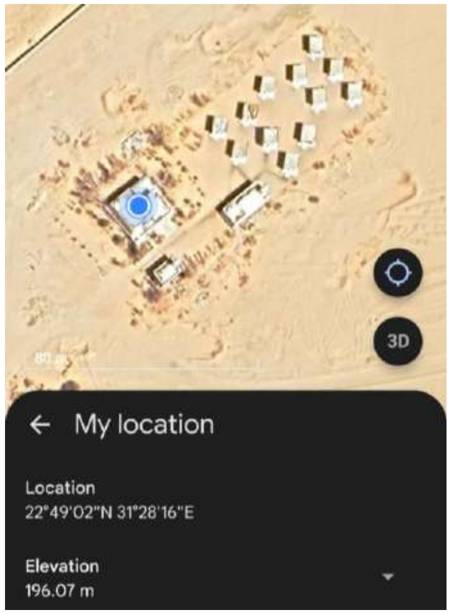

Figure (1): Testing Location

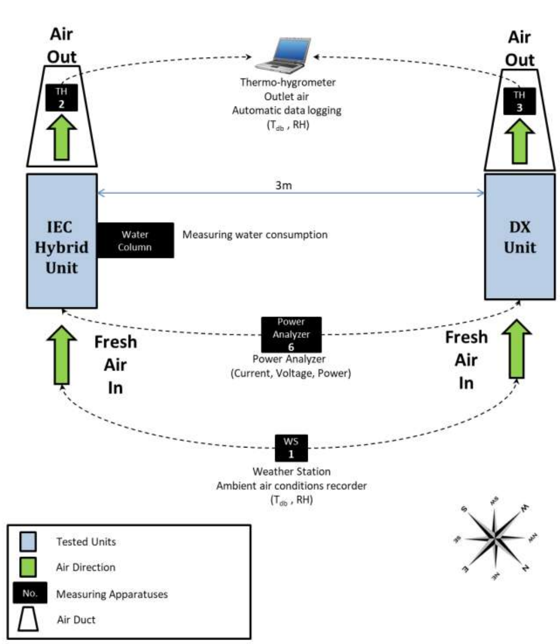

Figure (2): Schematic Diagram of the testing Units and Measuring Instruments

IX. Measurement Apparatus:

- Thermo-Hygrometers: Placed at the outlet of both the IEC-H prototypes and DX units, the thermo-hygrometers recorded the dry bulb temperature (Tdb_{out}) and relative humidity (RH_{out}) of the outlet air, automatically logging these values hourly for detailed analysis of the air conditioning performance.
- Weather Station (WS): Located on roof top of one building in the site away from the

exit of tested units. The weather station continuously recorded ambient air conditions, specifically the dry bulb temperature (Tdb_{amb}) and relative humidity (RH_{amb}), wind speed, wind direction, solar radiation, and barometric pressure providing a reference for evaluating the effectiveness of the cooling systems under local climate conditions.

- Power and Water Consumption Monitoring: Each DX unit was connected to a power meter to monitor the total power consumption ($Pw._{TotDX}$). While Each IEC-H prototype was connected to a power analyzer to monitor the total power consumption ($Pw._{TotIEC-H}$). Additionally, four power meters were connected to the IEC-H prototype to monitor the power consumption of the pump, supply fan, exhaust fan, and the compressor. A water level (W_{LVL}) sensor measured the water consumed by the IEC-H prototype, with hourly data logged to calculate the total water usage across the 24-hour test period.
- All measuring apparatuses are calibrated in accredited laboratories; the calibration certificates are included in Annex 2.

X. Supporting Equipment:

- Generator: A generator was provided to ensure stable power supply, as local electricity was inconsistent due to high summer loads. Heavy equipment was used to transport and position the generator on site.
- Water Pump: Installed to supply the IEC-H prototypes with the required water feed for evaporative cooling.
- Forklifts and Vehicles: Forklifts were rented to transport and position the units at the designated testing locations, while vehicles facilitated transport of personnel and equipment between the testing site and accommodations.

XI. Data Collection and Analysis:

- The tests were conducted for each OEM over a continuous 24-hour period, with all measurements (temperature, humidity, power consumption, and water usage) recorded on an hourly basis. This allowed for a comprehensive analysis of each unit's performance in terms of energy efficiency, cooling capacity, and resource consumption.
- This setup enabled a detailed comparison between the IEC-H and DX units, facilitating performance evaluation in Climatic Zone 8's challenging environmental conditions. The hourly readings and controlled testing environment ensured reliable data, which will contribute to assessing the thermodynamic efficiency of the IEC-H system compared to traditional DX systems under real-world conditions.

1.2. Method of tabulating results

The purpose of this report is to outline the methodology used to tabulate results for performance tests conducted on four OEMs

- VOLTA Egypt
- Delta Construction & Manufacturing (DCM)

- Smart Sustainable Air Technology (SS Air Technology)
- TIBA Engineering Industries Co. (TIBA).

These tests were conducted to assess the airflow characteristics of the IEC-H prototypes and DX units associated with each OEM. Testing was carried out on specific dates and with airflow rates held constant to ensure consistency in results.

The results for each OEM were tabulated as per **Annex 1: Results of Tests of All OEMs**

I. Test Details and Schedule:

Testing was conducted over four days, with each OEM's units being evaluated on a specific date:

- **OEM 2**: August 26, 2024
- **OEM 3**: August 28-29, 2024
- **OEM 7** : August 30-31, 2024
- **OEM 6**: August 31 – September 1, 2024

The testing dates modified from the scheduled plan as per specified in Table (1):

Table (1): The testing dates modified from the scheduled plan

Date	Scheduled Action	Changes in Scheduled Plan	Remarks
24rd August	Arrival of some of HBRC team & **OEM 2** Team at Abu-Simbel Airport Arrival of **OEM 2** units Connecting of **OEM2** units	No Changes	N.A
25th August	**Testing of OEM 2 units***	Testing postponed to the next day	Unstable electricity in the site. Power generator is rented to solve the problem.
26th August	**Disconnecting of OEM 2 units*** Arrival of **OEM 3** units Connecting of **OEM 3** units	Testing of **OEM 2** units started @ 12:00 am	A storm started at 6:30 pm, which sharply increased the ambient relative humidity and decreased the ambient dry bulb temperature
27th August	**Testing of OEM 3 units***	Testing postponed to the next day	Dew to the storm occurred on the previous day, the

Date	Scheduled Action	Changes in Scheduled Plan	Remarks
			ambient relative humidity was higher than usual values in this location.
28th August	**Disconnecting of OEM 3 units***	Testing of **OEM 3** units started @ 10:00 am	
29th August	Arrival of **OEM 7** units Connecting of **OEM 7** units	No Changes	**OEM 7** used the DX unit of **OEM 3** company A storm started at 8:00 pm
30th August	Testing of **OEM 7** units	Testing of **OEM 7** started @ 9:00 am	Testing of **OEM 7** was going to be started at 12:00 am, The storm caused a heavy rain and power shortage all over the city. The testing was postponed to 9:00 am when the weather became more stable Due to the storm, the ambient relative humidity throughout the testing day was higher than usual
31st August	Disconnecting of **OEM 7** units Arrival of **OEM 6** units Connection of TIBA units	Testing of **OEM 6** units started @ 8:00 pm	N.A
1st September	**Testing of OEM 6 units***	Testing started at the previous day Disconnection of the units	N.A
2nd September	departure of HBRC team & **OEM 6** Team at Abu-Simbel Airport		N.A
Note: (*): Changed from the original Schedule			

II. Standard Conditions for Testing:

To ensure comparability between results, the airflow rates for both the IEC-H prototype and DX unit were set as follows:

- **OEM 2**: 1189 CFM
- **OEM 3**: 1320 CFM
- **OEM 7**: 1320 CFM
- **OEM 6**: 1800 CFM

These values were used consistently throughout testing to provide a controlled environment for comparing the performance of each OEM's equipment under similar conditions.

III. Tabulating Results:

Results were monitored and automatically logged to provide clarity and ease of analysis. The tabulation process was organized according to the following principles:

a. Date and OEM Identification: Each set of results is associated with the specific OEM tested on a particular date, ensuring easy traceability and review of test data.

b. Airflow Measurements: The airflow rate was a critical variable in this testing process, and it was carefully documented for both the IEC-H prototype and DX units of each OEM. The values were kept constant as per the standard conditions, ensuring consistency.

c. Measured Metrics: For each OEM, performance metrics (such as ambient conditions, primary air outlet temperature and relative humidity, water consumption, and power consumption) were recorded for the IEC-H prototype and DX unit and organized into a table format. These values were measured under the constant airflow conditions outlined above to provide comparable results across all OEMs.

d. Calculated Parameters: The testing process involved comprehensive measurements at both ambient conditions and during operation of the IEC-H prototype and DX unit. These parameters were essential for evaluating the performance of each OEM’s system. Below is a summary of the specific metrics calculated in each case.

e. Ambient Condition Calculated parameters: The following parameters were calculated at ambient conditions to establish baseline environmental data for each test:

   - Pressure at Given Altitude (Pa): Calculated based on the testing location’s altitude to adjust for atmospheric pressure.
   - Saturation Vapor Pressure (hPa): The maximum vapor pressure at the ambient temperature.
   - Partial Vapor Pressure (Pa): The pressure exerted by water vapor present in the ambient air.

- Humidity Ratio: The ratio of the mass of water vapor to the mass of dry air.
- Partial Pressure of Dry Air (Pa): The pressure component of dry air in the ambient conditions.
- Density of Ambient Air (kg/m^3): Calculated based on pressure, temperature, and humidity conditions.
- Enthalpy of Ambient Air (kJ/kg): Total heat content of the ambient air per unit mass.

f. IEC-H Prototype and DX Unit Calculated parameters: For the IEC-H prototype and DX unit, the following parameters were calculated to evaluate its performance under operating conditions:

- Saturation Vapor Pressure (hPa): Calculated for the air exiting the tested unit to assess moisture content.
- Partial Vapor Pressure (Pa): The pressure component of water vapor in the outlet air.
- Humidity Ratio: Measured for the air exiting the tested unit.
- Partial Pressure of Dry Air (Pa): Calculated for the outlet air.
- Density of Outlet Primary Air (kg/m^3): The density of the air leaving the IEC-H prototype.
- Enthalpy of Outlet Primary Air (kJ/kg): Total heat content of the outlet air per unit mass.
- Water Consumed (mm^3/hr): The amount of water used by the IEC-H prototype during operation.
- Total Power Consumption (kW): The energy consumed during the operation of the IEC-H prototype.
- Mass Flow Rate (kg/s): The rate at which air is supplied through the tested unit.
- Total Refrigeration Capacity (BTU/hr): The cooling capacity of the tested unit.
- Coefficient of Performance (COP): The ratio of cooling capacity to power consumption, indicating efficiency.
- Energy Efficiency Ratio (EER) (BTU/W.hr): The cooling capacity per unit power input.

IV. Accuracy of Measuring Instruments:

In order to ensure reliable results, all measurements were carried out using instruments that have been calibrated at accredited laboratories. The accuracy of the measurements was scrutinized to determine the degree to which each calculated or measured value closely approximates the actual value. Since a measuring instrument can only record values within its specific precision limits, the selection and calibration of each instrument played a critical role in the accuracy of the results.

All instruments used in this testing were calibrated, and calibration certificates to this report to verify compliance with international standards. Calibration certificates are listed in Annex (2).

The accuracy of our measurements was guaranteed through the following procedures:

- Collecting Data: All measurement data were electronically recorded using the equipment's software, which facilitated the direct transfer of information to tools such as spreadsheets for further analysis.
- Sorting Values: Data points were sorted systematically to help determine the range of values collected, providing an initial view of consistency and variability.
- Average Value Calculation: The average value of each set of measurements was calculated, representing a central value that serves as a reference point for accuracy.
- Calculating Absolute Deviations: Each individual measurement was subtracted from the average value, producing a set of absolute deviations. These deviations illustrate how close each individual reading is to the average, providing insight into data consistency.
- Determining Precision: Precision was calculated as the average value plus or minus the average deviation, reflecting the repeatability and reliability of the measurements.
- Calculating Uncertainty: To determine overall measurement uncertainty, all potential sources of uncertainty were identified, and the uncertainty contributions from each source were combined for an overall estimation.
- Annex 3: provides details instrument used, including the model number, serial number, and measured parameter.

1.3. Ambient Conditions During the Tests:

The tests conducted on the OEM units (OEM 2, OEM 3, OEM 7, and OEM 6) between August 25, 2024, and September 1, 2024, were subject to varying ambient conditions, which significantly impacted the relative humidity levels throughout the testing period. Understanding these conditions and their relationship to relative humidity is essential for evaluating the performance results accurately.

a. Testing of OEM 2 Units (August 26, 2024)

- Initial Delay: Testing was initially scheduled for August 25 but was postponed due to unstable electricity at the site, requiring a power generator.
- Weather Impact on August 26: A storm began at 6:30 pm, which had a notable impact on the ambient conditions. The storm led to a sharp increase in relative humidity and a decrease in the ambient dry bulb temperature, creating a more humid environment than expected for this location.
- Effect on Testing: Higher relative humidity due to the storm likely affected the **OEM 2** unit's performance, as the system would have to account for increased moisture in the air. This may have impacted both cooling capacity and energy efficiency.

b. Testing of OEM 3 Units (August 28-29, 2024)

- Ambient Conditions on August 27: Testing was delayed by another day due to residual effects of the previous day's storm. The relative humidity remained unusually high because of dew formation, a direct consequence of the storm.
- Testing on August 28: Testing began at 10:00 am on August 28. Due to the delay, the ambient relative humidity returned to normal conditions.
- Effect on Testing: **OEM 3** units were tested under normal conditions.

c. Testing of OEM 7 Units (August 30-31, 2024)

- Weather on August 29: **OEM 7**'s units arrived and were connected, with no changes in the initial plan. However, on the evening of August 29, a storm started around 8:00 pm.
- Testing Delays on August 30: Testing for **OEM 7** was initially planned for midnight but was postponed to 9:00 am due to heavy rain and a power outage caused by the storm. As a result of the storm, relative humidity remained high throughout the day.
- Effect on Testing: Prolonged high relative humidity during the **OEM 7** unit testing would impact cooling efficiency and dehumidification load. The ambient conditions likely demanded more energy for maintaining required conditions, potentially influencing the power consumption and efficiency metrics.

d. Testing of OEM 6 Units (August 31 - September 1, 2024)

- Testing Start on August 31: The **OEM 6** units were installed and tested starting at 8:00 pm. No specific issues with ambient conditions were noted on this date.
- Continuation on September 1: Testing continued briefly into September 1 before the disconnection of the units.
- Effect on Testing: no storm or other significant weather impact on August 31. Therefore, it is reasonable to assume that ambient relative humidity levels returned to typical values, allowing **OEM 6** units to be tested under more normal conditions.

Summary of Ambient Condition Impact on Relative Humidity

The testing period experienced significant weather fluctuations, particularly during the first few days. The following conclusions can be drawn regarding the relationship between ambient conditions and relative humidity during testing:

- Storm Events: Storms on August 26 and August 29 caused spikes in relative humidity levels, which lingered for the following day or more. These high humidity levels would likely affected the performance metrics of the tested units.
- Impact on Performance: Increased humidity generally necessitates more energy for dehumidification, which could reduce the efficiency of the IEC-H prototypes. The increased humidity also impacts air density and enthalpy, which are critical factors in calculating the total refrigeration capacity and efficiency of the units.

- Environmental Control Considerations: These variations in ambient conditions emphasize the importance of accounting for external weather impacts in HVAC performance testing; as such conditions can affect system efficiency and load characteristics.

1.4. Summary of Results:

I. Results of OEM 2 (August 26, 2024):

a. Energy Saving:

- Power Consumption of DX Unit (over 1 day): **225501.9 Watts**
- Power Consumption of IEC-H Unit (over 1 day): **276501 Watts**
- **Energy Saved by IEC-H Prototype w.r.t DX Unit (%) ≈ 18.5 %**

b. Outlet Primary Air:

- DX Unit (Maximum Outlet Primary Temperature): **15.2 ^{o}C**
- IEC-H Prototype (Maximum Outlet Primary Temperature): **14.1 ^{o}C**
- DX Unit (Minimum Outlet Primary Temperature): **8.1 ^{o}C**
- IEC-H Prototype (Minimum Outlet Primary Temperature): **8.1 ^{o}C**

c. EER:

- DX Unit (Maximum EER): **7.3 BTU/W.hr**
- IEC-H Prototype (Maximum EER): **8.6 BTU/W.hr**
- DX Unit (Minimum EER): **4.5 BTU/W.hr**
- IEC-H Prototype (Minimum EER): **5.4 BTU/W.hr**

d. Total Refrigeration Capacity

- DX Unit (Maximum Total Refrigeration Capacity): **77,652 BTU/hr**
- IEC-H Prototype (Maximum Total Refrigeration Capacity): **79,101 BTU/hr**
- DX Unit (Minimum Total Refrigeration Capacity): **52,269 BTU/hr**
- IEC-H Prototype (Minimum Total Refrigeration Capacity): **50,537 BTU/hr**

II. Testing of OEM 3 (August 28-29, 2024):

a. Energy Saving:

- Power Consumption of DX Unit (over 1 day): **286451 Watts**
- Power Consumption of IEC-H Unit (over 1 day): **149606.7 Watts**
- **Energy Saved by IEC-H Prototype w.r.t DX Unit (%) ≈ 47.8 %**

b. Outlet Primary Air:

- DX Unit (Maximum Outlet Primary Temperature): **14.7 ^{o}C**

- IEC-H Prototype (Maximum Outlet Primary Temperature): **14 ^{o}C**
- DX Unit (Minimum Outlet Primary Temperature): **9.1 ^{o}C**
- IEC-H Prototype (Minimum Outlet Primary Temperature): **10.6 ^{o}C**

c. EER:

- DX Unit (Maximum EER): **8.1 BTU/W.hr**
- IEC-H Prototype (Maximum EER): **14.9 BTU/W.hr**
- DX Unit (Minimum EER): **5.8 BTU/W.hr**
- IEC-H Prototype (Minimum EER): **8.6 BTU/W.hr**

d. Total Refrigeration Capacity

- DX Unit (Maximum Total Refrigeration Capacity): **93,129 BTU/hr**
- IEC-H Prototype (Maximum Total Refrigeration Capacity): **90,984 BTU/hr**
- DX Unit (Minimum Total Refrigeration Capacity): **66,797 BTU/hr**
- IEC-H Prototype (Minimum Total Refrigeration Capacity): **49,524 BTU/hr**

III. Results of OEM 7 (August 30-31, 2024):

a. Energy Saving:

- Power Consumption of DX Unit (over 1 day): **278840 Watts**
- Power Consumption of IEC-H Unit (over 1 day): **189891 Watts**
- **Energy Saved by IEC-H Prototype w.r.t DX Unit (%) ≈ 31.9 %**

b. Outlet Primary Air:

- DX Unit (Maximum Outlet Primary Temperature): **17.3 ^{o}C**
- IEC-H Prototype (Maximum Outlet Primary Temperature): **17.4 ^{o}C**
- DX Unit (Minimum Outlet Primary Temperature): **13.4 ^{o}C**
- IEC-H Prototype (Minimum Outlet Primary Temperature): **12.3 ^{o}C**

c. EER:

- DX Unit (Maximum EER): **8.7 BTU/W.hr**
- IEC-H Prototype (Maximum EER): **11.6 BTU/W.hr**
- DX Unit (Minimum EER): **4.7 BTU/W.hr**
- IEC-H Prototype (Minimum EER): **6.8 BTU/W.hr**

d. Total Refrigeration Capacity

- DX Unit (Maximum Total Refrigeration Capacity): **96,172 BTU/hr**
- IEC-H Prototype (Maximum Total Refrigeration Capacity): **91,961 BTU/hr**

- DX Unit (Minimum Total Refrigeration Capacity): **57,482 BTU/hr**
- IEC-H Prototype (Minimum Total Refrigeration Capacity): **52,535 BTU/hr**

IV. Results of OEM 6 (August 31 – September 1, 2024):

a. Energy Saving:

- Power Consumption of DX Unit (over 1 day): **245209 Watts**
- Power Consumption of IEC-H Unit (over 1 day): **137732 Watts**
- **Energy Saved by IEC-H Prototype w.r.t DX Unit (%) ≈ 43.8 %**

b. Outlet Primary Air:

- DX Unit (Maximum Outlet Primary Temperature): **21.0 ^oC**
- IEC-H Prototype (Maximum Outlet Primary Temperature): **17.4 ^oC**
- DX Unit (Minimum Outlet Primary Temperature): **11.6 ^oC**
- IEC-H Prototype (Minimum Outlet Primary Temperature): **7.5 ^oC**

c. EER:

- DX Unit (Maximum EER): **11.2 BTU/W.hr**
- IEC-H Prototype (Maximum EER): **16.9 BTU/W.hr**
- DX Unit (Minimum EER): **7.4 BTU/W.hr**
- IEC-H Prototype (Minimum EER): **13 BTU/W.hr**

d. Total Refrigeration Capacity

- DX Unit (Maximum Total Refrigeration Capacity): **102,573 BTU/hr**
- IEC-H Prototype (Maximum Total Refrigeration Capacity): **123,792 BTU/hr**
- DX Unit (Minimum Total Refrigeration Capacity): **67,309 BTU/hr**
- IEC-H Prototype (Minimum Total Refrigeration Capacity): **39,442 BTU/hr**

1.5. Challenges and Problems Associated with the Testing:

During the testing period from August 25 to September 1, 2024, several challenges and technical problems arose that affected the testing schedule and potentially impacted the results. These issues ranged from environmental conditions, such as storms and humidity fluctuations, to technical and power-related challenges. Below is a summary of the main challenges encountered.

I. Unstable Electricity Supply

The testing site experienced unstable electricity, which led to several delays and operational difficulties:

- **OEM 2 Units:** Prior to the start of testing on August 25, the pump of the OEM 2 unit subjected to electrical shortage due to fluctuations in the power supply. This issue necessitated the postponement of testing and the rental of a power generator to stabilize the electricity supply. The delay disrupted the schedule and may have impacted the readiness of the unit for testing.
- **OEM 3 Units:** Similarly, OEM 3 units encountered issues with unstable electricity before testing could begin. This issue delayed the testing schedule, as additional steps were required to stabilize the power supply.
- **OEM 7 Units:** OEM 7 units also experienced power connection issues, causing further delays and the need for troubleshooting before testing could proceed.

These power-related challenges underscored the need for a stable and reliable electricity supply at the testing site. The lack of consistent power created interruptions and delays, which impacted the testing timeline and added unforeseen variables that could influence the performance metrics of each OEM's equipment.

II. Weather-Related Challenges

Several storms during the testing period added further complications:

- August 26 Storm: A storm on the evening of August 26 sharply increased the ambient relative humidity and lowered the dry bulb temperature. This change in weather conditions impacted the testing environment for the **OEM 2** units, adding an additional load on the system to handle the increased moisture in the air.
- August 29 Storm: Another storm on the night of August 29 caused heavy rain, which led to high humidity conditions and power outages throughout the city. This affected the testing of **OEM 7** units, which had to be postponed until the weather stabilized on the morning of August 30. The high humidity levels lingered, influencing the environmental conditions during the testing.

The weather-related challenges significantly impacted relative humidity levels, leading to higher latent loads and potentially skewing results for parameters such as cooling efficiency, power consumption, and the overall coefficient of performance (COP). These fluctuations made it challenging to maintain consistent ambient conditions across all tests.

III. Technical Problems with Testing Equipment

In addition to power and environmental issues, several technical problems with the tested unit emerged:

- **OEM 2** Pump Malfunction: Due to the initial unstable electricity, the pump encountered electrical issues before testing started. This necessitated repairs and recalibration, further delaying the testing schedule.
- **OEM 6** Fan Issues: Prior to the start of testing, the fan encountered technical problems, which required troubleshooting and repair.

- **OEM 7** Power Connection: the units faced connection problems with the power meters, delaying the setup and testing process. This issue required additional adjustments to ensure the unit was properly connected and ready for testing.

These delays and last-minute repairs also increased the workload for the testing team, potentially influencing the precision and timing of data collection.

IV. Impact of Challenges on Testing Results

Scheduling Delays: The frequent delays due to power instability, weather conditions, and equipment malfunctions disrupted the original testing schedule, resulting in adjustments that affected both the timeline and the operational flow.

These challenges highlight the complex and unpredictable nature of conducting environmental testing, especially when external factors like weather and power supply play a significant role. Moving forward, improved infrastructure for stable electricity, thorough pre-testing equipment checks, and contingency plans for weather fluctuations would enhance the reliability and consistency of test results. The issues encountered during this testing period underscore the importance of accounting for external factors when interpreting data and drawing conclusions from performance evaluations.

Chapter 2: Review and Recommend How to Update National Guidelines to Include New Technologies

2.1. Review of the results of testing in CZ 2, 5 and 8:

I. Developing Guidelines and Codes for Direct/Indirect Evaporative Cooling (IEC)

Establish specific guidelines and codes for IEC Systems: Given the promising results of IEC systems under various climatic conditions in Egypt, it is recommended that specific guidelines and codes for Direct Indirect Evaporative Cooling (IEC) be developed. These codes should define the design, testing, and performance requirements for IEC systems to ensure safety, efficiency, and adaptability across different climatic zones.

Include IEC Performance Metrics: The guidelines should specify essential performance metrics for IEC systems, such as Energy Efficiency Ratio (EER), cooling capacity, and water consumption. Testing results from climatic zones 2, 5 and 8 demonstrate that IEC systems perform well compared to conventional DX systems, particularly in high-temperature and low-humidity conditions.

II. Guidelines for Not-In-Kind (NIK) Cooling Technologies

Adopt Flexible Frameworks for Emerging Technologies: Not-In-Kind (NIK) cooling technologies, such as IEC, represent a significant shift from traditional vapor-compression systems. National guidelines should include frameworks that allow for the inclusion of other NIK technologies as they evolve, ensuring that national codes remain relevant and up-to-date.

Focus on Environmental Impact: As NIK technologies are generally less reliant on high-GWP refrigerants; the guidelines should emphasize lower GWP refrigerant options (such as R-32 or R-454B) and the potential for reduced greenhouse gas emissions. This aligns with international efforts to phase out HCFCs and other high-GWP substances.

III. Expand Testing Requirements Across Climatic Zones

Broaden Testing to All Egyptian Climatic Zones: Current testing has been conducted in climatic zones 2, 5 and 8, highlighting the adaptability of IEC systems in varying humidity and temperature conditions. To fully capture the potential of IEC across Egypt, guidelines should mandate testing in additional zones, where high dry bulb temperatures and low humidity conditions prevail. This would provide comprehensive data on the efficiency and practicality of IEC systems across the country.

IV. **Establish Calibration and Certification Protocols**

Regular Calibration of IEC Systems: Guidelines should include protocols for the calibration and maintenance of IEC systems to ensure ongoing accuracy in performance and efficiency measurements. This will maintain the systems' reliability over time and across different operational conditions.

Certification for Installers and Manufacturers: A certification program for installers and manufacturers of IEC systems should be established to standardize installation practices and ensure compliance with national guidelines.

V. **Promote Awareness and Training for IEC Technology**

Educational Campaigns: Implement educational and outreach campaigns targeting HVAC professionals, developers, and policymakers to promote the advantages of IEC technology, such as reduced energy consumption and environmental impact. The outreach conducted as part of this project demonstrated strong interest, highlighting the need for a wider, formalized program.

Technical Training: Provide specialized training for HVAC engineers and technicians on the design, installation, and maintenance of IEC systems. This training should emphasize the differences between IEC and conventional DX systems, including unique operational and environmental considerations.

VI. **Economic Feasibility Analysis Requirements**

Incorporate Life-Cycle Cost Analysis: The guidelines should mandate a comprehensive life-cycle cost analysis for IEC systems to evaluate their long-term economic benefits compared to traditional DX systems. This includes capital investment, operational costs, maintenance, water consumption, and savings in energy usage.

Financial Incentives: To encourage adoption, the government may consider offering financial incentives, such as tax credits or rebates, for projects implementing IEC technology. This would offset the initial higher investment cost, which the report identified as a barrier despite favorable IRRs and NPVs for IEC system.

VII. **Define Quality Assurance and Testing Procedures**

Quality Assurance Standards: National guidelines should include quality assurance standards specifically for IEC systems, based on both local and international benchmarks such as EUROVENT recommendations. These standards would ensure consistent product quality and reliable performance data.

Specific Testing Procedures: Define testing procedures for key metrics, including cooling capacity, EER, and water consumption, to provide standardized data that would help in evaluating the systems' efficiency across various conditions. This would help build a reference for further developments and improvements in IEC systems.

VIII. Conclusion

Updating national guidelines to include Direct Indirect Evaporative Cooling (IEC) and Not-In-Kind (NIK) technologies would provide a framework to support the adoption of more energy-efficient and environmentally friendly cooling options in Egypt. By implementing specific codes, expanding testing protocols, and providing financial and educational support, the guidelines can facilitate a transition towards sustainable cooling solutions aligned with Egypt's environmental goals and the HCFC Phase-Out Management Plan.

2.2. Recommendations for Updating National Guidelines

I. Develop Specific Guidelines and a Code for IEC Technology

Create national code for Design, Installation, and Performance: Introduce a national code specifically for IEC systems that covers design specifications, installation practices, and performance criteria. This code should provide clear definitions and minimum performance standards for IEC systems under different climatic conditions.

Align with International Standards: Reference international standards such as EUROVENT and ASHRAE for guidance on classification, testing, and certification of IEC systems. Adapt these standards to suit local conditions and market needs in Egypt.

II. Expand Testing and Performance Evaluation All Climate Zones

Broaden Testing to All Climate Zones: Current testing has been focused on specific zones (2, 5 and 8), which limits the understanding of IEC system performance in other climates. Guidelines should require testing in additional zones. This will validate IEC technology performance across the diverse climatic conditions of Egypt.

Standardize Testing Conditions and Procedures: Establish standardized testing procedures for IEC systems to ensure consistency and reliability in performance data. This includes defining metrics such as cooling capacity, water consumption, and EER under controlled conditions.

III. Promote Lower-GWP Refrigerants and Environmental Sustainability

Mandate Low-GWP Refrigerants: Given that IEC systems often work with lower GWP refrigerants or avoid traditional refrigerants altogether, the guidelines should prioritize refrigerants with minimal environmental impact, such as R-32 or R-454B. This supports Egypt’s HCFC Phase-Out Management Plan (HPMP) and aligns with global efforts to reduce greenhouse gas emissions.

Encourage Water and Energy Efficiency: Define water and energy efficiency benchmarks for IEC systems, given the increased use of water in evaporative cooling. National guidelines should require manufacturers to disclose water and energy consumption data for transparency.

IV. Incorporate Life-Cycle Cost Analysis and Economic Feasibility Assessments

Require Life-Cycle Cost Analysis for Project Approval: Include a requirement for life-cycle cost analysis to assess the economic feasibility of IEC systems compared to traditional DX systems. This analysis should consider initial investment, maintenance costs, water consumption, and energy savings over the system's lifespan.

Financial Incentives for IEC Adoption: Encourage the adoption of IEC systems by offering financial incentives, such as tax credits or rebates, for projects that utilize IEC or other NIK cooling technologies. This can offset initial higher costs and accelerate the market transition toward more sustainable technologies.

V. Develop Calibration and Quality Assurance Protocols

Regular Calibration and Maintenance Standards: Establish guidelines for the regular calibration and maintenance of IEC systems, especially for components like fans, pumps, and water distribution systems. This will ensure systems operate efficiently and provide reliable performance over time.

Certification for Installers and Technicians: To maintain installation quality, establish a certification program for HVAC installers and technicians specifically for IEC systems. This would ensure proper handling of IEC technology and compliance with national standards.

VI. Raise Awareness and Provide Training for IEC and NIK Technologies

Educational Campaigns for Stakeholders: Develop educational programs to increase awareness about the benefits of IEC and NIK technologies among HVAC professionals, policymakers, and the public. Highlight key advantages like energy efficiency, environmental sustainability, and cost-effectiveness.

Technical Training for Engineers and Technicians: Offer specialized training on the design, installation, and maintenance of IEC systems. This training should emphasize the differences between IEC and conventional DX systems, covering topics like water management, fan and pump controls, and evaporative cooling principles.

VII. Quality Assurance and Certification for IEC Technology

Quality Standards and Labeling for IEC Units: Introduce mandatory quality standards and efficiency labeling for IEC systems to provide a transparent comparison for consumers and to encourage manufacturers to maintain high performance standards.

Certification of IEC System Components: Ensure that all components used in IEC systems meet quality standards. Certification should cover key parts such as evaporative cooling pads, water pumps, and control systems.

VIII. Continuous Monitoring and Data Collection for IEC System Performance

Establish a National Database for IEC Performance Data: Collect data on IEC systems' performance across various climatic zones to continuously assess their efficiency and environmental impact. This data can help refine performance benchmarks and inform future updates to the guidelines.

Require Reporting of Operational Data: Implement requirements for reporting operational data, including water and energy usage, for large-scale IEC installations. This can provide insight into long-term performance and help in optimizing designs for future projects.

IX. Incorporate Environmental and Sustainability Criteria

Water Usage Management in Arid Regions: Due to the water requirements of IEC technology, introduce guidelines on water conservation strategies, such as water recycling or closed-loop systems, especially in arid regions. This will make IEC systems more sustainable in areas with water scarcity.

Carbon Footprint Reduction Targets: Set carbon footprint reduction targets for new HVAC projects utilizing IEC and other NIK technologies to align with national sustainability goals.

X. Summary

These recommendations aim to provide a comprehensive update to national guidelines, promoting the adoption of IEC and other NIK technologies as sustainable alternatives to traditional air conditioning systems. By addressing design standards, testing protocols, economic feasibility, environmental impact, and educational initiatives, these updated guidelines can drive a transition toward energy-efficient, environmentally friendly cooling solutions tailored to Egypt's diverse climate.

Chapter 3: Reporting on the Outreach Campaign

3.1. The outreach campaign:

Date: November 3, 2024

Location: Housing & Building National Research Center (HBRC), Cairo, Egypt

I. Introduction

The outreach campaign on Direct/Indirect Evaporative Cooling (IEC) technology was held on November 3, 2024, at HBRC in Cairo, Egypt. This event, supported by UNIDO, UNEP, the National Ozone Unit (NOU), aimed to raise awareness of the technological advances and environmental benefits of IEC systems, specifically focusing on their role in phasing out HCFC in the commercial air conditioning sector. The campaign was part of Egypt's HCFC Phase-out Management Plan (HPMP) under UNIDO's management, emphasizing sustainable alternatives to traditional cooling technologies; **Annex 4**.

II. Campaign Objective

The campaign focused on promoting IEC technology as a sustainable cooling solution. It encouraged stakeholders to contribute to the phase-out of HCFCs in the commercial air conditioning sector by adopting this innovative, energy-efficient technology. The event included presentations on technical findings, testing outcomes, and future recommendations to integrate IEC technology within the national guidelines.

III. Program Agenda:

The event's schedule included:

- Registration
- Welcome & Remarks by Prof. Sayed Shebl (Project Team Leader).
- Prof. Ezzat Lewis discussed the critical role of the Multilateral Fund, NOU, UNIDO, and UNEP in supporting Egypt's transition away from HCFCs and promoting sustainable cooling technologies.
- Presentation of Project Findings by Prof. Alaa Olama (Technical Consultant) and Prof. Sayed Shebl, summarizing key results from recent testing.
- Public Hearing Session, allowing stakeholders to discuss and question the research findings and recommendations.

IV. Key Presentations

Prof. Ezzat Lewis's emphasized the support provided by the Multilateral Fund and the collaboration between NOU, UNIDO, and UNEP in funding and guiding the project. He highlighted their role in addressing climate and environmental challenges through sustainable cooling solutions, facilitating Egypt's compliance with international environmental agreements, and fostering innovation in the HVAC industry.

The research team, led by Prof. Alaa Olama and Prof. Sayed Shebl, presented the following findings:

- Testing in Multiple Climatic Zones: The IEC systems were evaluated across different climatic conditions, including zones 2, 5, and recently, zone 8 (Aswan - Toshky). The latter presented extreme conditions, providing valuable insights into the systems' performance under high dry bulb temperatures and low humidity.
- Performance Metrics: Results indicated that IEC-H units generally demonstrated higher Energy Efficiency Ratios (EER) than traditional DX system, underscoring the technology's superior efficiency.
- Economic Advantages: IEC systems, despite their relatively lower initial compressor capacity, showed favorable cooling capacity and economic feasibility. Comparative financial analysis from previous testing in climatic zones 2 and 5 showed that IEC systems offer substantial operational savings over DX systems.
- Challenges in Testing: During testing in zone 8, environmental factors such as dust storms impacted results, causing transient spikes in relative humidity and occasional compressor instability. These anomalies were addressed to ensure data accuracy, highlighting the need for robust testing environments.

V. Discussions

About 30 persons attended the 4 hours Outreach campaign.

The following are the most important questions and answers made during the campaign:

a. Question: Eng. Mohamed Mansour asked about the humidity ratios and relative humidity of the ambient air.

Answer: Dr. Olama responded, explaining the humidity measurements taken and their correlation with the two storms that occurred during testing, which significantly raised the area's humidity levels.

b. Question: Eng. Abdel Sallam Mahrous, a consulting engineer, inquired about which OEMs demonstrated the highest EERs.

Answer: Prof. Olama clarified that a key principle of the program is to refrain from sharing data aimed at identifying the best-performing prototypes or DX units. For this reason, the OEMs are represented by code numbers rather than by their names.

c. Question: Eng. Maarouf, a consulting engineer, asked whether the maintenance requirements for IEC-H units, if produced regularly, would be higher or lower than those for DX units.

Answer: Prof. Olama responded that IEC-H units have higher maintenance costs compared to DX units due to the increased expenses associated with maintaining the evaporation pads.

d. **Question:** Posed by Eng. Abdel Sallam Mahrous, to provide clarification on the distinct roles of various UN agencies and bodies.

   Answer: Dr. Ezzat Lewis, head of the Egyptian NOU, provided clarification on the distinct roles of various UN agencies and bodies. Dr. Ezzat elaborated on future funding opportunities for programs in Egypt and discussed the mechanisms for funding replenishment for individual countries.

e. **Question:** asked by Eng. Hassan el Mogi, chairman of the consulting firm El-AMAAR, when will the IEC-H specification code be ready to be used by consulting engineers?

   Answer: Prof. Olama clarified that the first guidelines on IEC evaporative cooling will first be written as guidance for a forthcoming code, and then a complete code will be written when the third testing program is made and all Climatic Zones in Egypt are covered.

f. **Question:** An unnamed engineer asked if there is a plan to establish a code and legislate the use of IEC-H systems across Egypt's eight climatic zones.

   Answer: Prof. Olama responded that there is hope for a future program phase that will enable OEMs and HVAC practitioners to use a formula to predict compressor sizes and key design parameters of IEC-H units for all eight climatic zones in Egypt. Once performance can be reliably predicted across these zones, binding legislation could be implemented to promote an energy-efficient cooling system nationwide using low-GWP and HC refrigerants.

VI. Outcomes and Future Recommendations

The outreach campaign emphasized the advantages of adopting IEC technology, presenting it as both a technically and economically viable alternative for Egypt's climate. The following recommendations were proposed:

- Development of National Guidelines and Code: Given the successful testing results, there is a need to develop national codes specifically for IEC systems, covering design, performance standards, and testing protocols. These guidelines should be applicable across all climatic zones in Egypt, especially focusing on zones with extreme conditions.
- Education and Training Initiatives: Stakeholder training programs were suggested to ensure proper understanding and implementation of IEC systems, encouraging industry-wide adoption of these sustainable cooling solutions.

VII. Conclusion

The outreach campaign successfully raised awareness about IEC technology and fostered a collaborative atmosphere among government agencies, industry professionals, and environmental organizations. The attendees expressed interest in the future development of national guidelines, continued testing, and integration of IEC systems in Egypt's HVAC sector. The campaign underscored the potential of IEC technology as a key component of Egypt's environmental strategy to reduce HCFC reliance and promote sustainable development.

Chapter 4: Conclusions and Future Work

The testing and evaluation of Direct/Indirect Evaporative Cooling (IEC) Hybrid prototypes across different climatic zones in Egypt (CZ 2, CZ 5, and CZ 8) have demonstrated the effectiveness and energy efficiency of IEC technology as a sustainable alternative to traditional Direct Expansion (DX) systems. The IEC-H systems consistently outperformed DX units in terms of Energy Efficiency Ratio (EER) and overall cooling capacity, even under Egypt's extreme climatic conditions. This performance advantage, along with the reduced environmental impact due to the use of lower Global Warming Potential (GWP) refrigerants, positions IEC technology as a promising solution for reducing reliance on HCFCs in Egypt's commercial air conditioning sector.

4.1. Key findings:

Superior EER: IEC-H systems showed higher EER compared to DX systems, particularly in arid climates with high dry bulb temperatures and low relative humidity, like those in CZ 8.

Economic Benefits: The life-cycle cost analysis showed that IEC-H systems offer significant operational savings, making them economically viable options for long-term applications.

Operational Resilience: The IEC-H systems performed effectively despite challenges such as dust storms and large fluctuations in humidity in a single day, reinforcing their suitability for Egypt’s diverse and challenging climates.

This report provides a strong foundation for developing national guidelines and standards for IEC technology in Egypt. By transitioning to IEC-H systems, Egypt can align with its HCFC Phase-out Management Plan (HPMP) and support global efforts to reduce greenhouse gas emissions.

4.2. Suggested Stage III

To further strengthen the implementation and scaling of IEC technology, the following future work is recommended:

a. Mathematical Modeling for IEC Performance Prediction: Develop a mathematical model to predict EER and refrigeration capacity of IEC-H prototypes across Egypt’s remaining five climatic zones. This model would enable stakeholders to estimate IEC-H performance in various conditions, supporting more targeted and optimized deployments.

b. Comprehensive Testing Across All Climatic Zones: Conduct additional testing in other climatic zones (beyond CZ 2, CZ 5, and CZ 8) to gather comprehensive data that will inform national guidelines. This will ensure that the IEC systems' performance is fully validated across Egypt's diverse climatic conditions.

c. Development of National Standards and Codes: Draft national standards and codes for IEC systems, encompassing design requirements, performance standards, and testing protocols. These standards should include specific guidelines for water and energy efficiency to maximize the sustainability of IEC systems.

d. Stakeholder Training and Capacity Building: Provide training and educational programs for HVAC professionals, policy makers, and industry stakeholders to promote the adoption of IEC technology. Training should cover IEC-specific installation, maintenance, and operational practices to ensure proper implementation.

e. Establishment of a National Database for IEC System Performance: Create a centralized database to monitor IEC performance across different regions and installations. This data will be valuable for ongoing analysis, improvements, and updates to the national standards as the technology matures.

f. Financial Incentives and Support Mechanisms: Encourage the adoption of IEC technology by implementing financial incentives, such as rebates, tax credits, or low-interest loans, for projects that use IEC or other Not-In-Kind (NIK) cooling technologies. Financial support will help offset the initial costs and accelerate market adoption.

g. Further Research on Water Conservation in Arid Regions: Investigate water conservation strategies for IEC systems in arid regions, including water recycling or closed-loop designs, to address water usage concerns in water-scarce areas.

h. By addressing these areas, Egypt can build a robust framework for integrating IEC technology nationwide, fostering a more sustainable, energy-efficient cooling industry and making significant progress toward environmental and climate goals.

Annex 1: Results of Tests of All OEMs:

A.1. Results of OEM 2:

Basic Information			
Tested Units Name	DX (Direct Expansion Unit)		
	IEC Hybrid (Indirect Evaporative Cooling Hybrid Unit)		
OEM No.	2		
Refrigerant	R-32		
Air Flow Rate	0.561 m3/s for DX and IEC hybrid Units		
Capacity	DX	2	Compressors
	IEC hybrid	2	Compressors
Water Bath Area	1000*900		mm2
Climatic Zone	8 (South Egypt)		
Altitude	196.07 meter (From Sea Level)		
Location	22°49' 02" N 31°28' 16" E		
Test Date	26-Aug-24		

Used Apparatus

Used Apparatus	Code of Used Apparatus	Measured Property	Measurement Unit
Weather Station, Dry bulb temperature	**WS; T-amb**	Ambient dry bulb temperature for both Units	°C
Weather Station, Relative Humidity	**WS; Rh-amb**	Ambient Relative humidity for both Units	%
Air Quality 4 - Dry bulb temperature	**AQ4; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 4 - Relative Humidity	**AQ4; RH-amb**	Ambient Relative humidity for both Units	%
Air Quality 6 - Dry bulb temperature	**AQ6; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 6 - Relative Humidity	**AQ6; RH-amb**	Ambient Relative humidity for both Units	%
Fluke 975 - Dry bulb temperature	**F975; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 1 - Dry bulb temperature	**AQ1; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Air Quality 1 - Relative Humidity	**AQ1; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Air Quality 3 - Dry bulb temperature	**AQ3; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Air Quality 3 - Relative Humidity	**AQ3; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Lutron 1 - Dry bulb temperature	**L1; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Lutron 1 - Relative Humidity	**L1; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Air Quality 2 - Dry bulb temperature	**AQ2; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
Air Quality 2 - Relative Humidity	**AQ2; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Lutron 2 - Dry bulb temperature	**L2; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
Lutron 2 - Relative Humidity	**L2; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
UNI T - Dry bulb temperature	**U; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
UNI T - Relative Humidity	**U; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Tabular level gauge for measuring the Water level change	**W.Lvl; IEC-H**	make up of evaporated water of the IEC hybrid unit	mm/hr
Water volume in Litres/hour (calculated)	**W.Vol; IEC-H**	hourly consumption rate of evaporated water for IEC hybrid unit	Litres/hr
Compressor power meter - IEC hybrid unit	**Comp.; IEC-H**	Power consumption of the Compressor of the IEC hybrid Unit	Watts
Pump power meter - IEC hybrid unit	**Pump; IEC-H**	Power consumption of the Pump of the IEC hybrid Unit	Watts
Evaporative Fan power meter - IEC hybrid unit	**Evap. Fan; IEC-H**	Power consumption of the Evaporator Fan of the IEC hybrid Prototype	Watts
Supply fan power meter - IEC hybrid unit	**Sup. Fan; IEC-H**	Power consumption of the Supply Fan of the IEC hybrid Prototype	Watts
Power meter of total power consumption of IEC hybrid Unit	**Pw.Tot; IEC-H**	Total Input power of IEC Hybrid Prototype	Watts
Power meter of total power consumption of DX Unit	**Pw.Tot; DX**	Total Input power of DX Unit	Watts

Time	Ambient Conditions								
	Dry Bulb Temperature; °F	Relative Humidity; %	Pressure at the given altitude Pa	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3	Enthalpy of Ambient Air; kJ/kg
	Tdb amb	**RH amb**	**P**	**Psat amb**	**Pv amp**	**ω amb**	**Pd amb**	**ρ amb**	**h amb**
0:00	33.4	27.5	98992.08	51.37	1412.61	0.009004	97579.47	1.118995	56.62
1:00	32.6	30.3	98992.08	49.04	1487.67	0.009490	97504.41	1.121691	57.02
2:00	32.2	28.4	98992.08	48.15	1369.18	0.008724	97622.90	1.123396	54.73
3:00	32.2	22.5	98992.08	48.09	1083.54	0.006884	97908.54	1.124720	49.99
4:00	31.9	20.7	98992.08	47.35	978.46	0.006209	98013.62	1.126187	47.98
5:00	30.2	21.1	98992.08	42.98	906.88	0.005751	98085.21	1.132809	45.08
6:00	30.4	25.7	98992.08	43.35	1112.66	0.007071	97879.42	1.131356	48.61
7:00	31.4	26.1	98992.08	45.89	1196.26	0.007608	97795.82	1.127279	51.00
8:00	35.2	21.3	98992.08	56.93	1214.46	0.007726	97777.62	1.113128	55.23
9:00	36.1	17.5	98992.08	59.82	1044.80	0.006635	97947.28	1.110611	53.34
10:00	38.1	15.1	98992.08	66.51	1004.37	0.006375	97987.71	1.103823	54.66
11:00	39.8	12.2	98992.08	72.78	890.30	0.005645	98101.78	1.098395	54.48
12:00	39.8	13.2	98992.08	73.07	966.94	0.006136	98025.14	1.097809	55.82
13:00	40.6	12.5	98992.08	75.94	946.76	0.006006	98045.32	1.095356	56.23
14:00	43.2	11.0	98992.08	87.07	960.69	0.006095	98031.40	1.086295	59.10
15:00	41.1	10.9	98992.08	78.09	853.73	0.005411	98138.35	1.093916	55.23
16:00	40.4	11.3	98992.08	75.34	848.84	0.005380	98143.24	1.096292	54.46
17:00	40.7	11.3	98992.08	76.55	865.02	0.005483	98127.07	1.095176	55.03
18:00	40.0	10.4	98992.08	73.75	767.04	0.004857	98225.04	1.098036	52.71
19:00	31.3	36.3	98992.08	45.57	1654.11	0.010570	97337.97	1.125762	58.46
20:00	30.9	38.2	98992.08	44.61	1702.45	0.010884	97289.63	1.126941	58.87
21:00	32.1	33.1	98992.08	47.75	1582.05	0.010102	97410.03	1.123030	58.10
22:00	33.0	30.1	98992.08	50.16	1509.78	0.009633	97482.30	1.120130	57.80
23:00	31.7	35.2	98992.08	46.61	1642.36	0.010494	97349.72	1.124335	58.67
0:00	31.0	38.0	98992.08	44.80	1700.78	0.010873	97291.30	1.126670	58.92

IEC Hybrid Unit									
Dry Bulb Temperature; °F	Relative Humidity; %	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3	Enthalpy of outlet Air; kJ/kg	Water Consumed; mm/hour	Water Consumed; m3/hour
Tdb out IEC-H	**RH out IEC-H**	**Psat out IEC-H**	**Pv out IEC-H**	**ω out IEC-H**	**Pd out IEC-H**	**ρ out IEC-H**	**h out IEC-H**	**W.Lvl IEC-H**	**W.Vol IEC-H**
11.4	82.9	13.51	1120.40	0.007120	97871.68	1.206622	29.4494051	0	0
11.2	83.5	13.30	1111.18	0.007061	97880.90	1.207655	29.06239976	10	0.009
11.4	83.1	13.45	1117.70	0.007103	97874.38	1.206918	29.33780956	23	0.0207
9.9	81.3	12.20	991.63	0.006294	98000.45	1.213758	25.80553815	14	0.0126
8.7	77.6	11.28	874.57	0.005544	98117.51	1.219328	22.73249885	27	0.0243
8.1	77.6	10.80	837.77	0.005309	98154.31	1.222247	21.49751699	35	0.0315
8.3	79.8	10.97	875.31	0.005549	98116.78	1.221058	22.33824467	20	0.018
8.8	81.8	11.30	924.76	0.005865	98067.32	1.218950	23.57481653	30	0.027
9.2	79.1	11.66	922.50	0.005851	98069.58	1.216946	24.01248916	33	0.0297
10.6	75.1	12.75	957.78	0.006077	98034.30	1.211063	25.93646559	30	0.027
11.4	71.2	13.48	959.76	0.006090	98032.32	1.207507	26.81549931	30	0.027
11.9	70.3	13.90	976.87	0.006199	98015.21	1.205451	27.56636153	40	0.036
15.2	66.2	17.27	1142.94	0.007265	97849.14	1.190758	33.65140652	18	0.0162
12.5	68.3	14.46	988.28	0.006272	98003.80	1.202866	28.36086296	12	0.0108
13.5	63.6	15.47	984.16	0.006246	98007.93	1.198549	29.34465218	30	0.027
12.2	64.2	14.24	914.36	0.005799	98077.72	1.204191	26.9287023	20	0.018
11.2	64.2	13.30	854.45	0.005416	98137.63	1.208844	24.91249156	20	0.018
11.5	65.5	13.57	888.80	0.005635	98103.29	1.207411	25.7711045	20	0.018
11.3	66.5	13.42	892.01	0.005656	98100.07	1.208104	25.65370663	20	0.018
10.8	65.4	12.92	845.26	0.005357	98146.82	1.210732	24.32460083	30	0.027
13.8	82.7	15.75	1301.59	0.008287	97690.49	1.195978	34.77342262	34	0.0306
13.3	85.3	15.24	1300.52	0.008280	97691.56	1.198071	34.24575608	30	0.027
11.7	83.7	13.75	1151.34	0.007319	97840.74	1.205350	30.22289336	20	0.018
11.3	68.8	13.42	923.32	0.005856	98068.76	1.207959	26.15915299	37	0.0333
11.5	83.8	13.60	1139.18	0.007241	97852.91	1.206112	29.85571674	30	0.027

IEC Hybrid Unit									
Compressor power consumption; Watts	Pump power consumption; Watts	Evaporative Fan power consumption; Watts	Supply Fan power consumption; Watts	IEC Hybrid Unit total power consumption; Watts	Mass flow rate; kg/s	Total Cooling Capacity kW	Total Cooling Capacity BTU/hr	Coefficient of Performance W/W	Energy Efficiency Ratio BTU/W.hr
Comp. IEC-H	Pump IEC-H	Evap. Fan IEC-H	Sup. Fan IEC-H	Pw.Tot IEC-H	m'	Qtot IEC-H	Qtot IEC-H	COP	EER
6947	805.2	405.0	756.0	8913.1	0.6769	18.3921	62756.4974	2.0635	7.0409
6884	808.7	412.1	766.4	8871.2	0.6775	18.9419	64632.5528	2.1352	7.2857
6348	810.7	410.2	756.6	8325.5	0.6771	17.1899	58654.3430	2.0647	7.0452
7427	809.3	401.7	764.4	9402.4	0.6809	16.4666	56186.3805	1.7513	5.9757
6573	810.3	416.7	750.8	8550.7	0.6840	17.2720	58934.6249	2.0200	6.8924
6970	811.1	423.8	753.4	8958.3	0.6857	16.1713	55178.7587	1.8052	6.1595
7106	814.1	429.0	755.3	9104.4	0.6850	17.9961	61405.3547	1.9766	6.7446
6898	815.7	428.4	756.0	8898.0	0.6838	18.7569	64001.0616	2.1080	7.1927
6378	817	410.8	845.0	8450.8	0.6827	21.3113	72717.1897	2.5218	8.6048
6642	817	416.7	744.3	8619.9	0.6794	18.6212	63538.1718	2.1603	7.3711
7045	816.3	397.8	738.4	8997.5	0.6774	18.8631	64363.4589	2.0965	7.1535
7315	817	405.6	730.6	9268.2	0.6763	18.2028	62110.4004	1.9640	6.7014
7323	841.8	413.4	728.0	9306.2	0.6680	14.8110	50537.0716	1.5915	5.4305
7285	941.2	424.5	746.2	9396.9	0.6748	18.8041	64162.3799	2.0011	6.8281
7283	834.1	440.7	756.0	9313.8	0.6724	20.0065	68264.9438	2.1481	7.3295
7210	837	446.6	757.9	9251.5	0.6756	19.1163	65227.4849	2.0663	7.0505
7301	836.7	458.9	758.6	9355.2	0.6782	20.0381	68372.9817	2.1419	7.3086
7294	832.4	459.6	767.7	9353.6	0.6774	19.8196	67627.2174	2.1189	7.2301
7216	834.5	470.0	767.7	9288.1	0.6777	18.3364	62566.5424	1.9742	6.7362
7239	837.1	472.6	773.5	9322.2	0.6792	23.1821	79100.5569	2.4868	8.4852
7021	801.2	457.6	764.4	9044.2	0.6709	16.1707	55176.7739	1.7880	6.1008
6893	801.8	447.9	769.6	8912.3	0.6721	16.0343	54711.3703	1.7991	6.1389
6868	799.5	450.5	774.2	8892.1	0.6762	18.6459	63622.3092	2.0969	7.1549
6896	790.7	414.1	752.7	8853.5	0.6777	22.0311	75173.1799	2.4884	8.4908
6888	802.6	408.9	753.4	8852.8	0.6766	19.6684	67111.4290	2.2217	7.5808

DX Unit						
Dry Bulb Temperature; °C	Relative Humidity; %	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3
Tdb out DX	**RH out DX**	**Psat out IEC-H**	**Pv out IEC-H**	**ω out IEC-H**	**Pd out IEC-H**	**ρ out IEC-H**
8.9	79.4	11.38	903.35	0.005728	98088.73	1.218618
9.2	82.5	11.66	962.54	0.006107	98029.54	1.216759
10.2	82.2	12.42	1020.27	0.006477	97971.82	1.212483
9.2	81.7	11.61	948.93	0.006020	98043.15	1.217110
8.4	80.0	11.02	881.85	0.005591	98110.23	1.220738
8.1	82.0	10.80	885.65	0.005615	98106.43	1.222022
8.8	82.1	11.35	932.35	0.005914	98059.74	1.218626
9.9	82.7	12.17	1006.05	0.006386	97986.03	1.213834
9.4	85.1	11.77	1001.82	0.006359	97990.26	1.216002
10.6	76.7	12.78	979.93	0.006219	98012.15	1.210818
10.6	75.9	12.75	967.98	0.006142	98024.10	1.211016
11.2	74.6	13.33	994.99	0.006315	97997.09	1.208052
13.0	71.1	14.98	1065.38	0.006767	97926.70	1.200269
12.7	73.4	14.69	1078.43	0.006851	97913.65	1.201469
12.2	75.5	14.18	1071.07	0.006803	97921.01	1.203749
13.0	73.8	15.01	1108.23	0.007042	97883.85	1.199932
12.7	73.8	14.72	1086.68	0.006904	97905.41	1.201291
12.0	73.3	14.03	1028.51	0.006530	97963.57	1.204649
11.5	75.8	13.54	1025.84	0.006513	97966.24	1.206919
11.1	74.7	13.21	987.54	0.006268	98004.54	1.208653
14.1	84.0	16.12	1354.45	0.008628	97637.64	1.194209
13.6	86.2	15.54	1340.20	0.008536	97651.89	1.196635
12.5	85.4	14.46	1235.11	0.007859	97756.97	1.201728
12.5	85.0	14.46	1228.84	0.007818	97763.24	1.201757
12.8	86.4	14.75	1273.92	0.008109	97718.16	1.200288

DX Unit						
Enthalpy of outlet Air; kJ/kg	DX Unit total power consumption; Watts	Mass flow rate; kg/s	Total Cooling Capacity kW	Total Cooling Capacity BTU/hr	Coefficient of Performance W/W	Energy Efficiency Ratio BTU/W.hr
h out IEC-H	Pw.Tot DX	m'	Qtot IEC-H	Qtot IEC-H	COP	EER
23.33146224	10620	0.6836	22.7574	77651.6399	2.1429	7.3118
24.65825319	10708	0.6826	22.0910	75377.6363	2.0630	7.0394
26.53940038	10685	0.6802	19.1726	65419.7484	1.7944	6.1226
24.37101048	10560	0.6828	17.4916	59683.7185	1.6564	5.6519
22.51126106	10415	0.6848	17.4435	59519.7306	1.6748	5.7148
22.26783086	10403	0.6856	15.6402	53366.7119	1.5034	5.1299
23.76482472	10239	0.6836	16.9850	57955.2822	1.6589	5.6602
26.00454545	10181	0.6810	17.0236	58086.8891	1.6721	5.7054
25.4278966	10383	0.6822	20.3292	69366.1543	1.9579	6.6807
26.3282235	10918	0.6793	18.3513	62617.3113	1.6808	5.7352
26.10124023	11349	0.6794	19.4031	66206.2279	1.7097	5.8337
27.21544419	11603	0.6777	18.4799	63055.8848	1.5927	5.4344
30.15211431	11797	0.6734	17.2855	58980.6322	1.4652	4.9996
30.05839136	11361	0.6740	17.6381	60183.7649	1.5525	5.2974
29.39629044	12102	0.6753	20.0584	68442.1241	1.6574	5.6554
30.88111486	12333	0.6732	16.3881	55918.4320	1.3288	4.5340
30.22603827	12146	0.6739	16.3320	55727.1258	1.3446	4.5881
28.53747868	11994	0.6758	17.9047	61093.3669	1.4928	5.0937
27.95178484	12041	0.6771	16.7625	57195.9184	1.3921	4.7501
26.95950109	11728	0.6781	21.3557	72868.5815	1.8209	6.2132
36.00983074	10677	0.6700	15.3185	52268.7818	1.4347	4.8955
35.1987533	10637	0.6713	15.3753	52462.8553	1.4455	4.9321
32.36492534	10530	0.6742	17.1457	58503.6967	1.6283	5.5559
32.26300953	10607	0.6742	17.8028	60745.8126	1.6784	5.7270
33.30239352	10484	0.6734	17.2526	58868.2981	1.6456	5.6151

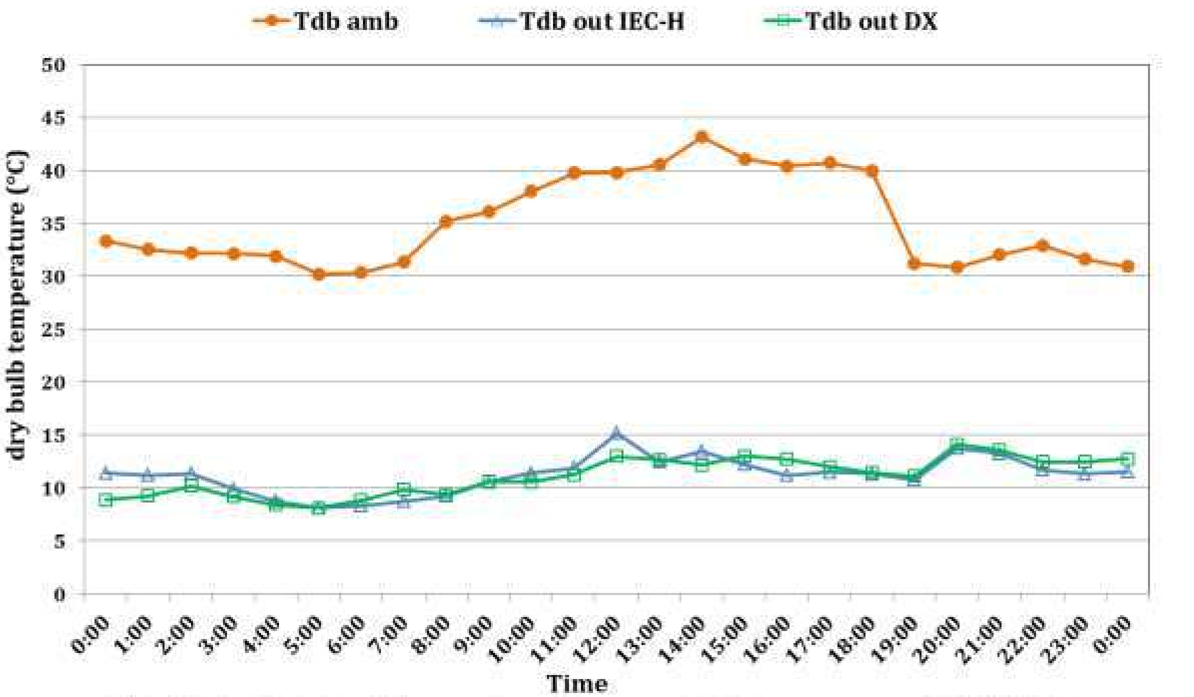

Fig. 1. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units for OEM 2 in CZ 8

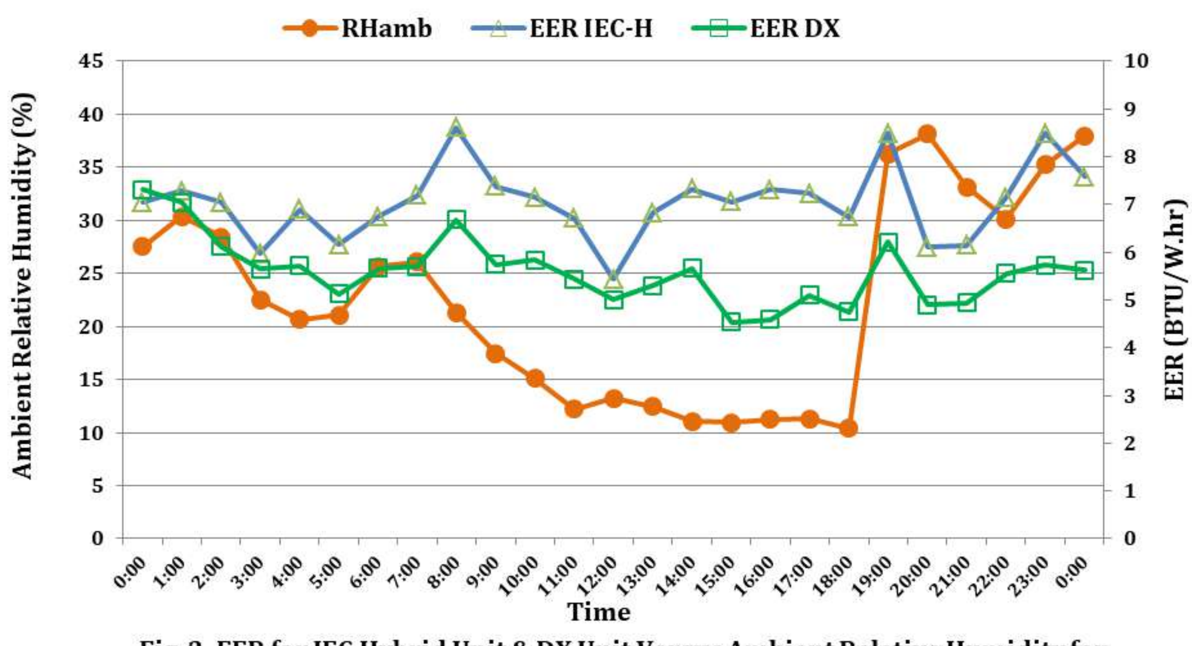

Fig. 2. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity for OEM 2 in CZ 8

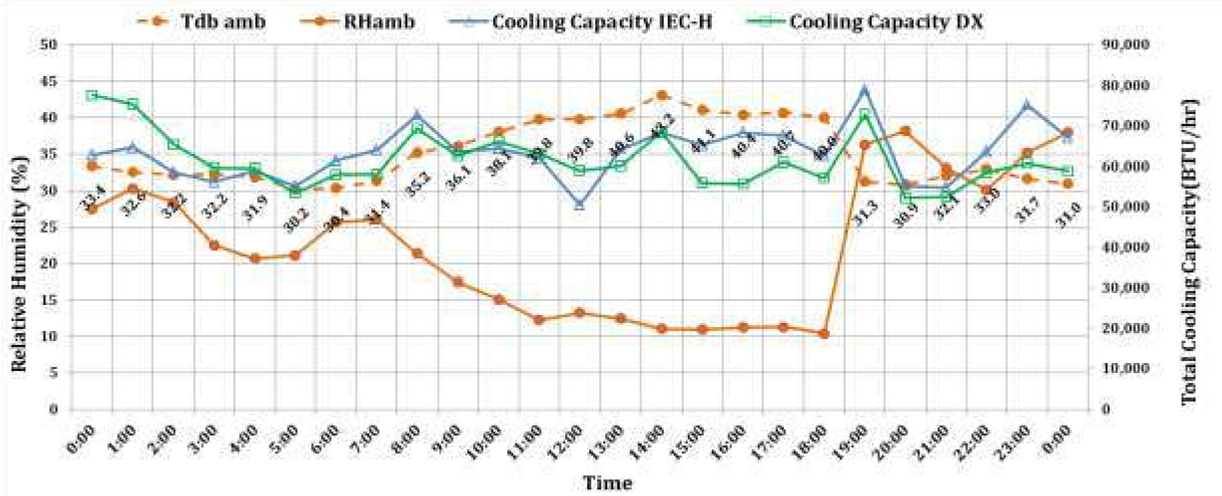

Fig. 3. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions for OEM 2 in CZ 8

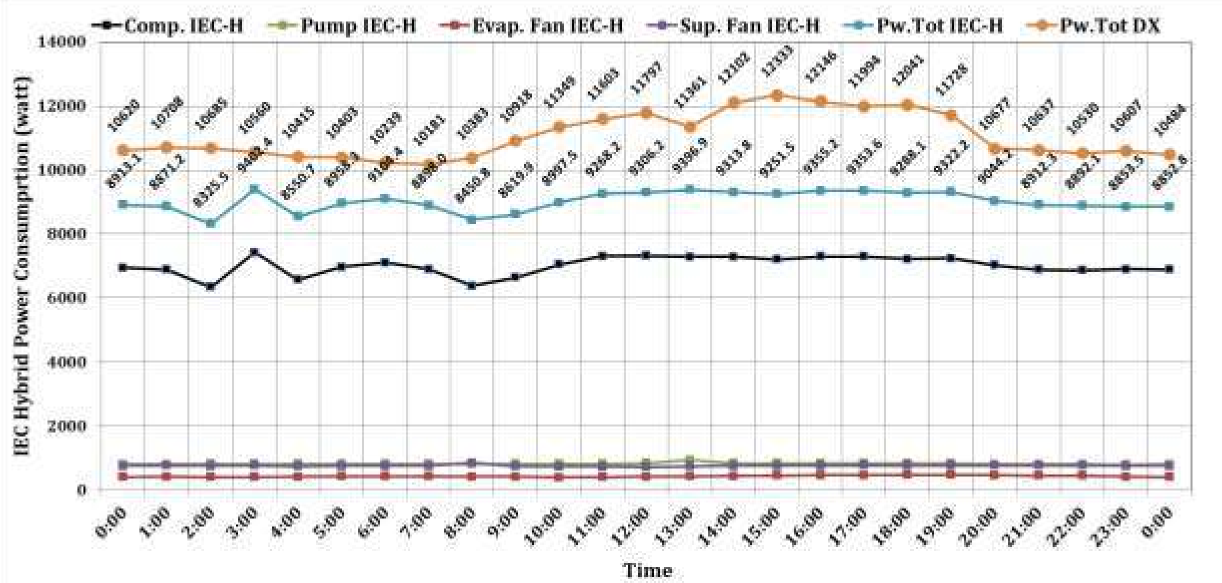

Fig. 4. Power Consumption of DX Unit and IEC Hybrid Unit Components for OEM2 in CZ 8

A.2. Results of OEM 3:

Basic Information			
Tested Units Name	DX (Direct Expansion Unit)		
	IEC Hybrid (Indirect Evaporative Cooling Hybrid Unit)		
OEM No.	3		
Refrigerant	R-32		
Air Flow Rate	1320 C.F.M for DX and IEC hybrid Units		
Capacity	DX	2	Compressors
	IEC hybrid	1	Compressor
Water Bath Area	1728.5*623		mm2
Climatic Zone	8 (South Egypt)		
Altitude	196.07 meter (From Sea Level)		
Location	22°49' 02" N 31°28' 16" E		
Test Date	28-Aug-24		

Used Apparatus

Used Apparatus	Code of Used Apparatus	Measured Property	Measurement Unit
Weather Station, Dry bulb temperature	**WS; T-amb**	Ambient dry bulb temperature for both Units	°C
Weather Station, Relative Humidity	**WS; Rh-amb**	Ambient Relative humidity for both Units	%
Air Quality 5 - Dry bulb temperature	**AQ4; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 5 - Relative Humidity	**AQ4; RH-amb**	Ambient Relative humidity for both Units	%
Air Quality 6 - Dry bulb temperature	**AQ6; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 6 - Relative Humidity	**AQ6; RH-amb**	Ambient Relative humidity for both Units	%
Fluke 975 - Dry bulb temperature	**F975; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 1 - Dry bulb temperature	**AQ1; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Air Quality 1 - Relative Humidity	**AQ1; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Air Quality 2 - Dry bulb temperature	**AQ3; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Air Quality 2 - Relative Humidity	**AQ3; RH-out; DX**	Outlet Relative humidity for DX Unit	%
UNI T - Dry bulb temperature	**U; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
UNI T - Relative Humidity	**U; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Lutron 1 - Dry bulb temperature	**L1; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Lutron 1 - Relative Humidity	**L1; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Air Quality 3 - Dry bulb temperature	**AQ2; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
Air Quality 3 - Relative Humidity	**AQ2; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Air Quality 4 - Dry bulb temperature	**AQ2; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
Air Quality 4 - Relative Humidity	**AQ2; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Lutron 2 - Dry bulb temperature	**L2; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
Lutron 2 - Relative Humidity	**L2; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Tabular level gauge for measuring the Water level change	**W.Lvl; IEC-H**	make up of evaporated water of the IEC hybrid unit	mm/hr
Water volume in Litres/hour (calculated)	**W.Vol; IEC-H**	hourly consumption rate of evaporated water for IEC hybrid unit	Litres/hr
Compressor power meter - IEC hybrid unit	**Comp.; IEC-H**	Power consumption of the Compressor of the IEC hybrid Unit	Watts
Pump power meter - IEC hybrid unit	**Pump; IEC-H**	Power consumption of the Pump of the IEC hybrid Unit	Watts
Evaporative Fan power meter - IEC hybrid unit	**Evap. Fan; IEC-H**	Power consumption of the Evaporator Fan of the IEC hybrid Prototype	Watts
Supply fan power meter - IEC hybrid unit	**Sup. Fan; IEC-H**	Power consumption of the Supply Fan of the IEC hybrid Prototype	Watts
Power meter of total power consumption of IEC hybrid Unit	**Pw.Tot; IEC-H**	Total Input power of IEC Hybrid Prototype	Watts
Power meter of total power consumption of DX Unit	**Pw.Tot; DX**	Total Input power of DX Unit	Watts

Time	Ambient Conditions								
	Dry Bulb Temperature; °F	Relative Humidity; %	Pressure at the given altitude Pa	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3	Enthalpy of Ambient Air; kJ/kg
	Tdb amb	**RH amb**	**P**	**Psat amb**	**Pv amp**	**ω amb**	**Pd amb**	**ρ amb**	**h amb**
10:00	42.2	19.1	98992.08	82.85	1579.72	0.010087	97412.37	1.086982	68.43
11:00	44.3	15.9	98992.08	92.43	1472.65	0.009393	97519.44	1.080236	68.79
12:00	44.7	14.2	98992.08	94.35	1339.82	0.008534	97652.27	1.079426	66.98
13:00	45.6	13.0	98992.08	98.82	1284.63	0.008178	97707.45	1.076607	66.97
14:00	45.8	12.0	98992.08	99.83	1201.34	0.007641	97790.74	1.076275	65.79
15:00	47.1	11.2	98992.08	106.66	1198.19	0.007621	97793.89	1.071919	67.06
16:00	46.5	11.1	98992.08	103.46	1151.89	0.007323	97840.19	1.074122	65.68
17:00	44.7	12.1	98992.08	94.35	1141.67	0.007257	97850.41	1.080247	63.68
18:00	43.0	12.2	98992.08	86.39	1051.11	0.006675	97940.97	1.086433	60.44
19:00	41.8	15.1	98992.08	81.13	1222.35	0.007776	97769.73	1.089857	62.06
20:00	39.0	18.6	98992.08	69.91	1302.70	0.008294	97689.38	1.099294	60.54
21:00	38.8	19.0	98992.08	69.17	1314.14	0.008368	97677.94	1.099950	60.53
22:00	37.9	20.0	98992.08	65.89	1317.76	0.008392	97674.32	1.103118	59.67
23:00	38.9	18.0	98992.08	69.54	1251.68	0.007965	97740.40	1.099861	59.59
0:00	37.4	17.0	98992.08	64.13	1090.14	0.006926	97901.94	1.105859	55.39
1:00	36.5	18.0	98992.08	61.06	1099.03	0.006983	97893.05	1.109035	54.62
2:00	35.5	18.0	98992.08	57.80	1040.36	0.006606	97951.73	1.112879	52.64
3:00	34.9	19.0	98992.08	55.91	1062.38	0.006748	97929.70	1.114952	52.39
4:00	34.5	21.6	98992.08	54.69	1179.47	0.007500	97812.61	1.115901	53.91
5:00	33.9	23.0	98992.08	52.90	1216.59	0.007739	97775.49	1.117922	53.91
6:00	33.8	25.2	98992.08	52.60	1323.80	0.008431	97668.28	1.117826	55.58
7:00	34.9	24.0	98992.08	55.91	1341.96	0.008548	97650.12	1.113757	57.01
8:00	37.9	23.0	98992.08	65.89	1515.42	0.009670	97476.66	1.102281	62.95
9:00	40.4	18.0	98992.08	75.34	1356.13	0.008639	97635.95	1.094161	62.86
10:00	41.6	16.0	98992.08	80.28	1284.47	0.008177	97707.61	1.090289	62.89

IEC Hybrid Unit								
Dry Bulb Temperature; °F	Relative Humidity; %	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3	Enthalpy of outlet Air; kJ/kg	Water Consumed; mm/hour
Tdb out IEC-H	RH out IEC-H	Psat out IEC-H	Pv out IEC-H	ω out IEC-H	Pd out IEC-H	ρ out IEC-H	h out IEC-H	W.Lvl IEC-H
14.0	81.0	16.02	1297.63	0.008262	97694.45	1.194886	34.98094337	0
13.3	80.3	15.27	1225.97	0.007800	97766.11	1.198274	33.06585291	10
13.5	80.2	15.44	1238.85	0.007883	97753.23	1.197518	33.44542911	23
13.4	78.8	15.37	1210.93	0.007703	97781.15	1.197925	32.92316943	14
13.0	78.5	15.01	1178.78	0.007496	97813.30	1.199608	32.02674264	27
13.0	77.3	15.01	1160.27	0.007377	97831.82	1.199693	31.72595702	35
12.7	79.0	14.65	1157.65	0.007360	97834.44	1.201244	31.30989144	20
12.7	79.2	14.69	1163.12	0.007395	97828.96	1.201079	31.4326942	30
12.3	80.2	14.34	1149.78	0.007309	97842.30	1.202683	30.84266148	33
13.3	82.2	15.24	1253.28	0.007976	97738.81	1.198288	33.47629318	30
13.4	84.1	15.41	1295.22	0.008246	97696.86	1.197398	34.32946638	30
13.8	85.3	15.78	1345.44	0.008570	97646.64	1.195638	35.52255208	40
13.7	86.1	15.64	1346.34	0.008576	97645.74	1.196190	35.40108645	18
14.0	86.5	15.95	1380.29	0.008795	97611.79	1.194784	36.26157105	12
10.9	82.9	13.01	1079.03	0.006855	97913.05	1.209222	28.202277	30
11.3	83.8	13.42	1125.08	0.007151	97867.00	1.207025	29.42342696	20
10.6	83.3	12.78	1064.72	0.006763	97927.36	1.210425	27.69921696	20
11.4	83.8	13.45	1126.67	0.007161	97865.41	1.206876	29.48318097	20
13.5	83.0	15.47	1284.36	0.008176	97707.73	1.197170	34.22043981	20
13.7	82.3	15.64	1287.42	0.008196	97704.66	1.196460	34.44038634	30
13.6	82.7	15.61	1291.39	0.008222	97700.69	1.196581	34.47114019	34
13.6	83.1	15.58	1294.82	0.008244	97697.26	1.196704	34.493044	30
14.0	82.0	16.02	1313.65	0.008365	97678.43	1.194812	35.24215594	20
13.5	82.0	15.44	1265.61	0.008055	97726.47	1.197395	33.88115959	37
13.7	81.3	15.71	1277.30	0.008131	97714.78	1.196229	34.34357657	30

IEC Hybrid Unit										
Water Consumed; m3/hour	Compressor power consumption; Watts	Pump power consumption; Watts	Evaporative Fan power consumption; Watts	Supply Fan power consumption; Watts	IEC Hybrid Unit total power consumption; Watts	Mass flow rate; kg/s	Total Cooling Capacity kW	Total Cooling Capacity BTU/hr	Coefficient of Performance W/W	Energy Efficiency Ratio BTU/W.hr
W.Vol IEC-H	**Comp. IEC-H**	**Pump IEC-H**	**Evap. Fan IEC-H**	**Sup. Fan IEC-H**	**Pw.Tot IEC-H**	**m'**	**Qtot IEC-H**	**Qtot IEC-H**	**COP**	**EER**
0	4282.1	542.1	239.2	878.6	6057.4	0.7444	24.8980	84955.3823	4.1104	14.0251
0.010768555	4295.3	539.7	231.4	899.7	6089.5	0.7465	26.6647	90983.9017	4.3788	14.9412
0.024767677	4305.8	540.1	234.0	893.1	6149.2	0.7460	25.0142	85352.1263	4.0679	13.8802
0.015075977	4283.1	537.3	237.9	870.0	6107.4	0.7463	25.4110	86705.8366	4.1607	14.1967
0.029075099	4330.8	534.7	241.8	906.4	6097.7	0.7473	25.2317	86094.2556	4.1379	14.1191
0.037689943	4331.7	533.7	246.4	906.3	6064.5	0.7474	26.4094	90112.4670	4.3547	14.8589
0.02153711	4343.6	534.7	243.1	901.5	6066.7	0.7483	25.7204	87761.5122	4.2396	14.4662
0.032305665	4341.7	534.2	243.8	898.5	6068.6	0.7482	24.1260	82321.2025	3.9756	13.5651
0.035536232	4334.2	532.7	241.2	899.5	6065.0	0.7492	22.1779	75674.1976	3.6567	12.4772
0.032305665	4397.8	548.7	243.8	902.6	6141.5	0.7465	21.3390	72811.5803	3.4746	11.8557
0.032305665	4417.4	547.8	244.4	903.2	6203.0	0.7459	19.5518	66713.5207	3.1520	10.7551
0.04307422	4419	548.8	245.1	881.9	6230.8	0.7448	18.6238	63547.1949	2.9890	10.1989
0.019383399	4344.6	551.6	247.7	890.2	6123.4	0.7452	18.0833	61702.6531	2.9532	10.0766
0.012922266	4379.6	550.6	249.0	881.5	6156.4	0.7443	17.3649	59251.6248	2.8207	9.6245
0.032305665	4151.3	553	249.6	876.1	5862.5	0.7533	20.4808	69883.4422	3.4935	11.9204
0.02153711	4131.9	551.5	249.6	879.9	5863.4	0.7519	18.9468	64649.2243	3.2314	11.0259
0.02153711	4235.2	553.4	249.0	878.1	6091.0	0.7541	18.8034	64159.8962	3.0871	10.5336
0.02153711	3931.9	551.5	252.9	877.2	5670.0	0.7518	17.2209	58760.1151	3.0372	10.3633
0.02153711	3954.4	547.4	251.6	877.9	5792.0	0.7458	14.6856	50109.5059	2.5355	8.6515
0.032305665	3938.5	546.4	253.5	870.9	5732.0	0.7454	14.5140	49523.9553	2.5321	8.6399
0.036613087	3877	543.2	252.9	875.4	5613.0	0.7454	15.7376	53699.0605	2.8038	9.5669
0.032305665	3781.9	543.9	252.2	879.3	5669.0	0.7455	16.7842	57270.0208	2.9607	10.1023
0.02153711	4232	550.3	248.3	882.0	5932.0	0.7443	20.6274	70383.6012	3.4773	11.8651
0.039843654	4207	545.6	247.0	887.8	5936.0	0.7459	21.6146	73752.0675	3.6413	12.4245
0.032305665	4140.4	547	245.1	884.7	5825.0	0.7452	21.2734	72587.8429	3.6521	12.4614

DX Unit						
Dry Bulb Temperature; °C	Relative Humidity; %	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3
Tdb out DX	**RH out DX**	**Psat out DX**	**Pv out DX**	**ω out DX**	**Pd out DX**	**ρ out DX**
13.6	73.0	15.60	1138.85	0.007239	97853.24	1.197316
13.8	72.2	15.78	1139.65	0.007244	97852.43	1.196582
14.1	72.4	16.12	1165.97	0.007413	97826.11	1.195108
14.7	71.5	16.75	1197.86	0.007619	97794.22	1.192471
14.4	70.9	16.41	1163.13	0.007395	97828.95	1.193978
14.6	71.1	16.57	1178.19	0.007492	97813.89	1.193287
14.5	71.6	16.54	1183.73	0.007528	97808.35	1.193365
14.0	72.0	15.96	1148.29	0.007300	97843.79	1.195813
14.2	71.1	16.14	1148.09	0.007298	97844.00	1.195086
13.8	71.7	15.75	1129.93	0.007182	97862.15	1.196731
13.8	75.6	15.73	1189.43	0.007564	97802.65	1.196562
13.4	77.7	15.40	1196.48	0.007610	97795.60	1.197887
13.0	77.4	14.95	1157.72	0.007360	97834.37	1.199949
13.4	80.5	15.37	1237.58	0.007875	97754.50	1.197803
10.6	74.3	12.78	949.36	0.006023	98042.72	1.210960
10.3	74.5	12.53	933.36	0.005920	98058.73	1.212316
9.9	75.0	12.16	911.12	0.005778	98080.96	1.214347
9.5	75.4	11.85	893.78	0.005667	98098.30	1.216039
9.3	76.1	11.71	891.51	0.005653	98100.57	1.216803
9.1	76.2	11.52	877.18	0.005561	98114.91	1.217948
9.5	76.4	11.85	905.63	0.005743	98086.45	1.215984
10.5	76.9	12.65	972.81	0.006173	98019.27	1.211492
11.8	78.5	13.86	1088.34	0.006914	97903.75	1.205112
11.5	74.0	13.59	1006.14	0.006387	97985.94	1.206763
12.0	72.2	14.05	1014.29	0.006439	97977.79	1.204609

DX Unit						
Enthalpy of outlet Air; kJ/kg	DX Unit total power consumption; Watts	Mass flow rate; kg/s	Total Cooling Capacity kW	Total Cooling Capacity BTU/hr	Coefficient of Performance W/W	Energy Efficiency Ratio BTU/W.hr
h out DX	**Pw.Tot DX**	**m'**	**Qtot DX**	**Qtot DX**	**COP**	**EER**
31.98067507	11637	0.7459	27.1865	92764.1492	2.3362	7.9715
32.17203516	11826	0.7454	27.2934	93128.8955	2.3079	7.8749
32.93076979	11898	0.7445	25.3471	86487.7810	2.1304	7.2691
34.06104187	12015	0.7429	24.4500	83426.8114	2.0350	6.9436
33.1647953	11801	0.7438	24.2668	82801.8365	2.0563	7.0165
33.56260419	11944	0.7434	24.9030	84972.5539	2.0850	7.1142
33.62727262	11838	0.7434	23.8288	81307.3782	2.0129	6.8683
32.49065914	11896	0.7450	23.2321	79271.0700	1.9529	6.6637
32.66551876	11840	0.7445	20.6807	70565.4829	1.7467	5.9599
31.98854965	11755	0.7455	22.4204	76501.5765	1.9073	6.5080
32.93022734	11584	0.7454	20.5812	70225.8899	1.7767	6.0623
32.7136392	11497	0.7462	20.7550	70819.0817	1.8053	6.1598
31.62511555	11497	0.7475	20.9628	71527.9201	1.8233	6.2214
33.35674085	11425	0.7462	19.5764	66797.3873	1.7135	5.8466
25.83448963	11189	0.7544	22.2965	76078.8041	1.9927	6.7994
25.27126425	11116	0.7552	22.1657	75632.6406	1.9940	6.8039
24.45539947	11137	0.7565	21.3183	72741.0648	1.9142	6.5315
23.7950707	11116	0.7576	21.6607	73909.3861	1.9486	6.6489
23.58076083	11001	0.7580	22.9917	78450.9821	2.0900	7.1313
23.09602817	10954	0.7587	23.3822	79783.3456	2.1346	7.2835
23.9861115	10952	0.7575	23.9355	81671.2366	2.1855	7.4572
26.06068097	10949	0.7547	23.3557	79692.9130	2.1331	7.2786
29.32841221	11174	0.7507	25.2450	86139.3776	2.2593	7.7089
27.69234025	11198	0.7518	26.4363	90204.4201	2.3608	8.0554
28.33265448	11212	0.7504	25.9332	88487.9106	2.3130	7.8922

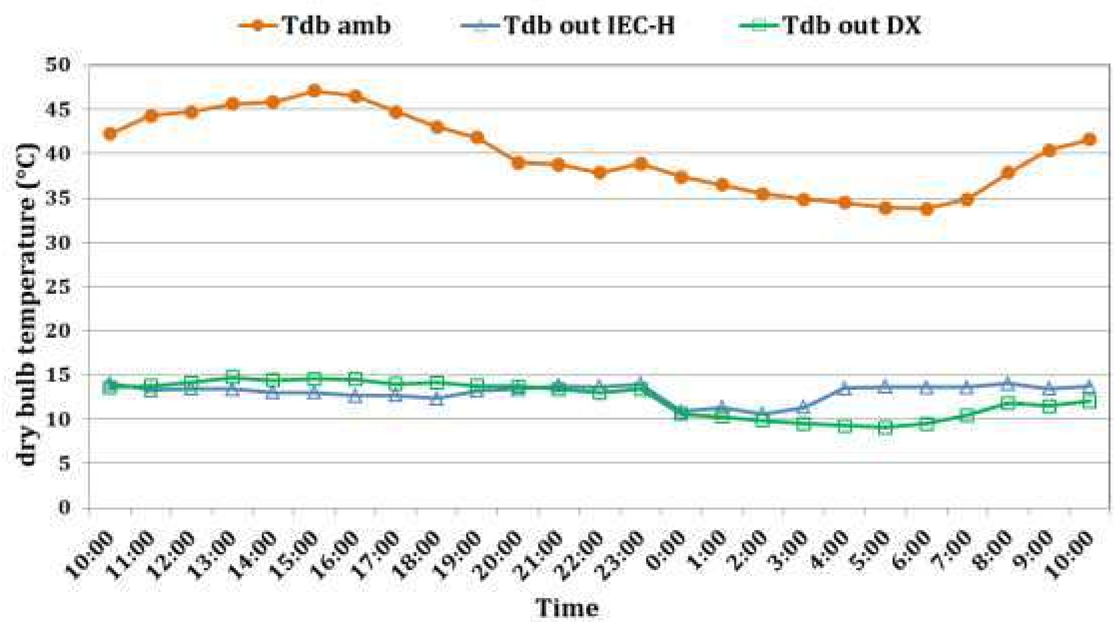

Fig. 1. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units for OEM3 in CZ 8

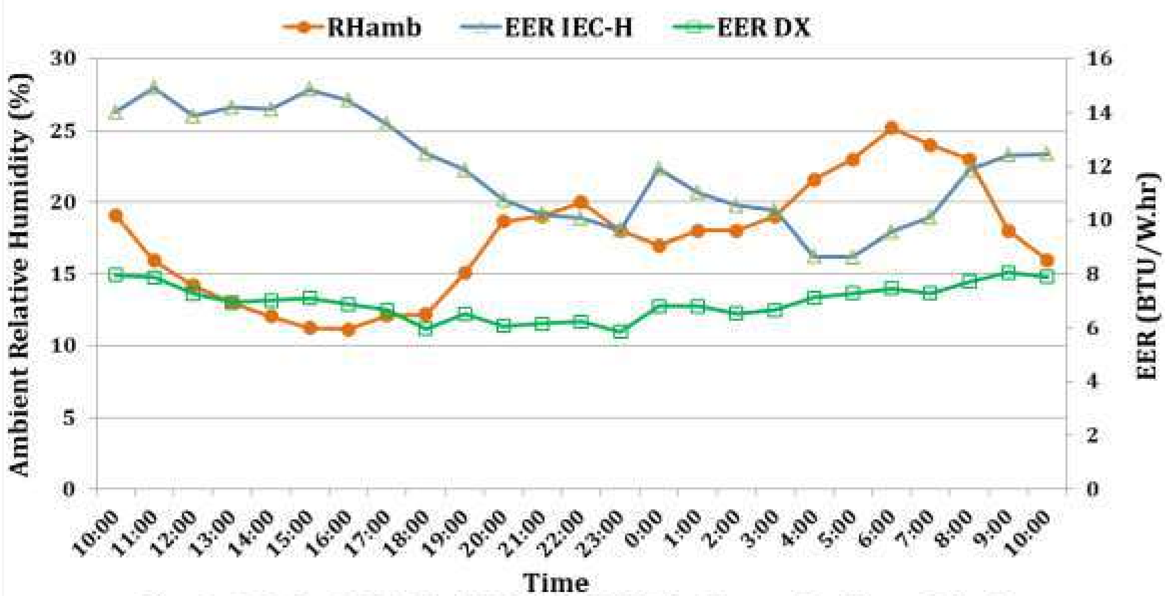

Fig. 2. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity for OEM3 in CZ 8

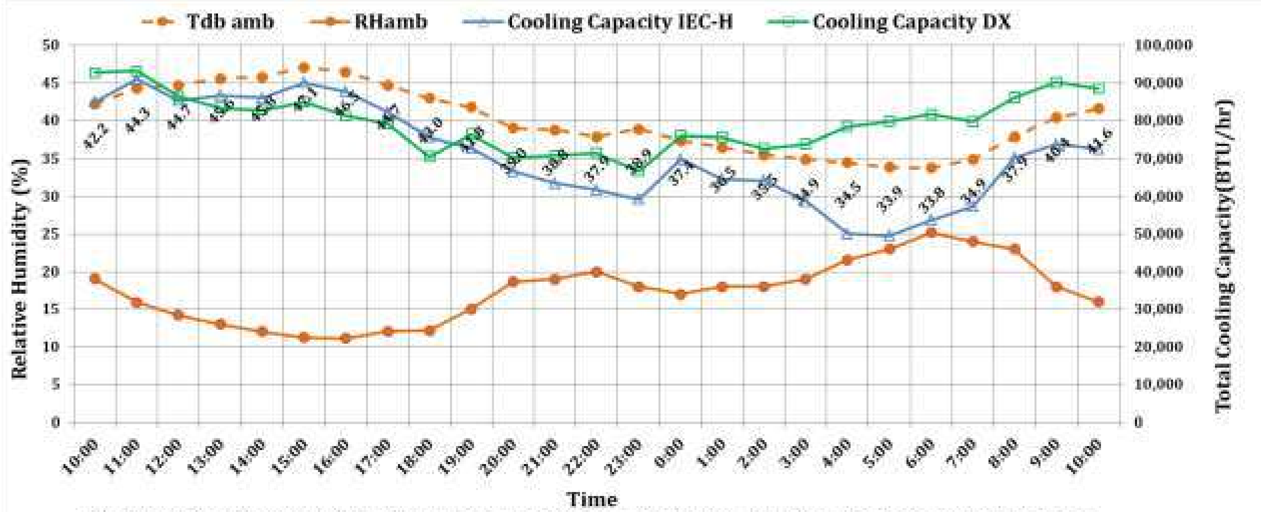

Fig. 3. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions for OEM3 in CZ 8

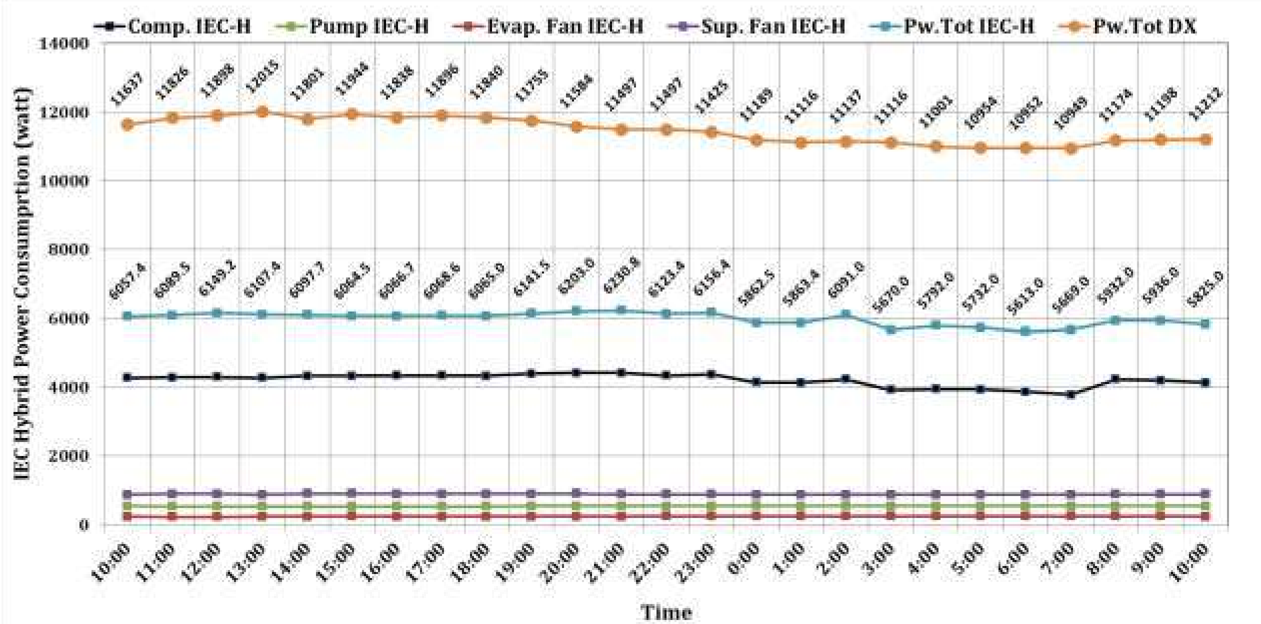

Fig. 4. Power Consumption of DX Unit and IEC Hybrid Unit Components for OEM3 in CZ 8

A.3. Results of OEM 7:

Basic Information			
Tested Units Name	DX (Direct Expansion Unit)		
	IEC Hybrid (Indirect Evaporative Cooling Hybrid Unit)		
OEM No.	7		
Refrigerant	R-32		
Air Flow Rate	1320 C.F.M for DX and IEC hybrid Units		
Capacity	DX	2	Compressors
	IEC hybrid	1	Compressor
Water Bath Area	560X1020		mm2
Climatic Zone	8 (South Egypt)		
Altitude	196.07 meter (From Sea Level)		
Location	22°49' 02" N 31°28' 16" E		
Test Date	30-Aug-24		

Used Apparatus

Used Apparatus	Code of Used Apparatus	Measured Property	Measurement Unit
Weather Station, Dry bulb temperature	**WS; T-amb**	Ambient dry bulb temperature for both Units	°C
Weather Station, Relative Humidity	**WS; Rh-amb**	Ambient Relative humidity for both Units	%
Air Quality 5 - Dry bulb temperature	**AQ5; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 5 - Relative Humidity	**AQ5; RH-amb**	Ambient Relative humidity for both Units	%
Air Quality 6 - Dry bulb temperature	**AQ6; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 6 - Relative Humidity	**AQ6; RH-amb**	Ambient Relative humidity for both Units	%
Fluke 975 - Dry bulb temperature	**F975; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 1 - Dry bulb temperature	**AQ1; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Air Quality 1 - Relative Humidity	**AQ1; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Air Quality 2 - Dry bulb temperature	**AQ2; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Air Quality 2 - Relative Humidity	**AQ2; RH-out; DX**	Outlet Relative humidity for DX Unit	%
UNI T 1 - Dry bulb temperature	**U1; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
UNI T 1 - Relative Humidity	**U1; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Lutron 1 - Dry bulb temperature	**L1; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Lutron 1 - Relative Humidity	**L1; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Air Quality 3 - Dry bulb temperature	**AQ3; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
Air Quality 3 - Relative Humidity	**AQ3; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Air Quality 4 - Dry bulb temperature	**AQ4; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
Air Quality 4 - Relative Humidity	**AQ4; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
UNI T 2 - Dry bulb temperature	**U2; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
UNI T 2 - Relative Humidity	**U2; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Lutron 2 - Dry bulb temperature	**L2; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C

Lutron 2 - Relative Humidity	**L2; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Tabular level gauge for measuring the Water level change	**W.Lvl; IEC-H**	make up of evaporated water of the IEC hybrid unit	mm/hr
Water volume in Litres/hour (calculated)	**W.Vol; IEC-H**	hourly consumption rate of evaporated water for IEC hybrid unit	Litres/hr
Compressor power meter - IEC hybrid unit	**Comp.; IEC-H**	Power consumption of the Compressor of the IEC hybrid Unit	Watts
Pump power meter - IEC hybrid unit	**Pump; IEC-H**	Power consumption of the Pump of the IEC hybrid Unit	Watts
Evaporative Fan power meter - IEC hybrid unit	**Evap. Fan; IEC-H**	Power consumption of the Evaporator Fan of the IEC hybrid Prototype	Watts
Supply fan power meter - IEC hybrid unit	**Sup. Fan; IEC-H**	Power consumption of the Supply Fan of the IEC hybrid Prototype	Watts
Power meter of total power consumption of IEC hybrid Unit	**Pw.Tot; IEC-H**	Total Input power of IEC Hybrid Prototype	Watts
Power meter of total power consumption of DX Unit	**Pw.Tot; DX**	Total Input power of DX Unit	Watts

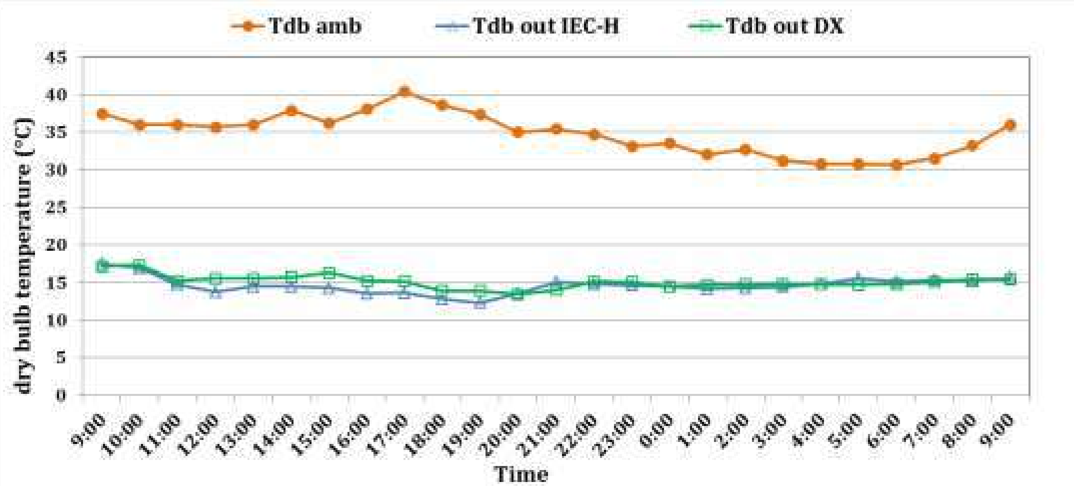

Fig. 1. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units for OEM7 in CZ 8

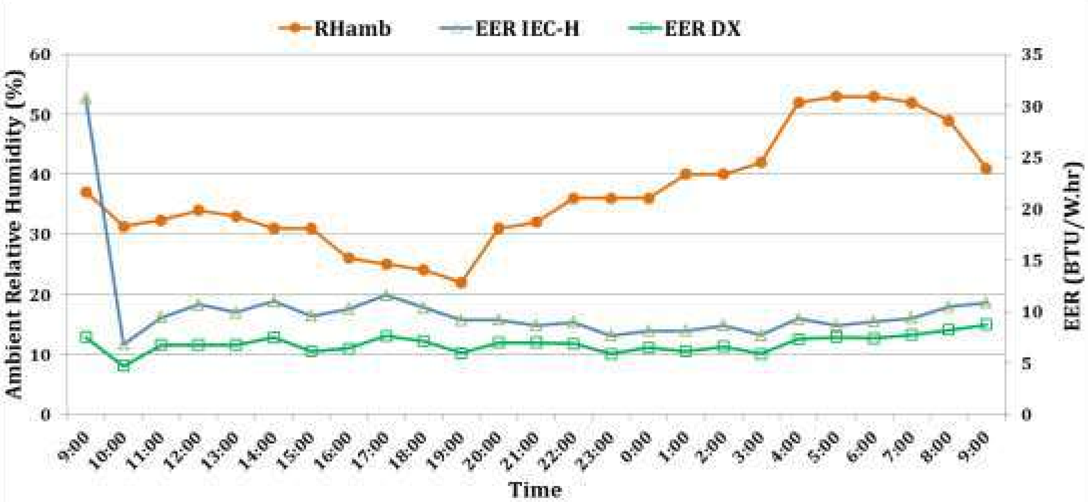

Fig. 2. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity for OEM7 in CZ 8

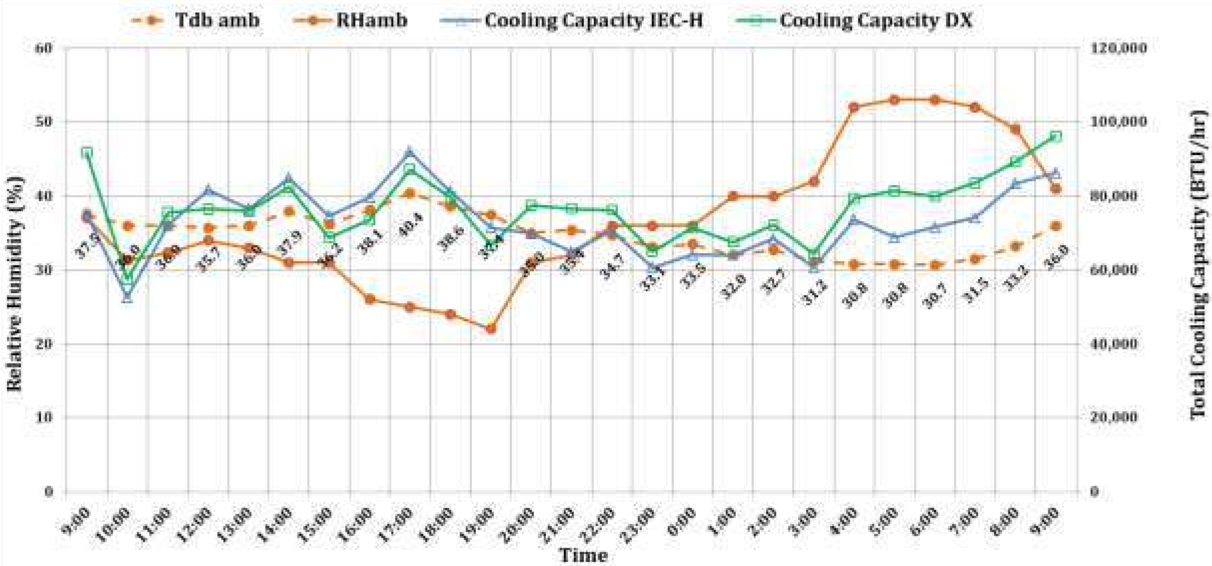

Fig. 3. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions for OEM7 in CZ 8

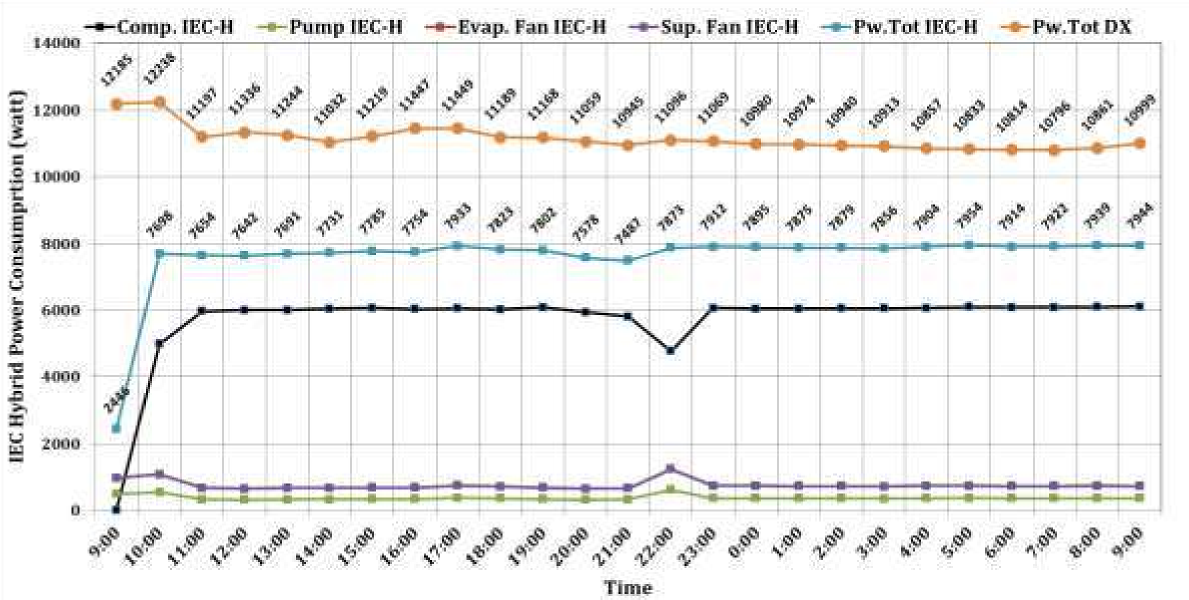

Fig. 4. Power Consumption of DX Unit and IEC Hybrid Unit Components for OEM7 in CZ 8

Time	Ambient Conditions								
	Dry Bulb Temperature; °F	Relative Humidity; %	Pressure at the given altitude Pa	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3	Enthalpy of Ambient Air; kJ/kg
	Tdb amb	**RH amb**	**P**	**Psat amb**	**Pv amp**	**ω amb**	**Pd amb**	**ρ amb**	**h amb**
9:00	37.5	37.1	98992.08	64.48	2389.88	0.015388	96602.20	1.099993	77.24
10:00	36.0	31.3	98992.08	59.41	1861.45	0.011920	97130.63	1.107581	66.79
11:00	36.0	32.3	98992.08	59.41	1920.86	0.012308	97071.22	1.107328	67.79
12:00	35.7	34.0	98992.08	58.44	1986.86	0.012740	97005.22	1.108123	68.59
13:00	36.0	33.0	98992.08	59.41	1960.47	0.012567	97031.62	1.107160	68.45
14:00	37.9	31.0	98992.08	65.89	2042.53	0.013104	96949.55	1.100049	71.79
15:00	36.2	31.0	98992.08	60.06	1861.95	0.011924	97130.13	1.106863	67.00
16:00	38.1	26.0	98992.08	66.60	1731.72	0.011075	97260.37	1.100657	66.77
17:00	40.4	25.0	98992.08	75.34	1883.51	0.012064	97108.57	1.091946	71.68
18:00	38.6	24.0	98992.08	68.43	1642.20	0.010493	97349.88	1.099270	65.79
19:00	37.4	22.0	98992.08	64.13	1410.77	0.008993	97581.31	1.104499	60.70
20:00	35.0	31.0	98992.08	56.22	1742.97	0.011148	97249.11	1.111682	63.78
21:00	35.4	32.0	98992.08	57.48	1839.36	0.011776	97152.72	1.109829	65.80
22:00	34.7	36.0	98992.08	55.30	1990.78	0.012765	97001.30	1.111705	67.62
23:00	33.1	36.0	98992.08	50.58	1820.98	0.011656	97171.11	1.118244	63.13
0:00	33.5	36.0	98992.08	51.73	1862.20	0.011925	97129.88	1.116608	64.23
1:00	32.0	40.0	98992.08	47.55	1901.85	0.012184	97090.23	1.121926	63.36
2:00	32.7	40.0	98992.08	49.46	1978.38	0.012684	97013.70	1.119028	65.36
3:00	31.2	42.0	98992.08	45.44	1908.42	0.012227	97083.66	1.124846	62.64
4:00	30.8	52.0	98992.08	44.42	2309.60	0.014859	96682.48	1.124588	68.97
5:00	30.8	53.0	98992.08	44.42	2354.02	0.015151	96638.06	1.124396	69.71
6:00	30.7	53.0	98992.08	44.16	2340.63	0.015063	96651.45	1.124824	69.38
7:00	31.5	52.0	98992.08	46.22	2403.40	0.015477	96588.68	1.121599	71.27
8:00	33.2	49.0	98992.08	50.87	2492.48	0.016066	96499.61	1.114992	74.54
9:00	36.0	41.0	98992.08	59.41	2435.73	0.015691	96556.35	1.105135	76.47

IEC Hybrid Unit								
Dry Bulb Temperature; °F	Relative Humidity; %	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3	Enthalpy of outlet Air; kJ/kg	Water Consumed; mm/hour
Tdb out IEC-H	RH out IEC-H	Psat out IEC-H	Pv out IEC-H	ω out IEC-H	Pd out IEC-H	ρ out IEC-H	h out IEC-H	W.Lvl IEC-H
17.4	92.3	19.87	1833.31	0.011737	97158.77	1.178612	47.21910525	0
16.9	92.3	19.28	1780.47	0.011392	97211.62	1.180782	45.85888147	50
14.8	90.1	16.81	1514.35	0.009663	97477.73	1.190817	39.28059584	100
13.8	89.3	15.73	1404.91	0.008955	97587.18	1.195573	36.44224867	100
14.5	89.0	16.51	1469.95	0.009375	97522.13	1.192158	38.27228531	100
14.5	89.1	16.51	1470.78	0.009381	97521.31	1.192155	38.2857968	100
14.3	88.4	16.30	1440.46	0.009185	97551.62	1.193123	37.58538915	100
13.6	87.4	15.52	1356.08	0.008639	97636.00	1.196632	35.44083252	100
13.6	86.9	15.60	1356.09	0.008639	97636.00	1.196319	35.51753913	80
12.8	88.7	14.76	1309.42	0.008338	97682.66	1.200090	33.88904029	80
12.3	88.6	14.31	1267.07	0.008065	97725.01	1.202282	32.7148644	80
13.6	90.3	15.58	1406.06	0.008962	97586.02	1.196193	36.30782049	75
15.1	90.5	17.11	1548.26	0.009883	97443.82	1.189525	40.11783613	70
14.8	91.1	16.86	1536.10	0.009804	97455.98	1.190510	39.68822553	100
14.7	90.9	16.67	1514.69	0.009665	97477.39	1.191332	39.15827392	75
14.5	91.4	16.51	1508.75	0.009627	97483.33	1.191981	38.90757293	80
14.2	91.6	16.17	1480.18	0.009442	97511.90	1.193460	38.10736121	80
14.3	91.6	16.27	1490.61	0.009509	97501.47	1.192997	38.38038957	70
14.4	91.5	16.43	1503.10	0.009590	97488.99	1.192317	38.73823723	70
14.8	92.0	16.83	1548.36	0.009883	97443.72	1.190558	39.86356968	75
15.6	93.4	17.72	1654.88	0.010575	97337.21	1.186773	42.43163952	70
15.1	93.4	17.16	1602.17	0.010233	97389.92	1.189073	41.05348143	70
15.4	93.7	17.47	1636.41	0.010455	97355.67	1.187783	41.89756618	80
15.3	93.5	17.33	1620.29	0.010350	97371.79	1.188372	41.50474299	70
15.6	92.5	17.75	1641.11	0.010485	97350.97	1.186733	42.23093238	70

IEC Hybrid Unit										
Water Consumed; m3/hour	Compressor power consumption; Watts	Pump power consumption; Watts	Evaporative Fan power consumption; Watts	Supply Fan power consumption; Watts	IEC Hybrid Unit total power consumption; Watts	Mass flow rate; kg/s	Total Cooling Capacity kW	Total Cooling Capacity BTU/hr	Coefficient of Performance W/W	Energy Efficiency Ratio BTU/W.hr
W.Vol IEC-H	**Comp. IEC-H**	**Pump IEC-H**	**Evap. Fan IEC-H**	**Sup. Fan IEC-H**	**Pw.Tot IEC-H**	**m'**	**Qtot IEC-H**	**Qtot IEC-H**	**COP**	**EER**
0	0	489.2	978.4	978.4	2446	0.7342	22.0458	75223.4637	9.0130	30.7536
0.02856	4985	542.6	1085.2	1085.2	7698	0.7356	15.3965	52534.9238	2.0001	6.8245
0.05712	5969	337	674	674	7654	0.7418	21.1464	72154.5628	2.7628	9.4270
0.05712	6004	327.6	655.2	655.2	7642	0.7448	23.9405	81688.3109	3.1328	10.6894
0.05712	6007	336.8	673.6	673.6	7691	0.7427	22.4128	76475.8203	2.9142	9.9435
0.05712	6049	336.4	672.8	672.8	7731	0.7427	24.8796	84892.8909	3.2182	10.9808
0.05712	6066	343.8	687.6	687.6	7785	0.7433	21.8659	74609.4228	2.8087	9.5837
0.05712	6040	342.8	685.6	685.6	7754	0.7455	23.3563	79695.0691	3.0122	10.2779
0.045696	6061	374.4	748.8	748.8	7933	0.7453	26.9510	91960.4886	3.3973	11.5921
0.045696	6023	360	720	720	7823	0.7476	23.8477	81371.7438	3.0484	10.4016
0.045696	6093	341.8	683.6	683.6	7802	0.7490	20.9619	71525.1485	2.6867	9.1675
0.04284	5943	327	654	654	7578	0.7452	20.4726	69855.4084	2.7016	9.2182
0.039984	5812	335	670	670	7487	0.7410	19.0339	64946.4383	2.5423	8.6746
0.05712	4770	620.6	1241.2	1241.2	7873	0.7417	20.7175	70691.1148	2.6315	8.9789
0.04284	6067	369	738	738	7912	0.7422	17.7941	60715.8308	2.2490	7.6739
0.045696	6048	369.4	738.8	738.8	7895	0.7426	18.8068	64171.3315	2.3821	8.1281
0.045696	6047	365.6	731.2	731.2	7875	0.7435	18.7723	64053.6786	2.3838	8.1338
0.039984	6060	363.8	727.6	727.6	7879	0.7432	20.0492	68410.8742	2.5446	8.6827
0.039984	6060	359.2	718.4	718.4	7856	0.7428	17.7566	60588.0863	2.2603	7.7123
0.04284	6065	367.8	735.6	735.6	7904	0.7417	21.5842	73648.4633	2.7308	9.3179
0.039984	6096	371.6	743.2	743.2	7954	0.7393	20.1706	68824.9073	2.5359	8.6529
0.039984	6092	364.4	728.8	728.8	7914	0.7408	20.9868	71609.8541	2.6519	9.0485
0.045696	6093	365.8	731.6	731.6	7922	0.7400	21.7350	74162.8495	2.7436	9.3616
0.039984	6100	367.8	735.6	735.6	7939	0.7403	24.4540	83440.6826	3.0802	10.5102
0.039984	6108	367.2	734.4	734.4	7944	0.7393	25.3138	86374.3190	3.1865	10.8729

DX Unit						
Dry Bulb Temperature; °C	Relative Humidity; %	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3
Tdb out DX	**RH out DX**	**Psat out DX**	**Pv out DX**	**ω out DX**	**Pd out DX**	**ρ out DX**
17.2	74.2	19.56	1451.96	0.009259	97540.12	1.181357
17.3	83.3	19.69	1639.83	0.010477	97352.26	1.180099
15.2	81.0	17.30	1400.56	0.008926	97591.53	1.189478
15.6	79.5	17.67	1404.46	0.008952	97587.62	1.188121
15.6	79.7	17.69	1410.70	0.008992	97581.39	1.187990
15.7	81.2	17.84	1447.45	0.009230	97544.63	1.187308
16.3	78.1	18.50	1445.63	0.009218	97546.45	1.184958
15.2	80.2	17.30	1387.58	0.008843	97604.50	1.189537
15.2	78.7	17.27	1359.87	0.008664	97632.21	1.189767
13.9	80.4	15.86	1274.05	0.008110	97718.03	1.195653
13.9	80.3	15.88	1274.93	0.008115	97717.15	1.195545
13.4	80.5	15.37	1237.58	0.007875	97754.50	1.197803
14.0	83.7	16.01	1339.36	0.008531	97652.72	1.194729
15.2	80.3	17.22	1381.77	0.008805	97610.31	1.189873
15.1	80.7	17.14	1382.40	0.008809	97609.68	1.190180
14.5	80.8	16.51	1334.55	0.008500	97657.53	1.192778
14.7	81.1	16.75	1357.86	0.008651	97634.23	1.191739
14.8	81.5	16.78	1368.02	0.008716	97624.06	1.191589
14.8	82.5	16.83	1388.85	0.008851	97603.23	1.191287
14.8	84.1	16.78	1411.23	0.008995	97580.85	1.191392
14.7	84.4	16.75	1413.14	0.009008	97578.94	1.191486
14.8	84.2	16.86	1419.76	0.009051	97572.33	1.191042
15.1	83.7	17.11	1431.93	0.009129	97560.15	1.190057
15.5	83.5	17.55	1466.14	0.009351	97525.95	1.188251
15.4	81.3	17.50	1422.07	0.009066	97570.01	1.188658

DX Unit						
Enthalpy of outlet Air; kJ/kg	DX Unit total power consumption; Watts	Mass flow rate; kg/s	Total Cooling Capacity kW	Total Cooling Capacity BTU/hr	Coefficient of Performance W/W	Energy Efficiency Ratio BTU/W.hr
h out DX	**Pw.Tot DX**	**m'**	**Qtot DX**	**Qtot DX**	**COP**	**EER**
40.68682776	12185	0.7360	26.9046	91802.3062	2.2080	7.5340
43.87464465	12238	0.7352	16.8463	57481.9492	1.3766	4.6970
37.87807442	11197	0.7410	22.1619	75619.6328	1.9793	6.7536
38.27398013	11336	0.7402	22.4355	76553.0116	1.9791	6.7531
38.40148881	11244	0.7401	22.2389	75882.1436	1.9778	6.7487
39.13081276	11032	0.7397	24.1535	82415.1155	2.1894	7.4705
39.68874461	11219	0.7382	20.1635	68800.8472	1.7973	6.1325
37.66592577	11447	0.7410	21.5689	73596.3120	1.8842	6.4293
37.18760842	11449	0.7412	25.5655	87233.1798	2.2330	7.6193
34.43516994	11189	0.7449	23.3527	79682.8757	2.0871	7.1215
34.47499939	11168	0.7448	19.5336	66651.2465	1.7491	5.9681
33.35674085	11059	0.7462	22.7022	77463.2015	2.0528	7.0045
35.65301816	10945	0.7443	22.4403	76569.3703	2.0503	6.9958
37.49430249	11096	0.7413	22.3327	76202.3105	2.0127	6.8675
37.42803828	11069	0.7414	19.0597	65034.4697	1.7219	5.8754
36.05949116	10980	0.7431	20.9357	71435.4218	1.9067	6.5060
36.66963581	10974	0.7424	19.8126	67603.4323	1.8054	6.1603
36.86114719	10940	0.7423	21.1534	72178.2772	1.9336	6.5976
37.25258414	10913	0.7421	18.8438	64297.8159	1.7267	5.8919
37.56727378	10857	0.7422	23.3037	79515.4217	2.1464	7.3239
37.57302345	10833	0.7423	23.8571	81403.6472	2.2023	7.5144
37.78335577	10814	0.7420	23.4479	80007.6327	2.1683	7.3985
38.21237753	10796	0.7414	24.5087	83627.0990	2.2702	7.7461
39.18115937	10861	0.7402	26.1716	89301.2090	2.4097	8.2222
38.40879046	10999	0.7405	28.1852	96171.7890	2.5625	8.7437

A.4. Results of EOM 6:

Basic Information			
Tested Units Name	DX (Direct Expansion Unit)		
	IEC Hybrid (Indirect Evaporative Cooling Hybrid Unit)		
OEM No.	6		
Refrigerant	R-32		
Air Flow Rate	1800 C.F.M for DX and IEC hybrid Units		
Capacity	DX	2	Compressors
	IEC hybrid	1	Compressor
Water Bath Area	(1308.3^2-900.3^2)		mm2
Climatic Zone	8 (South Egypt)		
Altitude	196.07 meter (From Sea Level)		
Location	22°49' 02" N 31°28' 16" E		
Test Date	31-Aug-24		

Used Apparatus

Used Apparatus	Code of Used Apparatus	Measured Property	Measurement Unit
Weather Station, Dry bulb temperature	**WS; T-amb**	Ambient dry bulb temperature for both Units	°C
Weather Station, Relative Humidity	**WS; Rh-amb**	Ambient Relative humidity for both Units	%
Air Quality 6 - Dry bulb temperature	**AQ6; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 6 - Relative Humidity	**AQ6; RH-amb**	Ambient Relative humidity for both Units	%
Fluke 975 - Dry bulb temperature	**F975; T-amb**	Ambient dry bulb temperature for both Units	°C
Air Quality 3 - Dry bulb temperature	**AQ3; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Air Quality 3 - Relative Humidity	**AQ3; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Air Quality 4 - Dry bulb temperature	**AQ4; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Air Quality 4 - Relative Humidity	**AQ4; RH-out; DX**	Outlet Relative humidity for DX Unit	%
Lutron 1 - Dry bulb temperature	**L1; T-out; DX**	Outlet dry bulb temperature for DX Unit	°C
Lutron 1 - Relative Humidity	**L1; RH-out; DX**	Outlet Relative humidity for DX Unit	%
UNI T - Dry bulb temperature	**U; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
UNI T - Relative Humidity	**U; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Lutron 2 - Dry bulb temperature	**L2; T-out; IEC-H**	Outlet dry bulb temperature for IEC Hybrid Prototype	°C
Lutron 2 - Relative Humidity	**L2; RH-out; IEC-H**	Outlet Relative humidity for IEC Hybrid Prototype	%
Tabular level gauge for measuring the Water level change	**W.Lvl; IEC-H**	make up of evaporated water of the IEC hybrid unit	mm/hr
Water volume in Litres/hour (calculated)	**W.Vol; IEC-H**	hourly consumption rate of evaporated water for IEC hybrid unit	Litres/hr
Compressor power meter - IEC hybrid unit	**Comp.; IEC-H**	Power consumption of the Compressor of the IEC hybrid Unit	Watts
Pump power meter - IEC hybrid unit	**Pump; IEC-H**	Power consumption of the Pump of the IEC hybrid Unit	Watts
Evaporative Fan power meter - IEC hybrid unit	**Evap. Fan; IEC-H**	Power consumption of the Evaporator Fan of the IEC hybrid Prototype	Watts
Supply fan power meter - IEC hybrid unit	**Sup. Fan; IEC-H**	Power consumption of the Supply Fan of the IEC hybrid Prototype	Watts
Power meter of total power consumption of IEC hybrid Unit	**Pw.Tot; IEC-H**	Total Input power of IEC Hybrid Prototype	Watts
Power meter of total power consumption of DX Unit	**Pw.Tot; DX**	Total Input power of DX Unit	Watts

Time	Ambient Conditions								
	Dry Bulb Temperature; °F	Relative Humidity; %	Pressure at the given altitude Pa	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3	Enthalpy of Ambient Air; kJ/kg
	Tdb amb	**RH amb**	**P**	**Psat amb**	**Pv amp**	**ω amb**	**Pd amb**	**ρ amb**	**h amb**
20:00	38.9	17.3	98992.08	69.66	1201.68	0.007643	97790.40	1.099955	58.80
21:00	37.6	19.8	98992.08	64.83	1283.55	0.008171	97708.53	1.104328	58.79
22:00	36.7	22.3	98992.08	61.84	1379.04	0.008787	97613.04	1.107010	59.49
23:00	35.8	17.7	98992.08	58.65	1035.20	0.006573	97956.88	1.111940	52.82
0:00	35.1	17.6	98992.08	56.43	990.39	0.006286	98001.69	1.114657	51.37
1:00	34.1	19.6	98992.08	53.59	1050.31	0.006670	97941.78	1.117786	51.41
2:00	33.4	20.8	98992.08	51.44	1067.37	0.006780	97924.71	1.120387	50.94
3:00	32.7	21.3	98992.08	49.37	1049.05	0.006662	97943.03	1.123152	49.90
4:00	32.2	22.5	98992.08	48.18	1081.57	0.006871	97910.51	1.124606	49.99
5:00	31.6	23.2	98992.08	46.39	1074.03	0.006822	97918.06	1.127099	49.19
6:00	30.7	24.0	98992.08	44.16	1057.70	0.006718	97934.38	1.130384	48.04
7:00	32.4	22.0	98992.08	48.63	1069.89	0.006796	97922.19	1.124042	49.97
8:00	39.7	18.0	98992.08	72.58	1306.49	0.008319	97685.59	1.096818	61.32
9:00	38.7	17.4	98992.08	68.79	1197.02	0.007613	97795.06	1.100798	58.48
10:00	38.3	17.1	98992.08	67.45	1150.00	0.007311	97842.08	1.102292	57.33
11:00	41.2	13.0	98992.08	78.60	1021.84	0.006488	97970.24	1.092777	58.13
12:00	42.3	11.7	98992.08	83.43	972.00	0.006168	98020.08	1.089059	58.46
13:00	44.0	11.1	98992.08	91.16	1011.87	0.006424	97980.21	1.083057	60.84
14:00	44.4	9.5	98992.08	92.90	882.59	0.005595	98109.49	1.082342	59.08
15:00	45.6	9.7	98992.08	98.82	953.59	0.006050	98038.49	1.077974	61.47
16:00	44.3	9.5	98992.08	92.43	873.42	0.005537	98118.66	1.082721	58.82
17:00	43.4	10.4	98992.08	88.06	911.41	0.005780	98080.67	1.085756	58.50
18:00	42.4	11.3	98992.08	83.87	943.56	0.005986	98048.52	1.088833	58.09
19:00	39.9	15.1	98992.08	73.49	1109.73	0.007052	97882.35	1.096828	58.29
20:00	38.3	16.3	98992.08	67.45	1099.42	0.006986	97892.67	1.102506	56.49

IEC Hybrid Unit								
Dry Bulb Temperature; °F	Relative Humidity; %	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3	Enthalpy of outlet Air; kJ/kg	Water Consumed; mm/hour
Tdb out IEC-H	**RH out IEC-H**	**Psat out IEC-H**	**Pv out IEC-H**	**ω out IEC-H**	**Pd out IEC-H**	**ρ out IEC-H**	**h out IEC-H**	**W.Lvl IEC-H**
8.2	94.4	10.84	1022.51	0.006492	97969.57	1.221164	24.52457591	0
8.6	94.9	11.17	1060.38	0.006735	97931.70	1.219037	25.59396471	40
8.8	95.4	11.33	1079.94	0.006860	97912.14	1.218081	26.11358688	40
17.3	96.3	19.69	1895.74	0.012144	97096.34	1.178938	48.09715373	40
10.4	96.6	12.57	1213.65	0.007720	97778.43	1.210800	29.8584185	40
14.4	96.9	16.35	1584.53	0.010118	97407.55	1.192255	39.99616046	40
16.3	97.1	18.53	1799.61	0.011517	97192.47	1.183245	45.53339571	25
16.3	97.3	18.47	1796.66	0.011498	97195.42	1.183463	45.43333048	20
16.0	97.4	18.18	1770.04	0.011324	97222.04	1.184607	44.73784686	35
15.8	97.3	17.89	1741.08	0.011136	97251.00	1.185764	44.00410947	25
15.8	97.4	17.89	1742.87	0.011147	97249.21	1.185756	44.03358563	20
13.4	97.6	15.37	1500.47	0.009573	97491.62	1.196594	37.64679275	15
17.3	96.5	19.69	1899.68	0.012170	97092.40	1.178920	48.16228927	30
7.8	93.7	10.55	988.16	0.006272	98003.92	1.223064	23.5637229	50
17.1	96.8	19.44	1880.64	0.012046	97111.44	1.179819	47.64190001	50
9.7	94.1	11.99	1128.65	0.007173	97863.43	1.214193	27.76717948	70
8.4	93.8	11.02	1033.97	0.006565	97958.11	1.220027	24.96382551	33
17.4	96.2	19.87	1910.82	0.012243	97081.26	1.178261	48.50081279	65
8.6	93.8	11.14	1043.99	0.006630	97948.10	1.219330	25.2782303	40
10.0	94.3	12.28	1157.32	0.007358	97834.77	1.212559	28.58804044	80
10.2	94.8	12.40	1175.20	0.007473	97816.88	1.211834	29.03081702	65
8.5	94.1	11.06	1040.25	0.006606	97951.83	1.219781	25.11610375	40
8.2	94.4	10.84	1023.05	0.006495	97969.03	1.221162	24.53332228	90
8.4	95.1	11.02	1048.30	0.006657	97943.78	1.219960	25.19525683	65
7.5	95.1	10.33	982.58	0.006236	98009.50	1.224398	23.16868544	90

IEC Hybrid Unit										
Water Consumed; m3/hour	Compressor power consumption; Watts	Pump power consumption; Watts	Evaporative Fan power consumption; Watts	Supply Fan power consumption; Watts	IEC Hybrid Unit total power consumption; Watts	Mass flow rate; kg/s	Total Cooling Capacity kW	Total Cooling Capacity BTU/hr	Coefficient of Performance W/W	Energy Efficiency Ratio BTU/W.hr
W.Vol IEC-H	Comp. IEC-H	Pump IEC-H	Evap. Fan IEC-H	Sup. Fan IEC-H	Pw.Tot IEC-H	m'	Qtot IEC-H	Qtot IEC-H	COP	EER
0	6683	196	579	390	7849	1.0374	35.5534	121313.3512	4.5298	15.4564
0.036044352	6600	187	602	389	7777	1.0356	34.3814	117314.1739	4.4208	15.0843
0.036044352	5854	167	602	389	7011	1.0348	34.5407	117857.7697	4.9268	16.8109
0.036044352	0	199	605	385	4767	1.0015	4.7319	16145.7488	0.9926	3.3869
0.036044352	5268	233	601	385	4911	1.0286	22.1287	75506.2948	4.5061	15.3756
0.036044352	4923	212	599	382	3034	1.0128	11.5592	39441.5834	3.8105	13.0020
0.02252772	0	211	601	389	2837	1.0052	5.4382	18555.9175	1.9170	6.5411
0.018022176	0	213	599	387	2848	1.0054	4.4867	15309.1076	1.5754	5.3755
0.031538808	0	217	597	385	2643	1.0063	5.2853	18034.2284	2.0000	6.8244
0.02252772	0	226	594	385	2595	1.0073	5.2212	17815.5601	2.0121	6.8655
0.018022176	0	240	592	386	2644	1.0073	4.0329	13760.9754	1.5250	5.2036
0.013516632	4898	244	592	385	2796	1.0165	12.5242	42734.3244	4.4789	15.2825
0.027033264	0	250	594	385	2220	1.0015	13.1749	44954.6599	5.9338	20.2470
0.04505544	6067	261	593	388	7310	1.0390	36.2798	123791.8201	4.9632	16.9352
0.04505544	0	264	594	387	3516	1.0023	9.7098	33131.1746	2.7612	9.4217
0.063077616	5808	272	593	386	7059	1.0315	31.3159	106854.2003	4.4361	15.1366
0.02973659	6054	278	595	388	7314	1.0364	34.7121	118442.4680	4.7458	16.1934
0.058572072	0	282	595	390	5565	1.0009	12.3551	42157.2319	2.2201	7.5751
0.036044352	6184	250	595	386	7414	1.0358	35.0106	119461.1014	4.7220	16.1122
0.072088704	6518	219	597	387	7721	1.0301	33.8726	115577.9976	4.3869	14.9688
0.058572072	6529	213	597	391	7730	1.0295	30.6717	104656.2261	3.9676	13.5381
0.036044352	6486	193	597	392	7669	1.0362	34.5976	118051.9284	4.5113	15.3932
0.081099792	6350	219	597	391	7557	1.0374	34.8087	118772.2967	4.6062	15.7168
0.058572072	6367	213	601	390	7571	1.0364	34.3010	117039.9237	4.5307	15.4593
0.081099792	6173	232	579	388	7373	1.0401	34.6620	118271.7184	4.7014	16.0419

DX Unit						
Dry Bulb Temperature; °C	Relative Humidity; %	Saturation vapor pressure hPa	Partial vapor pressure Pa	Humidity Ratio	Partial pressure of dry air Pa	Density of Ambient Air; kg/m3
Tdb out DX	**RH out DX**	**Psat out DX**	**Pv out DX**	**ω out DX**	**Pd out DX**	**ρ out DX**
15.5	56.8	17.61	999.64	0.006345	97992.44	1.190174
15.7	62.5	17.87	1117.18	0.007100	97874.90	1.188677
14.9	66.2	16.91	1118.68	0.007109	97873.40	1.192247
14.2	60.1	16.16	970.63	0.006159	98021.45	1.195830
13.2	59.3	15.17	899.33	0.005703	98092.75	1.200195
12.4	61.9	14.40	891.80	0.005654	98100.28	1.203592
12.1	64.7	14.15	915.44	0.005806	98076.64	1.204608
11.9	64.4	13.90	895.31	0.005677	98096.77	1.205828
11.6	64.8	13.66	885.14	0.005612	98106.95	1.207004
11.8	63.0	13.84	872.00	0.005528	98120.08	1.206218
13.4	57.3	15.41	882.31	0.005594	98109.77	1.199296
15.6	52.0	17.72	921.00	0.005841	98071.08	1.190120
16.5	49.2	18.81	926.13	0.005874	98065.95	1.186263
20.6	39.9	24.26	968.97	0.006149	98023.11	1.169648
16.0	52.9	18.18	961.24	0.006099	98030.85	1.188291
17.5	50.3	20.04	1008.08	0.006399	97984.00	1.181810
18.7	43.3	21.57	934.50	0.005928	98057.59	1.177418
19.3	45.2	22.39	1012.68	0.006429	97979.41	1.174650
19.9	43.5	23.24	1010.07	0.006412	97982.02	1.172257
21.0	44.2	24.92	1101.47	0.006999	97890.61	1.167332
18.7	47.0	21.57	1014.29	0.006439	97977.79	1.177058
18.2	48.3	20.86	1008.06	0.006399	97984.02	1.179241
17.8	49.2	20.42	1005.54	0.006383	97986.54	1.180603
16.5	54.5	18.81	1025.20	0.006509	97966.88	1.185812
15.7	55.6	17.80	989.61	0.006281	98002.47	1.189533

DX Unit						
Enthalpy of outlet Air; kJ/kg	DX Unit total power consumption; Watts	Mass flow rate; kg/s	Total Cooling Capacity kW	Total Cooling Capacity BTU/hr	Coefficient of Performance W/W	Energy Efficiency Ratio BTU/W.hr
h out DX	**Pw.Tot DX**	**m'**	**Qtot DX**	**Qtot DX**	**COP**	**EER**
31.6290197	9972	1.0111	27.4681	93725.2113	2.7545	9.3988
33.77549271	9900	1.0098	25.2635	86202.6812	2.5519	8.7073
32.91750321	9777	1.0128	26.9170	91844.5634	2.7531	9.3939
29.80331926	9781	1.0159	23.3837	79788.4959	2.3907	8.1575
27.66762419	9688	1.0196	24.1686	82466.5421	2.4947	8.5122
26.73360102	9614	1.0225	25.2295	86086.6491	2.6242	8.9543
26.84446954	9591	1.0233	24.6612	84147.3666	2.5713	8.7736
26.24860676	9548	1.0244	24.2235	82653.8801	2.5370	8.6567
25.81358545	9453	1.0254	24.7894	84584.8005	2.6224	8.9479
25.80470646	9394	1.0247	23.9600	81754.9442	2.5506	8.7029
27.6295885	9265	1.0188	20.7915	70943.6234	2.2441	7.6572
30.45597842	9013	1.0110	19.7264	67309.4199	2.1887	7.4680
31.48723404	9151	1.0077	30.0610	102572.4759	3.2850	11.2089
36.31550361	9259	0.9936	22.0248	75151.9128	2.3788	8.1166
31.51446214	9846	1.0095	26.0595	88918.7163	2.6467	9.0309
33.83360461	9829	1.0040	24.3903	83223.0293	2.4815	8.4671
33.82429167	10143	1.0002	24.6373	84066.0463	2.4290	8.2881
35.70493996	10444	0.9979	25.0858	85596.4600	2.4019	8.1957
36.27260129	10433	0.9958	22.7104	77490.9879	2.1768	7.4275
38.91559135	10168	0.9917	22.3678	76322.0866	2.1998	7.5061
35.12097607	10372	0.9999	23.7019	80874.1693	2.2852	7.7974
34.4773982	10274	1.0018	24.0699	82129.8107	2.3428	7.9939
34.09737243	10254	1.0029	24.0606	82098.0252	2.3465	8.0064
33.09471104	10084	1.0074	25.3834	86611.6351	2.5172	8.5890
31.63576743	9956	1.0105	25.1189	85709.2007	2.5230	8.6088

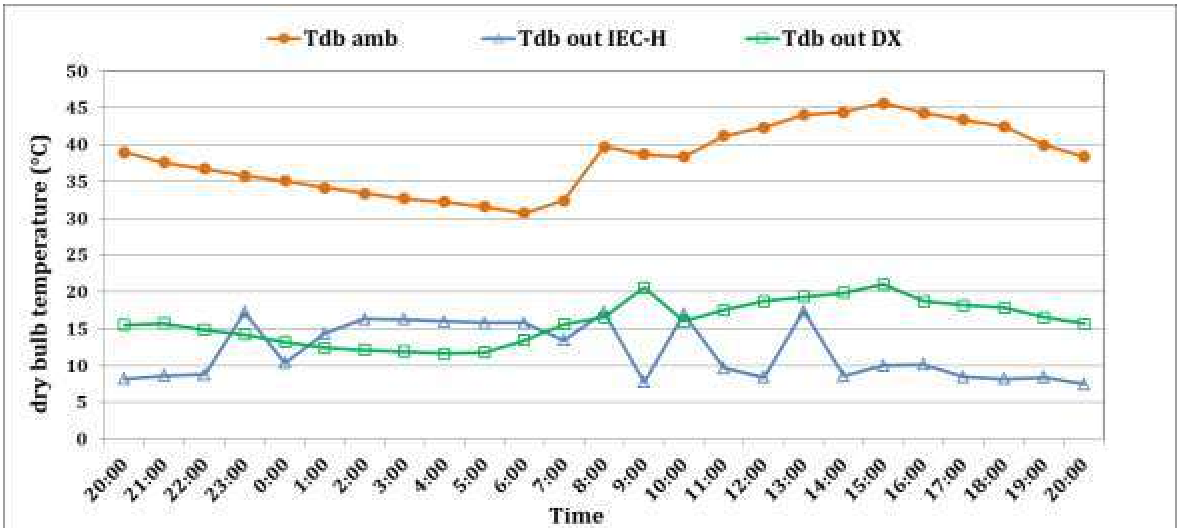

Fig. 1. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units for OEM6 in CZ 8

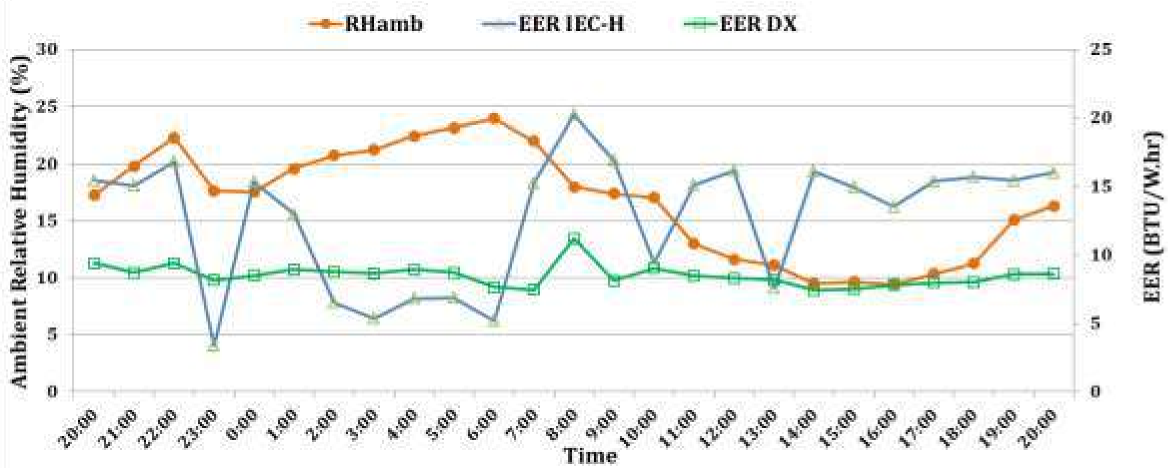

Fig. 2. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity for OEM6 in CZ 8

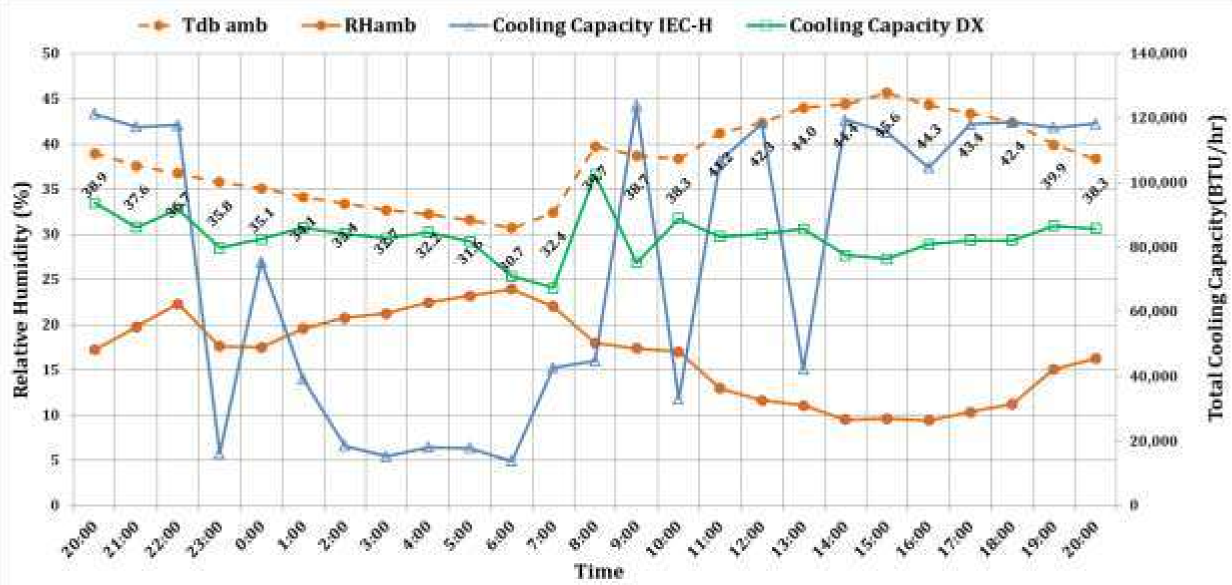

Fig. 3. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions for OEM6 in CZ8

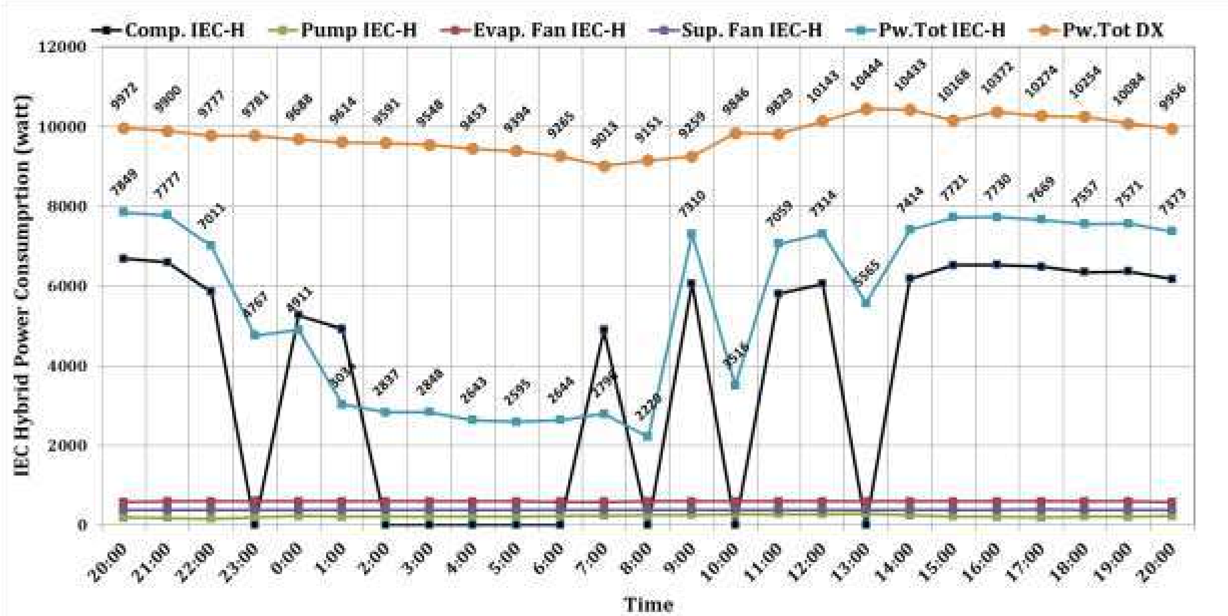

Fig. 4. Power Consumption of DX Unit and IEC Hybrid Unit Components for OEM6 in CZ 8

Annex 2: Calibration Certificates

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No:	762/32C012/290/1319/2024

- **NIS Lab** أسم المعمل : **Thermal Metrology Laboratory**
- **Issued For** صادر الى : المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني
- **Contact Information of the Customer** بيانات التواصل بالزبون : 01022852637
- **Location of Calibration** مكان اجراء المعايرة : NIS
- **Device Description** اسم ووصف الجهاز تحت المعايرة : Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity
  - **Manufacturer** اسم الشركة المنتجة : Lutron
  - **Model/Type** موديل الجهاز : PM-1064SD
  - **Serial Number** الرقم المسلسل للجهاز : 085019
  - **Code** كود : --------
- **Date of Receipt** تاريخ الاستلام : 01/05/2024
- **Date of Calibration** تاريخ المعايرة : 09/05/2024
- **Issue Date** تاريخ الإصدار : 15/05/2024
- **Due Date** تاريخ إعادة المعايرة : ------

Approved by

Head of Laboratory	**NIS President**
Prof. Dr.Essam El-Din Mahmoud	Prof. Dr. M. G. Ahmed

CERTIFICATE OF CALIBRATION
شهادة معايرة

▪ Certificate No.	762/32C012/290/1319/2024		
▪ Customer	المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني		
▪ Calibrated by	Ahmed Sayed Ahmed	▪ Date of Calibration	09/05/2024
▪ Number of pages	3	▪ File name	2570/13/24/02/HK

• Device Under Calibration

Device Description	Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity		
Serial Number	085019	Code	--------

• Enviromental Conditions

Temperature (°C)	(25±2)	Humidity (%)	(45±15)

• Calibration Method

The calibration was carried out according to calibration method No. NIS-32-OP-7.2.1.1-05 " Thermo hygrometers, Data loggers and Thermo hygrographs Calibration Method "

• Traceability

Description of Reference Device	Serial Number	Due Date	Certificate No.	Relative Expanded Uncertainty	Traceability
Standard thermo-hygrometer	0060957711	May,2024	4851/32C012/4 25/1522/2023	0.3 °C, 1%	NIS

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-32-OP-6.4.10-01 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

Calibrated by

Ahmed Sayed

Reviewed by

Elsayed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	762/32C012/290/1319/2024		
Serial Number	085019	Code	--------

Calibration results of humidity

Standard relative humidity RHs %	Measured relative humidity RHm %	Correction ΔRH = RHs - RHm %
30.0	28.3	1.7
35.0	33.5	1.5
40.0	38.9	1.1
45.0	42.9	2.1
50.0	47.2	2.8
55.0	52.0	3.0
60.0	56.8	3.2
65.0	61.5	3.5
70.0	66.5	3.5

Uncertainty at C.L. 95 % (K=2): ± 1.7 %

Calibration results of temperature

Temperature on ITS-90 t_s °C	Measured temperature t_m °C	Correction $\Delta t = ts - tm$ °C
25.0	24.4	0.6
30.0	29.7	0.3
35.0	34.3	0.7
40.0	39.3	0.7
45.0	44.1	0.9

Uncertainty at C.L. 95 % (K=2): ± 0.4 °C

* The calibration points are selected according to customer's request

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by
Ahmed Sayed

Reviewed by
ELsayed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No: 762/32C012/292/1322/2024

▪ NIS Lab اسم المعمل	: **Thermal Metrology Laboratory**
▪ Issued For صادر الى	: المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني
▪ Contact Information of the Customer بيانات التواصل بالزبون	: 01022852637
▪ Location of Calibration مكان اجراء المعايرة	: NIS
▪ Device Description اسم ووصف الجهاز تحت المعايرة	: Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity
▪ Manufacturer اسم الشركة المنتجة	: Lutron
▪ Model/Type موديل الجهاز	: PM-1064SD
▪ Serial Number الرقم المسلسل للجهاز	: 085018
▪ Code كود	: --------

▪ Date of Receipt تاريخ الاستلام	: 01/05/2024	**▪ Date of Calibration** تاريخ المعايرة	: 09/05/2024
▪ Issue Date تاريخ الإصدار	: 15/05/2024	**▪ Due Date** تاريخ إعادة المعايرة	: ------

Approved by

Head of Laboratory	**NIS President**
F/ Mostafa	
Prof. Dr.Essam El-Din Mahmoud	Prof. Dr. M. G. Ahmed

CERTIFICATE OF CALIBRATION
شهادة معايرة

▪ Certificate No.	762/32C012/292/1322/2024		
▪ Customer	المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني		
▪ Calibrated by	Ahmed Sayed Ahmed	▪ Date of Calibration	09/05/2024
▪ Number of pages	3	▪ File name	2570/13/24/04/HK

• Device Under Calibration

Device Description	Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity		
Serial Number	085018	Code	--------

• Enviromental Conditions

Temperature (°C)	(25±2)	Humidity (%)	(45±15)

• Calibration Method

The calibration was carried out according to calibration method No. NIS-32-OP-7.2.1.1-05 " Thermo hygrometers, Data loggers and Thermo hygrographs Calibration Method "

• Traceability

Description of Reference Device	Serial Number	Due Date	Certificate No.	Relative Expanded Uncertainty	Traceability
Standard thermo-hygrometer	0060957711	May,2024	4851/32C012/4 25/1522/2023	0.3 °C, 1%	NIS

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-32-OP-6.4.10-01 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

Calibrated by
Ahmed Sayed

Reviewed by
ElSayed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	762/32C012/292/1322/2024		
Serial Number	085018	Code	--------

Calibration results of humidity

Standard relative humidity RHs %	Measured relative humidity RHm %	Correction ΔRH = RHs - RHm %
30.0	29.1	0.9
35.0	33.7	1.3
40.0	39.5	0.5
45.0	43.7	1.3
50.0	48.5	1.5
55.0	53.2	1.8
60.0	58.6	1.4
65.0	63.4	1.6
70.0	69.0	1.0

Uncertainty at C.L. 95 % (K=2): ± 1.7 %

Calibration results of temperature

Temperature on ITS-90 t_s °C	Measured temperature t_m °C	Correction $\Delta t = t_s - t_m$ °C
25.0	24.8	0.2
30.0	29.8	0.2
35.0	34.7	0.3
40.0	39.7	0.3
45.0	44.6	0.4

Uncertainty at C.L. 95 % (K=2): ± 0.4 °C

*** The calibration points are selected according to customer's request**

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by
Ahmed Saad

Reviewed by
El sayed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No:	762/32C012/285/1312/2024

▪ NIS Lab أسم المعمل	:	**Thermal Metrology Laboratory**
▪ Issued For صادر الى	:	المركز القومى لبحوث الاسكان والبناء - معهد بحوث الاعمال الكهروميكانيكية في المباني
▪ Contact Information of the Customer بيانات التواصل بالزبون	:	01022852637
▪ Location of Calibration مكان اجراء المعايرة	:	**NIS**
▪ Device Description اسم ووصف الجهاز تحت المعايرة	:	Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity
▪ Manufacturer اسم الشركة المنتجة	:	Lutron
▪ Model/Type موديل الجهاز	:	PM-1064SD
▪ Serial Number الرقم المسلسل للجهاز	:	085017
▪ Code كود	:	--------
▪ Date of Receipt تاريخ الاستلام	:	01/05/2024
▪ Date of Calibration تاريخ المعايرة	:	09/05/2024
▪ Issue Date تاريخ الاصدار	:	15/05/2024
▪ Due Date تاريخ إعادة المعايرة	:	------

Approved by

Head of Laboratory

F1 Mostafa

Prof. Dr.Essam El-Din Mahmoud

NIS President

Prof. Dr. M. G. Ahmed

CERTIFICATE OF CALIBRATION
شهادة معايرة

▪ Certificate No.	762/32C012/285/1312/2024		
▪ Customer	المركز القومى لبحوث الاسكان والبناء - معهد بحوث الاعمال الكهروميكانيكية في المباني		
▪ Calibrated by	Ahmed Sayed Ahmed	▪ Date of Calibration	09/05/2024
▪ Number of pages	3	▪ File name	2570/13/24/01/HK

• Device Under Calibration

Device Description	**Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity**		
Serial Number	085017	Code	--------

• Enviromental Conditions

Temperature (°C)	(25±2)	Humidity (%)	(45±15)

• Calibration Method

The calibration was carried out according to calibration method No. NIS-32-OP-7.2.1.1-05 " Thermo hygrometers, Data loggers and Thermo hygrographs Calibration Method "

• Traceability

Description of Reference Device	Serial Number	Due Date	Certificate No.	Relative Expanded Uncertainty	Traceability
Standard thermo-hygrometer	0060957711	May,2024	4851/32C012/425/1522/2023	0.3 °C, 1%	NIS

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-32-OP-6.4.10-01 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

Calibrated by
Ahmed Sayed

Reviewed by
ElSayed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	762/32C012/285/1312/2024		
Serial Number	085017	Code	--------

Calibration results of humidity

Standard relative humidity RHs %	Measured relative humidity RHm %	Correction ΔRH = RHs - RHm %
30.0	29.7	0.3
35.0	34.8	0.2
40.0	39.6	0.4
45.0	44.4	0.6
50.0	48.9	1.1
55.0	53.8	1.2
60.0	59.1	0.9
65.0	64.1	0.9
70.0	69.4	0.6

Uncertainty at C.L. 95 % (K=2): ± 1.7 %

Calibration results of temperature

Temperature on ITS-90 t_s °C	Measured temperature t_m °C	Correction $\Delta t = ts - tm$ °C
25.0	24.5	0.5
30.0	29.7	0.3
35.0	34.3	0.7
40.0	39.3	0.7
45.0	44.2	0.8

Uncertainty at C.L. 95 % (K=2): ± 0.4 °C

* The calibration points are selected according to customer's request

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by
Ahmed Sayed

Reviewed by
ElSayed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No: 762/32C012/294/1324/2024

- **NIS Lab** أسم المعمل : **Thermal Metrology Laboratory**
- **Issued For** صادر الى : المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني
- **Contact Information of the Customer** بيانات التواصل بالزبون : 01022852637
- **Location of Calibration** مكان اجراء المعايرة : NIS
- **Device Description** اسم ووصف الجهاز تحت المعايرة : Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity
  - **Manufacturer** اسم الشركة المنتجة : Lutron
  - **Model/Type** موديل الجهاز : PM-1064SD
  - **Serial Number** الرقم المسلسل للجهاز : 085016
  - **Code** كود : --------
- **Date of Receipt** تاريخ الاستلام : 01/05/2024
- **Date of Calibration** تاريخ المعايرة : 09/05/2024
- **Issue Date** تاريخ الإصدار : 15/05/2024
- **Due Date** تاريخ إعادة المعايرة : ------

Approved by

Head of Laboratory	**NIS President**
Prof. Dr.Essam El-Din Mahmoud	Prof. Dr. M. G. Ahmed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	762/32C012/294/1324/2024		
Customer	المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني		
Calibrated by	Ahmed Sayed Ahmed	**Date of Calibration**	09/05/2024
Number of pages	3	**File name**	2570/13/24/06/HK

• Device Under Calibration

Device Description	**Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity**		
Serial Number	085016	Code	--------

• Enviromental Conditions

Temperature (°C)	(25±2)	**Humidity (%)**	(45±15)

• Calibration Method

The calibration was carried out according to calibration method No. NIS-32-OP-7.2.1.1-05 " Thermo hygrometers, Data loggers and Thermo hygrographs Calibration Method "

• Traceability

Description of Reference Device	Serial Number	Due Date	Certificate No.	Relative Expanded Uncertainty	Traceability
Standard thermo-hygrometer	0060957711	May,2024	4851/32C012/425/1522/2023	0.3 °C, 1%	NIS

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-32-OP-6.4.10-01 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

Calibrated by
AhmedSayed

Reviewed by
Elsayed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	762/32C012/294/1324/2024		
Serial Number	085016	Code	--------

Calibration results of humidity

Standard relative humidity RHs %	Measured relative humidity RHm %	Correction $\Delta RH = RHs - RHm$ %
30.0	29.3	0.7
35.0	34.0	1.0
40.0	39.9	0.1
45.0	43.8	1.2
50.0	49.0	1.0
55.0	53.6	1.4
60.0	59.1	0.9
65.0	64.2	0.8
70.0	69.6	0.4

Uncertainty at C.L. 95 % (K=2): ± 1.7 %

Calibration results of temperature

Temperature on ITS-90 t_s °C	Measured temperature t_m °C	Correction $\Delta t = ts - tm$ °C
25.0	24.4	0.6
30.0	30.0	0.0
35.0	34.6	0.4
40.0	39.7	0.3
45.0	44.5	0.5

Uncertainty at C.L. 95 % (K=2): ± 0.4 °C

* The calibration points are selected according to customer's request

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by
Ahmed Sobhy

Reviewed by
Elsayed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهـادة معايـرة

Certificate No:	762/32C012/293/1323/2024

- **NIS Lab** أسم المعمل : **Thermal Metrology Laboratory**
- **Issued For** صادرالى : المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني
- **Contact Information of the Customer** بيانات التواصل بالزبون : 01022852637
- **Location of Calibration** مكان اجراء المعايرة : NIS
- **Device Description** اسم ووصف الجهاز تحت المعايرة : Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity
  - **Manufacturer** اسم الشركة المنتجة : Lutron
  - **Model/Type** موديل الجهاز : PM-1064SD
  - **Serial Number** الرقم المسلسل للجهاز : 085015
  - **Code** كود : --------

- **Date of Receipt** تاريخ الاستلام : 01/05/2024
- **Date of Calibration** تاريخ المعايرة : 09/05/2024
- **Issue Date** تاريخ الإصدار : 15/05/2024
- **Due Date** تاريخ إعادة المعايرة : ------

Approved by

Head of Laboratory	**NIS President**
F/ Mostafa	
Prof. Dr.Essam El-Din Mahmoud	Prof. Dr. M. G. Ahmed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

▪ Certificate No.	762/32C012/293/1323/2024		
▪ Customer	المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني		
▪ Calibrated by	Ahmed Sayed Ahmed	▪ Date of Calibration	09/05/2024
▪ Number of pages	3	▪ File name	2570/13/24/05/HK

• Device Under Calibration

Device Description	Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity		
Serial Number	085015	Code	--------

• Enviromental Conditions

Temperature (°C)	(25±2)	Humidity (%)	(45±15)

• Calibration Method

The calibration was carried out according to calibration method No. NIS-32-OP-7.2.1.1-05 " Thermo hygrometers, Data loggers and Thermo hygrographs Calibration Method "

• Traceability

Description of Reference Device	Serial Number	Due Date	Certificate No.	Relative Expanded Uncertainty	Traceability
Standard thermo-hygrometer	0060957711	May,2024	4851/32C012/425/1522/2023	0.3 °C, 1%	NIS

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-32-OP-6.4.10-01 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

Calibrated by AhmedSayed

Reviewed by Elsayed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	762/32C012/293/1323/2024		
Serial Number	085015	Code	--------

Calibration results of humidity

Standard relative humidity RHs %	Measured relative humidity RHm %	Correction ΔRH = RHs - RHm %
30.0	28.9	1.1
35.0	33.7	1.3
40.0	39.6	0.4
45.0	43.5	1.5
50.0	48.6	1.4
55.0	53.0	2.0
60.0	58.3	1.7
65.0	63.2	1.8
70.0	68.7	1.3

Uncertainty at C.L. 95 % (K=2): ± 1.7 %

Calibration results of temperature

Temperature on ITS-90 t_s °C	Measured temperature t_m °C	Correction $\Delta t = t_s - t_m$ °C
25.0	24.8	0.2
30.0	29.8	0.2
35.0	34.7	0.3
40.0	39.7	0.3
45.0	44.5	0.5

Uncertainty at C.L. 95 % (K=2): ± 0.4 °C

* The calibration points are selected according to customer's request

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by

Ahmed Sayed

Reviewed by

Sayed

CERTIFICATE OF CALIBRATION
شهـادة معايـرة

Certificate No:	762/32C012/291/1320/2024

- **NIS Lab** اسم المعمل : **Thermal Metrology Laboratory**
- **Issued For** صادر الى : المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني
- **Contact Information of the Customer** بيانات التواصل بالزبون : 01022852637
- **Location of Calibration** مكان اجراء المعايرة : **NIS**
- **Device Description** اسم ووصف الجهاز تحت المعايرة : Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity
  - **Manufacturer** اسم الشركة المنتجة : Lutron
  - **Model/Type** موديل الجهاز : PM-1064SD
  - **Serial Number** الرقم المسلسل للجهاز : 085014
  - **Code** كود : --------
- **Date of Receipt** تاريخ الاستلام : 01/05/2024
- **Date of Calibration** تاريخ المعايرة : 09/05/2024
- **Issue Date** تاريخ الإصدار : 15/05/2024
- **Due Date** تاريخ إعادة المعايرة : ------

Approved by

Head of Laboratory

Prof. Dr.Essam El-Din Mahmoud

NIS President

Prof. Dr. M. G. Ahmed

CERTIFICATE OF CALIBRATION
شهادة معايرة

▪ Certificate No.	762/32C012/291/1320/2024		
▪ Customer	المركز القومى لبحوث الاسكان والبناء -معهد بحوث الاعمال الكهروميكانيكية في المباني		
▪ Calibrated by	Ahmed Sayed Ahmed	▪ Date of Calibration	09/05/2024
▪ Number of pages	3	▪ File name	2570/13/24/03/HK

• Device Under Calibration

Device Description	Digital thermo-hygrometer, resolution 0.1°C for temperature & resolution 0.1% for relative humidity		
Serial Number	085014	Code	--------

• Enviromental Conditions

Temperature (°C)	(25±2)	Humidity (%)	(45±15)

• Calibration Method

The calibration was carried out according to calibration method No. NIS-32-OP-7.2.1.1-05 " Thermo hygrometers, Data loggers and Thermo hygrographs Calibration Method "

• Traceability

Description of Reference Device	Serial Number	Due Date	Certificate No.	Relative Expanded Uncertainty	Traceability
Standard thermo-hygrometer	0060957711	May,2024	4851/32C012/425/1522/2023	0.3 °C, 1%	NIS

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-32-OP-6.4.10-01 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

Calibrated by
Ahmed Sayed

Reviewed by
Elsayed

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION

شهادة معايرة

Certificate No.	762/32C012/291/1320/2024		
Serial Number	085014	Code	--------

Calibration results of humidity

Standard relative humidity RHs %	Measured relative humidity RHm %	Correction ΔRH = RHs - RHm %
30.0	28.4	1.6
35.0	33.1	1.9
40.0	38.4	1.6
45.0	42.7	2.3
50.0	47.0	3.0
55.0	51.7	3.3
60.0	58.6	1.4
65.0	61.3	3.7
70.0	66.5	3.5

Uncertainty at C.L. 95 % (K=2): ± 1.7 %

Calibration results of temperature

Temperature on ITS-90 t_s °C	Measured temperature t_m °C	Correction $\Delta t = t_s - t_m$ °C
25.0	24.7	0.3
30.0	30.0	0.0
35.0	34.6	0.4
40.0	39.5	0.5
45.0	44.3	0.7

Uncertainty at C.L. 95 % (K=2): ± 0.4 °C

* The calibration points are selected according to customer's request

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by
Ahmed Sayed

Reviewed by
Elsayed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No:	8062/32C012/693/2698/2023

- **NIS Lab** اسم المعمل : **Thermal Metrology Laboratory**
- **Issued For** صادرالى : المركز القومي لبحوث الاسكان و البناء
- **Contact Information of the Customer** بيانات التواصل بالزبون : 01115196088
- **Location of Calibration** مكان اجراء المعايرة : **NIS**
- **Device Description** اسم ووصف الجهاز تحت المعايرة : Digital thermohygrometer, resolution 0.1% for relative humidity and resolution 0.1°C for temperature .
  - **Manufacturer** اسم الشركة المنتجة : Lutron
  - **Model/Type** موديل الجهاز : HT-305E
  - **Serial Number** الرقم المسلسل للجهاز : R.029189 — **Code** كود : --------
- **Date of Receipt** تاريخ الاستلام : 11/10/2023 — **Date of Calibration** تاريخ المعايرة : 18/10/2023
- **Issue Date** تاريخ الإصدار : 29/10/2023 — **Due Date** تاريخ إعادة المعايرة : ---------

Approved by

Head of Laboratory	**NIS President**
Prof. Dr.Essam EL-Din Mahmoud	Prof. Dr. Noha E. Khaled

Ministry of Higher Education
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National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	8062/32C012/693/2698/2023		
Customer	المركز القومي لبحوث الاسكان و البناء		
Calibrated by	Ahmed Sayed Ahmed	**Date of Calibration**	18/10/2023
Number of pages	3	**File name**	5903/40/23/01/AS

• Device Under Calibration

Device Description	**Digital thermohygrometer, resolution 0.1% for relative humidity and resolution 0.1°C for temperature .**		
Serial Number	**R.029189**	**Code**	--------

• Enviromental Conditions

Temperature (°C)	**(25±2)**	**Humidity (%)**	**(45±15)**

• Calibration Method

The calibration was carried out according to calibration method No. NIS-32-OP-7.2.1.1-05 " Thermo hygrometers, Data loggers and Thermo hygrographs Calibration Method "

• Traceability

Description of Reference Device	Serial Number	Due Date	Certificate No.	Relative Expanded Uncertainty	Traceability
Standard thermo-hygrometer	0060957711	May,2024	4851/32C012/29 /1059/2023	0.3 °C, 1%	NIS

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-32-OP-6.4.10-01 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

Caibrated by
Ahmed Sayed

Reviewed by
Ebtesam

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	8062/32C012/693/2698/2023		
Serial Number	R.029189	Code	--------

Calibration results of humidity

Standard relative humidity RHs %	Measured relative humidity RHm %	Correction ΔRH = RHs - RHm %
40.0	45.3	-5.3
50.0	55.0	-5.0
60.0	64.1	-4.1

Uncertainty a C.L. 95 % (K=2): ± 1.7 %

Calibration results of temperature

Temperature on ITS-90 t_s °C	Measured temperature t_m °C	Correction Δt = ts - tm °C
18.0	18.3	-0.3
19.0	19.3	-0.3
20.0	20.3	-0.3
22.0	22.3	-0.3
24.0	24.2	-0.2
26.0	26.2	-0.2
28.0	28.1	-0.1
30.0	30.1	-0.1

Uncertainty a C.L. 95 % (K=2): ± 0.4 °C

* The calibrated points are selected according to the customer's request

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by
Ahmed Sayed

Reviewed by
Ebtesam

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No:	882/23C012/75/339/2024

- **NIS Lab** اسم المعمل : **High Voltage Metrology Lab.**
- **Issued For** صادرالى : معهد بحوث الاعمال الكهروميكانيكية في المباني (مركز بحوث الاسكان والبناء)
- **Contact Information of the Customer** بيانات التواصل بالزبون : العنوان : 87 شارع التحرير
- **Location of Calibration** مكان اجراء المعايرة : High Voltage Metrology Lab., NIS.
- **Device Description** اسم ووصف الجهاز تحت المعايرة : POWER QUALITY AND ENERGY ANALYZER
  - **Manufacturer** اسم الشركة المنتجة : FLUKE
  - **Model/Type** موديل الجهاز : 434
  - **Serial Number** الرقم المسلسل للجهاز : DM9130018
  - **Code** كود : ----
- **Date of Receipt** تاريخ الاستلام : 9/5/2024
- **Date of Calibration** تاريخ المعايرة : 19/5/2024
- **Issue Date** تاريخ الإصدار : 22/5/2024
- **Due Date** تاريخ إعادة المعايرة : --------

Approved by

Head of Laboratory	NIS President
Dr. Eng. Ahmed S. Haiba	Prof. Dr. M. G. Ahmed

CERTIFICATE OF CALIBRATION
شهادة معايرة

• Certificate No.	882/23C012/75/339/2024		
• Customer	معهد بحوث الاعمال الكهروميكانيكية في المباني (مركز بحوث الاسكان والبناء)		
• Location	High Voltage Metrology Lab., NIS	• Date of Receipt	9/5/2024
• Calibrated by	Eng. Eman Mohamed Hosny	• Date of Calibration	19/5/2024
• Number of pages	6	• Issue Date	22/5/2024
		• Due Date	--------
• Device Under Calibration			
Device Description	POWER QUALITY AND ENERGY ANALYZER		
Manufacturer	FLUKE	other	-----
Model/Type	434	other	-----
Serial Number	DM9130018	other	-----
Code	-----	other	-----
Other	-----	-----	-----
• Enviromental Conditions			
Temperature (°C)	(23±2)	Humidity (%)	(50±10)
Other	-----	-----	-----

• Calibration Method

The calibration was carried out according to E.S. 1021/2020 "معايرة اجهزة القياس الكهربية"

• Traceability

Description of Reference Device	Serial Number	Calibration Date	Certificate No.	Expanded Uncertainty	Traceability
3-Phase Comparator Reference Standard	98-717-1	2/2024	10175/23C012/28/148/2024	Uv=0.005%,Ui= 0.003%, Up=0.005%	NIS, Egypt.

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-23-OP-7.6 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

Calibrated by

Eman M. Hosny

Reviewed by

Samah A. Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	882/23C012/75/339/2024	Serial Number	DM9130018

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

• Calibration Results

1. AC Voltage Calibration, 50 Hz:-

1.1. Phase (1)

Nominal Value (V)	Measured Value (V) UUC*	Actual Value (V) Ref**	Error*** %	Expanded Uncertainty ±(mV)
60	59.9	59.890	0.017	58
120	119.8	119.774	0.022	58
220	219.6	219.565	0.016	59
300	299.4	299.403	-0.001	59

1.2. Phase (2)

Nominal Value (V)	Measured Value (V) UUC	Actual Value (V) Ref	Error %	Expanded Uncertainty ±(mV)
60	59.9	59.890	0.017	58
120	119.8	119.774	0.022	58
220	219.6	219.565	0.016	59
300	299.4	299.403	-0.001	59

1.3. Phase (3)

Nominal Value (V)	Measured Value (V) UUC	Actual Value (V) Ref	Error %	Expanded Uncertainty ±(mV)
60	59.9	59.890	0.017	58
120	119.8	119.774	0.022	58
220	219.6	219.565	0.016	59
300	299.4	299.403	-0.001	59

*UUC:Unit Under Calibration

**Ref.:Reference value of standard instrument

$$***Error = \frac{Measured\ Value - Actual\ Value}{Actual\ Value} \times 100$$

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by

Eman M. Hosny

Reviewed by

Samah A. Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	882/23C012/75/339/2024	Serial Number	DM9130018
• Conformity Statement			
Conformity Criterion	Not applicable		
Decision	-----		

• Calibration Results

2. AC Current Calibration, 50 Hz:-

2.1. Phase (1), with clamp, S.N.: 90800112

Nominal Value (A)	Measured Value (A) UUC	Actual Value (A) Ref	Error %	Expanded Uncertainty ±(A)
10	10	9.986	0.140	0.58
20	20	19.994	0.030	0.58
50	50	49.984	0.032	0.58
100	99	99.966	-0.966	0.65
150	149	149.950	-0.634	0.73
300	298	299.834	-0.612	1.1
400	398	399.778	-0.445	1.3

2.2. Phase (2), with clamp, S.N.: 90780311

Nominal Value (A)	Measured Value (A) UUC	Actual Value (A) Ref	Error %	Expanded Uncertainty ±(A)
10	10	9.986	0.140	0.58
20	20	19.994	0.030	0.58
50	50	49.984	0.032	0.58
100	100	99.966	0.034	0.65
150	150	149.950	0.033	0.73
300	299	299.834	-0.278	1.1
400	399	399.778	-0.195	1.3

2.3. Phase (3), with clamp, S.N.: 90780313

Nominal Value (A)	Measured Value (A) UUC	Actual Value (A) Ref	Error %	Expanded Uncertainty ±(A)
10	10	9.986	0.140	0.58
20	20	19.994	0.030	0.58
50	50	49.984	0.032	0.58
100	99	99.966	-0.966	0.65
150	149	149.950	-0.634	0.73
300	299	299.834	-0.278	1.1
400	398	399.778	-0.445	1.3

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by
Eman M. Hosny

Reviewed by
Sabah A-Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	882/23C012/75/339/2024	Serial Number	DM91.00[illegible]

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

• Calibration Results

3. AC Active Power Calibration, 220 V, 50 Hz:-

3.1. Phase (1), with clamp, S.N.: 90800112 :

Nominal Value		Measured Value (kW)	Actual Value (kW)	Error	Expanded Uncertainty
I (A)	P.F	UUC	Ref	%	±(W)
1	1	0.2	0.220	-9.091	0.06
5	1	1.1	1.097	0.273	0.09
5	0.5L*	0.6	0.551	8.893	0.06
5	0.5C**	0.5	0.546	-8.425	0.06
10	1.0	2.2	2.194	0.273	0.10
10	0.5L	1.1	1.102	-0.181	0.09
10	0.5C	1.1	1.092	0.733	0.09
20	1.0	4.4	4.389	0.251	0.12
20	0.5L	2.2	2.204	-0.181	0.12
20	0.5C	2.1	2.185	-3.890	0.12
50	1	10.9	10.973	-0.665	0.62
80	1	17.4	17.558	-0.900	0.77

L*: Inductive
C**: Capacitive

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by: Eman M. Hosny

Reviewed by: [illegible] A. Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	882/23C012/75/339/2024	Serial Number	DM91.[illegible]

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

• Calibration Results

3.2. Phase (2), with clamp, S.N.: 90780311 :

Nominal Value		Measured	Actual	Error	Expanded
I (A)	P.F	Value (kW) UUC	Value (kW) Ref	%	Uncertainty ±(W)
1	1	0.2	0.220	-9.091	0.06
5	1	1.1	1.097	0.273	0.09
5	0.5L	0.6	0.551	8.893	0.06
5	0.5C	0.5	0.546	-8.425	0.06
10	1	2.2	2.194	0.273	0.10
10	0.5L	1.1	1.102	-0.181	0.09
10	0.5C	1.1	1.092	0.733	0.09
20	1	4.4	4.389	0.251	0.12
20	0.5L	2.2	2.204	-0.181	0.12
20	0.5C	2.1	2.185	-3.890	0.12
50	1	10.9	10.973	-0.665	0.62
80	1	17.5	17.558	-0.330	0.77

3.3. Phase (3), with clamp, S.N.: 90780313 :

Nominal Value		Measured	Actual	Error	Expanded
I (A)	P.F	Value (kW) UUC	Value (kW) Ref	%	Uncertainty ±(W)
1	1	0.2	0.220	-9.091	0.06
5	1	1.1	1.097	0.273	0.09
5	0.5L	0.5	0.551	-9.256	0.06
5	0.5C	0.5	0.546	-8.425	0.02
10	1	2.2	2.194	0.273	0.08
10	0.5L	1.1	1.102	-0.181	0.07
10	0.5C	1.1	1.092	0.733	0.08
20	1	4.3	4.389	-2.028	0.11
20	0.5L	2.2	2.204	-0.181	0.11
20	0.5C	2.1	2.185	-3.890	0.10
50	1	10.9	10.973	-0.665	0.62
80	1	17.4	17.558	-0.900	0.77

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by Eman M. Hosny

Reviewed by Samah A. Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No:	882/23C012/74/326/2024

- **NIS Lab** أسم المعمل : **High Voltage Metrology Lab.**
- **Issued For** صادرإلى : معهد بحوث الاعمال الكهروميكانيكية في المباني (مركز بحوث الاسكان والبناء)
- **Contact Information of the Customer** بيانات التواصل بالزبون : العنوان : 87 شارع التحرير
- **Location of Calibration** مكان اجراء المعايرة : High Voltage Metrology Lab., NIS.
- **Device Description** اسم ووصف الجهاز تحت المعايرة : POWER QUALITY AND ENERGY ANALYZER
  - **Manufacturer** اسم الشركة المنتجة : FLUKE
  - **Model/Type** موديل الجهاز : 435
  - **Serial Number** الرقم المسلسل للجهاز : 19673107
  - **Code** كود : ----

- **Date of Receipt** تاريخ الاستلام : 9/5/2024
- **Date of Calibration** تاريخ المعايرة : 19/5/2024
- **Issue Date** تاريخ الإصدار : 22/5/2024
- **Due Date** تاريخ إعادة المعايرة : --------

Approved by

Head of Laboratory	**NIS President**
Dr. Eng. Ahmed S. Haiba	Prof. Dr. M. G. Ahmed

CERTIFICATE OF CALIBRATION
شهادة معايرة

• Certificate No.	882/23C012/74/326/2024		
• Customer	معهد بحوث الاعمال الكهروميكانيكية في المباني (مركز بحوث الاسكان والبناء)		
• Location	High Voltage Metrology Lab., NIS	• Date of Receipt	9/5/2024
• Calibrated by	Eng. Eman Mohamed Hosny	• Date of Calibration	19/5/2024
• Number of pages	6	• Issue Date	22/5/2024
		• Due Date	--------

• Device Under Calibration

Device Description	POWER QUALITY AND ENERGY ANALYZER		
Manufacturer	FLUKE	other	-----
Model/Type	435	other	-----
Serial Number	19673107	other	-----
Code	----	other	-----
Other	-----	-----	-----

• Enviromental Conditions

Temperature (°C)	(23±2)	Humidity (%)	(50±10)
Other	-----	-----	-----

• Calibration Method

The calibration was carried out according to E.S. 1021/2020 " معايرة اجهزة القياس الكهربية"

• Traceability

Description of Reference Device	Serial Number	Calibration Date	Certificate No.	Expanded Uncertainty	Traceability
3-Phase Comparator Reference Standard	98-717-1	2/2024	10175/23C012/28/148/2024	Uv=0.005%,Ui=0.003%, Up= 0.005%	NIS, Egypt.

• Uncertainty Statement

The combined standard uncertainty is calculated based on NIS-23-OP-7.6 which include at least the standard uncertainty reported for the reference standard, the standard uncertainty for the measurement process, the standard uncertainty for any uncorrected errors. The combined standard uncertainty is multiplied by a coverage factor (k) of 2 to provide an expanded uncertainty, which defines a level of confidence of approximately 95 percent (95.45 %). The expanded uncertainty presented in this certificate/report is consistent with the ISO/IEC GUIDE 98-3:2008 "Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

• ISO 17025 Statement

All NIS laboratories implement the NIS unified quality management system which was built to be in compliance with ISO 17025:2017. It is the customer responsibility to indicate - on the calibration label - the due date for calibration in accordance with the aforementioned ISO/SOP calibration procedure and in compliance with ISO 17025:2017.

Calibrated by	Reviewed by
Eman M. Hosny	Samah A-Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	882/23C012/74/326/2024	Serial Number	19673107

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

• Calibration Results

1. AC Voltage Calibration, 50 Hz:-

1.1. Phase (1)

Nominal Value (V)	Measured Value (V) UUC*	Actual Value (V) Ref**	Error*** %	Expanded Uncertainty ±(mV)
60	59.88	59.890	-0.017	5.9
120	119.72	119.774	-0.045	9.0
220	219.50	219.565	-0.030	12
300	299.27	299.400	-0.043	12

1.2. Phase (2)

Nominal Value (V)	Measured Value (V) UUC	Actual Value (V) Ref	Error %	Expanded Uncertainty ±(mV)
60	59.88	59.890	-0.017	5.9
120	119.72	119.774	-0.045	9.0
220	219.50	219.565	-0.030	12
300	299.25	299.400	-0.050	12

1.3. Phase (3)

Nominal Value (V)	Measured Value (V) UUC	Actual Value (V) Ref	Error %	Expanded Uncertainty ±(mV)
60	59.88	59.890	-0.017	5.9
120	119.72	119.774	-0.045	9.0
220	219.50	219.565	-0.030	12
300	299.25	299.400	-0.050	12

*UUC:Unit Under Calibration

**Ref.:Reference value of standard instrument

$$***Error = \frac{Measured\ Value - Actual\ Value}{Actual\ Value} \times 100$$

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by: Eman M. Hosny

Reviewed by: Sarah A. Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	882/23C012/74/326/2024	Serial Number	19673107

• Conformity Statement

Conformity Criterion	Not applicable
Decision	-----

• Calibration Results

2. AC Current Calibration, 50 Hz:-

2.1. Phase (1), with Ampflex, S.N.:208200120-230965

Nominal Value (A)	Measured Value (A) UUC	Actual Value (A) Ref	Error %	Expanded Uncertainty ±(A)
10	9.9	9.986	-0.861	0.06
20	20.0	19.994	0.030	0.06
50	50.2	49.984	0.432	0.07
100	100.8	99.966	0.834	0.31
150	151.1	149.950	0.767	0.45
300	302.4	299.834	0.856	0.90
400	403.2	399.778	0.856	1.2

2.2. Phase (2), with Ampflex, S.N.:208200149-230965

Nominal Value (A)	Measured Value (A) UUC	Actual Value (A) Ref	Error %	Expanded Uncertainty ±(A)
10	10.1	9.986	1.142	0.07
20	20.2	19.994	1.030	0.06
50	50.7	49.984	1.432	0.06
100	100.7	99.966	0.734	0.31
150	151.2	149.950	0.834	0.45
300	302.6	299.834	0.923	0.90
400	403.5	399.778	0.931	1.2

2.3. Phase (3), with Ampflex, S.N.:208200140-230965

Nominal Value (A)	Measured Value (A) UUC	Actual Value (A) Ref	Error %	Expanded Uncertainty ±(A)
10	9.9	9.986	-0.861	0.07
20	19.9	19.994	-0.470	0.06
50	49.9	49.984	-0.168	0.06
100	100.7	99.966	0.734	0.31
150	151.0	149.950	0.700	0.45
300	302.1	299.834	0.756	0.90
400	402.6	399.778	0.706	1.2

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by Eman M. Hosny

Reviewed by Samah A. Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	882/23C012/74/326/2024	Serial Number	19673109
• Conformity Statement			
Conformity Criterion	Not applicable		
Decision	-----		

• Calibration Results

3. AC Active Power Calibration, 220 V, 50 Hz:-

3.1. Phase (1), with Ampflex, S.N.:208200120-230965 :

Nominal Value		Measured Value (kW)	Actual Value (kW)	Error	Expanded Uncertainty
I (A)	P.F	UUC	Ref	%	±(W)
1	1	0.2	0.220	-9.091	0.06
5	1	1.1	1.097	0.273	0.09
5	0.5L*	0.6	0.551	8.893	0.07
5	0.5C**	0.5	0.546	-8.425	0.06
10	1.0	2.2	2.194	0.273	0.10
10	0.5L	1.1	1.102	-0.181	0.09
10	0.5C	1.1	1.092	0.733	0.09
20	1.0	4.4	4.389	0.251	0.12
20	0.5L	2.2	2.204	-0.181	0.12
20	0.5C	2.2	2.185	0.686	0.12
50	1	11.0	10.973	0.246	0.62
80	1	17.6	17.558	0.239	0.77

L*: Inductive
C**: Capacitive

The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by Eman M. Hosny

Reviewed by Sanah A. Mohamed

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No.	882/23C012/74/326/2024	Serial Number	19673107
• Conformity Statement			
Conformity Criterion	Not applicable		
Decision	-----		

• Calibration Results

3.2. Phase (2), with Ampflex, S.N.:208200149-230965 :

Nominal Value		Measured Value (kW) UUC	Actual Value (kW) Ref	Error %	Expanded Uncertainty ±(W)
I (A)	P.F				
1	1	0.2	0.220	-9.091	0.06
5	1	1.1	1.097	0.273	0.09
5	0.5L	0.6	0.551	8.893	0.07
5	0.5C	0.5	0.546	-8.425	0.06
10	1	2.2	2.194	0.273	0.10
10	0.5L	1.1	1.102	-0.181	0.09
10	0.5C	1.1	1.092	0.733	0.09
20	1	4.4	4.389	0.251	0.12
20	0.5L	2.2	2.204	-0.181	0.12
20	0.5C	2.2	2.185	0.686	0.12
50	1	11.1	10.973	1.157	0.62
80	1	17.8	17.558	1.378	0.77

3.3. Phase (3), with Ampflex, S.N.:208200140-230965 :

Nominal Value		Measured Value (kW) UUC	Actual Value (kW) Ref	Error %	Expanded Uncertainty ±(W)
I (A)	P.F				
1	1	0.2	0.220	-9.091	0.06
5	1	1.1	1.097	0.273	0.09
5	0.5L	0.6	0.551	8.893	0.07
5	0.5C	0.5	0.546	-8.425	0.02
10	1	2.2	2.194	0.273	0.08
10	0.5L	1.1	1.102	-0.181	0.07
10	0.5C	1.1	1.092	0.733	0.07
20	1	4.4	4.389	0.251	0.11
20	0.5L	2.2	2.204	-0.181	0.11
20	0.5C	2.1	2.185	-3.890	0.10
50	1	10.9	10.973	-0.665	0.62
80	1	17.5	17.558	-0.330	0.77

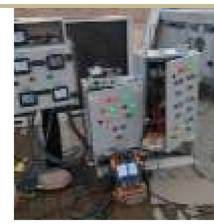
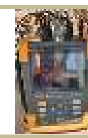
The data in the above table applies only to those items specifically listed on this calibration certificate

Calibrated by
Eman M. Hosny

Reviewed by
A. Mohamed

Annex 3: Testing Equipment Used:

Used Apparatus	Measured Property	Model	Serial Number	Item Photo
Air Flow Meter	Air flow	KIMO CP300	06072114	
Weather Station,	Inlet dry bulb temperature forboth Units Inlet Relative humidity for bothUnits	HOBO U30 ONSET	10221018	
Thermo-Hygrometer	Outlet dry bulb temperature for IEC Hybrid Unit Outlet Relative humidity for IECHybrid Unit	KIMO TH300	MEH1000821	
Air Quality Meter	Outlet dry bulb temperature for IEC Hybrid Unit Outlet Relative humidity for IECHybrid Unit	Lutron	085019 085018 085017 085016 085015 085014	
Compressor power meter - IEC hybrid unit	Power consumptionof the Compressor of the IEC hybrid Unit	ENTES	---	
Pump power meter - IEC hybrid unit	Power consumptionof the Pump of the IEC hybrid Unit	ENTES	---	

Used Apparatus	Measured Property	Model	Serial Number	Item Photo
Evaporative Fan power meter - IEC hybrid unit	**Power consumptionof the Evaporator Fan of the IEC hybrid Unit**	**ENTES**	**---**	
Supply fan power meter - IEC hybrid unit	**Power consumptionof the Supply Fan ofthe IEC hybrid Unit**	**ENTES**	**---**	
Power Analyzer of total power consumption of IEC hybrid Unit	**Total Input power of IEC Hybrid Unit**	**FLUKE**	**9340002**	
Power Analyzer of total power consumption of IEC hybrid Unit	**Total Input power of DX Unit**	**FLUKE**	**19673107**	

Annex 4: Outreach Campaign

Invitation to Outreach Campaign

DIRECT/INDIRECT EVAPORATIVE COOLING

TOGETHER, WE CAN SECURE PHASE OUT OF HCFC IN THE COMMERCIAL AIR CONDITIONING MANUFACTURING SECTOR.

GET INVOLVED TODAY AND MAKE A DIFFERENCE!

3 November 2024

HBRC - Cairo, Egypt

Info@hbrc.edu.eg | www.hbrc.edu.eg | 87 Tahrir st, Dokki, Giza

Program Outlines

(9:30 – 10:00 am)
Registration

(10:00 – 10:30 am)
Opening Session:

- Welcome & Open Remarks
  Prof. Mohamed Masoud - HBRC Chairman
  Prof. Ezzat Lewis - NOU
  Prof. Sayed Shebl

(10:30 –11:00 am)
Coffee Break

(11:00 am – 1:00 pm)

- Preview The Project Findings
  Prof. Alaa Olama
  Prof. Sayed Shebl
- Public Hearing Session

GUARANTEE YOUR LEAD.

Join us and contribute to an enlightened and collaborative spirit of sustainable ideas come to life.

Find Us!

+(20) 1065251505
87 Tahrir St., Dokki, Giza

Transformation of Commercial Air Conditioning Companies
HCFC Phase-out Management Plan (HPMP) EGYPT (Stage II), UNIDO ID:140400

Outreach Campaign

DIRECT/INDIRECT EVAPORATIVE COOLING

Presented by:

Prof. Alaa Olama;
The Project general Manager and Technical Consultant

Prof. Sayed Shebl;
Director of Electro-Mechanical Research Institute EMI, HBRC

وزارة الاسكان والمرافق المجتمعات العمرانية
Ministry of Housing Utilities & Urban Communities

المركز القومى لبحوث الإسكان والبناء
Housing and Building National Research Center

UNIDO

UN environment programme

NOU National Ozone Unit

OUR TEAM

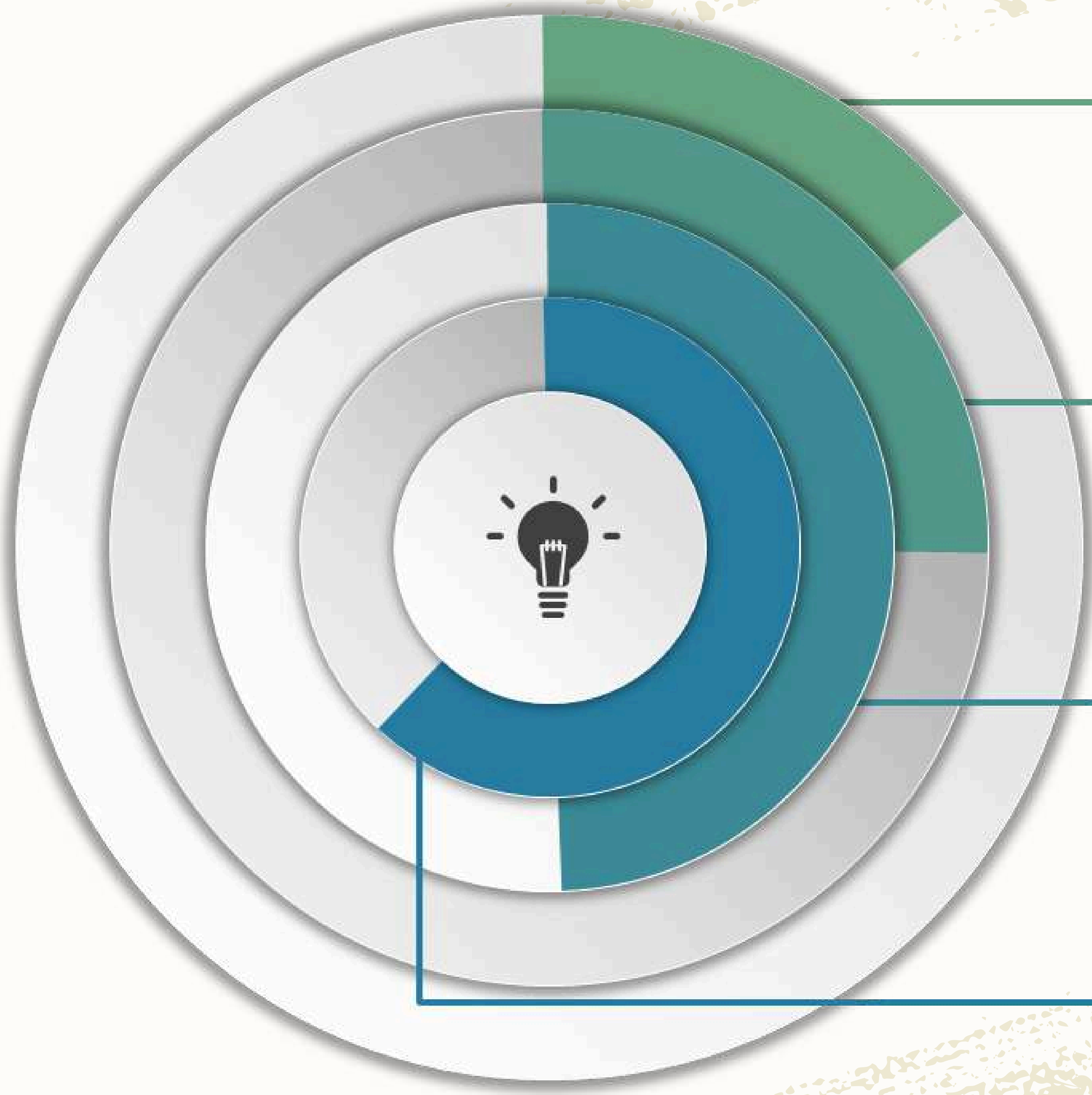
Approval committee

UNIDO & NOU	Steering Committee
UNEP	Advisor
EUROVENT	Provide a reference testing methodology for the IEC hybrid units suitable for Egypt's working conditions

OEMs

Delta Construction & Manufacturing (DCM)	**TIBA Engineering Industries Co.**
SS Air Technology	**VOLTA EGYPT**

MILESTONES



- *Phase-out of HCFC in the commercial air conditioning manufacturing sector.*
- *Incorporate IEC technology in existing systems*
- *Technical Assistance for product design*
- *Provide technical parameters obtained from field testing*

PREVIOUS WORK

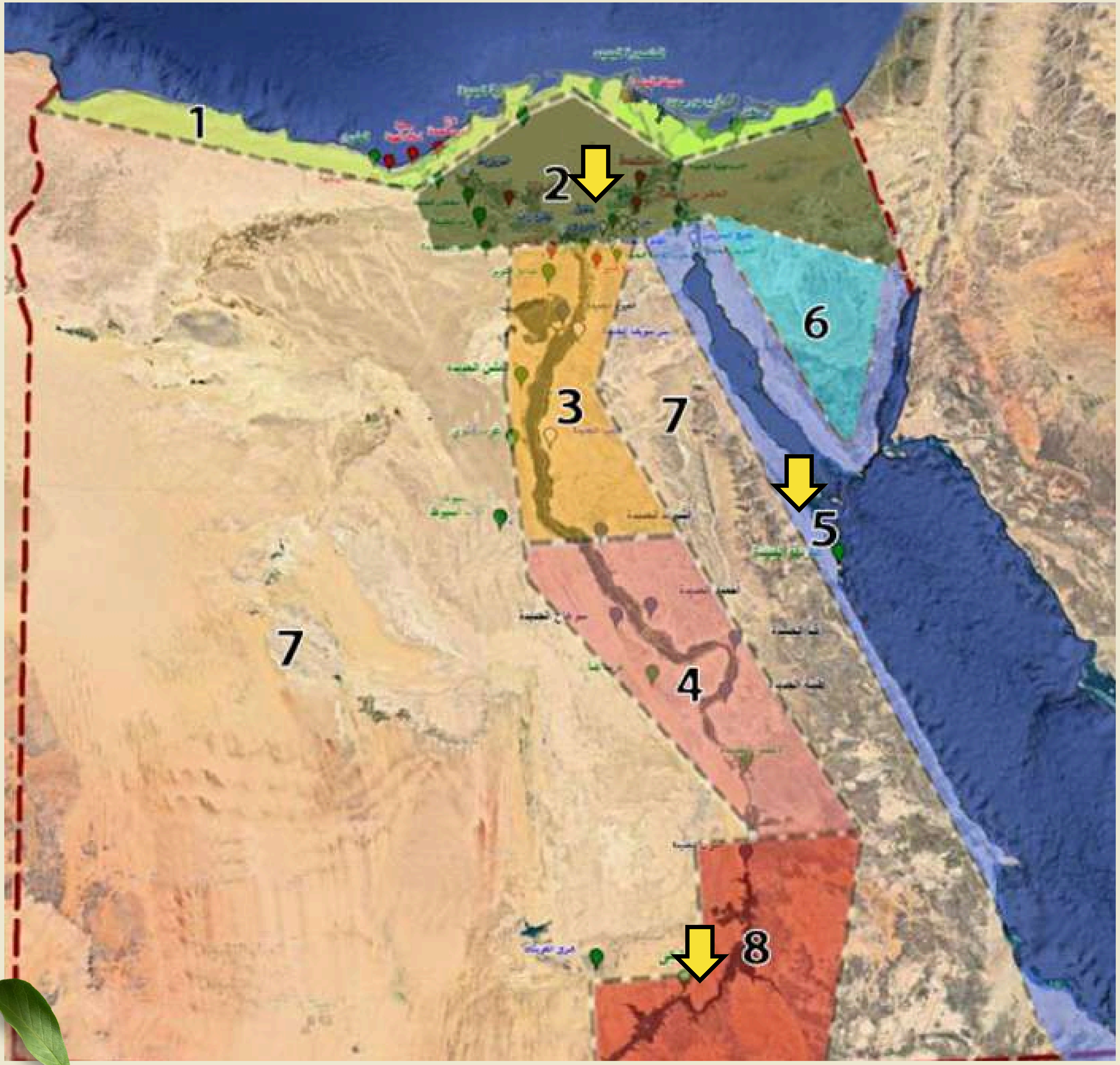
FOR ADOPTING THE NEW TECHNOLOGY

Which Climatic Zone?

Two climatic zones out of Eight representing Egypt

- Climatic Zone 2
- Climatic Zone 5

What about Climatic Zones 8?



TESTING LOCATION - CZ8 (ASWAN - TOSHKY)

Location

22°49' 02" N
31°28' 16" E

Altitude

196.07 m
(above sea level)

TESTING CONDITIONS

Full Fresh Air

Both units to be **full fresh air** with air discharge of one unit regulated so that it matches the other.

Compressor Size

Compressor size of IEC-H Unit left to each OEM to decide.

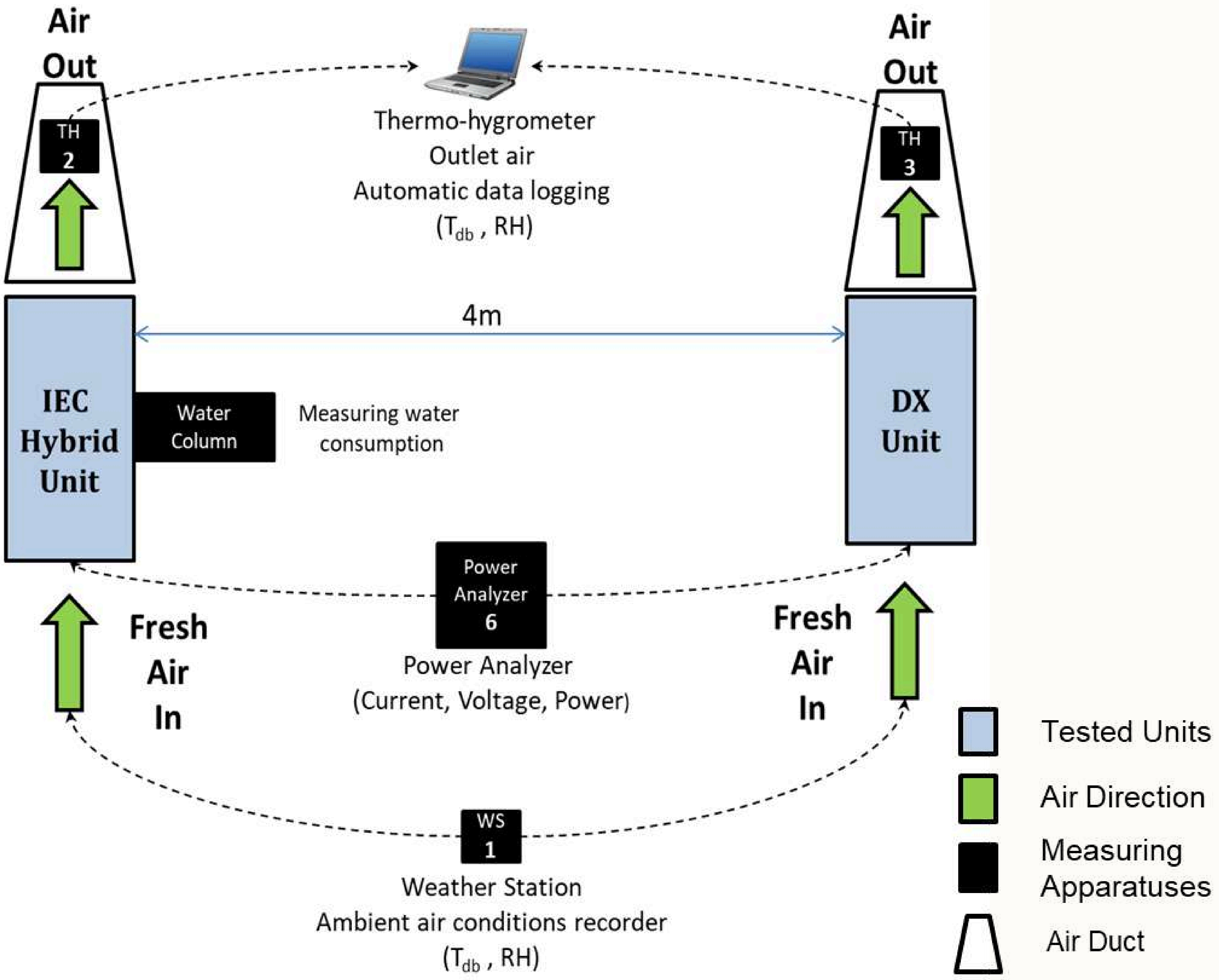
Primary Air Outlet

The primary air outlet dry bulb temperature maintained at 15°C

Low GWP refrigerant

Both units should use low GWP refrigerant, based on Montreal Protocol and Kigali Amendment

SCEMATIC DIAGRAM



THE PROJECT REQUIRED EACH OEM TO INDIVIDUALLY MANUFACTURE A CUSTOM-BUILT DIRECT/INDIRECT EVAPORATIVE COOLING HYBRID AIR CONDITIONER (IEC-H) PROTOTYPE AND A CENTRAL DX UNIT TO TEST AND COMPARE THEIR PERFORMANCES UNDER ACTUAL OPERATING CONDITIONS IN CLIMATIC ZONE 8 (CZ8) (ASWAN - TOSHKY).

USED EQUIPMENT

CALIBRATED HIGH ACCUARCY DEVICES

ARE USED FOR MEASURMENTS

Ministry of Higher Education
& Scientific Research
National Institute of Standards

وزارة التعليم العالى والبحث العلمى
المعهد القومى للمعايرة

El- Sadat (Tersa) St., El Haram, Giza, Egypt - P.O.Box 136 Giza - Code 12211 - Tel./ Fax: +202 - 33867462 - NIS Tel +202 - 37401113

CERTIFICATE OF CALIBRATION
شهادة معايرة

Certificate No:	882/23C012/74/326/2024

- NIS Lab : High Voltage Metrology Lab.
- Issued For : معهد بحوث الاعمال الكهروميكانيكية في المباني (مركز بحوث الاسكان والبناء)
- Contact Information of the Customer : العنوان : 87 شارع التحرير
- Location of Calibration : High Voltage Metrology Lab., NIS
- Device Description : POWER QUALITY AND ENERGY ANALYZER
  - Manufacturer : FLUKE
  - Model/Type : 435
  - Serial Number : 19673107
- Code : ----
- Date of Receipt : 9/5/2024
- Date of Calibration : 19/5/2024
- Issue Date : 22/5/2024
- Due Date : -------

Approved by

Head of Laboratory
Dr. Eng. Ahmed S. Haiba

NIS President
Prof. Dr. M. G. Ahmed

NIS-F-7.8.2

This certificate is issued in accordance with the laboratory accreditation requirements. It provides traceability of measurement to recognized National standards, and to the units of measurement realized at the NIS or other recognized national standards laboratories. This certificate May not be reproduced other than in full by photographic process. This certificate refers only to the particular item submitted for testing.

FIELD TEST

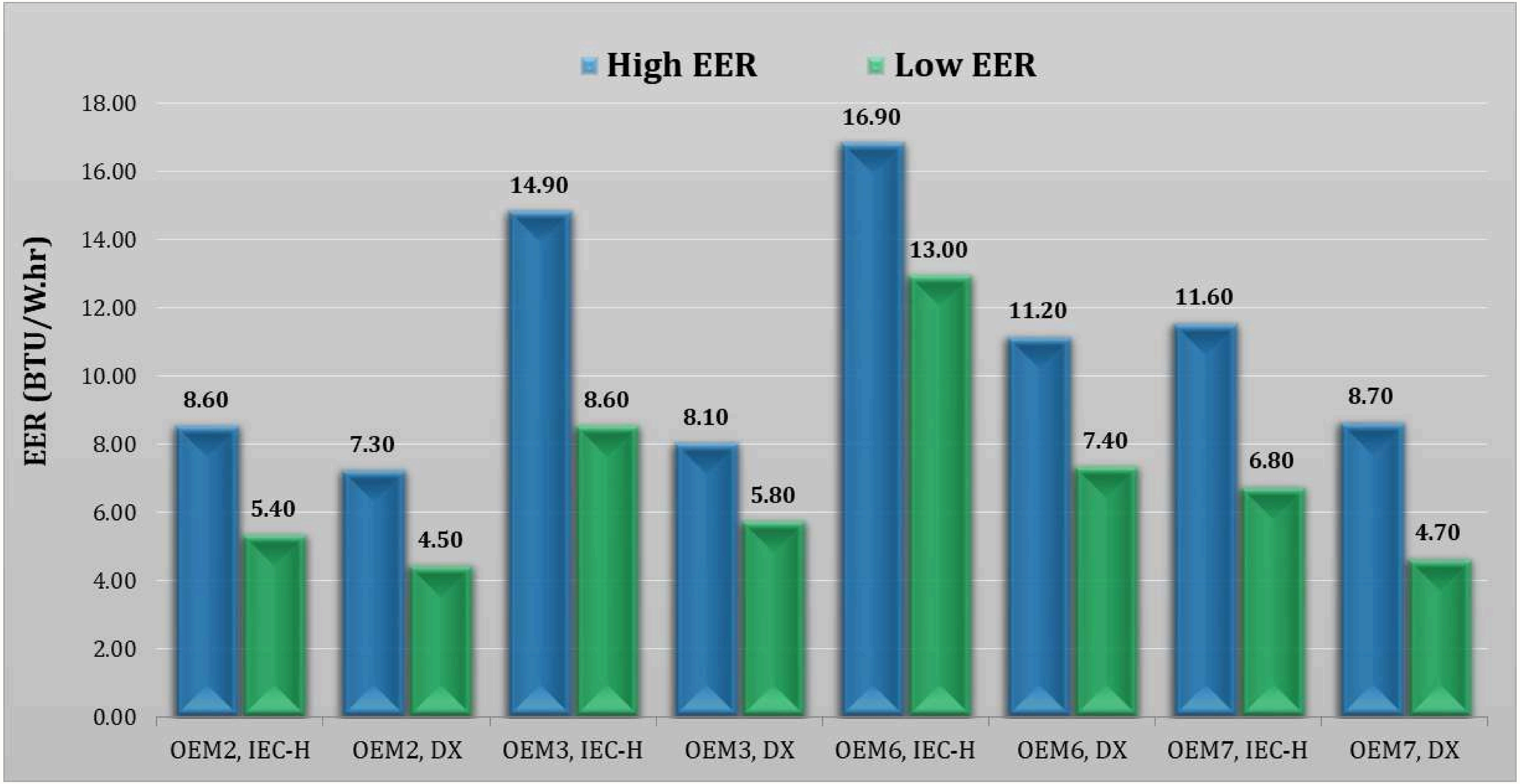
PROVIDE TECHNICAL PARAMETERS

Evaluate the performance

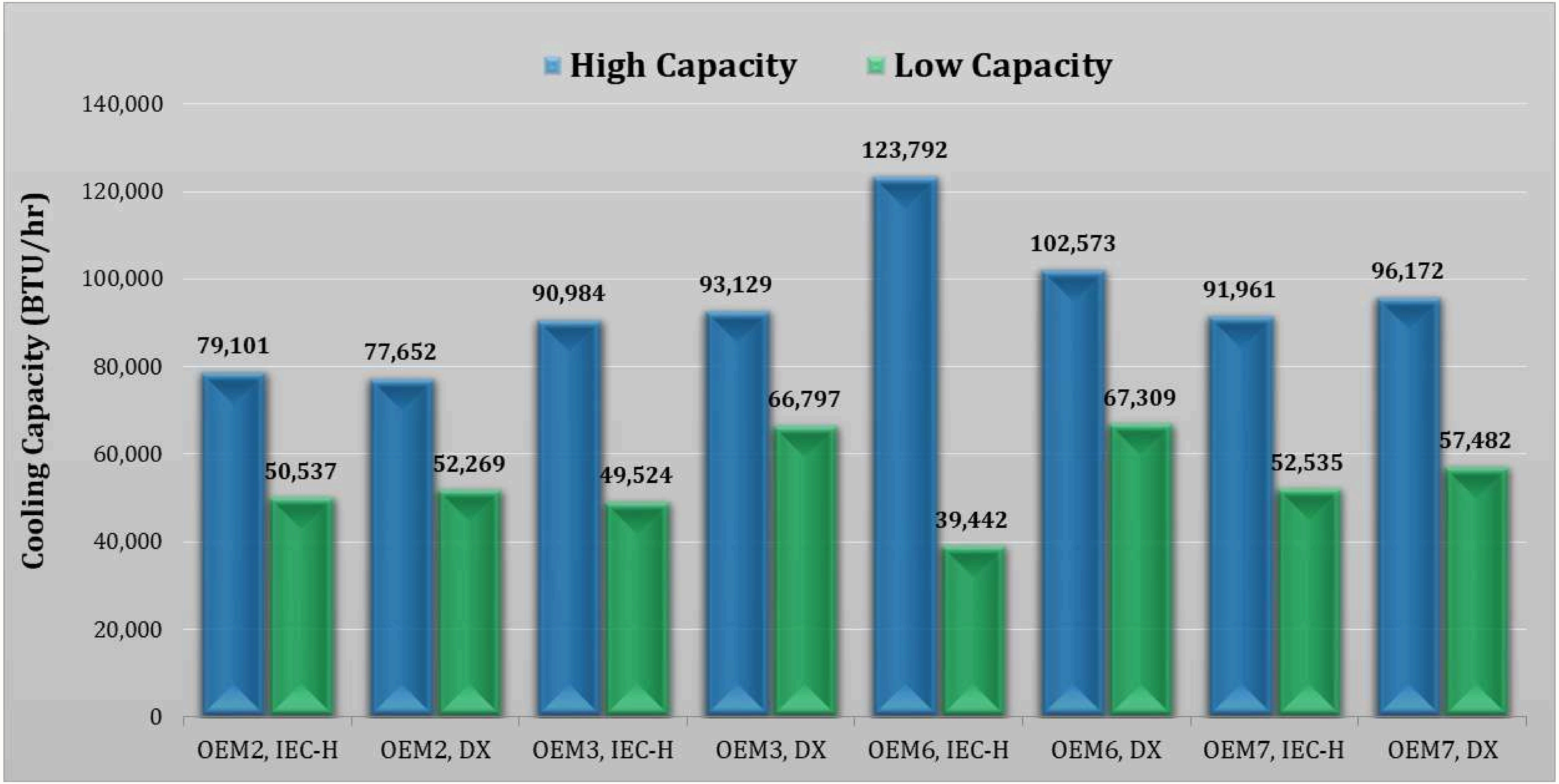
Compare DX Unit With IEC-H Unit at the Same operating conditions and record the measurements for 24 hours

- Energy Efficiency
- Total Cooling Capacity
- Operating Cost

TESTING RESULTS - EER



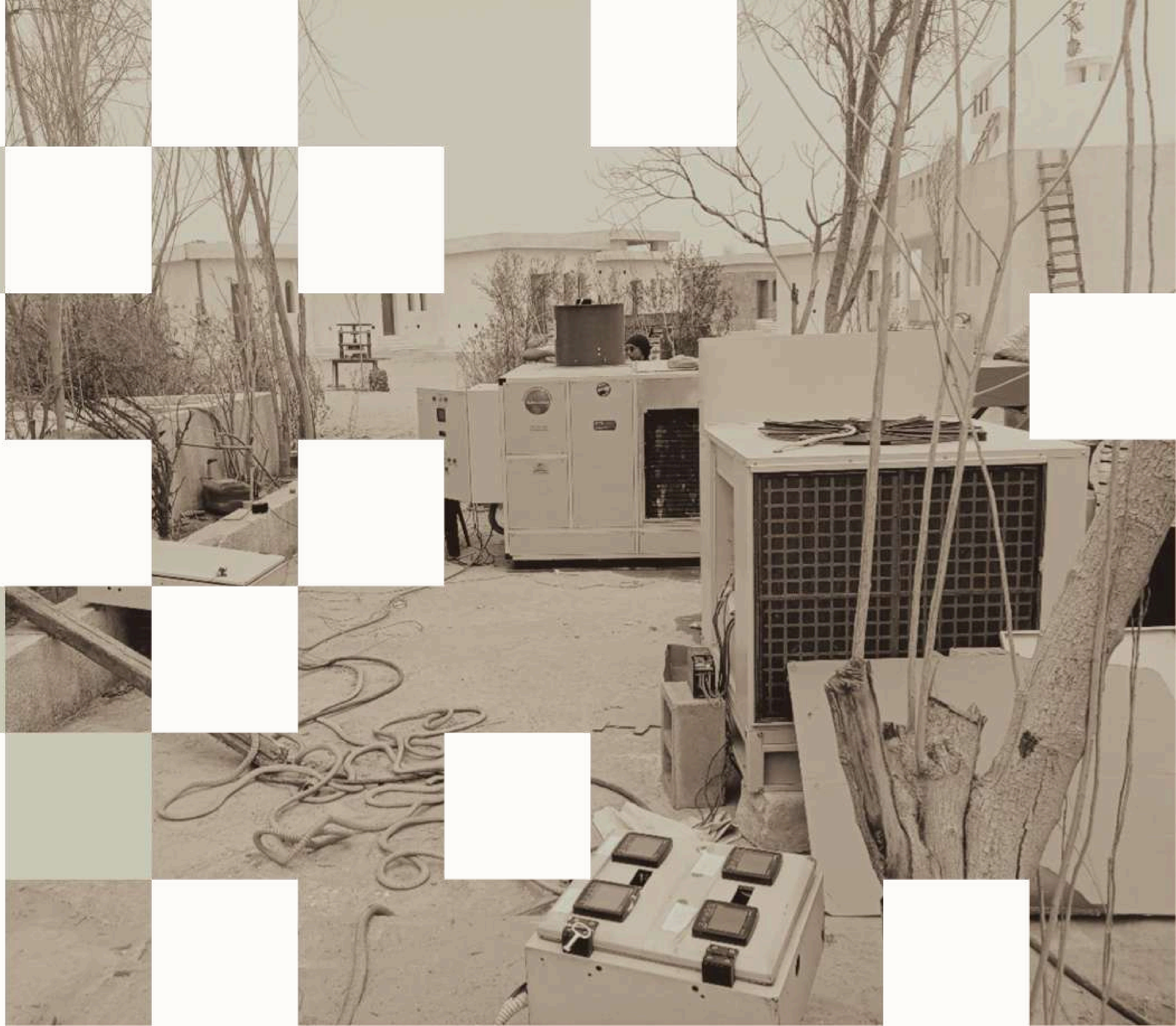
TESTING RESULTS - TOTAL COOLING CAPACITY



CONCLUSION

- All OEMs show EERs of the IEC-H units that are superior to corresponding DX units.
- IEC-H system is economically advantageous compared to a DX system
- Superior total cooling capacity of the IEC-H units despite the smaller capacity compressors used. The capacities of the IEC-H units.

THANK YOU



Annex 5: Testing Photos



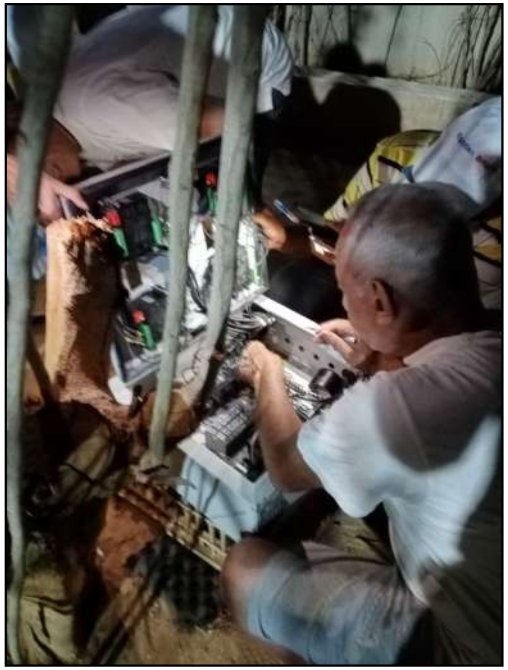





CLIMA GREEN


POWER ON







Fan



Fan








Fan
Smart Fan technology


Fan
Smart Fan technology


TOYOTA

Technical Report for the Group Project for Transformation of Commercial Air Conditioning Companies (HCFC Phase-out Management Plan (HPMP) EGYPT (Stage II)), UNIDO ID:140400

2024

Climatic Zone 8

Report

Project supported by
MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNITED NATIONS ENVIRONMENT

European Industry Association

By: Dr Alaa Olama

Disclaimer

Acknowledgement

We would like to acknowledge the assistance given by the governmental sectors and the National Ozone Unit Officers of Egypt and the National Housing & Building National Research Center (HBRC) for their support in the implementation of the project and their assistance in facilitating communication with different stakeholders.

We also acknowledge the International Technical Review Team “EUROPEAN INDUSTRY ASSOCIATION Eurovent” that assist the project team in reviewing the process, results and report of the project.

Acknowledgement also goes particularly to HBRC for providing the testing yard, facilities (Electrical feeding, water supply … etc.) and other logistic facilities at their installation in Toshka.

The project team also acknowledges the OEM manufacturers who built the IEC-H prototypes and DX systems to be tested at the location.

- Delta Construction & Manufacturing DCM
- TIBA Engineering Industries Co.
- VOLTA EGYPT
- SS Air

Acknowledgement also goes to the team’s technicians, technical assistance staff and drivers that assisted in the project successful completion in this remote location.

This Project is contracted between the UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION "UNIDO" and Housing & Building National Research Center “HBRC”. WHEREAS, UNIDO has been designated by the MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL as
IMPLEMENTING AGENCY; and has agreed to provide assistance to the Egyptian Government in carrying out the project entitled “HCFC PHASE-OUT MANAGEMENT PLAN (HPMP) EGYPT (STAGE II)”

The National Ozone Unit – Ministry of Environment, Egypt: The ministry team provided guidance and direction and participated at project meetings and discussions. The project is funded by the HCFC Phase-out Management Plan (HPMP) of Egypt.

The Project Management: UNIDO and UN Environment provided overall management and coordination of the project, established the link with the technology providers, and oversaw the development of the report of the project. The Project was managed by **Mr. Ole Nielsen, Dr. Iino Fukuya**, Program Officer- UNIDO, **Dr. Yunrui Zhou** also program officer-UNIDO and **Eng. Ayman El-Talouny**, International Partnership Coordinator, Ozone Action Program – UN Environment

EUROVENT (European Industry Association): Due to the absence of local testing standard or guidelines for IEC applications, the service of an International Advisory Partner was needed to offer recommendations, testing reference and quality review of the testing process.

“Eurovent AISBL / IVZW / INPA. (2023). Eurovent 15/1 - 2023 — Hybrid Indirect Evaporative Cooling Equipment - Classification Requirements and Test Conditions. Brussels: Eurovent.”

Ms. Viktorria Kotlubei and the Coordination Consultant **Eng. Ahmed El-Korashy** from UNIDO provided logistical support and coordination for the project.

The Project general Manager and Technical Consultant and writer of the report, Dr. Alaa Olama advisedOEMs during prototype design and construction. Devised testing methodology and testing TOR, consultedwith OEMs to provide technical solutions for problems as they arose wrote the report and provided analysis of data.

HBRC organized testing including testing results in both climatic zones, tabulated and created the excel sheets including figures, drawings and review and edit their report.

Table of Contents

List of Figures

List of Tables

Acronyms

HPMP	HCFC Phase-out Management Plan
IEC-H	Indirect Evaporative Cooling - Hybrid
DX	Direct Expansion
CZ	Climatic Zone
GWP	Global Warming Potential
NPV	Net Present Value
EFLH	Equivalent Full Load Hours Per Year
EER	Energy Efficiency Ratio
COP	Coefficient of Performance
IRR	The internal rate of return
EGP	Egyptian Pound
$T_{db\ amb}$	Ambient dry bulb temperature for both Units
$T_{wb\ amb}$	Ambient wet bulb temperature for both Units
RH_{amb}	Ambient Relative Humidity for both Units
$T_{db\ out}$ IEC-H	Outlet dry bulb temperature for IEC Hybrid Unit
$T_{wb\ out}$ IEC-H	Outlet wet bulb temperature for IEC Hybrid Unit
RH_{out} IEC-H	Outlet Relative Humidity for IEC Hybrid Unit
W_{Lvl} IEC-H	Water level change for IEC Hybrid Unit per hour
W_{Vol} IEC-H	Evaporated Water Consumed for IEC Hybrid Unit per hour (Volumetric Flow Rate)
Comp. IEC-H	Compressor power consumption for IEC Hybrid Unit
Pump IEC-H	Pump consumption for IEC Hybrid Unit
Evap. Fan IEC-H	Evaporative Fan consumption for IEC Hybrid Unit
Sup. Fan IEC-H	Supply Fan consumption for IEC Hybrid Unit
Pw_{Tot} IEC-H	Total Power consumption for IEC Hybrid Unit
$T_{db\ out}$ DX	Outlet dry bulb temperature for DX Unit
$T_{wb\ out}$ DX	Outlet wet bulb temperature for DX Unit
RH_{out} DX	Outlet relative humidity for DX Unit
Pw_{Tot} DX	Total Power consumption for DX Unit
h_{amb}	Enthalpy of Ambient inlet Air
h_{out} DX	Enthalpy of outlet Air for DX Unit
h_{out} IEC-H	Enthalpy of outlet Air for IEC Hybrid Unit
ρ_{amb}	Density of Ambient Air

Executive Summary:

This Project is contracted to provide assistance to the Egyptian Government in carrying out the project entitled "HCFC PHASE-OUT MANAGEMENT PLAN (HPMP) EGYPT (STAGE II)"

The project required each OEMs to individually manufacture a custom-built Indirect Evaporative Cooling Hybrid Air Conditioner (IEC-H) prototypes and a central DX unit to test and compare their performances under actual operating conditions in three of the eight climatic zones (CZ) of Egypt.

The final report of 2022 showed the results of the tests in CZ 2 and 5. This report shows the results of the test in CZ 8, the hottest of all climatic zones in Egypt.

The four figures below show the results of OEM 3 only in the CZ 8. The figures belowshow the comparisons of the performance between the IEC-H unit and the DX unit over a 24 hours period.The tests results compared the values of the dry bulb temperatures out of the IEC-H and the DX unit, the wet bulb temperatures, the EERs and the unit's refrigeration capacity. The tests were conducted for each OEM's IEC-H and DX units simultaneously for a 24 hours period.

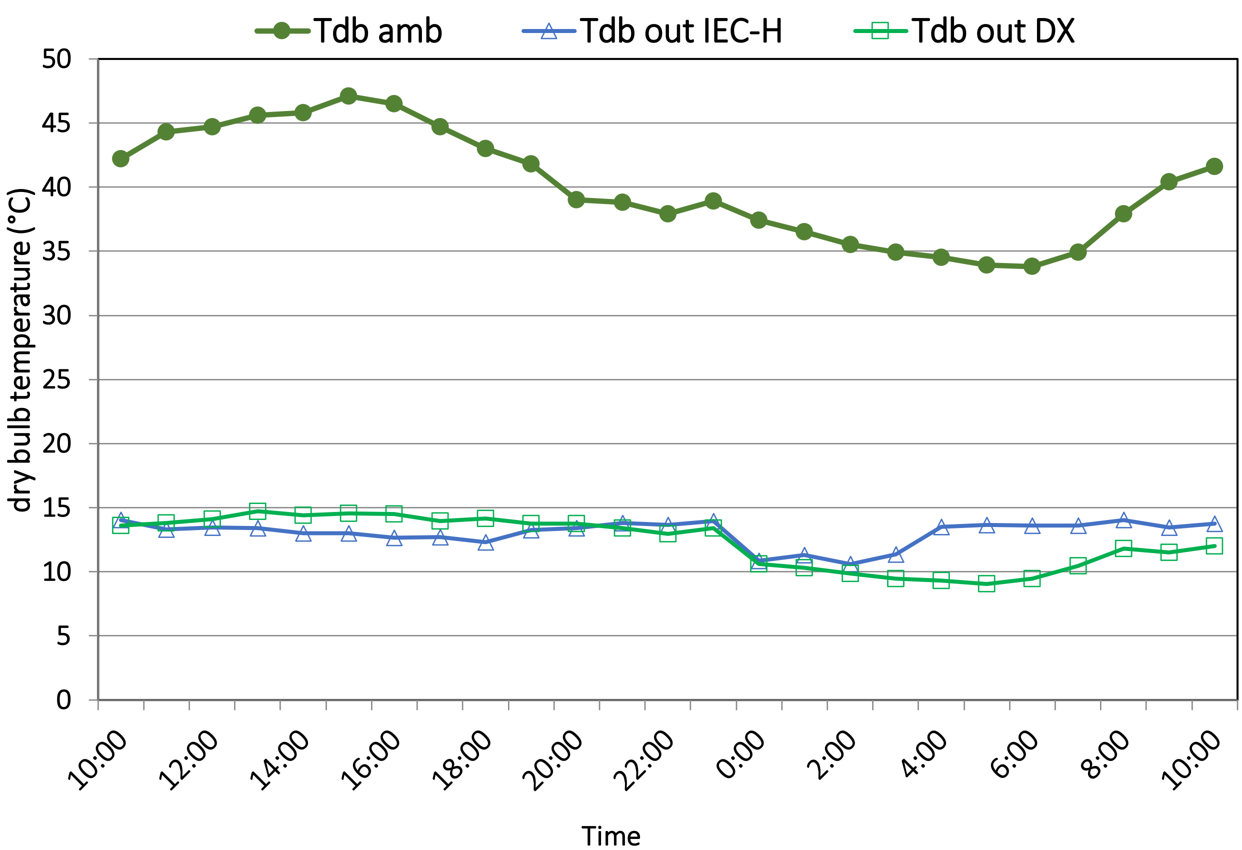


Fig. 1. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units, OEM 3 - CZ 8

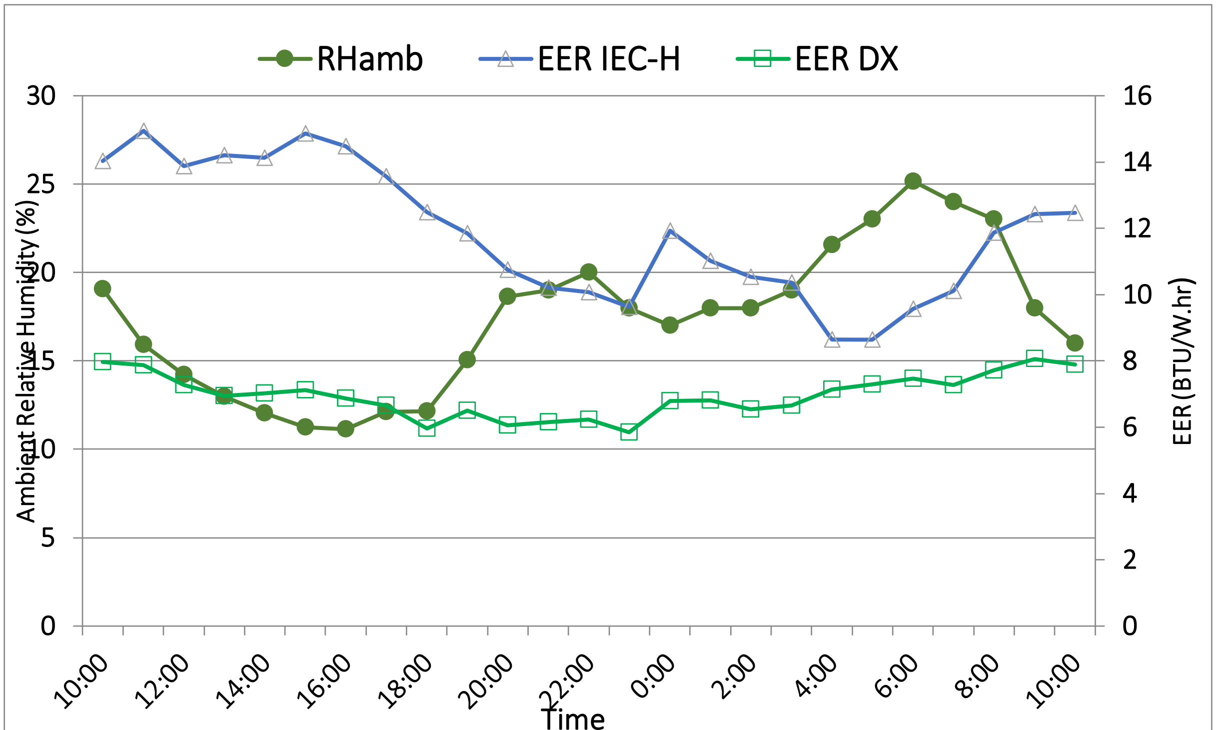


Fig. 2. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity - OEM 3- CZ 8

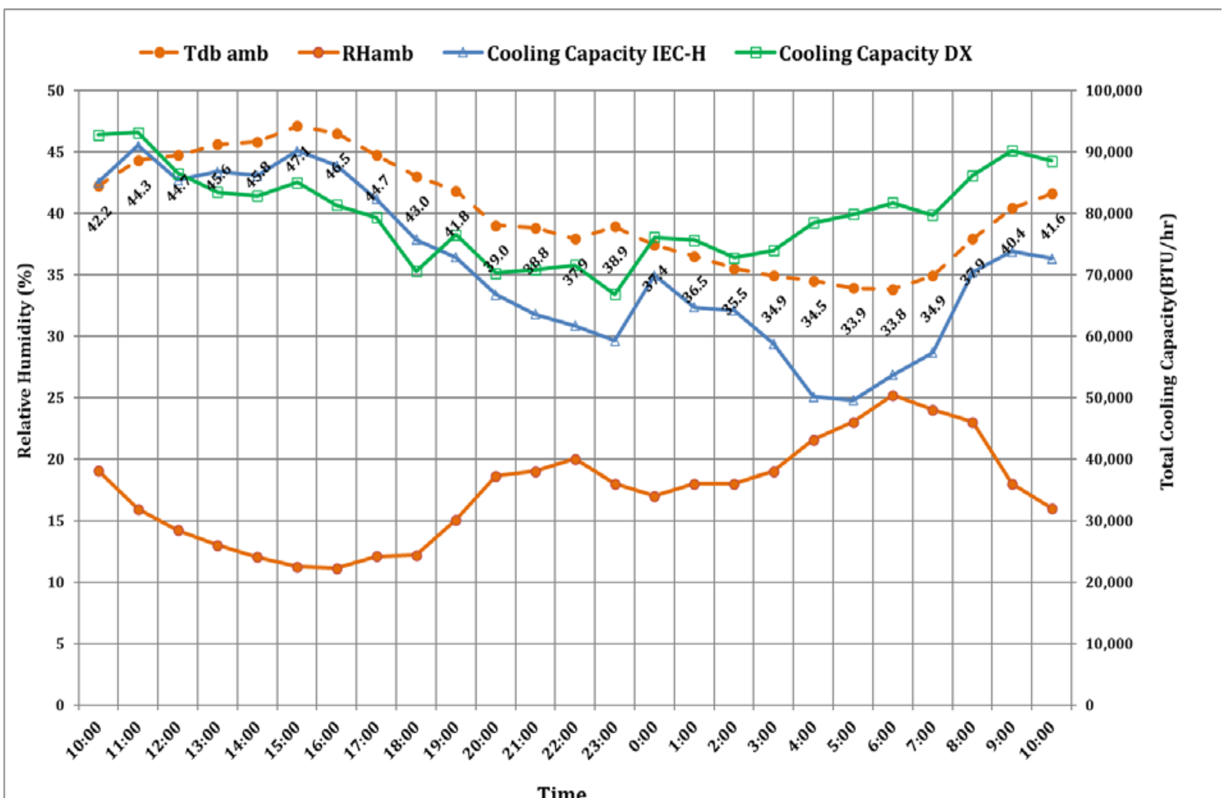


Fig. 3. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions OEM 3- CZ 8

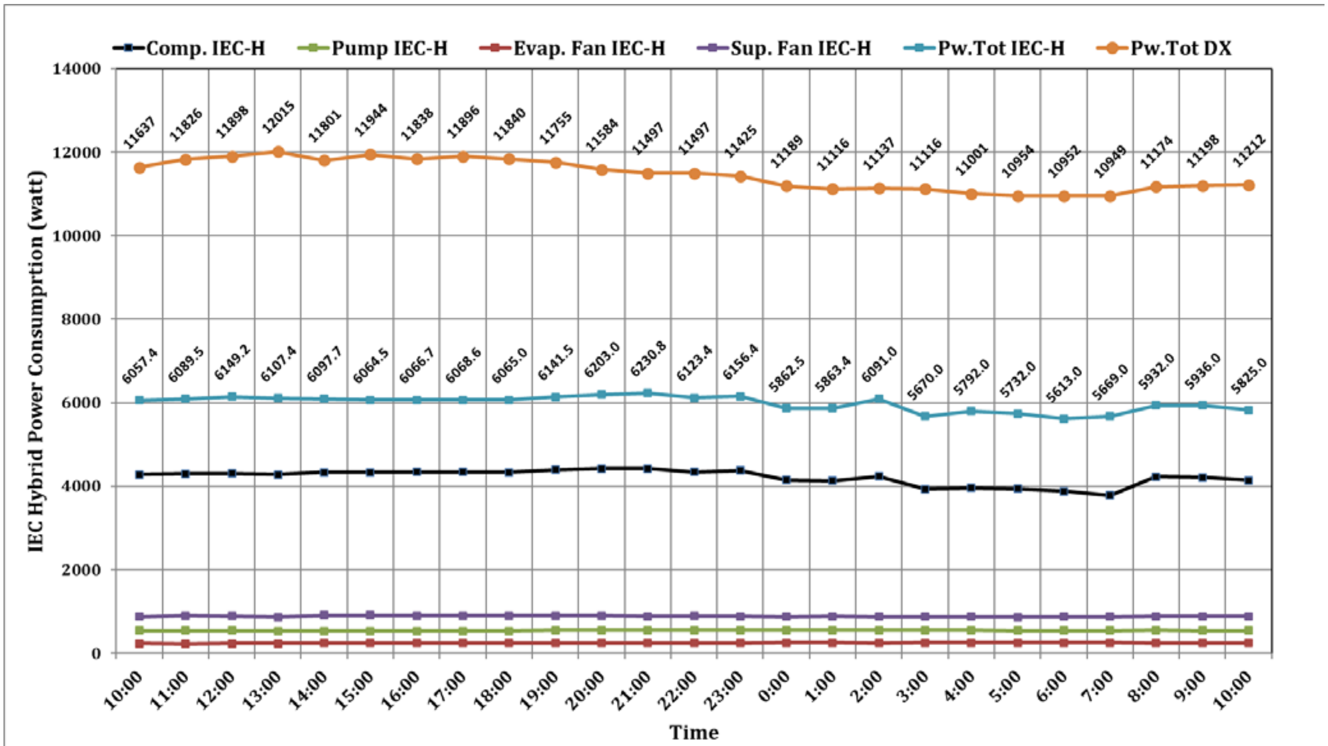


Fig. 4. Power Consumption of DX Unit and IEC Hybrid Unit Components
OEM 3- CZ 8

All OEMs results showed better EER for their IEC-H units compared to their respective DX unit in the CZ 8 where the tests were conducted. The highest and lowest EERs of all OEMs are shown below.

In that sense, this report for CZ 8 showed that an IEC-H system is superior thermodynamically to a DX system because it achieves higher EERs.

Fig 17: High and Low EER (in BTU/W.hr) for Climatic Zone 8

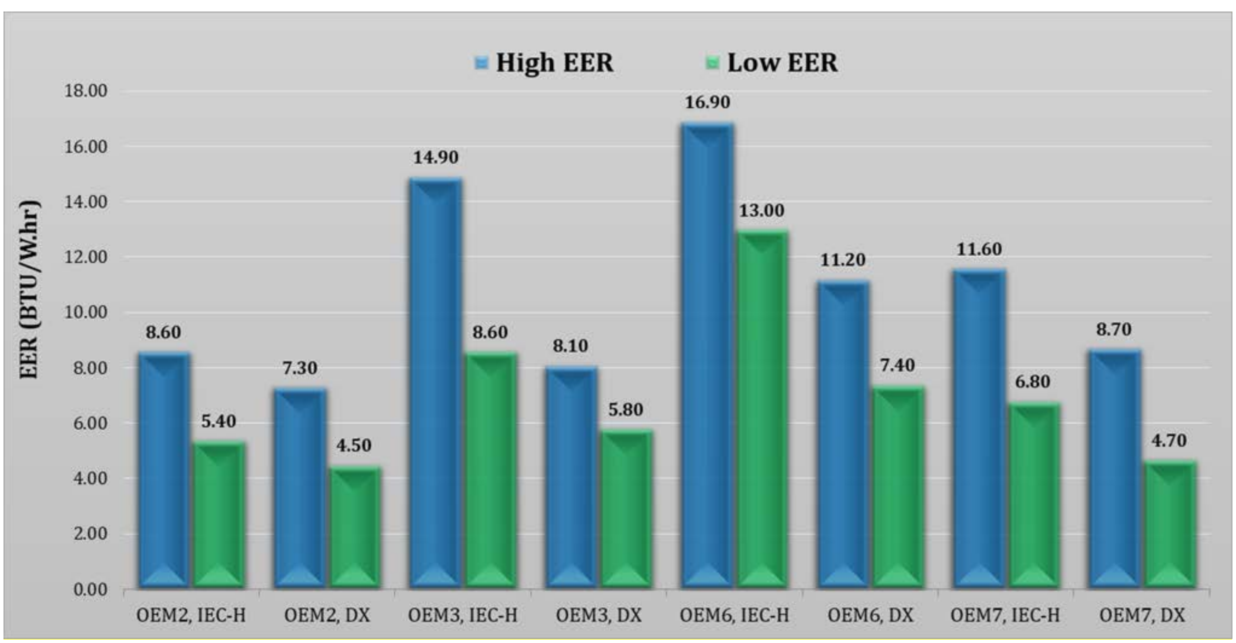
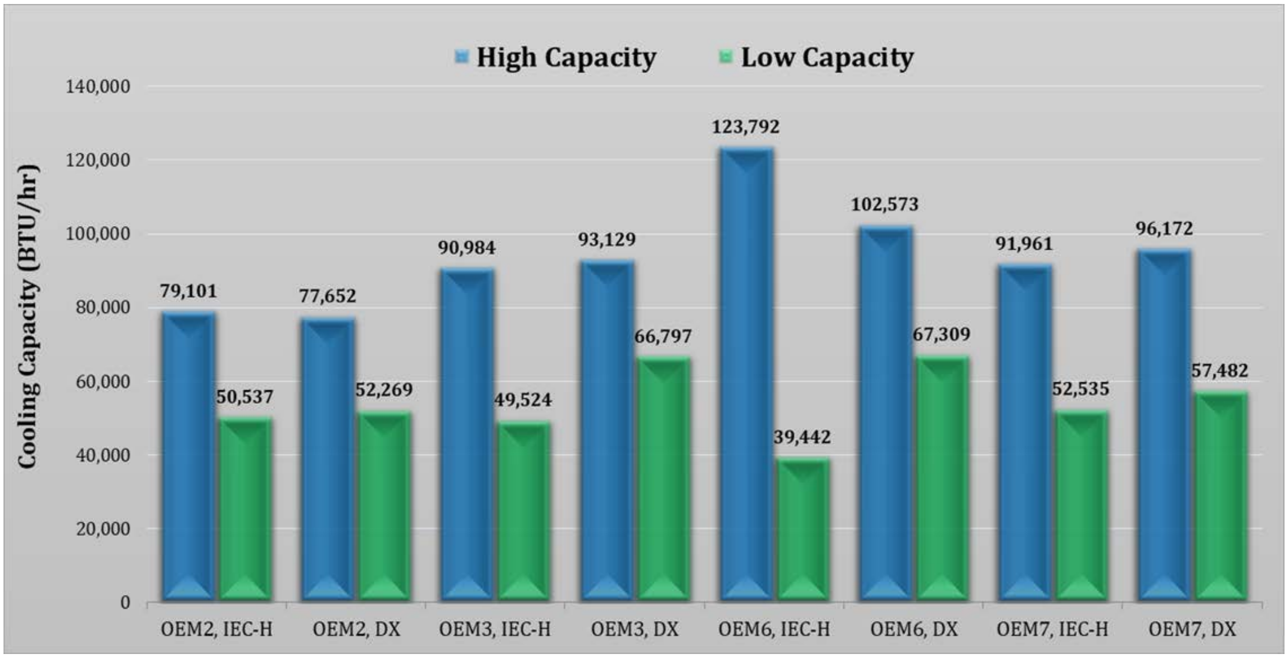


Fig 18: High and Low Capacity (in W) for Climatic Zone 8



The primary air discharge of both the IEC-H prototype and DX units for each OEM were the same and all fresh air. All compressors' capacities of all OEMs were also the same for IEC-H prototypes and DX units, except OEM 2 which used two compressors for its IEC-H prototype instead of one for all other OEMs.

The tests showed that the capacity of the IEC-H prototypes when compared to the refrigeration capacity of their respective DX unit also varied considerably, depending on the prototype design and the ambient relative humidity.

When the ambient relative humidity increased, the DX units tended to provide a better refrigeration capacity then corresponding IEC-H prototype, except OEM 2 which showed superior refrigeration capacity compared to the DX unit regardless of the relative humidity conditions.

Nevertheless, overall IEC-H refrigeration capacities at lower humidity periods, where higher than those of corresponding DX units.

The report breaks new ground for NIK air conditioning technologies and provides an alternative full fresh air system for air conditioning application that exceeds the efficiency of existing DX systems.

Although, both final reports for CZ 2 & 5 (2022) and this report for CZ 8 (2024) are sufficient to write guidelines for a code for direct/indirect evaporative cooling for Egypt, the report recommends further work to provide a mathematical formula and site testing to predict the EERs and refrigeration capacities for IEC-H prototypes for the remaining five climatic zones of Egypt, and substantiate the formula readings in other Climatic Zones of Egypt through site tests.

Chapter 1

1. Testing and Measurements of the Prototypes and DX units of all OEMs in Location CZ 8

1.1. Selection of CZ 8

Table 1: The Climatic Zones of Egypt

1	North Coast Region	5	Eastern Coast Region
2	Delta and Cairo region	6	High Heights Region
3	North Upper Egypt Region	7	Desert Region
4	Southern Upper Egypt Region	8	South of Egypt Region

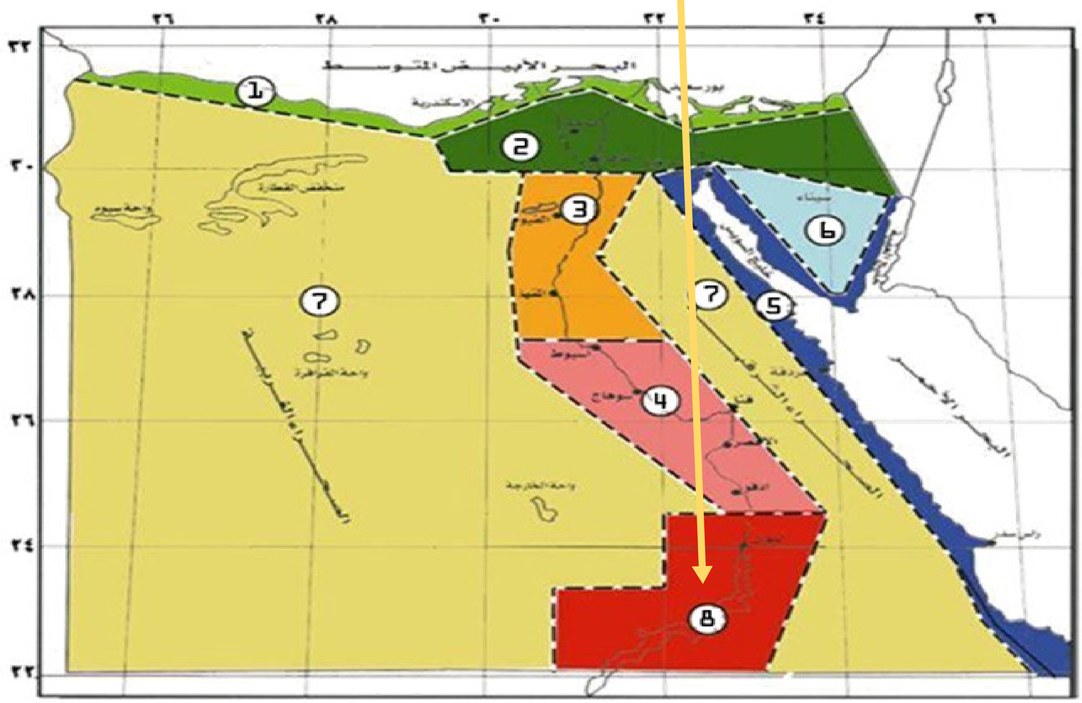


Fig 0: The eight Climatic Zones of Egypt

Ambient temperatures in Egypt's are at their highest during June, July and August. This is why these months were targeted for the tests.

The tests were performed in CZ 8 to show the effect of dry bulb temperature increaseversus relative humidity decrease on the efficiency and capacity of the prototypes at the hottest climatic zone in Egypt to complement tests made at CZ2 and CZ 5 in 2022. He results in these tests in CZ 8 would complement those done in CZ 2 and 5. With the tests in CZ 8 the viability of an IEC-H system in lower humidity/higher ambient climates when compared to a DX system.

Figure 0 shows the different climatic zones of Egypt. CZ 2 encompass the capital Cairoand its suburban cities across its latitude in the span west in the lower delta south of Alexandria's longitude and east across the Sinai Peninsula. CZ 2 would be generally characterized by its relatively higher humidity because it is in the lower delta with its extensive population clusters and its large agriculture fields. Tests in CZ 2 were performed at Badr city.

CZ 5 is the eco-climatic zone around the shores of the red sea from Suez in the north to Halayeb and Shalatein in the south and across south Sinai on the banks of the gulfs of Suez and Aqaba. Its dry bulb temperatures are moderate compared to further south in Egypt.

CZ 5 is characterized by its higher dry bulb temperatures compared to CZ 2 and its lower humidity. Tests were performed in Hurghada city in CZ 5.

Comparison between the results in these two climatic zones would indicate the feasibility of the IEC-H system compared to a DX system as the dry bulb increases and the humidity decreases.

CZ 8, is the hottest in Egypt with relatively lower humidity ratios compared to other climatic zones.

This is why testing in CZ 8 would complement the tests in CZ 2 & 5 done in 2022.

1.2. How the Tests were Performed?

Each OEM tested two of his units in the same 24 hours, one IEC-H prototype next to one DX unit.
Both units tested were full fresh air and had the same air flow rate.
All OEMs used R-32 for both their IEC-H prototype and their corresponding DX unit.

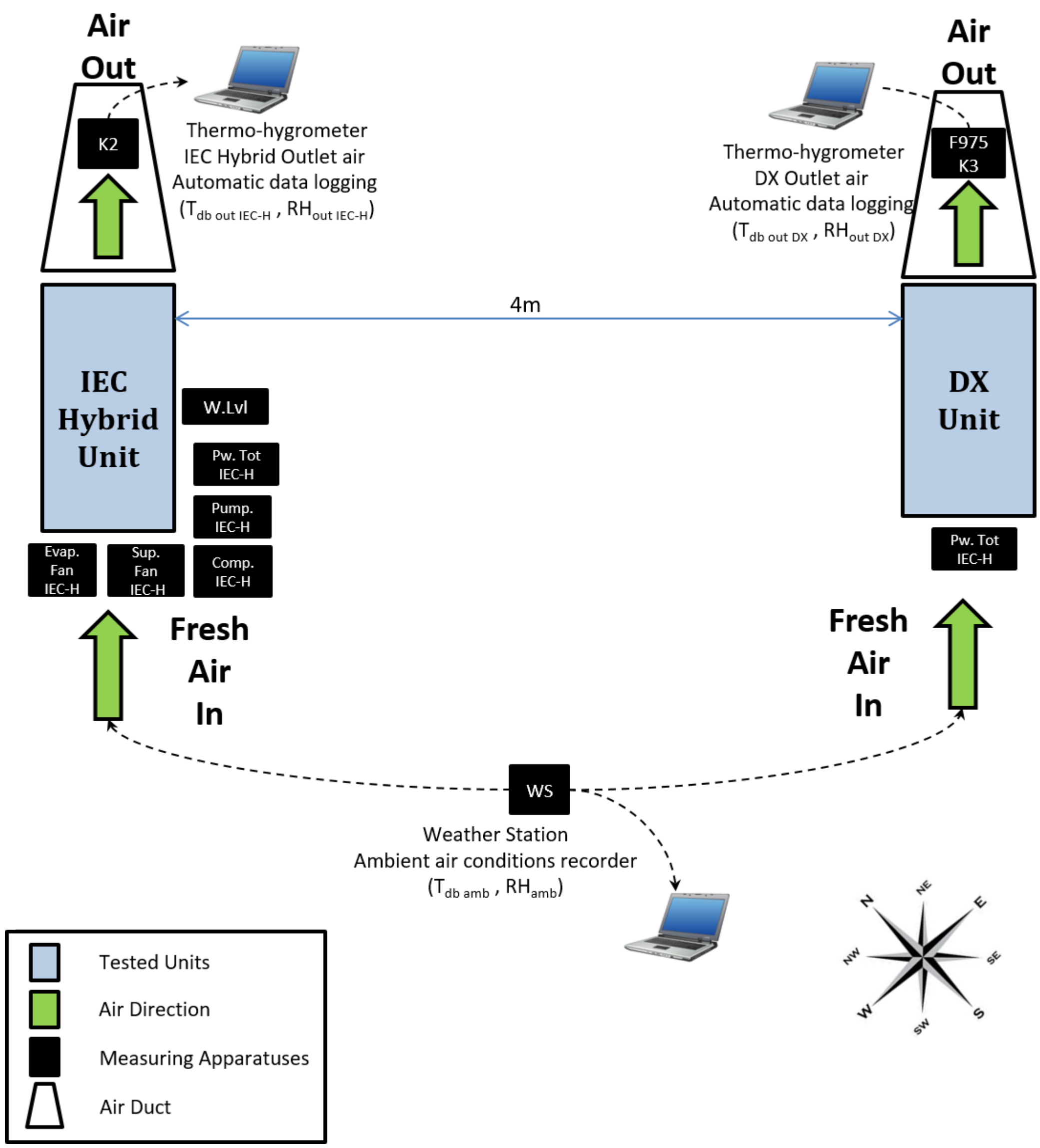
1.3. The Testing Methodology

This is a brief description of the testing methodology. The complete testing methodology is shown in **annex 3** of the final report of 2022. the testing methodology follows EUROVENT recommendations*

- There were no intentions to compare the performance of OEMs units, one against the other. This is why OEMs are labelled by a confidential number and not by their original name.
- The purpose of the tests is to find out if there are energy efficiency advantages obtained by adopting a hybrid IEC system, IEC-H, when compared to a DX or chilled water system for climatic CZ 8.
- Both IEC-H prototype and DX unit are tested simultaneously. Both units are full fresh air with rate of air discharge of one unit regulated so that it matches the other.
- To maintain 15 °C primary air outlet dry bulb temperature.
- For each OEM, testing was performed over a 24hr period for both units simultaneously.
- The tests performed for all OEMs, one after the other.
- The tests were considered completed once a 24 hours' cycle is recorded for both IEC hybrid and DX units. If any of the units stopped working during the test or suffered a performance anomaly such as freezing of the cooling coil the test result at this specific point were discarded.
- The tests meteorological readings were recorded.
- The tests were performed to obtain the total refrigeration capacities (Watts) and the energy efficiency ratio (BTU/W.hr) of both IEC-H and the DX unit for each OEM simultaneously and compare theresults over a 24 hours' period; see the Egyptian standard EOS 3795:2013.
- In this report, the test values are plotted and analyzed to help obtaining a definite understanding of the advantages of the system at various climatic zones.
- An economic comparison is made by an economic expert to compare the Net Present Value (NPV) of the IEC-H to a DX unit over its lifetime to check its economic feasibility for CZ 2 and 5 only.
- Figure 00 shows the Schematic Diagram of the Test Arrangement with Instrumentation.

* **"Eurovent AISBL / IVZW / INPA. (2023). Eurovent 15/1 - 2023 — Hybrid Indirect Evaporative Cooling Equipment - Classification Requirements and Test Conditions. Brussels: Eurovent."**

Fig 00: Schematic Diagram of the Test Arrangement with Instrumentation



Chapter 2

Tabulation Formats for Compiling and Presenting the Results of the Project (CZ 8)

The results obtained were tabulated in excel sheets tabs as follows:

- Basic information
- Graphs of capacities and EERs for IEC-H
- Graphs of capacities and EERs for DX

The tabs of the calculations of capacities and EERs for IEC-H units were used to plot the essential graphs.
The graphs show the following:

- The ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units across a whole day
- The EERs of both the IEC-H and the DX units and ambient RH across a whole day.
- The cooling capacities of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day
- The power consumptions of the DX unit and the IEC-H unit and its components.This was repeated for each OEM in CZ 8.

These graphs were used in calculating the highs and lows of each parameter that follows each OEM.
The final analysis, conclusions and recommendations for future work, in chapter 4 and 5 are derived from the results obtained and drawn from the graphs of chapter 3.
All tabulated excel sheets are made by HBRC and included HBRC final report.
HBRC were instrumental in setting-up the test site and testing rigs. They also collected the readings of the tests, tabulated the results and helped tremendously on the drawing process to obtain the best indicative graphs.

Chapter 3

Analysis of Testing Results and Measurements for the Prototypes and DX Units.

The testing results and measurements for the prototypes and DX units provide us with figures that show us if an IEC-H system is technically advantageous compared to a DX system. The testing results and measurements for all OEMs are listed in details in Annex.

3.1 OEM 3, Climatic Zone 8

Table 2: Basic Information for OEM3 at Climatic Zone 8

Basic Information

Tested Units Name	DX (Direct Expansion Unit)		
	IEC Hybrid (Indirect Evaporative Cooling Hybrid Unit)		
OEM No.	3		
Refrigerant	R-32		
Air Flow Rate	1320 C.F.M for DX and IEC hybrid Units		
Capacity	DX	2	Two compressors
	IEC hybrid	1	One compressor
Water Bath Area	1728.5*623		mm2
Climatic Zone	8 (South Egypt)		
Altitude	196.07 meter (From Sea Level)		
Location	22°49' 02" N 31°28' 16" E		
Test Date	28-Aug-24		

The figures below show the following

For OEM 3 in CZ 8, across a whole day:

- Figure 1: The ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units.
- Figure 2: The EERs of both the IEC-H and the DX units and ambient RH.
- Figure 3: The refrigeration capacity of the IEC-H and DX unit and the ambient dry bulb temperatureand RH.
- Figure 4: The power consumptions of the DX unit and the IEC-H unit and its components.

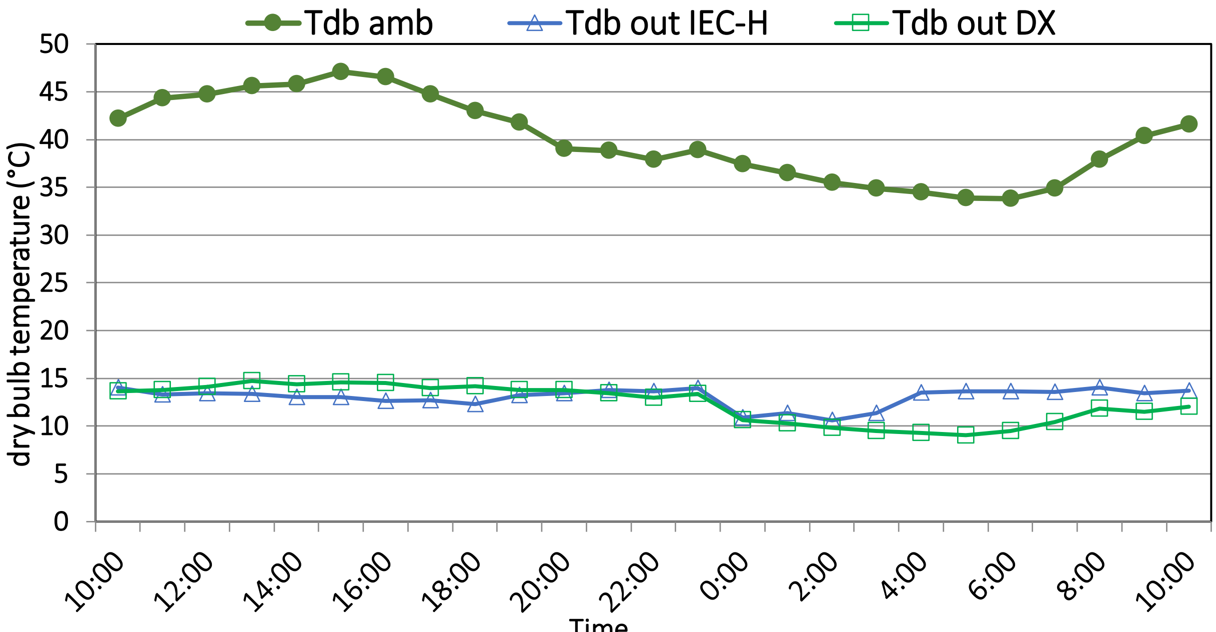


Fig. 1. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units,
OEM 3- CZ 8

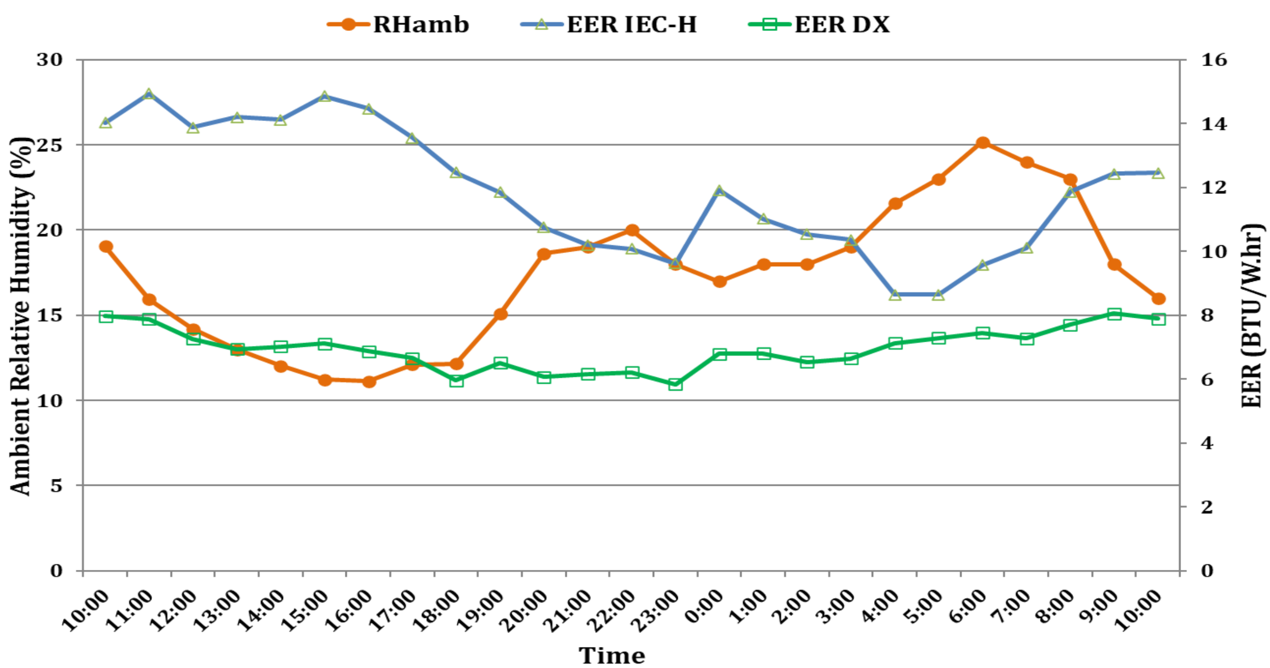


Fig. 2. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity
OEM 3- CZ 8

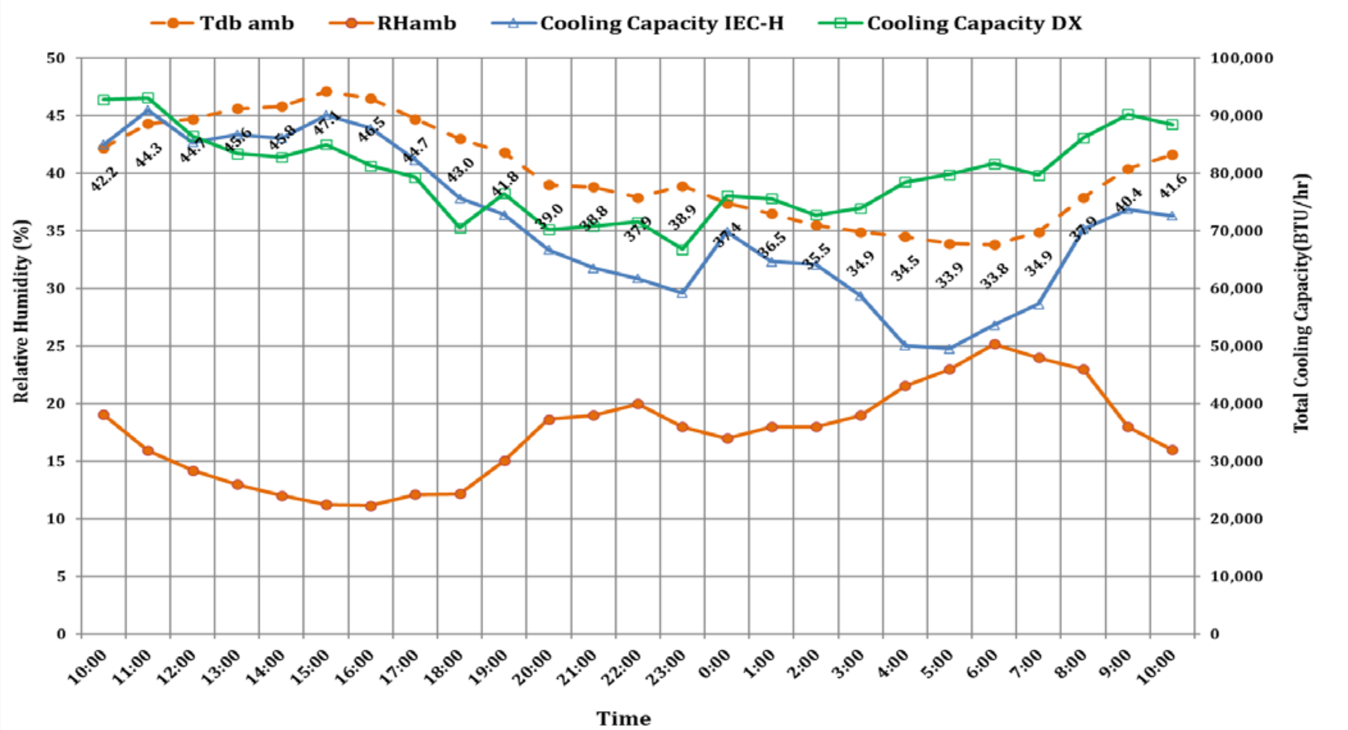


Fig. 3. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions
OEM 3- CZ 8

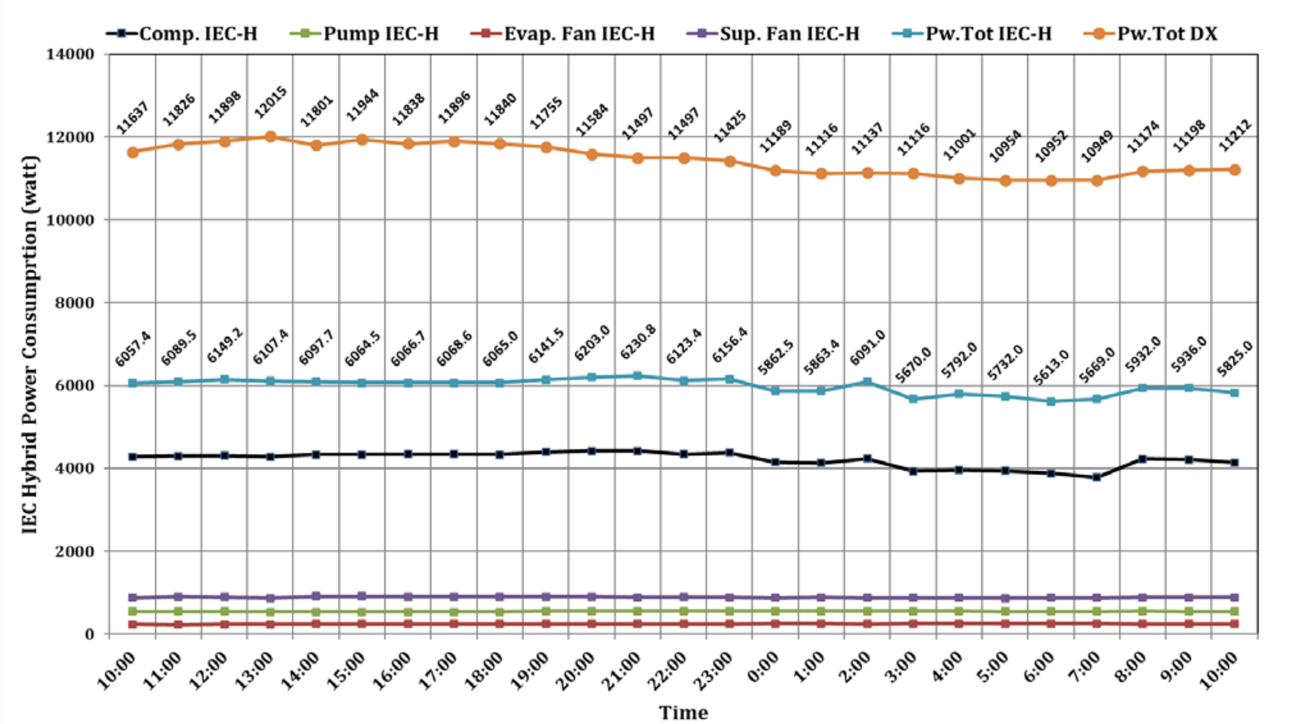


Fig. 4. Power Consumption of DX Unit and IEC Hybrid Unit Components
OEM 3- CZ 8

Analysis of the results of OEM 3 at CZ 8:

Table 3: High and Low readings for OEM3 at Climatic Zone 8

OEM 3, CZ 8				
High and Low Dry Bulb Temp. ℃, Relative humidity				
H and l	$T_{db\ out}$ IEC-H	$T_{db\ out}$ DX	RH_{amb}	$T_{db\ amb}$
High	14.0	14.7	24.0	47.1
Low	10.6	9.1	11.1	33.8

3.2 OEM 2, Climatic Zone 8

Basic Information

Table 4: Basic Information for OEM2 at Climatic Zone 8

Tested Units Name	DX (Direct Expansion Unit)		
	IEC Hybrid (Indirect Evaporative Cooling Hybrid Unit)		
OEM No.	2		
Refrigerant	R-32		
Air Flow Rate	1320 C.F.M for DX and IEC hybrid Units		
Capacity	DX	2	compressors
	IEC hybrid	2	compressors
Water Bath Area	1000*900		mm2
Climatic Zone	8 (South Egypt)		
Altitude	196.07 meter (From Sea Level)		
Location	22°49' 02" N 31°28' 16" E		
Test Date	26-Aug-24		

The figures below show the following

For OEM 2 in CZ 8, across a whole day:

- Figure 5: The ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units.
- Figure 6: The EERs of both the IEC-H and the DX units and ambient RH.
- Figure 7: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH.
- Figure 8: The power consumptions of the DX unit and the IEC-H unit and its components.

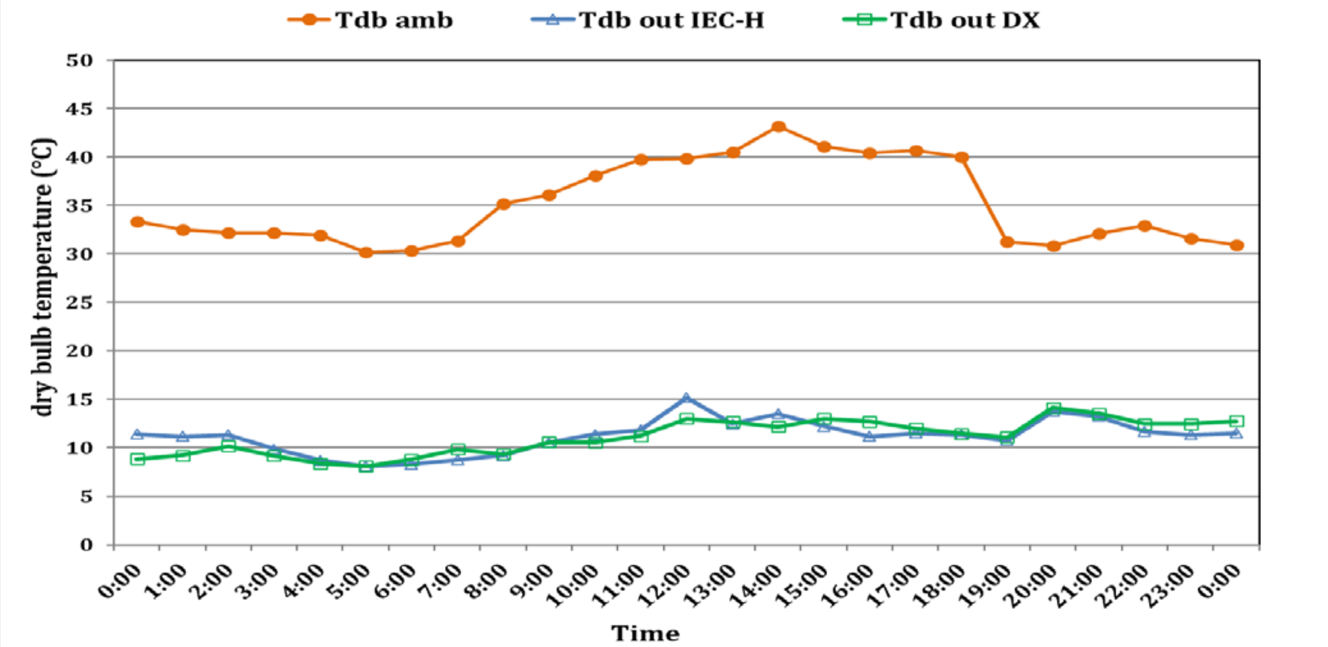


Fig. 5. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units OEM 2

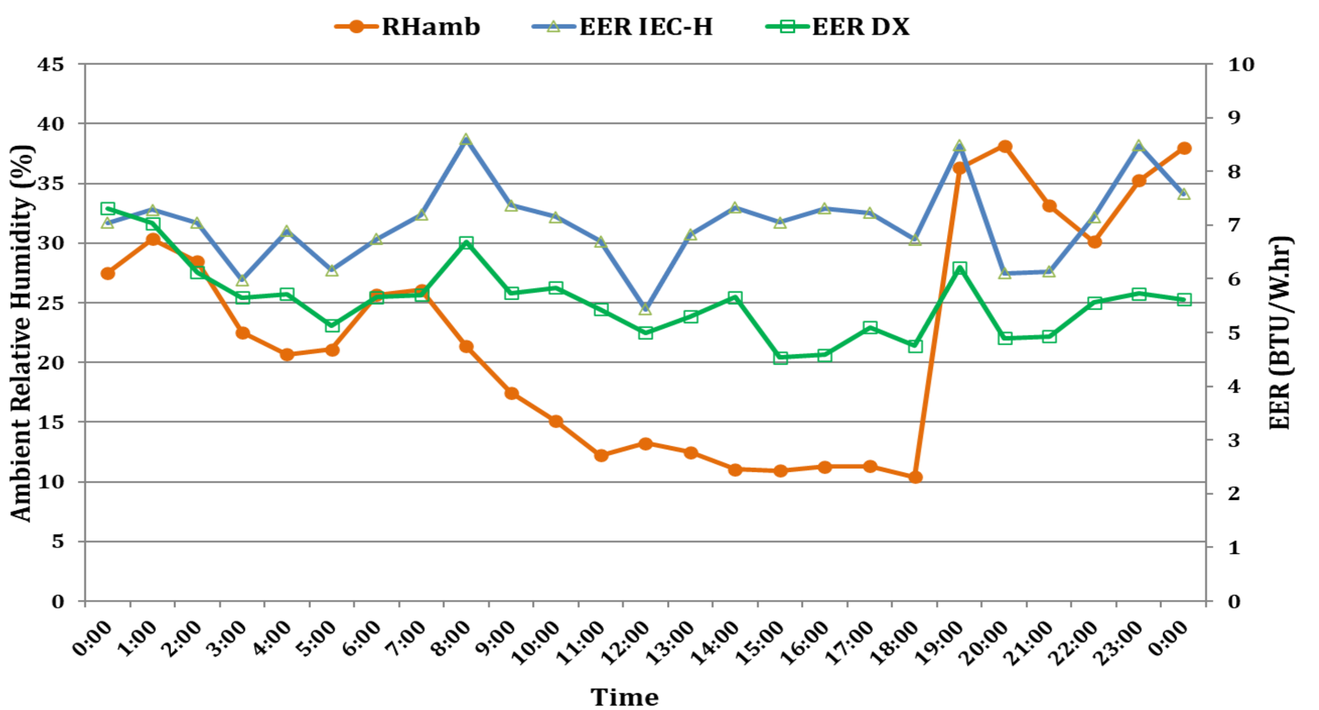


Fig. 6. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity- OEM2

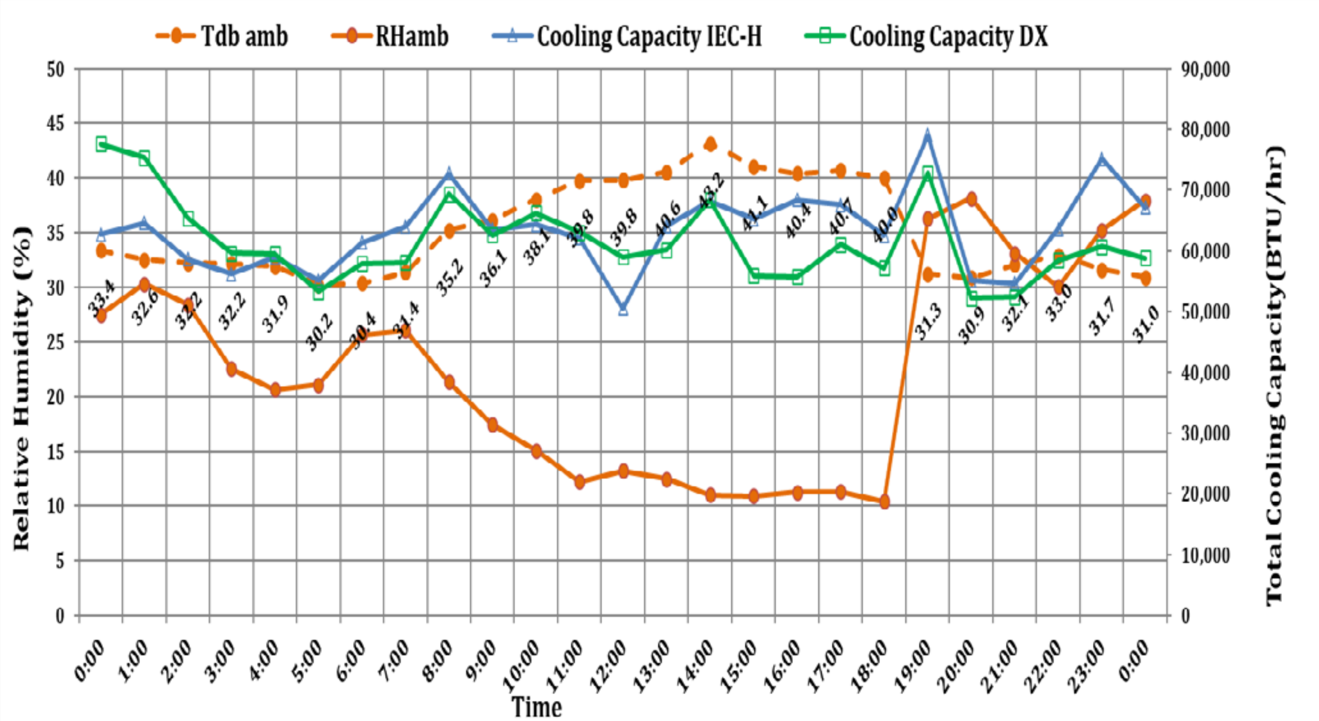


Fig. 7. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions
OEM 2

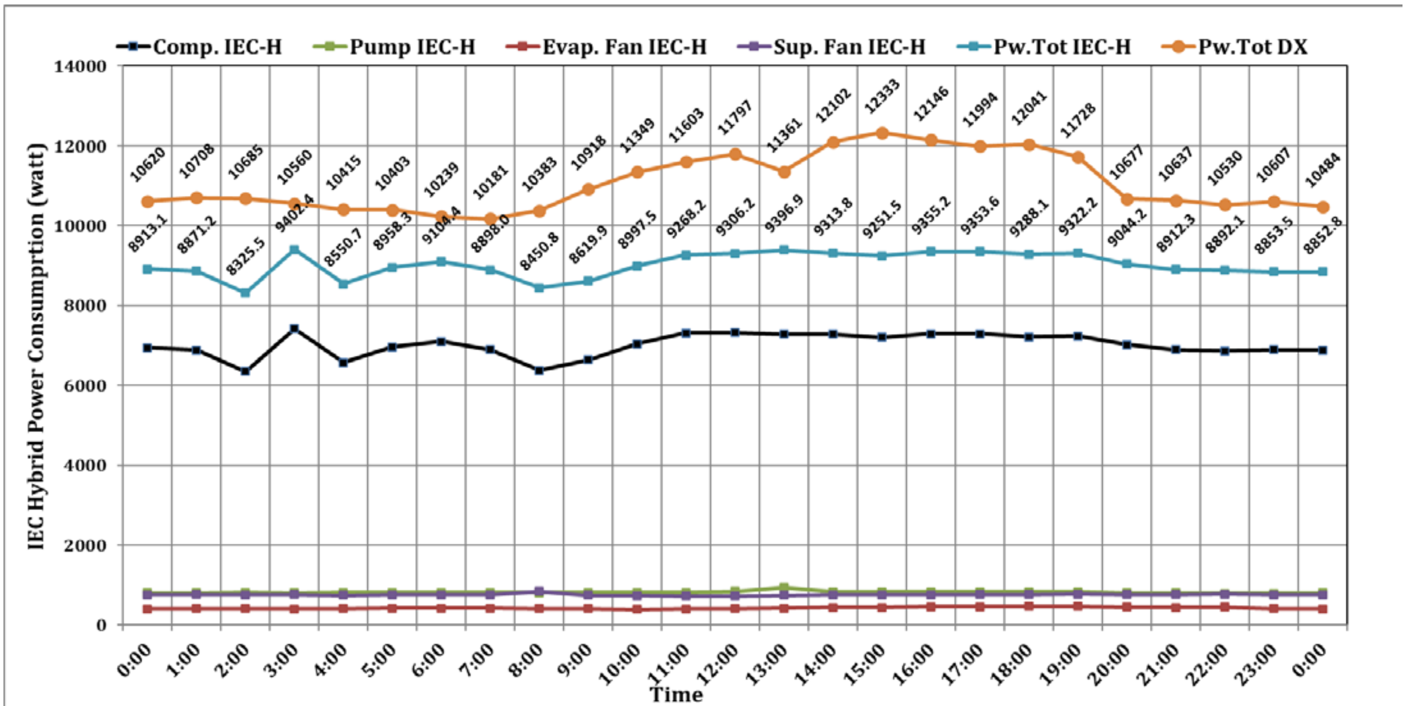


Fig. 8. Power Consumption of DX Unit and IEC Hybrid Unit Components
OEM 2

Table 5: High and Low readings for OEM2 at Climatic Zone 8

OEM 2, CZ 8				
High and Low Dry Bulb Temp. ℃ and Relative humidity				
H and l	**$T_{db\ out}$ IEC-H**	**$T_{db\ out}$ DX**	**RH_{amb}**	**$T_{db\ amb}$**
High	**15.2**	**14.1**	**38.2**	**43.2**
Low	**8.3**	**8.1**	**10.4**	**30.2**

3.3 OEM 6, Climatic Zone 8

Basic Information

Table 6: Basic Information for OEM 6 at Climatic Zone 8

Tested Units Name	DX (Direct Expansion Unit)		
	IEC Hybrid (Indirect Evaporative Cooling Hybrid Unit)		
OEM No.	6		
Refrigerant	R-32		
Air Flow Rate	1800 C.F.M for DX and IEC hybrid Units		
Capacity	DX	2	compressor
	IEC hybrid	1	compressors
Water Bath Area	(1308.3^2-900.3^2)		mm2
Climatic Zone	8 (South Egypt)		
Altitude	196.07 meter (From Sea Level)		
Location	22°49' 02" N 31°28' 16" E		
Test Date	31-Aug-24		

The figures below show the following

For OEM 6 in CZ 8, across a whole day:

- Figure 9: The ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units.
- Figure 10: The EERs of both the IEC-H and the DX units and ambient RH.
- Figure 11: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperatureand RH.
- Figure 12: The power consumptions of the DX unit and the IEC-H unit and its components

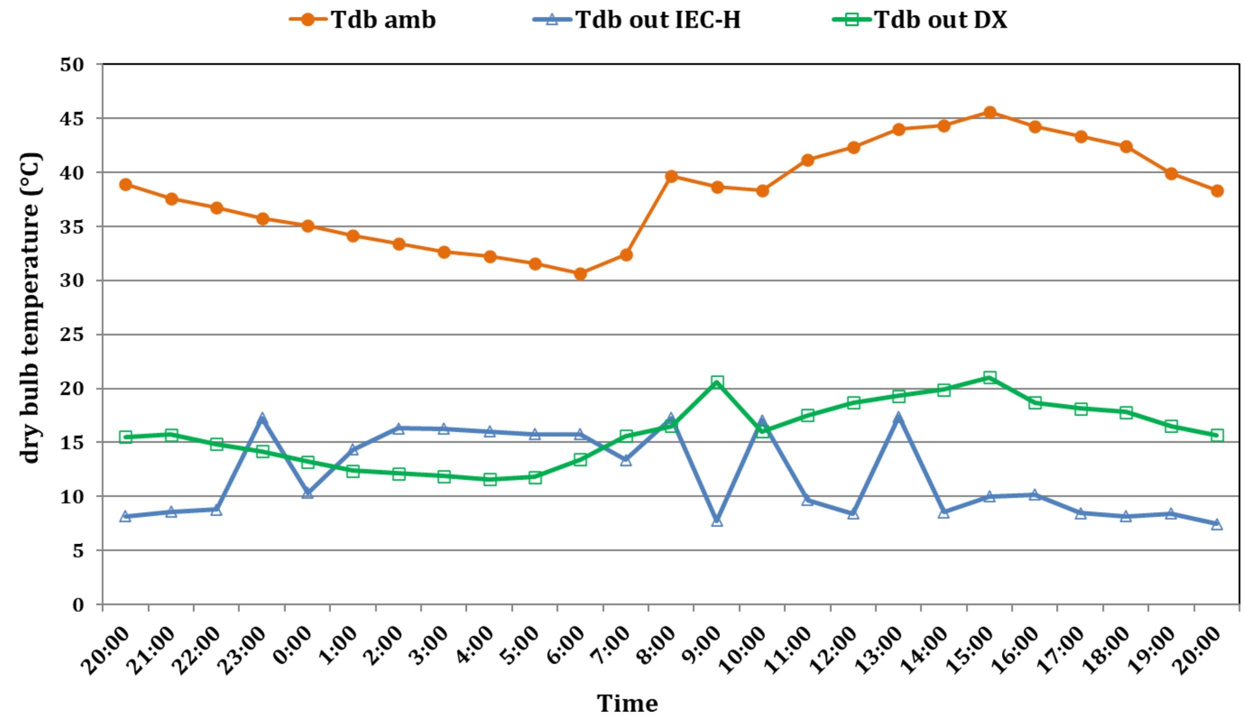


Fig. 9. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units- OEM 6 CZ 8

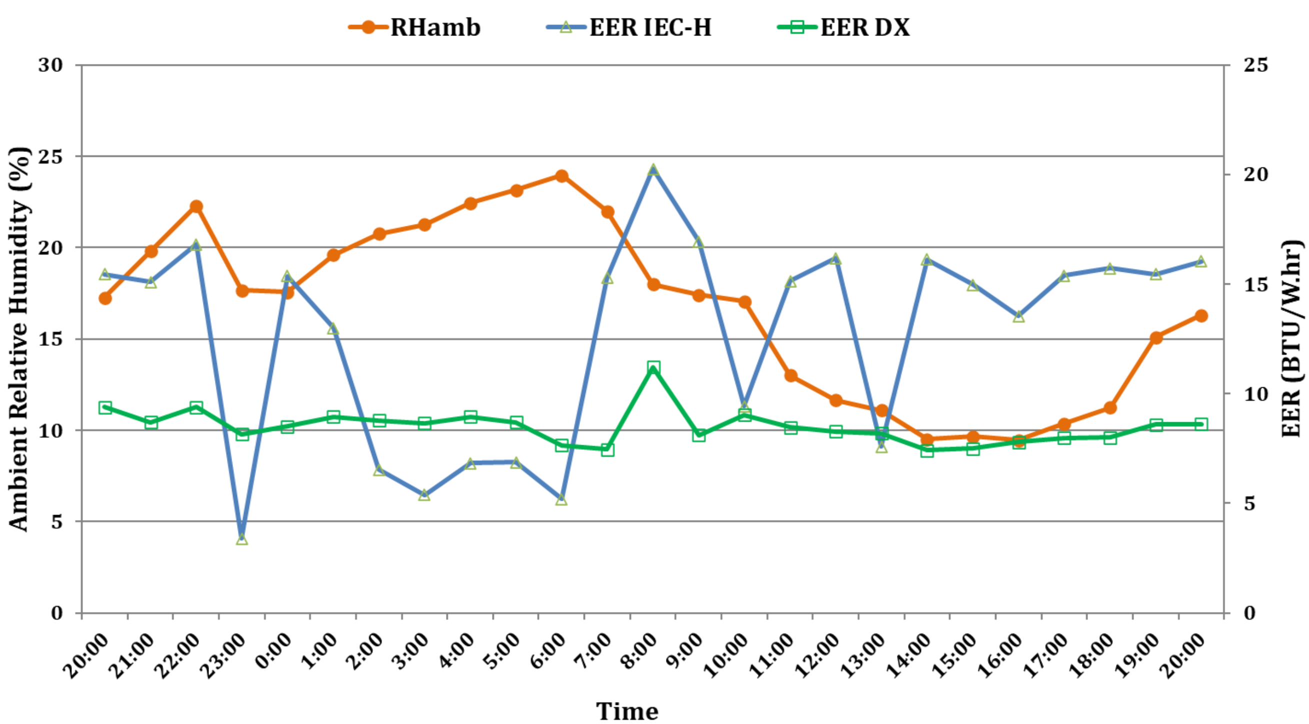


Fig. 10. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity OEM 6 CZ 8

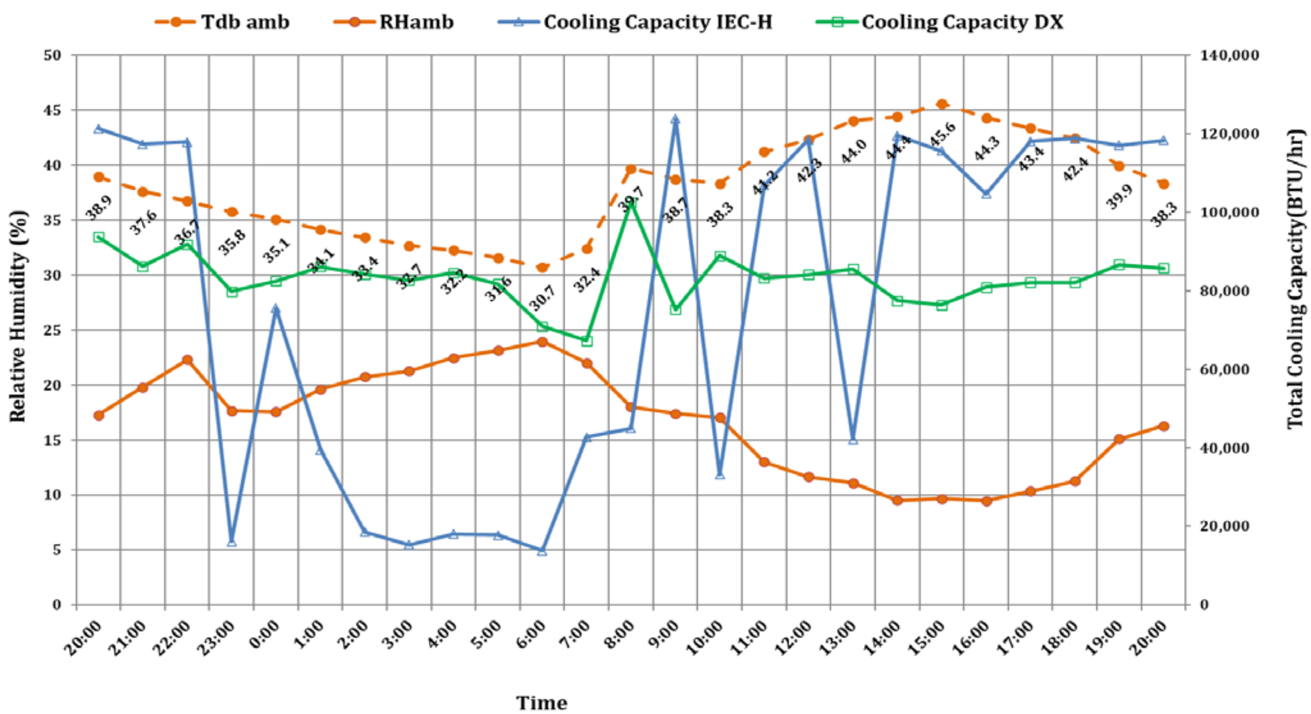


Fig. 11. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions
OEM 6 CZ 8

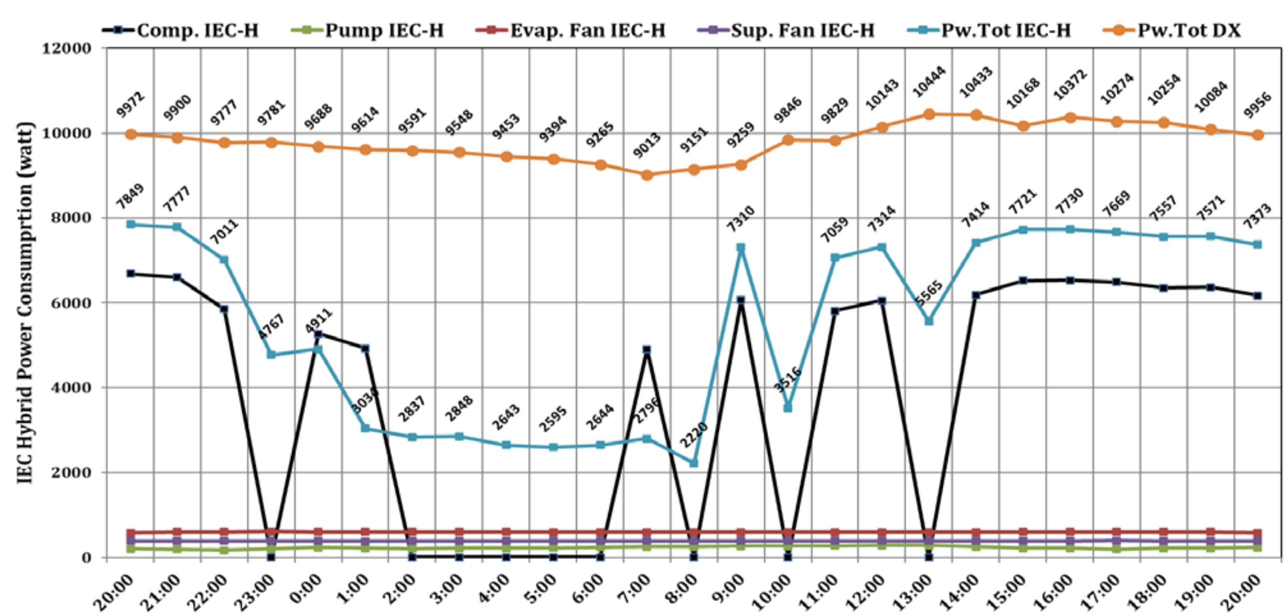


Fig. 12. Power Consumption of DX Unit and IEC Hybrid Unit Components
OEM 6 CZ 8

Table 7: High and Low readings for OEM 6 at Climatic Zone 8

OEM 6, CZ 8				
High and Low Dry Bulb Temp. ℃ and Relative humidity				
H and l	$T_{db\ out}$ IEC-H	$T_{db\ out}$ DX	RH_{amb}	$T_{db\ amb}$
High	17.4	17.8	24.0	45.6
Low	7.5	11.6	9.5	30.7

3.4 OEM 7, Climatic Zone 8

Basic Information

Table 8: Basic Information for OEM 7 at Climatic Zone 8

Tested Units Name	DX (Direct Expansion Unit)		
	IEC Hybrid (Indirect Evaborative Cooling Hybrid Unit)		
OEM No.	3		
Refrigerant	R-32		
Air Flow Rate	1320 C.F.M for DX and IEC hybrid Units		
Capacity	DX	1	compressor
	IEC hybrid	2	compressors
Water Bath Area	560X1020		mm2
Climatic Zone	8 (South Egypt)		
Altitude	196.07 meter (From Sea Level)		
Location	22°49' 02" N 31°28' 16" E		
Test Date	30-Aug-24		

The figures below show the following

For OEM 7 in CZ 8, across a whole day:

- Figure 13: The ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-Hand the DX units.
- Figure 14: The EERs of both the IEC-H and the DX units and ambient RH.
- Figure 15: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperatureand RH.
- Figure 16: The power consumptions of the DX unit and the IEC-H unit and its components

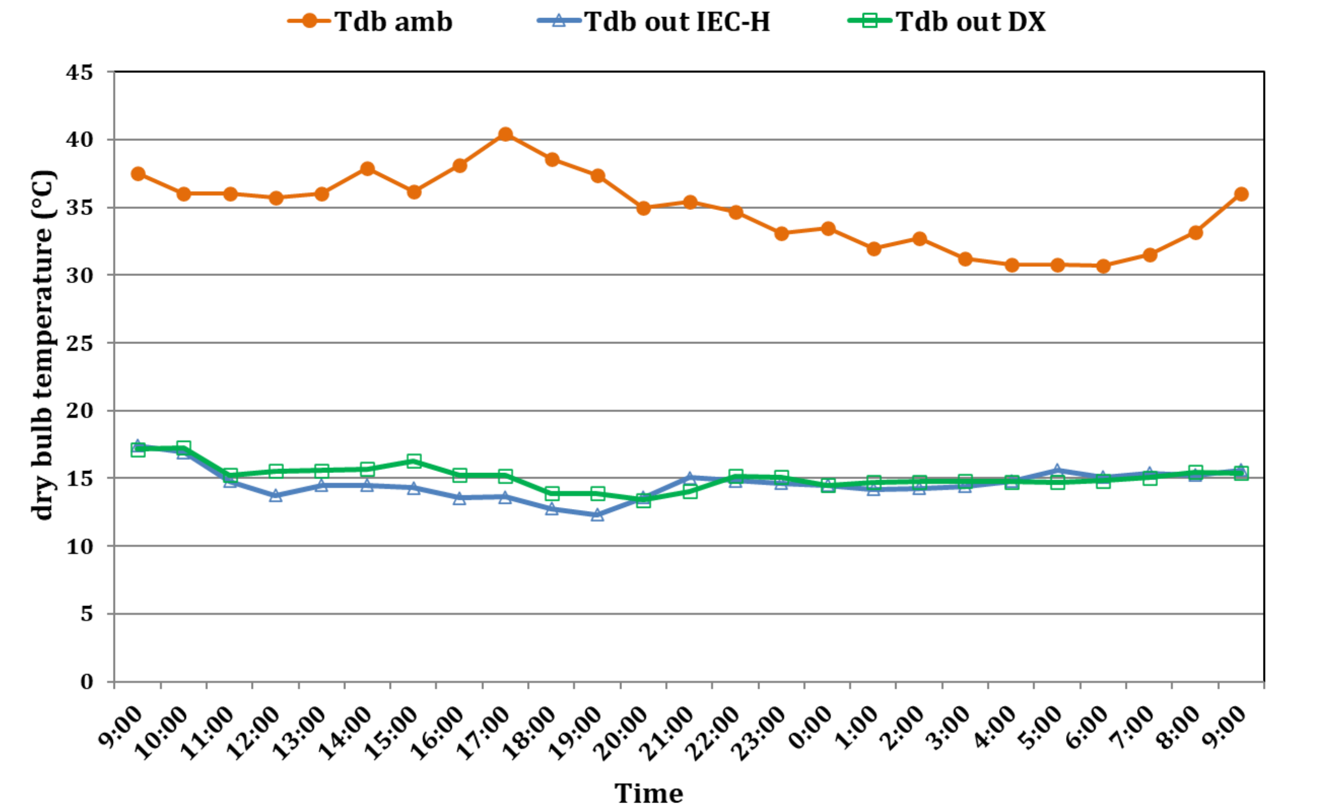


Fig. 13. Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units, OEM 7 CZ 8

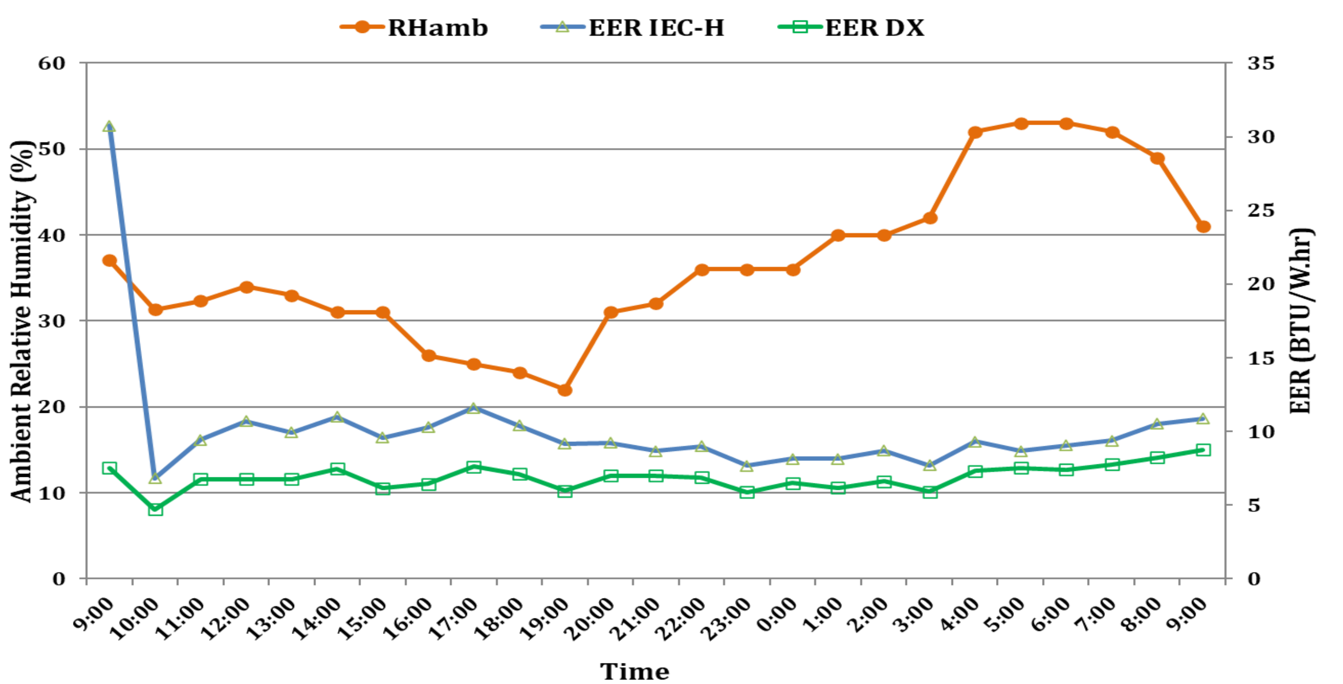


Fig. 14. EER for IEC Hybrid Unit & DX Unit Versus Ambient Relative Humidity, OEM 7 CZ 8

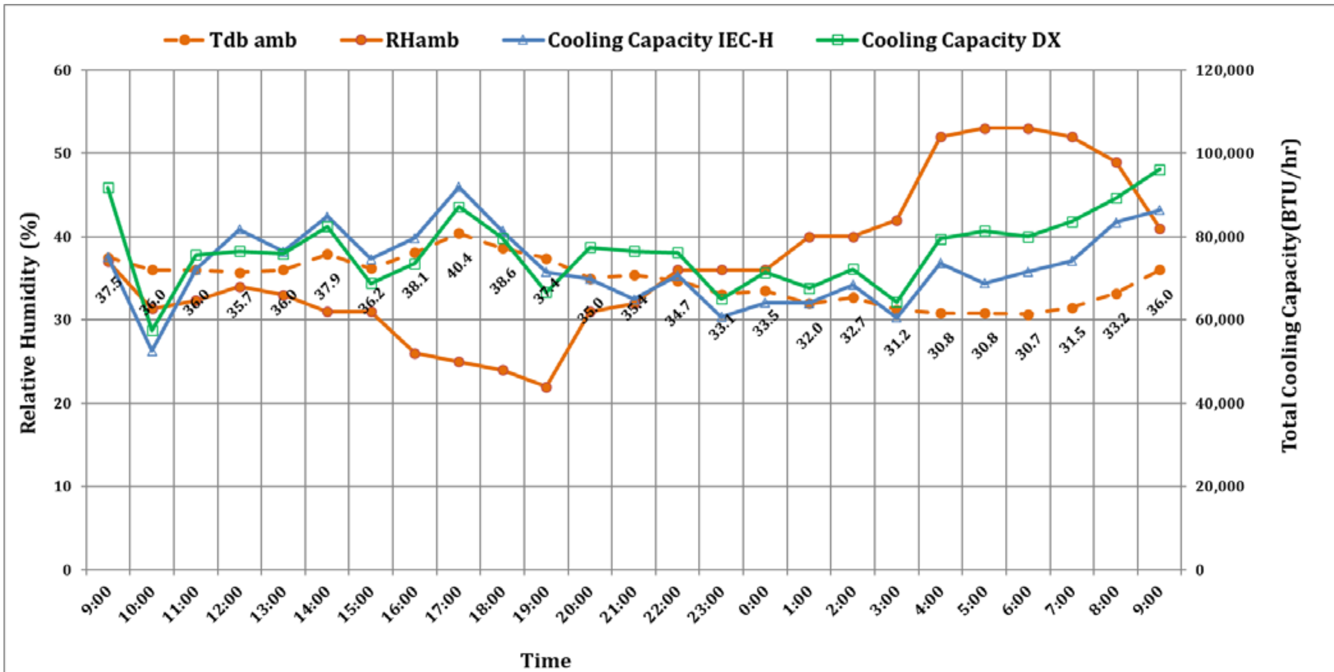


Fig. 15. Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions
OEM 7 CZ 8

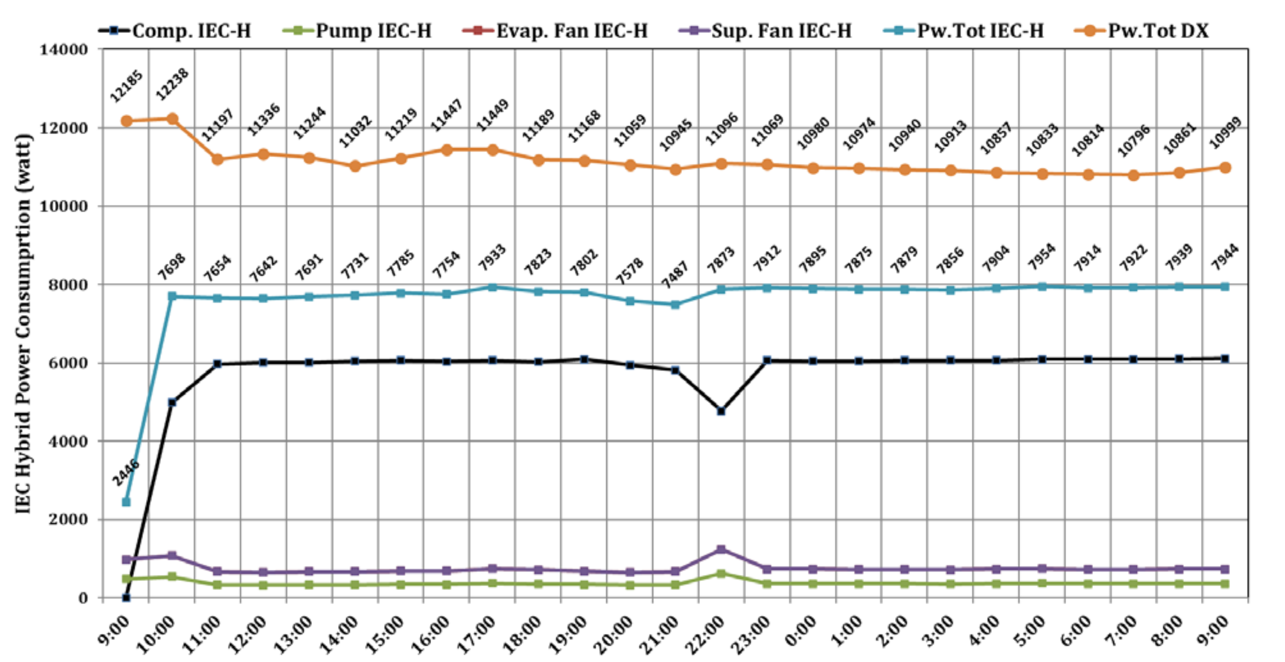


Fig. 16. Power Consumption of DX Unit and IEC Hybrid Unit Components
OEM 7 CZ 8

Table 9: High and Low readings for OEM 7 at Climatic Zone 8

OEM 7, CZ 8				
High and Low Dry Bulb Temp. ℃ and Relative humidity				
H and l	$T_{db\ out}$ IEC-H	$T_{db\ out}$ DX	RH_{amb}	$T_{db\ amb}$
High	17.4	17.3	49.0	40.4
Low	12.3	13.4	22.0	30.7

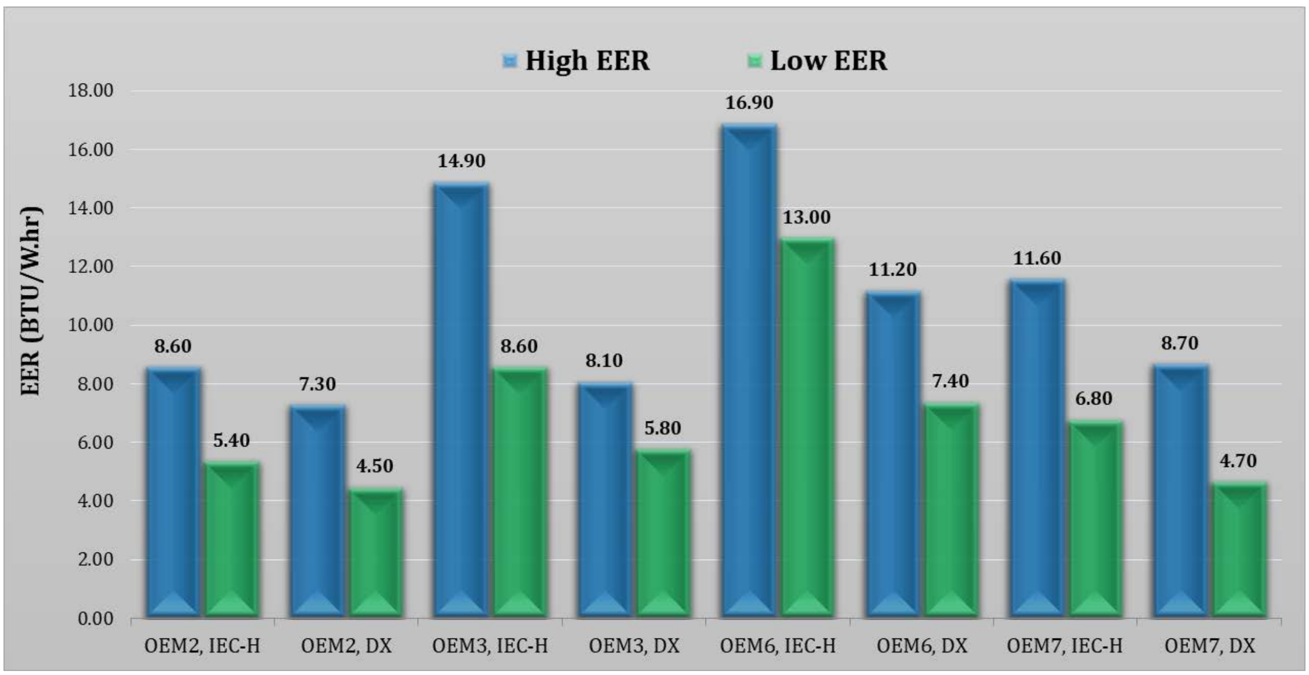
Chapter 4

The Final Results Analysis with Conclusion and Recommendation for Future Work

4.1 The Final Results Analysis

4.1.1 EER HIGH and LOW – CZ 8

Fig 17: High and Low EER (in BTU/W.hr) for Climatic Zone 8



4.1.2 CAPACITY HIGH and LOW – CZ 8

Fig 18: High and Low Cooling Capacity (in W) for Climatic Zone 8

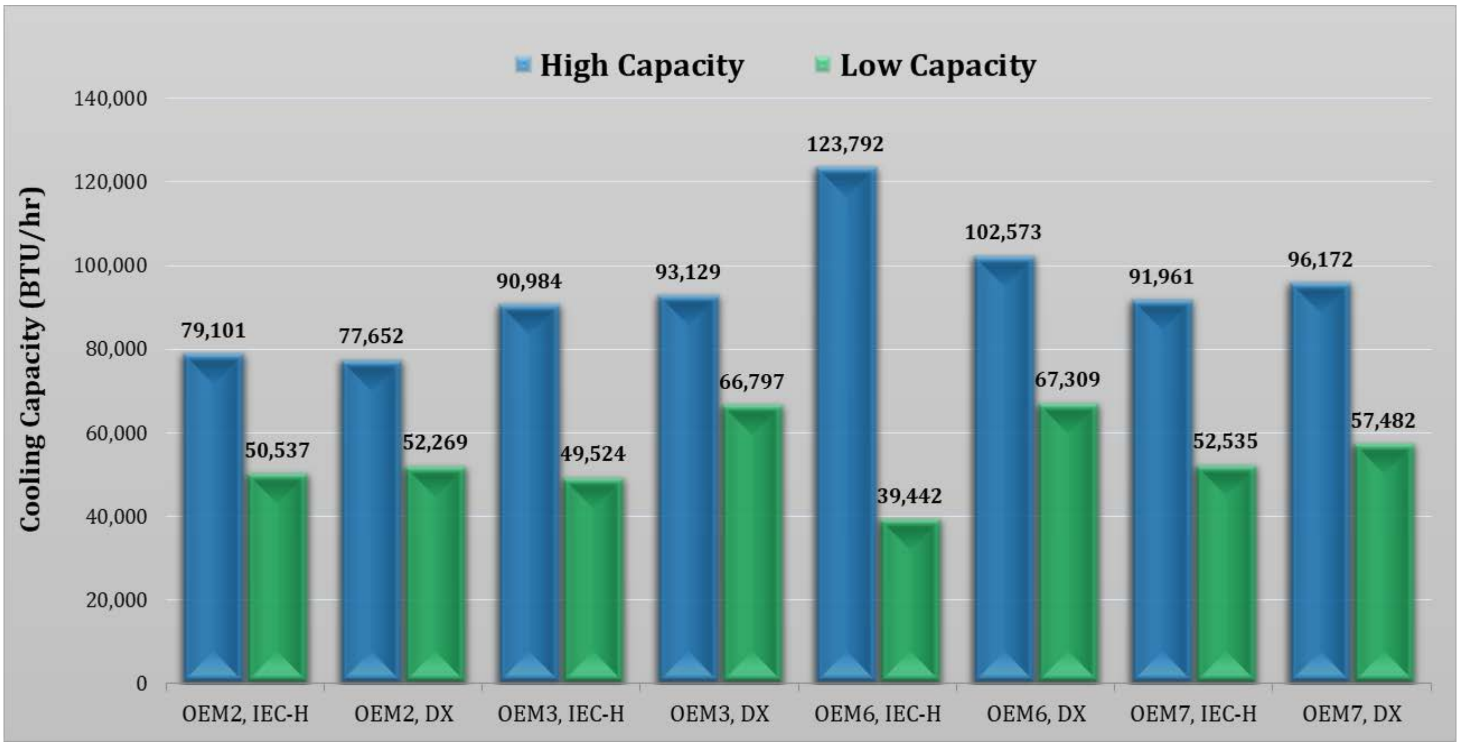


Table 10: High and Low EERs and Refrigeration capacity, all OEMs at Climatic Zone 8

EER				Capacities, W		
OEM #	High EER	Low EER		OEM #	High Capacity	Low Capacity
OEM2, IEC-H	8.60	5.40		OEM2, IEC-H	79,101	50,537
OEM2, DX	7.30	4.50		OEM2, DX	77,652	52,269
OEM3, IEC-H	14.90	8.60		OEM3, IEC-H	90,984	49,524
OEM3, DX	8.10	5.80		OEM3, DX	93,129	66,797
OEM6, IEC-H	16.90	13.00		OEM6, IEC-H	123,792	39,442
OEM6, DX	11.20	7.40		OEM6, DX	102,573	67,309
OEM7, IEC-H	11.60	6.80		OEM7, IEC-H	91,961	52,535
OEM7, DX	8.70	4.70		OEM7, DX	96,172	57,482

4.2 Conclusions

Due to the absence of local testing standard or guidelines for IEC applications, Eurovent Recommendation “Eurovent AISBL / IVZW / INPA. (2023). Eurovent 15/1 - 2023 — Hybrid Indirect Evaporative Cooling Equipment - Classification Requirements and Test Conditions. Brussels: Eurovent.” provided testing reference and quality review of the testing process.
Eurovent recommendations are followed except for the points that contradicts with confidentiality agreement related to stating the name of the manufacturers or trade name.
The analysis of the final results of all OEMs shows the following:

- All OEMs show EERs of the IEC-H prototypes that are superior to corresponding DX units.
- The IEC-H prototype and DX units compressor’s capacities are the same, 6 H.P at nominal conditions.
- Only one OEM used two compressors for its IEC-H prototype.

Table 11: Number of compressors, all OEMs at Climatic Zone 8

OEM	IEC-H	DX
3	One	Two
6	One	Two
7	One	Two
2	Two	Two

- The air discharge of both the IEC-H prototype and DX units for each OEM were the same.
- All OEMs used two compressors in their DX units.
- All OEMs used one compressor for their IEC-H prototypes, except OEM 2 whom used two compressors.
- The tests showed that the capacity of the IEC-H prototypes when compared to the capacity of their respective DX unit also varied considerably, depending on the prototype design and the ambient relative humidity.
- When the ambient relative humidity increased, the DX units tended to provide a better refrigeration capacity then corresponding IEC-H prototype.
- Except OEM 2, which used two compressors in its IEC-H prototype, higher refrigeration capacity was maintained even at high relative humidity ratios.

- Nevertheless, overall IEC-H refrigeration capacities at lower humidity periods, where higher than those of corresponding DX units.
- The report breaks new ground for NIK air conditioning technologies and provides an alternative full fresh air system for air conditioning application that exceeds the efficiency of existing DX systems.

4.3 Recommendation for Future Work

- Although, both final reports for CZ 2 & 5 (2022) and this report for CZ 8 (2024) are sufficient to write guidelines for a code for direct/indirect evaporative cooling for Egypt, the report recommends further work to provide a comprehensive formula to design IEC-H units in all Climatic Zones.
- There is a need for the industry to have a mathematical formula to predict the EERs and refrigeration capacities for IEC-H prototypes for the remaining five climatic zones of Egypt where tests were not performed in these locations.
- This formula once made, needs substantiation and proofing in the other Climatic Zones of Egypt where tests were not performed, through site tests.
- Therefore, future work would need to be made by OEMs to test IEC-H prototypes in these Climatic Zones and compare results with those obtained by the mathematical formula made in order to refine prediction on the design needed for IEC-H units in any of Egypt's climatic Zones.
- Only then can a definitive Direct/Indirect Evaporative Cooling Code be written which will help greatly in achieving energy efficiency for the industry and promote using lower GWP refrigerants.

Chapter 5

Reporting on the Advocacy and Outreach Campaign
3 November 2024

INTRODUCTION

Outreach marketing campaign helped in the enforcement of **Transformation of Commercial Air Conditioning Companies in EGYPT** by promoting and publishing the results of the technical study to stakeholders. The report of this outreach campaign are to be made available to all stakeholders. The outreach campaign was held on 3rd November 2024, at the auditorium of HBRC.

OUTREACH PLAN GOAL

The outreach marketing campaign had been targeting the following:

- ✓ Build awareness of the Phase-out Management Plan (HPMP).
- ✓ Promote and enhance transformation of commercial HVAC manufacturers in Egypt.
- ✓ Generate leads for the alternative refrigerants code and the forthcoming guidelines of direct/indirect evaporative cooling code.
- ✓ Effect collaborations between OEMs.

The objective of the outreach campaign is to disseminate the experience gained during testing the IEC-H prototypes and DX units in the additional Climatic Zones 8. The main discussions were on the results of the testing of IEC-H and DX units of all OEMs.

TARGET STAKEHOLDERS ATTENDING THE OUTREACH CAMPAIGN

The list of individuals/other entities having a role in the development and implementation of the Plan. The following are the stakeholder groups that were targeted in the outreach campaign:

1- The Ministry of Electricity

2- Organization of Specifications and Standards
3- Municipalities
4- All OEMs that were included in the program
5- Local Government Agency Officials and Department Heads
6- Public Sector HVAC Project Planners
7- Local Chapters of Regional/National Associations
8- Local Environmental Organizations
9- Local HVAC Organizations and Interest Groups
10- HVAC Companies
11- Developers
12- The General Public
13- Others interested parties

Question raised after the presentation

About 30 to 35 persons attended the 4 hours Outreach campaign. The following are the most important questions and answers made during the campaign:

I. Question by Eng Mohamed Mansour on humidity ratios and relative humidity of the ambient air:
   a. Dr Olama answered on the measurement of humidities made and their relations with the two storms encountered during testing that increased dramatically humidity in the area.

II. Question posed by Eng. Abdel Sallam Mahrous, consulting engineer on which of the OEMs exhibited the best EERs.
   a. Dr Olama replied that one of the cornerstones of the program is not to provide data for the purpose of determining which is the best performing prototypes or DX units. This is why the OEMs are listed by a numbering code and not by their names.

III. Question posed by Eng. Maarouf, consultant engineer, asking if the IEC-H units, when produced on a regular basis, would their maintenance will be higher or lower than that of DX units?
   a. Dr Olama answered that because of the higher costs of maintaining evaporation pads, IEC-H maintenance are higher than that of DX units.

IV. Comment posed by Dr. Ezzat Lewis (the head of the Egyptian NOU)

a. Dr. Ezzat, explained clearly the different roles of the UN agencies and bodies. He talked about the future funding for programs for Egypt and the mechanisms of replenishment for individual nations.

V. Question asked by Eng. Hassan el Mogi, chairman of the consulting firm El-AMAAR, when will the IEC-H specification code be ready to be used by consulting engineers?

a. Reply: first guidelines on IEC evaporative cooling will first be written as a guidance for a forthcoming code, then a complete code will be written when the third testing program is made and all Climatic Zines in Egypt are covered.

VI. An engineer (he has not given his name) inquired if there a plan to produce a code and then legislate the usage of IEC-H for the different eight climatic zones of Egypt?

a. Reply: Dr Olama replied that we hope there will be a future phase in the program that will allow OEMs and all practitioners in HVAC to use a formula to predict the size of the compressors and the basic design parameters of IEC-H units for all eight Climatic Zones of Egypt. Binding legislation can then be enacted given the assured ability to predict the performance of IEC-H units in all Climatic Zones and thus provide a proven energy efficient system of cooling for the country utilizing lower GWR refrigerants and HC refrigerants.

Dr Alaa Olama.