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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL
Ninety-fourth Meeting
Montreal, 27-31 May 2024
Item 9(d) of the provisional agenda[1]

PROJECT PROPOSAL: EGYPT

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

Phase-out

- HCFC phase-out management plan (stage II, fourth tranche) — UNIDO, UNDP, UNEP and Government of Germany

[1] UNEP/OzL.Pro/ExCom/94/1

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, Germany	79th	70% 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: 2023
Chemical	Aerosol	Foam	Fire-fighting	Refrigeration		Solvent	Process agent	Lab use	Total sector consumption
				Manufacturing	Servicing				
HCFC-22					236.64				236.64
HCFC-124					0.01				0.01

(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		2024	2025	2026	Total
UNIDO	ODS phase-out (ODP tonnes)	39.21	1.89	0.00	41.10
	Funding (US $)	4,322,172	208,650	0	4,530,822
UNDP	ODS phase-out (ODP tonnes)	0.00	0.00	0.00	0.00
	Funding (US $)	0	0	0	0
UNEP	ODS phase-out (ODP tonnes)	1.75	1.02	0.00	2.77
	Funding (US $)	201,506	118,105	0	319,611
Germany	ODS phase-out (ODP tonnes)	0.00	0.00	0.00	0.00
	Funding (US $)	0	0	0	0

(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					17,361,573
		Support costs	335,410	0	515,691	0	414,721					1,265,822
Total funds recommended for approval at this meeting (US $)		Project costs								2,480,298**		2,480,298**
		Support costs								182,527**		182,527**

* Maximum allowable total consumption of Annex C, Group I substances was reduced by 10 ODP tonnes upon approval at the 84th meeting of a domestic air-conditioning sector plan as part of stage II.
** Recommended at the present meeting, 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.
Note: The Agreement between the Government of Egypt and the Executive Committee was revised at the 84th meeting.

Secretariat's recommendation:	Individual consideration

PROJECT DESCRIPTION

1. On behalf of the Government of Egypt, UNIDO as the lead implementing agency has submitted a request for funding for the fourth tranche of stage II of the HCFC phase-out management plan (HPMP), at a total cost of US $4,523,678, consisting of US $4,039,413, plus agency support costs of US $282,759, for UNIDO and US $180,000, plus agency support costs of US $21,506, for UNEP.[2] The submission includes a progress report on the implementation of the third tranche, the verification report on HCFC consumption for 2021 to 2023, and the tranche implementation plan for 2024 to 2026.

Report on HCFC consumption

2. The Government of Egypt reported consumption of 236.65 ODP tonnes of HCFCs in 2023, which is 39 per cent below the country's HCFC baseline for compliance. The 2019-2023 HCFC consumption is shown in table 1.

Table 1. HCFC consumption in Egypt (2019-2023 Article 7 data)

HCFC	2019	2020	2021	2022	2023	Baseline
Metric tonnes (mt)						
HCFC-22	4,083.33	4,481.91	3,759.59	3,244.76	4,302.55	4,367.16
HCFC-123	3.75	0.00	7.75	2.50	0.00	5.25
HCFC-124	0.00	0.00	0.34	0.00	0.54	0.00
HCFC-141b	547.62	0.00	0.00	0.00	0.00	1,178.26
HCFC-142b	52.37	52.93	34.13	18.37	0.00	251.69
Total (mt)	**4,687.07**	**4,534.84**	**3,801.81**	**3,265.63**	**4,303.09**	**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	224.58	246.51	206.78	178.46	236.64	240.19
HCFC-123	0.08	0.00	0.16	0.05	0.00	0.11
HCFC-124	0.00	0.00	0.01	0.00	0.01	0.00
HCFC-141b	60.24	0.00	0.00	0.00	0.00	129.61
HCFC-142b	3.40	3.44	2.22	1.19	0.00	16.36
Total (ODP tonnes)	**288.30**	**249.95**	**209.16**	**179.71**	**236.65**	**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. In 2023, HCFC-22 was consumed exclusively to service existing refrigeration and air-conditioning (RAC) equipment; the increase in servicing consumption in 2023 is further discussed in paragraph 24 below. With the support of the conversions undertaken under the project, the country phased out consumption of HCFC-22 to manufacture RAC equipment and to manufacture extruded polystyrene (XPS) foam. HCFC-142b, which was used as a co-blowing agent with HCFC-22 in the manufacture of XPS foam, was similarly phased out, in line with the 1 January 2023 ban on the use of HCFCs to manufacture of XPS foam. The import and manufacture of HCFC-based equipment was banned on 1 January 2023, imports of R-406A on 1 January 2023, and imports of HCFC-141b on 1 January 2020 and of HCFC-141b contained in pre-blended polyols on 1 January 2018. Small quantities of HCFC-123 and HCFC-124 are used intermittently to service RAC equipment.

[2] As per the letter of 2 February 2024 from the Ministry of Environment of Egypt to UNIDO.

Country programme implementation report

4. The Government of Egypt reported HCFC sector consumption data under the 2023 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 Article 7 of the Montreal Protocol for 2021 to 2022 and under the CP data report for 2023 was correct (as shown in table 1 above). The verification concluded that Egypt was in compliance with the 2021-2023 maximum allowable consumption of all Annex C, Group I substances as in the Agreement with the Executive Committee

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

Legal framework

6. Effective as of 1 January 2023, the country implemented bans on the import and manufacture of HCFC-22-based equipment; on the use of HCFCs and HCFC blends in the manufacture of XPS foam; on the import of R-406A; and on the import of HCFC-142b. Imports of HCFC-141b were banned on 1 January 2020 and of HCFC-141b contained in pre-blended polyols on 1 January 2018. The Government of Egypt ratified the Kigali Amendment on 22 August 2023. In 2022, the Government amended the import customs tariffs to exempt low-global-warming-potential (GWP) refrigerants (including HFC-32, R-290, R-600a, R-717, and R-744) from the 5 per cent tariff assessed on HCFC-22, HFCs and blends of HFCs.

Activities in the manufacturing sector

Extruded polystyrene foam manufacturing

7. Stage II included the conversion of four XPS foam manufacturers (CMB, Insutech, Chema-Foam, and Modern Plastics) with a total consumption of 559.0 mt of HCFC-22 and 24.3 mt of HCFC-142b to a 60/40 blend of HFO-1234ze and dimethyl ether. Equipment for the four manufacturers was delivered and installed, and safety inspections initiated. Those conversions have been completed and memoranda of understanding finalized to enable the payment of incremental operating costs (IOCs), expected by December 2024.

Polyurethane foam manufacturing

8. Stage II included the phase-out of HCFC-141b through the conversion of the remaining enterprises in the polyurethane (PU) foam manufacturing sector, including the conversion to cyclopentane of eight enterprises manufacturing domestic refrigerators to phase-out 372.5 mt of HCFC-141b; of two enterprises manufacturing electric water heaters to phase-out 50.0 mt of HCFC-141b to cyclopentane; and a group project to replace 114.4 mt of HCFC-141b used by 38 small- and medium-sized enterprises (SMEs) with methyl formate. Those conversions have been completed with the exception of conversion at one enterprise, Bahgat.

9. At the 92nd meeting, UNIDO reported[3] that Bahgat had withdrawn from the project and exited the domestic refrigeration manufacturing sector given market changes following the COVID-19. As UNIDO had already purchased and delivered the equipment to convert the enterprise, in line with decision 79/34(e), UNIDO sought to find another enterprise who could use the equipment rather than attempt to auction it.

[3] Paragraphs 31 to 36 of document UNEP/OzL.Pro/ExCom/92/9.

While UNIDO had been unable to find an enterprise for which funding had not been requested, Tredco, an eligible enterprise that was participating in stage II of the HPMP, wished to purchase the existing manufacturing line from Bahgat and use the equipment procured by UNIDO to convert the line, effectively moving the manufacturing line to its own facility. Accordingly, UNIDO had proposed to provide the equipment to Tredco and use the remaining balances from the PU foam manufacturing project (US $7,214) to transport the equipment from Bahgat to Tredco, for any required engineering work, and to destroy/render unusable the existing HCFC-141b-based foaming machine. On an exceptional basis, the Executive Committee approved that request (decision 92/12).

10. Subsequently, UNIDO reported that the two enterprises Bahgat and Tredco had not been able to agree on terms for the transfer of the equipment and asked the Secretariat whether it could invite another PU foam manufacturing, Siltal, to purchase the existing manufacturing line from Bahgat so that Siltal could, with UNIDO's assistance, convert the line to cyclopentane. On an exceptional basis, and noting that the goal of the change of beneficiary at the 92nd and the present meeting remained the same, namely, to ensure that equipment procured by the Multilateral Fund would not need to be auctioned but could instead be used to assist an eligible enterprise by converting eligible HCFC capacity to cyclopentane, the Secretariat advised UNIDO to proceed with the change in beneficiary, noting that Siltal met the same conditions that Tredco had met at the 92nd meeting, i.e., (a) Siltal would otherwise need to purchase similar equipment, (b) the specifications of the existing equipment are consistent with Siltal's needs so that the enterprise can quickly use the equipment once the necessary civil works are completed, (c) the remaining balances (US $7,214) would not be used for civil works but the cost for any civil work would be covered by Siltal, and (d) the remaining balances will be used only to transport the equipment, for any necessary engineering, and to destroy/render unusable the existing HCFC-141b-based foaming machine.

11. The enterprises Siltal and Bahgat have concluded an agreement for the transfer of the equipment. At the time of finalization of the present document, UNIDO was making the required arrangements with the technology provider and the enterprises to complete the transfer and installation.

Residential air-conditioning manufacturing

12. Stage II included the conversion of five residential air-conditioning (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)). Equipment for El-Araby, Fresh, Power, and Unionaire has been delivered and installed, and commissioning has been completed at all enterprises except Power. Equipment for Miraco had been procured but, due to delays in importing the equipment, not yet delivered; delivery and installation are anticipated to be completed by December 2024.

13. In line with decision 88/70(a)(ii), UNIDO provided an update on the Government's timeline for the transition of residential AC manufacturing enterprises to the exclusive manufacture of low-GWP equipment for the local market. As had been proposed at the 88th meeting, the Government will require that the five manufacturers exclusively manufacture residential AC equipment with HFC-32 for the local market by 1 January 2028. However, with a view to establishing a timeline more rapid than that indicated in table 3 of document UNEP/OzL.Pro/ExCom/88/47, the Government would require enterprises to exclusively manufacture residential AC equipment with HFC-32 for the local market by 31 December 2026 in order to be eligible to receive IOCs. Accordingly, UNIDO signed contracts for disbursement of IOCs in line with that timeline for El-Araby and Fresh; Unionaire agreed to a more rapid timeline in its IOC contract (i.e., 1 January 2025). The contract with Power was expected to be signed in the third quarter of 2024; like Unionaire, the enterprise agreed to a more rapid timeline to exclusively manufacture residential AC equipment with HFC-32 for the local market by 1 January 2025. Given the delays in the conversion for Miraco, an IOC contract for that enterprise has not yet been developed.

14. In line with decision 88/70(a)(ii), UNIDO also submitted the results of the risk assessment and market assessment studies relating to the residential AC manufacturing sector; those reports are appended to the present document. The risk assessment inter alia found that for the scenarios considered, the likelihood an ignition source is present in conjunction with a flammable concentration of leaked HFC-32 refrigerant is 10^{-9} ("extremely difficult") across all severity categories, and therefore the risk associated with the use of HFC-32-based residential AC is considered acceptable. The key conclusions from the market acceptance study included inter alia that energy efficiency was a top priority for consumers; availability of robust after-sales service will be important to ensuring the market acceptance of HFC-32-based residential AC units; consumers are willing to accept a modest increase of 5 per cent in the price of AC units for eco-friendly specifications; and digital media platforms were recommended as the primary communication channel to convey the benefits of eco-friendly AC and engage with consumers.

Commercial air-conditioning manufacturing

15. Stage II included the 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 (IEC), resulting in a hybrid IEC-direct expansion unit (IEC-H). At the 88th meeting, UNIDO reported that during consultations with stakeholders, an additional three commercial AC manufacturers (Tiba Engineering Industries, Misr Engineering and Industries, and Miraco-Carrier)[4] expressed an interest to participate in the project; following consultations with the Secretariat, letters confirming their participation, including the commitment to ensure that that equipment would be converted to only low-GWP alternatives for the direct expansion component, were received.

16. UNIDO submitted a report on the outcome of the technical assistance provided to the commercial AC manufacturing enterprises that inter alia found 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. An economic analysis showed net savings of the IEC-H unit given the reduced electricity consumption of the unit relative to a direct-expansion unit, and after taking into account the initial higher cost of the IEC-H unit, and higher water costs. The break-even period for the unit was 3.11 years. The report is appended to the present document.

17. As part of the campaign to raise awareness of low-GWP, energy-efficient commercial AC equipment, IEC-H units manufactured by the enterprises were exhibited at the 15th International Conference on Sustainable Construction and Nano-technology Advances in Fire Safety, HVAC-R, and Built Environment held in Cairo, 2-3 March 2024. That exhibition also included an IEC-H unit manufactured by a seventh enterprise, Smart Sustainable Air Technology that became aware of the technology as a result of project. Four enterprises (DCM, Volta, Tiba Engineering Industries, Misr Engineering and Industries) were now offering IEC-H units as part of their regular manufacturing.

Refrigeration servicing sector

18. The following activities were implemented under the third tranche:

(a) Trainings were held for 115 customs officers and importers (including 19 women) covering illegal and fraudulent refrigerants, the refrigerant market surveillance programme, and implementation of the 1 January 2023 bans; and 375 (150 women) technicians were trained in good servicing practices for RAC equipment;

[4] 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.

(b) Green procurement training was conducted for 471 governmental officers and consultants (87 women) as part of refrigerant code enforcement training; another training is planned for May 2024;

(c) Equipment was procured for eight training centres (recovery units, vacuum pumps, Lokring sets, leak detectors, four-valve manifold gauges, and servicing tools); and

(d) Servicing tool kits and equipment were delivered to seven training centres.[5]

19. The following activities were delayed and were in various states of implementation:

(a) Regulatory and institutional tools to enforce the certification programme are still being designed, and training and outreach on local codes and standards have not yet taken place;

(b) The pilot technician certification programme was launched through a contract to certify after-sales technicians; the first batch of technicians has yet to be certified. The 167 previously procured recovery tool kits (e.g., recovery unit, cylinder, vacuum pump, set of servicing tools) are still awaiting distribution to service shops with certified technicians;

(c) Four national codes were reviewed, with updates to the code for district cooling completed; updates for the code related to sustainable cooling in new urban communities almost completed;[6] updates for the code related to heating, ventilation, and AC initiated; and updates for the code related to the cold chain to be started;

(d) Two hundred sets of equipment (e.g., recovery machines, vacuum pump and gauge, high-accuracy pressure gauges, cylinders, thermometer) were procured for the pilot refrigerant recovery and reclamation centre; those equipment sets will be distributed to workshops to collect controlled substances for reclamation at the centre that has been established. The reclamation centre is awaiting finalization of a work permit, expected to be issued by 31 May 2024, before receiving recovered refrigerants and beginning reclamation; the target recovery of at least 80 mt and reclamation at least 56 mt of refrigerants is expected to be met by June 2026;

(e) An assessment of equipment needs for the AC after-sales service network was completed and a contract was signed with a safety expert to advise on necessary safety measures for the after-sales service network's centres, with the procurement of portable service tool kits for field teams and support tools for after-sales centres not yet complete;

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

(g) The delivery of equipment for the training institute that had been selected to house the centre of excellence (COE) for flammable refrigerants, expected to be delivered by March 2022, has been delayed; the training material has been prepared and the centre is expected to be operational following delivery of the equipment;

[5] Including recovery units, a Lokring set, training appliances with different refrigerants, service tools and consumables.
[6] As highlighted by the Ministry of International Cooperation, new cities in the country will be established as part of the smart cities programme, which are to be powered by renewable energy and smart technology, sustainable and green infrastructure, and connected through multi-modal transport networks (https://sponsored.bloomberg.com/article/ministry-of-international-cooperation/egypts-new-cities; accessed 10 April 2024).

(h) The draft guidebook on good servicing practices for training curricula, expected to be finalized by December 2022, was prepared but is still under review and comment; and

(i) The development of the refrigerant tracking system based on the introduction of quick response (QR) codes for refrigerant cylinders has been initiated but not yet completed; QR codes for refrigerant cylinders are expected to be mandatory by 2026.

20. The following activities have not yet begun:

(a) Activities for the on-site training programme on good servicing practices for small workshops employing one or two technicians and consuming two to three cylinders of refrigerants per month has not yet started. Between 150 and 200 technicians were expected to be trained and receive participation certificates. Those trainings will be supplemented by additional trainings for small workshops under the fourth tranche; and

(b) Egypt had planned to introduce the Refrigeration Driving License (RDL) as a national parallel certification programme, with the pilot launch of the RDL expected in 2022; the country will continue with the after-sales certification programme and may introduce the RDL in 2029.

Project implementation and monitoring

21. 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 third tranche total US $125,702 (of the allocated US $245,000), including staff and operational costs (US $86,880), consultants (US $13,822), support to the domestic AC conversion (US $10,000), and contingency (US $15,000).

Level of fund disbursement

22. As of March 2024, of the US $17,361,573 approved so far, US $10,815,162 had been disbursed (US $7,236,700 for UNIDO, US $2,639,762 for UNDP, US $731,400 for UNEP, and US $207,300 for Germany), as shown in table 2. The balance of US $6,546,411 is expected to be disbursed between 2024 and 2026.

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

Tranche		UNIDO	UNDP	UNEP	Germany	Total	Disbursement rate (%)
First	Approved	3,356,641	1,042,352	230,000	0	4,628,993	95
	Disbursed	3,117,186	1,035,119	230,000	0	4,382,305	
Second	Approved	4,668,214	1,836,750	279,500	207,300	6,991,764	70
	Disbursed	2,960,540	1,448,333	279,500	207,300	4,895,673	
Third	Approved	4,664,196	816,620	260,000	0	5,740,816	27
	Disbursed	1,158,974	156,310	221,900	0	1,537,184	
Total	**Approved**	**12,689,051**	**3,695,722**	**769,500**	**207,300**	**17,361,573**	**62**
	Disbursed	**7,236,700**	**2,639,762**	**731,400**	**207,300**	**10,815,162**	
	Balance	**5,452,351**	**1,055,960**	**38,100**	**0**	**6,546,411**	

Implementation plan for the fourth tranche of stage II of the HCFC phase-out management plan

23. Activities under the fourth tranche will be implemented between June 2024 and December 2026 and are summarized in table 3.

Table 3. Summary and cost of activities to be implemented under the fourth tranche

Activity		**Agency**	**Cost (US $)**
Manufacturing	Complete the conversion of the five residential AC manufacturing enterprises	UNIDO	3,249,213
Policy and enforcement	Procure and deliver 15 refrigerants identifiers to customs and import agents	UNIDO	60,000
	Continued enforcement of the regulatory network and update of national codes	UNEP	10,000
	Five workshops to train 75 customs and related stakeholders on controlling the import and export of controlled substances	UNEP	15,000
	Five awareness-raising workshops for 60 customs stakeholders on the QR codes refrigerant tracking system	UNEP	15,000
	Update local codes and standards to support the refrigerant containment and leakage prevention programme, and hold four awareness-raising workshops for 200 participants to enforce the updated codes	UNEP	40,000
Refrigeration servicing	Provision of RAC servicing equipment for the upgrade of a further eight training centres (e.g., recovery units, vacuum pumps, Lokring sets, leak detectors, four-valve manifold gauges, and servicing tools)	UNIDO	80,000
	Complete provision of portable service tool kits for field teams and support tools to after-sales centres of five residential AC manufacturers (incudes three under the present tranche), and training and certifying 100 after-sales technicians	UNIDO	50,000
	A further ten on-site training workshops to train 150 to 200 technicians on good servicing practices for small workshops employing one or two technicians and consuming two to three cylinders	UNIDO	20,000
	Training of a further 375 technicians in good servicing practices for RAC equipment	UNEP	50,000
Recovery and reclamation	Provision of 200 additional recovery tool kits, including recovery units and cylinders, and distribution of all tool kits to service shops with certified technicians	UNIDO	250,000
	Support to the existing reclamation centre, and establishment of a second reclamation centre that has already been identified	UNIDO	150,200
Awareness-raising	An awareness campaign for consultants, contractors, and other relevant stakeholders on the existence and use of alternative refrigerant technologies	UNEP	15,000
Project management	Staff, meetings and travel, documentation and reporting, and operational expenses (US $90,000); consultants, monitoring and evaluation of implementation, and verification reports (US $40,000), support to the domestic AC conversions (US $35,000), and contingency (US $15,000)	UNIDO	180,000
	Meetings (US $9,000), consultants (US $10,000), and travel (US $16,000)	UNEP	35,000
Subtotal (UNIDO)			4,039,413
Subtotal (UNEP)			180,000
Total			**4,219,413**

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

Report on HCFC consumption

24. The Secretariat sought to understand the reasons why the country's reported consumption of HCFC-22 in the servicing sector almost tripled between 2022 and 2023. Further to a discussion, UNIDO clarified that this increase was because refrigerant suppliers stockpiled HCFC-22 given expected increases in the price of HCFC-22. That increase in price is expected due to the large reduction in quotas that will be implemented in 2025, in line with targets specified in the Agreement between the country and the Executive Committee.

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

Legal framework

25. The Government of Egypt has already issued HCFC import quotas for 2024 at 241.08 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.

Activities in the manufacturing sector

Residential air-conditioning manufacturing

26. In reviewing the planned regulatory measures submitted to the 88th meeting in line with decision 84/72(e)(i)d, the Secretariat had considered those measures would be insufficient to enable the successful uptake of the technology by the completion of stage II. Accordingly, the Executive Committee had inter alia requested UNIDO to present as part of the submission requesting the fourth tranche a comprehensive regulatory framework to ensure the uptake of the agreed low-GWP technology (decision 88/70(a)(ii)a.). Accordingly, UNIDO submitted a comprehensive summary the country's regulations. In reviewing that information, the Secretariat noted that the country has robust regulations in place to enable its compliance with the HCFC phase-out targets of the Montreal Protocol. However, with the exception of import tariffs granted to HFC-32 and low-GWP refrigerants, the Secretariat understands the Government has not yet implemented regulations designed to enable the uptake of HFC-32-based residential AC units versus R-410A-based residential AC units in the local market.

27. In addition, while noting the progress in converting the manufacturing lines to enable the manufacture of HFC-32-based residential AC units, the Secretariat sought clarification on the relative proportion of R-410A-based and HFC-32-based units that were manufactured by the five enterprises. UNIDO clarified that between 1 January 2023 and 13 March 2024, the enterprises had manufactured a total of 1,294,642 residential AC units, of which 507 (0.04 per cent) were based on HFC-32.

28. In light of the apparent absence of regulatory measures and limited manufacturing noted above, and noting that the country had ratified the Kigali Amendment on 22 August 2023 and that UNIDO planned to submit stage I of the country's Kigali HFC implementation plan (KIP) to the 95th or the 96th meeting, the Secretariat sought to better understand the nexus between the timeline of manufacturing low-GWP-based AC residential units for the local market under the HPMP and activities planned under KIP. UNIDO clarified that in addition to the five enterprises manufacturing residential AC units that were being converted under the HPMP, there were seven enterprises manufacturing R-410A-based residential AC units; that of those seven enterprises, UNIDO considered that six may be eligible under the country's KIP, though this remained to be confirmed; that the intention of the Government was to include the conversion of the entire

residential AC manufacturing sector to HFC-32 as part of stage I of the KIP; and that the timeline for the implementation of the KIP was 2025 to 2029. UNIDO further informed that as part of KIP preparation, a comprehensive survey and data collection was being undertaken on the additional residential AC manufacturing enterprises; therefore, data on the relative proportion of R-410A manufacturing of residential AC units for the local market at the five enterprises participating in the HPMP versus at the seven remaining enterprises was not yet available.

29. In reviewing the proposal at the 84th meeting, due to an inadvertent misunderstanding, the Secretariat had understood that the five enterprises being converted under the HPMP constituted the entire residential AC manufacturing sector and, on that basis, had proposed a number of policy and regulatory measures the Government could consider to ensure the successful implementation of the project; accordingly, the Executive Committee had noted the commitment of the Government to inter alia: ensure the full control of R-410A- and R-407C-based residential AC equipment, imported or placed in the local market; secure the uptake of the HFC-32 and, should the enterprises so decide once the technology became available, R-454B, by the local market; present an update on regulatory measures planned or introduced and a planned timeline for the enterprises to manufacture exclusively for the local market using HFC-32 or an alternative with lower GWP, as part of the submission of the third tranche in 2021 (decision 84/72(e)(i)b-d). The Secretariat is not clear how the Government could develop a comprehensive regulatory framework to ensure the uptake of the HFC-32 technology if some enterprises converted their manufacturing for the local market to HFC-32, while others continued to manufacture R-410A-based equipment for the local market. For example, the Secretariat is not clear whether the Government could, as proposed, impose an import tariff on R-410A-based equipment while enterprises in the country continued to manufacture such equipment given the World Trade Organization’s principle of non-discrimination.

30. In addition, the Secretariat noted that the Government had notified the Ozone Secretariat of its intent to use the high-ambient temperature exemption described in paragraphs 26 to 37 of decision XXVIII/2, which includes inter alia residential AC equipment as part of the list of exempted equipment.

31. Notwithstanding these circumstances, the Secretariat notes that in general, where Article 5 countries have decided to convert their residential AC to HFC-32 technology, those conversions have been implemented. The Secretariat considers the commitment by the Government and those enterprises 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 meaningful, and noted with appreciation UNIDO’s confirmation that it would not pay incremental operating costs until it had verified that the enterprises were manufacturing equipment using HFC-32, in line with decision 77/35(a)(vi). Accordingly, it was agreed that the Secretariat would recommend approving the funding allocated for the residential AC manufacturing sector under the fourth tranche except for the agreed IOCs for the two enterprises that had not yet signed IOC contracts (i.e., Miraco and Power, for which IOCs of US $1,454,835 and US $284,280 had been agreed), on the understanding that UNIDO, on behalf of the Government, could submit a request for the funding remaining under the fourth tranche (i.e., US $1,739,115) to the same meeting it submits stage I of the KIP or to the 96th meeting, whichever comes first.

Commercial air-conditioning manufacturing

32. The report submitted to the present meeting indicates that IEC-H units break new ground for not-in-kind AC technologies and provide an alternative system for AC applications that exceeds the efficiency of existing direct expansion systems. While the Secretariat agrees with that encouraging assessment, and notes that other Article 5 countries with commercial AC manufacturing may wish to consider the report’s findings, the Secretariat noted that the refrigerant used in the hybrid IEC-H units was R-410A rather than HFC-32 or a low-GWP alternative as agreed during project approval. UNIDO explained that this was because of a lack of availability of key components (e.g., compressors, expansion valves) at the time, but those components were now available. Accordingly, UNIDO expects to test HFC-32-based

(and, if available, R-454B-based) units at the climate zone with the highest dry-bulb ambient temperatures and lowest humidity during the summer of 2024.

33. At the 79th meeting, it was noted that the sustainability of the conversion in the commercial AC manufacturing sector was a primary concern given that the market already used high-GWP HFCs 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.[7] At the 88th meeting, UNIDO noted that the selection of policies and measures depended on the successful completion of the technical assistance activities, including the building and testing of prototypes, and for the development of the IEC-H technology, which was expected to be completed by September 2022. Accordingly, the Executive Committee had requested UNIDO to present, as part of the submission requesting the fourth tranche, proposed policy measures to ensure the sustainability of the conversion to low-GWP alternatives in the commercial AC manufacturing sector (decision 88/70(a)(ii)b.) UNIDO indicated that policy measures would be developed following the additional testing planned for the summer of 2024. The Executive Committee may also wish to consider any information related to the commercial AC manufacturing sector, including possible policy measures, when it considers stage I of the country's KIP, expected by the 96th meeting.

Refrigeration servicing sector

34. The Secretariat noted that a number of activities planned for the servicing sector had been delayed, including inter alia the development of regulatory and institutional tools to enforce the certification programme, and training and outreach on local codes and standards; the finalization of the guidebook for training curricula; the certification of 500 technicians under the pilot certification programme; the finalization of four national codes; the pilot inspection and certification of a few buildings; and the implementation of mandatory QR codes for refrigerant cylinders. While noting that the COVID-19 pandemic may have contributed to those delays, and the implementation of some of the planned measures were novel and may take time (e.g., building certification programme, QR codes for refrigerant cylinders), the Secretariat urged UNIDO and UNEP to intensify their efforts to assist the country, noting the large reduction in the 2025 target specified in the Agreement between the country and the Executive Committee.

35. In reviewing the proposal at the 79th meeting, the Secretariat had considered the training that would be provided to small workshops (i.e., those workshops with only one or two technicians, and consuming only two to three refrigerant cylinders each month) particularly useful given the likely limited capacity of those workshops. The Secretariat similarly encouraged UNIDO to intensify its efforts to provide the trainings that had been planned under the third tranche, and those planned under the fourth tranche. The Secretariat also noted that pending the outcomes of the after-sales certification programme, the country may introduce the RDL in 2029.

36. Given that the reclamation centre had been identified in 2021, the Secretariat sought to better understand the reason for the delay in securing the necessary permit to enable its operation. UNIDO clarified that while the centre had a permit for refilling refrigerants, it did not have a permit for reclamation activities, which was a new category of business operations recently created by the Ministry of Industry. While the second reclamation centre to be established under the fourth tranche similarly needed a permit for reclamation activities, UNIDO did not expect this would cause a delay as the new category of business had already been established.

37. There have been delays in the clearance by customs of equipment procured under the project, including for the COE for flammable refrigerants. In particular, while most of the equipment had

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

successfully cleared customs, some tools were still in the process of clearance; the training workshops to be undertaken at the COE would take place once the equipment had been delivered. At the 93rd meeting, the Executive Committee approved the extension, to 30 June 2024, of the completion date of training component implemented by Germany (EGY/PHA/84/INV/142). The Secretariat recommends extending the project to 31 October 2024 to allow the remaining equipment needed for the trainings to clear customs, and the trainings to be undertaken.

Gender policy implementation

38. Stage II of the HPMP was approved prior to the approval of the operational policy on gender mainstreaming (decision 84/92(d)). Nonetheless, female engineers participated in the conversion projects at El-Araby and Fresh, and the national ozone unit (NOU) tracked the participation of women in training activities (reported above). Three women participated in the train-the-trainers workshop, and three female engineers received certificates of appreciation from the Minister of Environment, Minister of Manpower, and the Minister of Social Solidarity, highlighting their contributions in organizing the train-the-trainers workshop and upgrading the training centre to be able to train on flammable refrigerants. It is hoped that those trainings and certificates of appreciation will help encourage further participation of female trainers and technicians in subsequent trainings. The draft policy to promote gender mainstreaming prepared by the NOU has yet to be finalized.

Sustainability of the HCFC phase-out and assessment of risks

39. To ensure the sustainability of the conversion in the XPS and PU foam sectors, the Government has implemented a ban on use of HCFCs to manufacture of XPS foam (as of 1 January 2023), on imports of HCFC-141b (1 January 2020) and of HCFC-141b contained in pre-blended polyols (1 January 2018). The Government has also banned the import of HCFC-142b and of R-406A, and banned the import and manufacture of HCFC-based equipment, on 1 January 2023. Those measures, and the implementation of the country's licensing and quota system, will help ensure the sustainability of the HCFC phase-out.

40. The substantial increase in consumption of HCFC-22 in 2023 was likely due to stockpiling; such stockpiling is unlikely to persist and may reduce imports of HCFC-22 in 2024 and 2025. The Secretariat noted the substantial reduction in consumption required to meet the 2025 target, and encouraged UNIDO and UNEP to continue to assist the country implement the planned activities under the HPMP that will help the country remain in compliance with its Agreement with the Executive Committee.

41. While the Secretariat considers the risks to the sustainability of the HCFC phase-out in the residential and commercial AC manufacturing sectors to be low, assessing the risks to the sustainable conversion to low-GWP technologies in those sectors is difficult given the dominant use of R-410A in the country for those applications and in the absence of the information that will be provided when the country submits stage I of the KIP, including how, if at all, the country would apply the high-ambient temperature exemption for those sectors; a comprehensive picture of the R-410A residential and commercial AC manufacturing sector in the country; additional conversions that may be included under that plan; and policy and regulatory measures that may be included under that plan that could help facilitate the market uptake of the technologies agreed under the HPMP. A joint submission of stage I of the country's KIP with a request for the remaining US $1,739,115, plus agency support costs for UNIDO, will enable the Executive Committee to have a comprehensive understand of those matters. Given the remaining balances held by UNIDO, the Secretariat considers that delaying the consideration of the remaining funding under the fourth tranche to the 95th or 96th meeting is unlikely to unduly delay the completion of the conversions in the residential AC manufacturing sector. Conversely, the Secretariat considers that the approval of the requested funding will help enable those residential AC manufacturing enterprises that had signed IOC contracts to exclusively manufacture residential AC equipment with HFC-32 for the local market by 1 January 2025 or 31 December 2026. That timeline, which is more rapid than that indicated in table 3 of

document UNEP/OzL.Pro/ExCom/88/47, will help build confidence in the technology and should facilitate subsequent conversions.

Conclusion

42. The country's import licensing and quota system is operational, and the verified 2021, 2022, and 2023 consumption is below the targets specified in the country's 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 third tranche is 27 per cent, and 62 per cent of the funds approved to date. While technical assistance has been undertaken to assist the commercial AC manufacturers in the country to manufacture equipment based on a novel technology, IEC-H, the enterprises are not yet manufacturing such equipment with HFC-32 or low-GWP alternatives. Additional testing, planned for the summer of 2024, will enable such manufacturing. In addition, while equipment to manufacture HFC-32-based residential AC units has been installed at four out of the five enterprises participating in the HPMP, manufacturing for the local market at those enterprises remains almost exclusively based on R-410A, and additional enterprises manufacturing R-410A-based residential AC units for the local market have been identified. The Secretariat considers the country's ratification of the Kigali Amendment and the decision by the Government to make IOCs available only to those enterprises that exclusively manufacture residential AC units with HFC-32 for the local market by 31 December 2026 (or earlier) to be important signals to industry and the market, and should help enable those conversions to HFC-32. Given the substantial reduction in the 2025 target, continued and sustained efforts on the part of the Government, with the support of UNIDO and UNEP, will be required to ensure the country continues to meet the targets specified in its Agreement with the Executive Committee.

RECOMMENDATION

43. The Executive Committee may wish to consider:

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

(b) Approving the extension, to 31 October 2024, of the completion date of stage II of the HPMP for Egypt (second tranche) (EGY/PHA/84/INV/142) to allow completion of the remaining ongoing activities; and

(c) Of the fourth tranche of stage II of the HPMP for Egypt, approving US $2,662,825, consisting of US $2,300,298, plus agency support costs of US $161,021, for UNIDO and US $180,000, plus agency support costs of US $21,506, for UNEP, and the corresponding 2024-2026 tranche implementation plan, on the understanding that UNIDO, on behalf of the Government, would submit the request for the remaining funding under the fourth tranche of US $1,739,115, plus agency support costs of US $121,738, for UNIDO to the same meeting that stage I of the country's Kigali HFC implementation plan is submitted or to the 96th meeting of the Executive Committee, whichever comes first.

Background

This component covers the risk assessment of the places where explosive atmospheres may occur by classification of areas followed by arrangements to deal with accidents and emergencies, in addition to instructions and training for people in the area, along with the design and installation of safety systems.

Residential Air Conditioning Risk Assessment from 1 to 3 ton using R32 chosen as a model in Egypt which considered a HAT country (High Ambient Temperature).

1- Flammability definition and classes

For a fire to happen there needs to be three elements: a rapid leak of the flammable gas, a concentration higher than the lower flammability level, and a source of ignition as shown in figure below.

Figure 1 shows the probability of ignition as the resultant of these three elements. Lower Flammability Limit (LFL), usually expressed in volume per cent, is the lower end of the concentration range over which a flammable gas can be ignited at a given temperature and pressure.

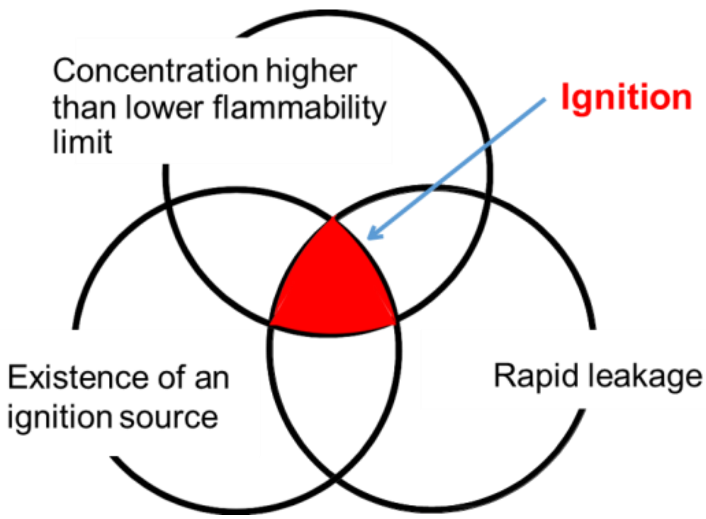

Figure 1: FACTORS AND PROBABILITY OF IGNITION

Probability = [rapid Leakage] x [High Concentration] x [Ignition Source]

Flammability Classification for Refrigerants: Table 1 shows the classes of flammability as defined in ISO 847 and ASHRAE 34.

TABLE 1: FLAMMABILITY CLASSIFICATION FOR REFRIGERANTS

Class	
1	No flame propagation when tested at 60°C and 101.3 kPa
2	Flame propagation and LFL > 0.1 kg/m3 and HOC < 19,000 kJ/kg
2L	Same as 2 except Burning Velocity < 10 cm/s
3	Flame propagation and LFL <= 0.1 kg/m3 and HOC >= 19,000 kJ/kg

2- Definition of Risk

- **Risk** is a combination of the probability of concurrence of harm and the severity of that harm.
- **Tolerable risk** is the level of risk that is accepted in a given context based on the current acceptable values by a community.
- **Residual risk** is the risk remaining after reduction measures have been implemented. Safety is freedom from risk which is not tolerable.

The risk levels depend on the severity of injury, the amount of damage to the environment, the frequency at which people are exposed to the danger and the duration of exposure.
Tolerable risk is determined by the search for an optimal balance between the ideal absolute safety and the demands to be met by a product. The factors influencing risk are the practicality and means to reduce risk, the benefit to users, cost effectiveness, and social conventions.

The concept of tolerable vs. unacceptable risk was introduced based on the probability of harm and the severity of harm as per Figure 2.

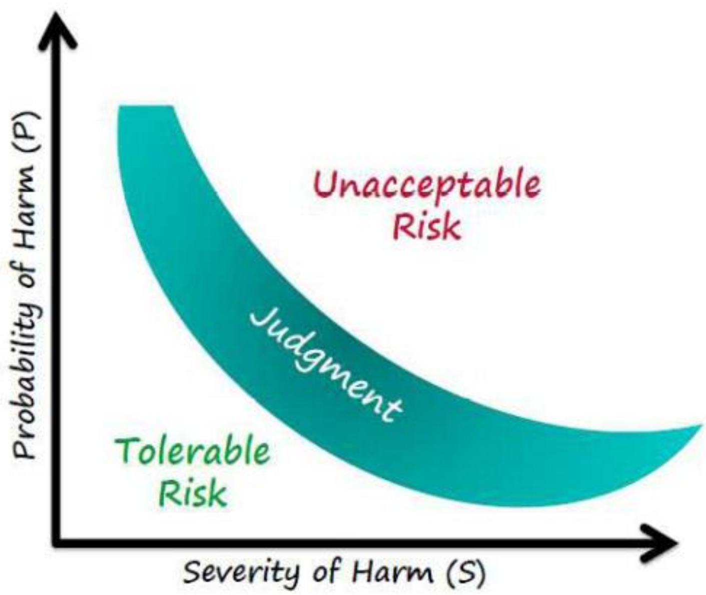

FIGURE 2: TOLERABLE VS. ACCEPTABLE RISK (SOURCE: UL)

3- Process of a Risk Assessment Model

The Risk Assessment model is based on the workshop that was held in japan in cooperation with Japan Refrigeration and Air Conditioning Industry Association (JARAIA) in April 2019. The workshop was dedicated to the study of a risk scenario prepared by the PRAHA team, and also the following should be taking into consideration;

- An outline of the methodology and the components that are the basis for the risk assessment model.
- A model of what data can be collected.

- Information on the regulatory regime and the enforcement mechanisms.
- International standards play a role in the next step of risk assessment in the form of recommendations for local standards.
- Rigorous regulations as those adopted in other regions must be adapted to HAT countries.
- Stakeholders: governments and local research institutions, industry and private sector, and UN Environment & UNIDO.

3.1. Selection of equipment type and Life stage for the risk assessment model

Residential air conditioning unit is chosen, as it is the most used type in number of units and where the risk might be greatest, also servicing of the indoor unit as the most relevant for the model. Figure 3 identify the life stages of the residential air conditioning.

FIGURE 3: AC LIFE STAGES

3.2. Procedure of Risk Assessment

The process that will be used is outlined in Figure 4, according to ISO/IEC 51 (Source: JRAIA)

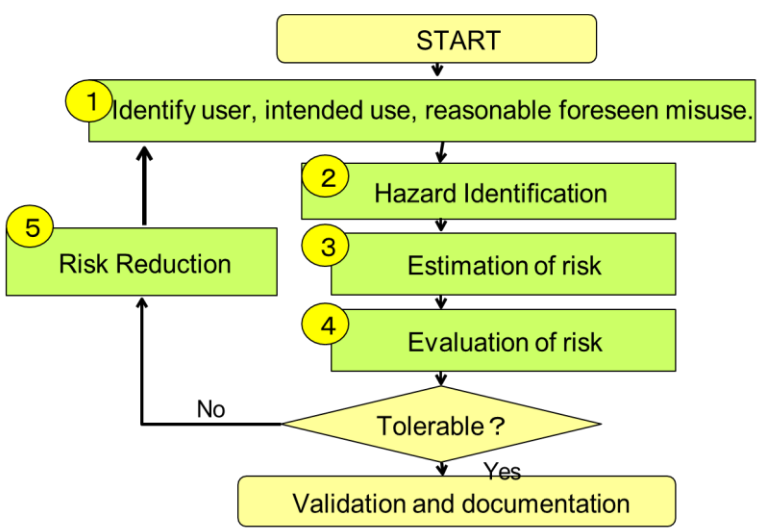

FIGURE 4: PROCEDURE OF RISK EVALUATION

3.3. Acceptable and tolerable risk:

Tolerable risk depends on the number of units in the market of the product identified, also on the frequency and severity of the accident.

JRAIA defines risk in terms of probability and frequency vs. severity. A low risk is where the probability of an accident is lower and the severity is least. An extreme risk is where the probability is high and the severity is also high.

Table 2 shows the frequency of accidents vs. severity. Frequent accidents leading to catastrophic events are the least acceptable, while improbable of incredible (as in incredibly low frequency) with the least severity are socially acceptable.

TABLE 2 RISK MATRIXES - FREQUENCY VS. SEVERITY (SOURCE JRAIA)

.	**None**	**Negligible** (slight injury)	**Marginal** (need for outpatient treatment)	**Critical** (serious injury or need to be hospitalized)	**Catastrophic** (death)
Frequent	C	B3	A1	A2	A3
Probable	C	B2	B3	A1	A2
Occasional	C	B1	B2	B3	A1
Remote	C	C	B1	B2	B3
Improbable	C	C	C	B1	B2
Incredible	C	C	C	C	C
A = Unacceptable risk levels: 1=least, 3= highest		B= Risk levels should be reduced 1= least, 3= highest		C= Socially acceptable risk levels	

3.4. Product Cycle

The life cycle range for assessment is shown in Figure 5. Each stage has to be assessed separately and added together to get to the total risk.

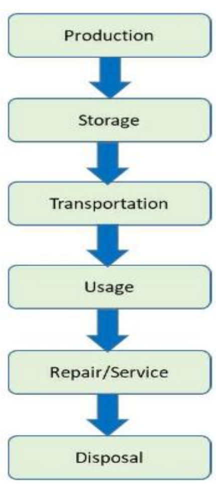

FIGURE 5: LIFE CYCLE RANGE FOR ASSESSMENT

The determination of tolerable risk depends on the population of products in the country. The example from Japan is in Table 3:

TABLE 3: DETERMINATION OF TOLERABLE RISK LEVELS

Product/System	Unit Population	Tolerable risk	
		Usage stage	Service stage
Residential AC	1×10^{8}	1×10^{-10}	1×10^{-9}

The JRAIA approach is used to set the tolerable risk for residential units at the following levels:

For the usage stage = 1 / 100 x unit population
For the service stage = 1 / 10 x unit population

And the risk map becomes as in Figure 6:

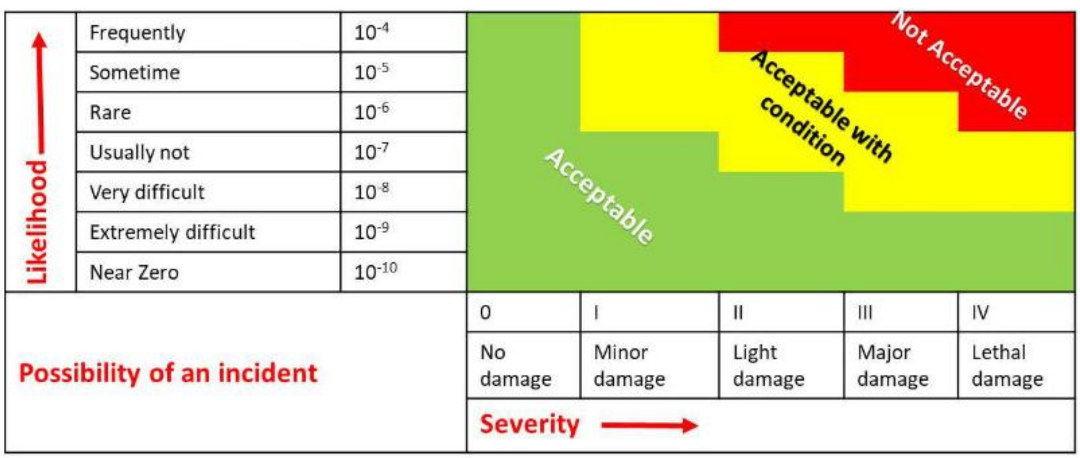

FIGURE 6: RISK MAP

4- Risk Scenarios

A critical stage of the risk assessment is to identify those scenarios in which an ignition source is present in conjunction with a flammable concentration of leaked refrigerant. To better understand these scenarios, one must consider the various triggering events which could cause refrigerant to be released, the location of the release, and the specific type of person that might be present (i.e., a worker, repair person or customer) at the time of the release. It is important to note that, during normal operations, the refrigerant will be contained within the system, and thus there is no risk of adverse events associated with these refrigerants during regular use.

However, if refrigerant leaks from the equipment and is not dispersed prior to accumulating to a flammable concentration and a sufficient energy source is present, refrigerant ignition could occur (AHRTI 8009)

The fault tree analysis (FTA) is chosen.

The risk assessment of flammable refrigerants considers two individual phenomena: the presence of an ignition source and the generation of a flammable volume. The risk scenarios that were considered were:

A. Refrigerant leak during maintenance work on the indoor unit during brazing and due to pipe breakage by corrosion with an ignition source caused by live wire, static electricity, or electric tool such as screw drivers

B. Refrigerant leak during brazing of outdoor unit with leakage caused by prior maintenance work or during maintenance work and an ignition source from the brazing torch;

C. Refrigerant leakage during normal home use caused by pipe breakage through corrosion, external pressure or natural causes such as earthquakes with an ignition source of an open flame, electric spark or static electricity.

5- Select Risk Analysis Sources

The input into the model is taken from data tables for the type of application and usage of the equipment that are being studied. Source for input into the volume of the flammable cloud can be taken from research done for the type of gas. Data for source and time of ignition can sometimes be available from the fire department.

6- Data Collection

Data collection takes into consideration the following:

a) Select the stages of the life cycle of the air conditioners. Choose the manner of classification of manufacturing, transportation, use, service, and disposal of an air conditioner into separate stages for evaluation. The evaluation of the manufacturing stages of each product is normally the responsibility of the manufacturer.

b) Investigate the conditions of installation of the selected air conditioner to determine the conditions to be evaluated during the risk assessment.

c) Determine the severity of the hazard focusing on the damage caused by flammability.

d) Set tolerance levels. Set socially acceptable probability of harm for the air conditioner.

e) Investigate refrigerant leakage rate, speed, and amount based on surveys conducted with air conditioning service companies. The initial leakage location and leakage concentration should also be determined.

f) Determine flammable time volume through CFD or calculations. For the conditions set as per point (b), the flammable time volume can be calculated by CFD simulation based on the leakage amount, speed, and concentration of the refrigerant as per point (e).

g) Consider ignition sources. Distinguish the ignition properties depending on whether the ignition source is a spark (for example, electrical contacts, lighter, and/or static electricity), or an open flame (for example, candles, matches, and/or combustion equipment).

7- **Fault Tree Analysis (FTA)**

It utilizes a "top-down" approach, starting with the undesired effect as the top event of a tree of logic. Fault trees (FTs) consist of various event boxes, which reflect the probability or frequency of key events leading up to a system failure. The event boxes are linked by connectors (gates), which describe how the contributing events may combine to produce the system failure. Events may be combined in different ways: in cases where a series of events must all occur to produce an outcome (e.g., ignition source and sufficient oxygen to support combustion), the probabilities or frequencies of the individual contributing events are multiplied via an "AND" gate; in cases where only one of a series of events is needed to produce an outcome (e.g., a strong spark, open flame, or a hot surface all possibly leading to refrigerant ignition), the probabilities are usually added via an "OR" gate. (AHRTI 8009, 2015).

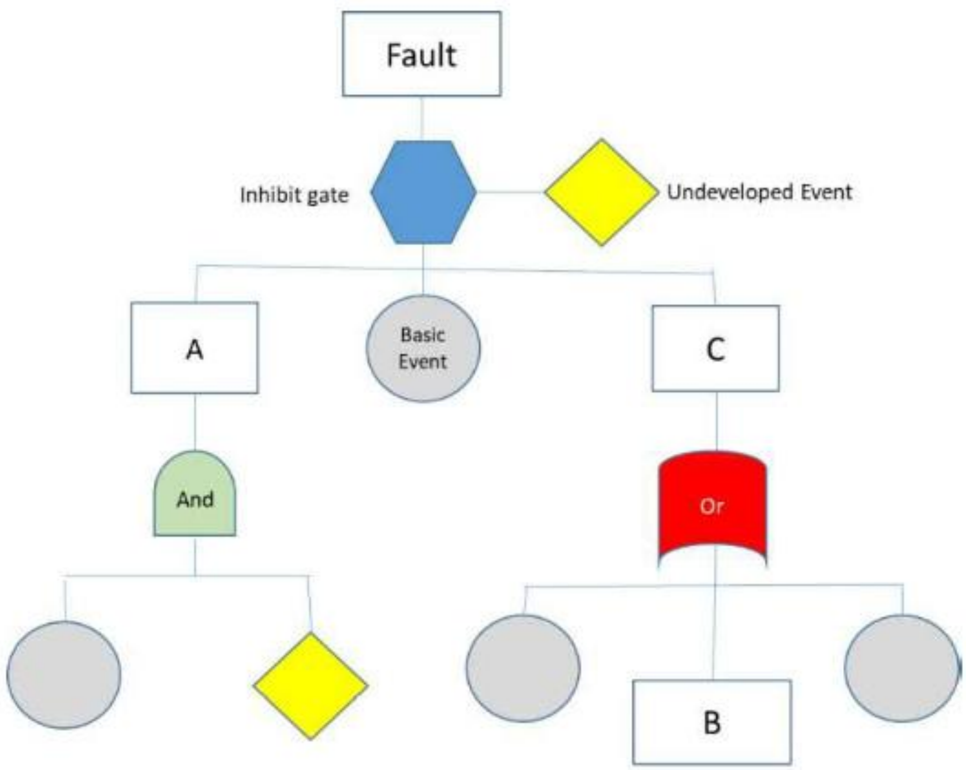

FIGURE 7: FAULT TREE ANALYSIS (FTA) MODEL

In the case of flammability, the probability of leakage is combined with ("and" gate) the possibility that the length of time that flammable cloud exits covered area would lead to ignition in case of the existence of an ignition source (another "and" gate).

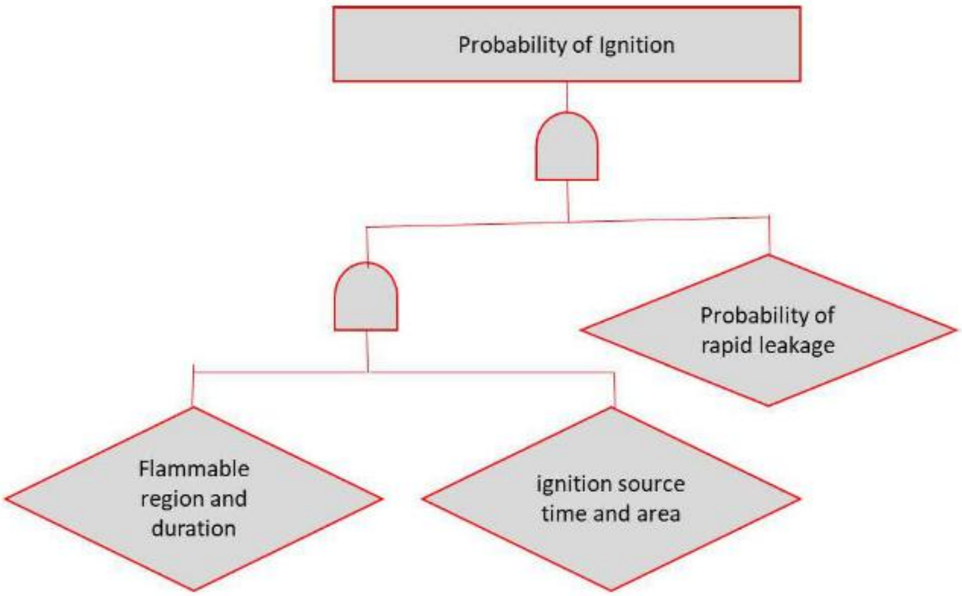

FIGURE 8: PROBABILITY OF IGNITION FTA

8- Suggest Measure to Mitigate Intolerable Risk

When the tolerance from the risk evaluation in the steps above is satisfactory, the risk assessment ends.

If the risk exceeds the tolerance, countermeasures to reduce the risk should be taken. These countermeasures include the implementation of regulations and other measures like introducing safety procedures in order to reduce the risk of accidents. In some instances, it might be necessary to revise laws and regulations in order to ensure that they cover the accepted probability. The reiterative process, which is explained in Figure 9, is as follows:

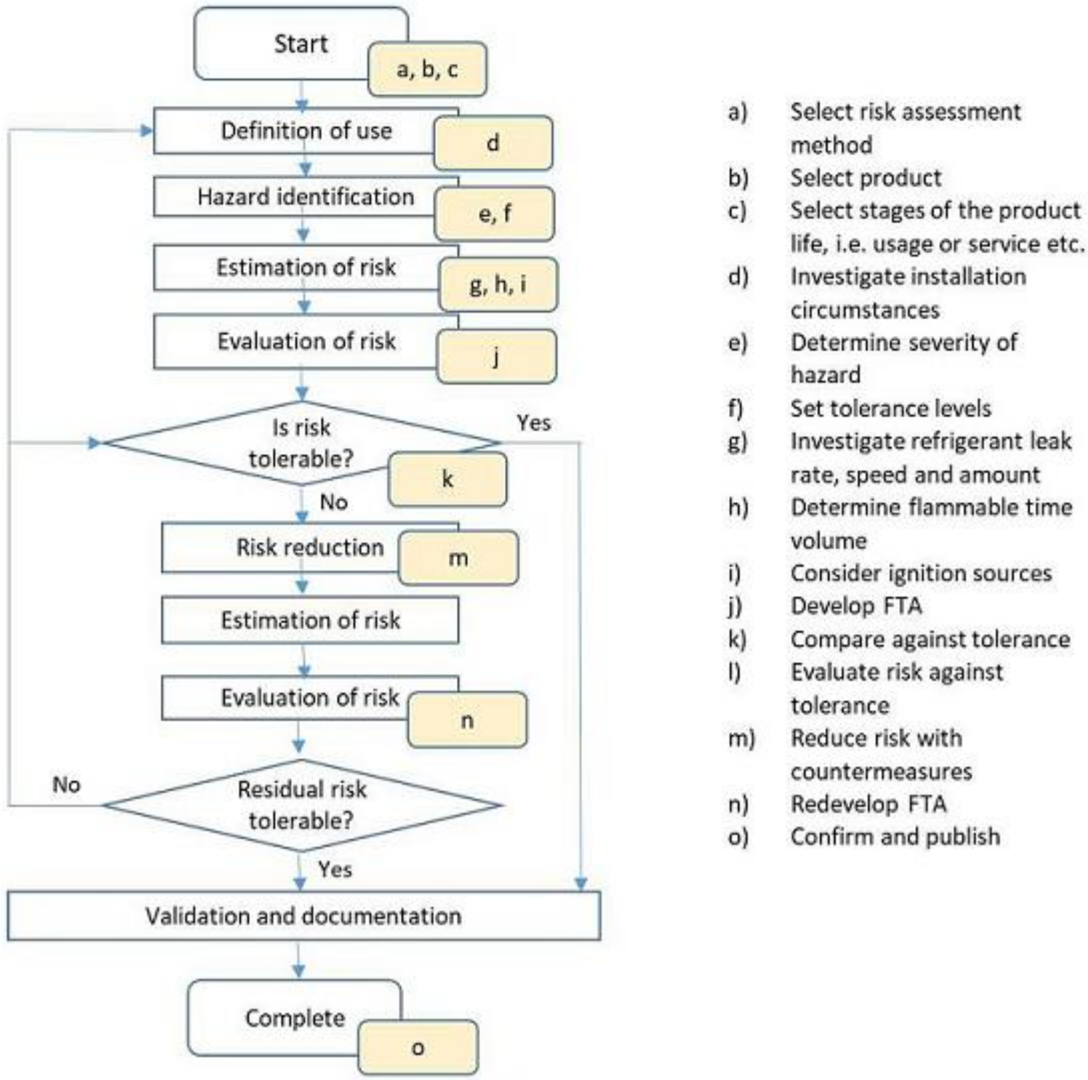

FIGURE 9: FTA REITERATIVE PROCESS

- Once the countermeasures have been introduced, the FTA factors are reviewed and these countermeasures are added in the appropriate position of the tree.
- A new calculation can then be made and repeated until the calculations confirm the accepted tolerance according to the risk map.
- The results can then be released to the public and standards and codes can be drawn.

9- Type of premises that residential AC applications likely to be deployed in.

3.1. Governmental offices
3.2. Barber shop
3.3. Home use
3.4. Retail shop
3.5. Educational premises

10- Data analysis of potential risks with Example of a Risk Assessment Model

Case study of an office space in a government building during the usage phase when the equipment is running and during the repair/service stage. The target product is a 5.3 kW split system using an A2L (R32) refrigerant. Fault Tree Analysis (FTA) method is selected. The target product and the indoor and outdoor conditions plus the service case are shown in the tables below.

The two cases study using the information provided by the PRAHA team for the Egyptian model is:

- During usage of an air conditioner in a government office. The sources of ignition are extreme including charcoal and lighter used for incense burning, an aroma candle, as well as cigarettes and lighters as smoking is still allowed.
- During the repair stage during brazing with sources of ignition including the brazing burner, a cigarette and a lighter.

Table 4 lists the equipment as well as the indoor and outdoor conditions

Target Product	Value
Model number	CS-PC36JKF
Type(cooling / HP)	HP
Capacity(kW)	10.5
Refrigerant type	A2L
Refrigerant amount(kg)	2.7
Alternative refrigerant type	HFC-32, R-454B

Indoor Condition during usage of target product		Value
Room size (m^2)	max	25
	min	16
Height of installation(m)		2.1
Ceiling height(m)		2.8
Ventilation	yes/no	YES
	Ventilation amount (m^3/hr.)	80
The area of the gap under the door (m^2)		0.02
other openings, if any (m^2)		0

Outdoor Condition during usage of target product		Value
Size of the place enclosed with walls , or fences etc.(m^2)	max	8
	min	4

Condition during repair of target product	value
Average size of outdoor spaces for repairs (m^3)	20
Percentage of single outdoor unit installations(A%)	50
Percentage of the installations of multiple outdoor units (B%)	50
Average working hours per repair (outdoor unit) (hr.)	1
Average working hours per repair (indoor unit)(hr.)	0.5
Wind condition (wind velocity) (m/s)	1 TO 3
Windless condition percentage (%)	10

(Windless condition; 0.1m/s or less. the windless rate in one year.)

Notes:

- Ventilation amount was calculated based on 1.5 air changes per hour;
- Gap under door was based on the door width is 1.00 m, gap with floor is 2 cm;
- The outdoor unit was assumed to be installed on a roof open area.

The methodology is to calculate the probability of ignition due to a space factor and a time factor.

Space Factor

The space factor takes into consideration the space volume, the volume of the flammable cloud, and the volume of the source of ignition. The volume of the flammable cloud depends on the leakage rate and other considerations such as pressure. The volume of the source of ignition can be very small as in the case of a spark, or sizeable as in the case of an open flame.

Time Factor

The time factor takes into consideration the number of occurrences of the ignition source and the duration of each occurrence.

Simulation of Time Factor and Space factor During Usage Stage

The data in Table 5 was provided by the PRAHA-II team for the Egyptian model.

TABLE 5: DATA FOR THE CALCULATION OF RISK FOR USAGE STAGE

Event	Ignition source	No. of Occurrence	Duration per day	T_S = Time of Source
A	Charcoal + lighter	2	1 hour	I hr/2
B	Cigarette+ lighter	2	0.2 hour	0.2 hr/2
C	Aroma candle	4	3 hours	3 hr/4

The FTA calculation for the usage stage is shown in Figure 10.

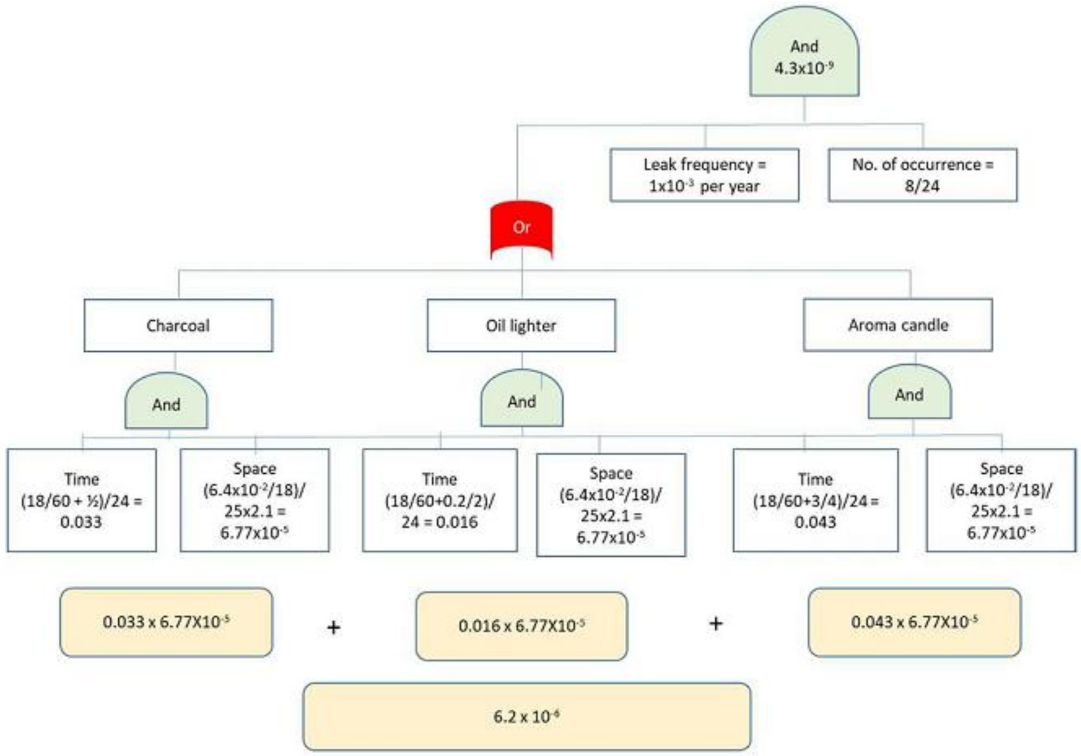

FIGURE 10: FTA FOR USAGE STAGE

For each event, i.e. charcoal, oil lighter, and aroma candle the probability of time and space are calculated according to **Fault Tree Analysis (FTA)** for the usage stage.

The calculation made by JRAIA during the workshop puts this Total calculated probability in the "Extremely Difficult" area of Figure 6: Risk Map.

Simulation of Time Factor and Space factor During Servicing Stage

TABLE 6: DATA FOR CALCULATION OF RISK FOR SERVICE STAGE

Event	Ignition source	No. of Occurrence	Duration per day	T_S = Time of Source
A	Burner	2	2 minutes	4/2
B	Cigarette	2	3 minutes	6/2
C	Lighter	2	10 seconds	0.167/2

The FTA for servicing stage is shown in Figure 11.

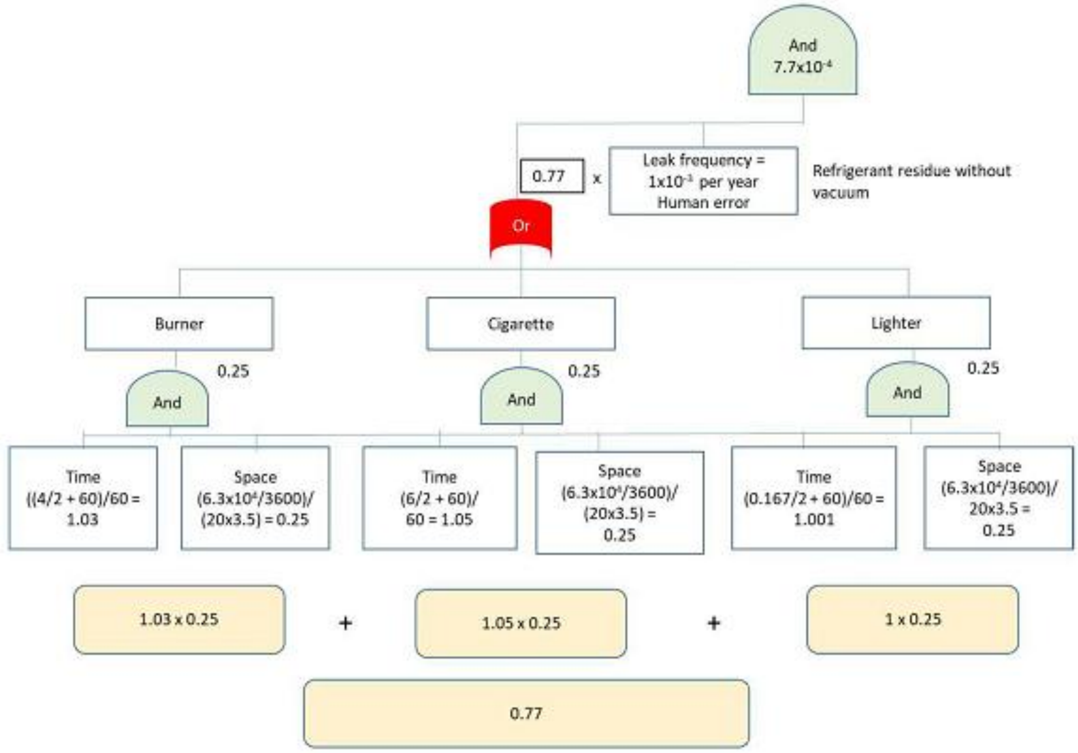

FIGURE 11: FTA FOR SERVICING STAGE

The calculation made by JRAIA during the workshop puts this Total calculated probability in the "Frequent" area of Figure 6: Risk Map and mitigation measures should be taken. One evident measure is to ban smoking in the service area!

11- Flammable gas region

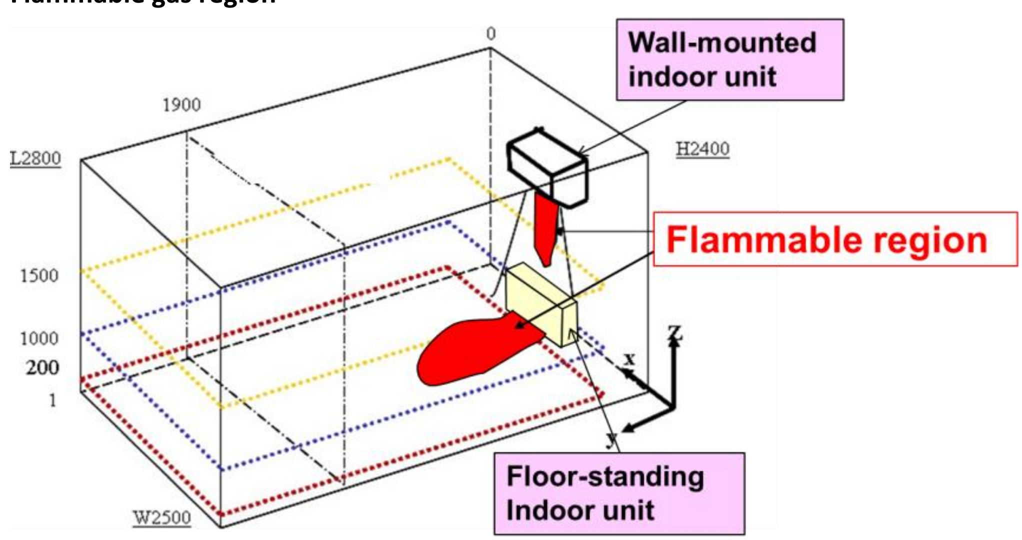

FIGURE 12: Flammable gas region

11.1. Flammable gas region of the wall mounted AC unit:

- Flammable region can only be seen near the unit.
- The small flammable region existed below the air outlet of indoor unit only.
- The flammable gas volume was small.
- After leakage, the flammable region vanished in less than a second.

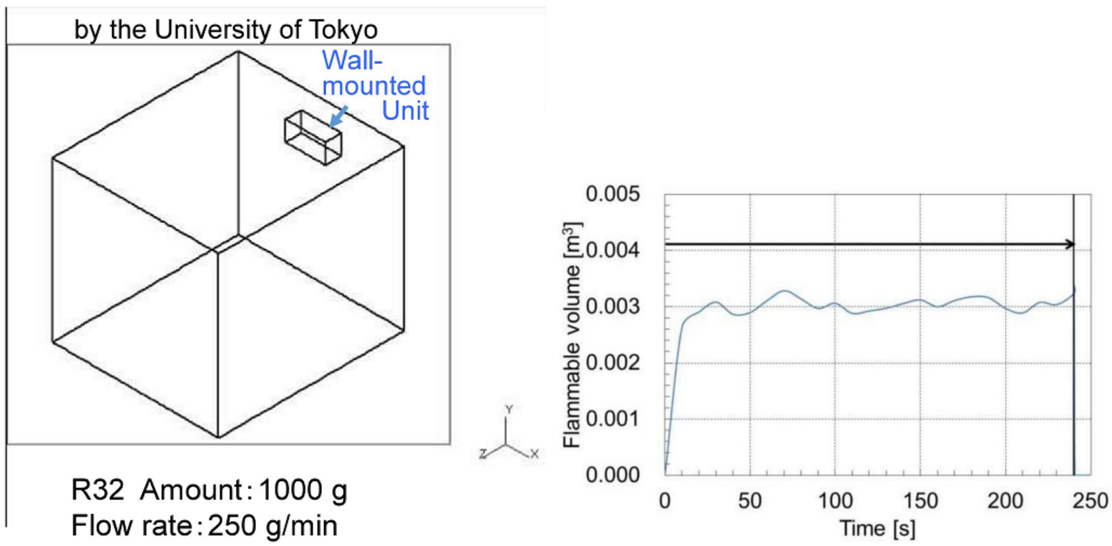

FIGURE 13: Flammable gas of the wall mounted AC

11.2. Flammable gas region of the floor mounted AC unit:

- Flammable region appears on the floor.
- There was a large flammable region spread on the floor.
- The flammable region did not vanish for some time.

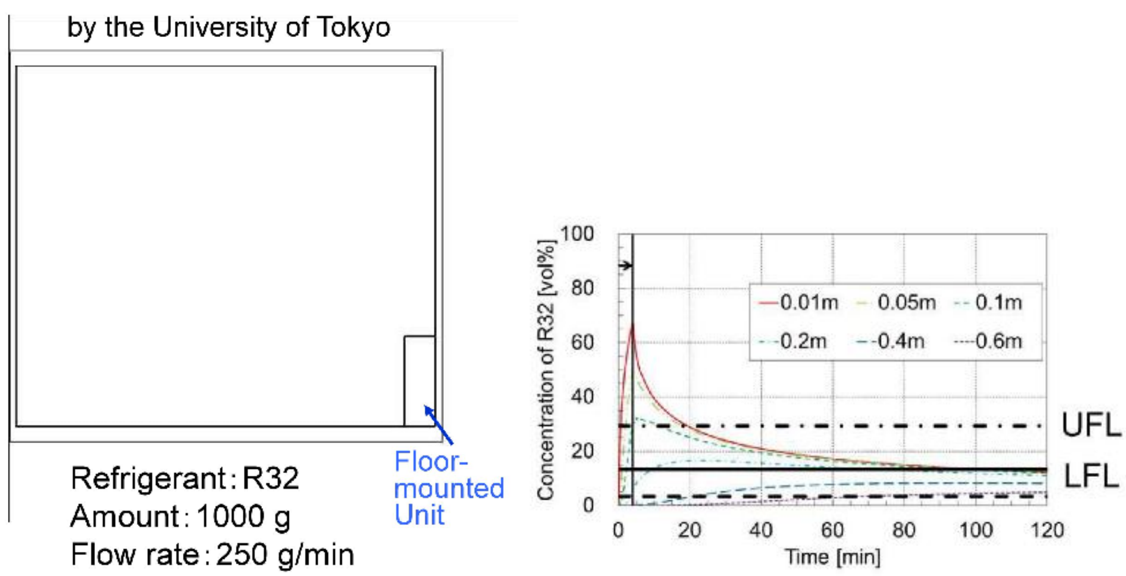

FIGURE 14: Flammable gas of the floor mounted AC

12- Conclusions and Recommendations from the Risk Assessment Element

The above two FTA were created in collaboration with HAT countries (Egypt, Kuwait) and Japan. The simulated risk scenario considers climate, product-usage, lifestyle and culture of the Egyptian market. The exercise has shown the need for a reliable data on leaks, practices etc.

Building a risk assessment model for Egypt which suits the climate and the service practices of the local technicians helps in understanding the risk associated with flammable refrigerants and adopting the needed regulations and training programs especially in relation to the logistics of lower-GWP based technologies i.e. installation, transportation, storage, servicing and decommissioning. The Measures to mitigate risks would depend on type of existing/operational standards and/or codes in Egypt.

The mini-split risk assessment for R32 in residential air conditioners, confirming that;

- The simulation of Time Factor and Space factor During Usage Stage indicate that the total calculated probability in the "Extremely Difficult" area of Figure 5: Risk Map.
- It can be used if certain measures are adhered.
- In order to reduce the risks, the manuals used during installation or servicing should be carefully reviewed.
- More precisely, in the "Piping construction manual for residential air conditioners using R32 refrigerant" measures should be adopted.
- Flammable region and concentration distribution for the wall mounted AC unit is relatively better compared with floor mounted type.

The recommendation is to continue the risk assessment based on actual situations, and reduce the risk by implementing various measures that are verified by FTA.
It is also important to minimize ignition probability by implementing various measures that are verified by FTA.
In addition, the risk assessments of other stages matching cultural and lifestyle aspects should be studied.

- **Risk Management Plan – RMP**

  It is recommended to implement a Risk Management Plan during service of AC units having A2L refrigerants, Annex 1 contain a template as a guide line, and the following control measure can be applied;

1- Warning signs must be placed during service time.
2- Ensure to open windows during service for well ventilation to ensure that the refrigerants are not concentrated to a large extent in case of a leak.
3- Using a portable detector to sense a leakage of refrigerant gases and give an alert if a leak is detected.

4- Maintaining a record in which all the details and actions that have been performed on each air conditioning unit, including maintenance, modification, recharging, repairs, and welds, are recorded by date and time.
5- Making an emergency plan to deal with any leaks that might go wrong during service activities.
6- Avoid any source of ignition inside the place.
7- All technicians must be aware of the risks posed by the presence of flammable refrigerant, and familiar with the applicable safety procedures.
8- All technicians must have training on the proper use of personal protective equipment (PPE), and how to use fire extinguishers.
9- Providing suitable fire extinguishing means to extinguish the different types of dangers present in the place.
10- Ensure that all electrical connections inside the place are off during the service time to avoid any electrical sparks to occur.
11- Manufacturers are required to include additional safety information in the installation and service manuals for air conditioners using flammable refrigerant. Technicians should follow these instructions.
12- Check the relevant material safety data sheets available from refrigerant wholesalers for specific safeguards when handling R32.
13- The electrical installation must be in accordance with the NEC and any local codes. This includes using the correct size wire and breaker for the circuit, and ensuring that the wiring is properly grounded.
14- Dry nitrogen should always be used when brazing to displace the oxygen and prevent oxidization on the inside of the pipework. This procedure is important as it is also required to displace the residual refrigerant and prevent concentration levels conducive to ignition.
15- Safety issues to be aware of when handling R32
16- Technicians need to take the relevant safety measures for the correct transport, storage, and handling of flammable gases. This includes ensuring that the gas is not exposed to open flames or other ignition sources. Toxic substances like hydrogen fluoride and carbon dioxide are created when R32 is burnt. Asphyxiation and freeze burns are also a risk.

    For transportation purposes, R32 is classified as a dangerous goods class A2L flammable gas, therefore requires additional handling and storage safeguards.

➢ **Equipment Safety**

- All equipment must be inspected regularly.
- Nitrogen must be used instead of air for leak testing.
- All equipment must be labeled with the type of refrigerant used.
- Refrigerants must be disposed of properly.

13- References

- AHRTI 8009, 2015. Risk Assessment of Refrigeration Systems Using A2L Flammable Refrigerants - April 2015
- JSRAE, 2017. Risk Assessment of Mildly Flammable Refrigerants - Final Report 2016 - March 2017
- US Nuclear Regulatory Commission (US NRC). 1981. "Fault Tree Handbook." NUREG-0492. 209p. January.
- Risk Assessment of Mildly Flammable Refrigerants Final Report 2016 by The Japan Society of Refrigerating and Air Conditioning Engineers – JSRAE
- PRAHA-II Project, JRAIA Workshop, April 2019 Tokyo, Japan
- ASHRAE 34 Designation & Safety Classification of Refrigerants.

Annex 1 – Risk Management Plan template

Risk management plan for refrigerants

The significance of a RMP.

Businesses need to be aware of their risks. Overall business success depends largely on effective management and minimization of risk – refrigerant is no different.

Under the Ozone Protection and Synthetic Greenhouse Gas Management it is important to apply a risk management plan (RMP), which outlines the handling and storage of refrigerant in the holder's business.

RMP to include.

An RMP must identify potential risks which could result in the emission of refrigerant to the atmosphere and identify processes and practices that minimize the possibility of those risks occurring. RMP must reflect the risks of emissions relevant to all parts of the business practices, including refrigerant handling, storage and transport. These apply whether the business is for a sole trader or employ 100 or more technicians.

Apply it for a specific business practices and do the following:

- Identify the type of works field
- Insert relevant person responsible against each risk
- Insert review date
- Read over the whole plan carefully and put lines through the areas that don't relate to your business. In particular, see the section 'Decommissioning end of life equipment'.
- Add further risks and control measures if relevant to your business.

Risk Management Plan

Activity steps	Potential hazards/risks	Risk control measures	Standards and Code of practice reference	Person responsible (full name)	Next review date (within 12 months)
Purchase of refrigerant	Loose, damaged or missing cylinder caps	• At time of purchase check that refrigerant cylinders are tightly capped • Ensure quarterly purchase records are kept up to date • Only accept refrigerant cylinders from wholesalers if they are properly sealed (bunged or capped).	✓		
	Poor cylinder condition (rusted, corroded, damaged). Expired, or close to expired 'Test Date'	• Check cylinder date markings/imprints – specifically, that they are 'In Test' • Good condition etc.	✓		
Transportation of refrigerant	Damaged cylinder during transportation	• Keep out of direct sunlight and/or in cooler area of vehicle • Safely stored/fixed when transporting • Fitted with safety equipment etc.	✓		
	Damage to gas cylinders during handling (hand-moved, equipment-moved)	• Implement proper handling techniques • Report accidents immediately.	✓		
Using equipment containing refrigerant	Leakage of refrigerant during charging of equipment	• Implement best practice procedure as per Standard and/or code of practice	✓		
	Improper care of cylinders	• After each use check that refrigerant cylinders are tightly capped • Check for leakage etc.	✓		
Handling	Unlicensed handling staff or contractors	• All refrigerant handling must be carried out by qualified licensed staff or contractors • Check temporary contractor's license before commencement of refrigerant handling work • Ensure quarterly refrigerant handling license holder records are up to date, taking particular note of expiry dates.	✓		
Installation, service and maintenance of equipment containing refrigerant	Lack of servicing of equipment containing refrigerant	• Adhere to manufacturers' recommendations and relevant standards • Maintain recommended servicing frequency: i. Obtain and keep warranties on repairs ii. Keep record of each service to equipment iii. Check cylinder weight regularly etc. • Refer to appropriate standards.	✓		
	Infrequent testing of equipment containing refrigerant	• Check that all test equipment is in good working condition at least once every three months. Test leak detectors and recovery units • Regularly monitor vacuum pump oil etc. • Ensure quarterly equipment maintenance records are kept up to date.	✓		
	Inadequate leak testing	• Implement best practice procedure as per Standard and/or code of practice • Check at least every three months • Ensure quarterly cylinder leak test & in-test expiry date records are kept up to date.	✓		

Risk Management Plan (continued)

Activity steps	Potential hazards/risks	Risk control measures	Standards and Code of practice reference	Person responsible (full name)	Next review date (within 12 months)
Recovery and recycling of refrigerant	Improper filling of cylinders	• Fill bulk refrigerant cylinders in-line with manufacturers' recommendations etc.	✓		
Decommission end of life equipment	Poor cleaning and flushing	• Never charge refrigerant into equipment with identified leaks • Refer to standards and Code of Practice for leak testing procedures.	✓		
	Venting	• Never vent fluorocarbon refrigerant where its release is avoidable etc.	✓		
	Leakage of refrigerant if pumped down and left in the equipment	• All refrigerant is to be reclaimed from all parts of the system at the time of decommissioning • After recovery refrigerant is to be recycled or returned to an authorized refrigerant supplier (see 'Disposal').	✓		
Storage of refrigerant	Poor storage of cylinders on premises	• Ensure all cylinders are stored in a safe and secure location: i. climate controlled (cool place, removed from direct sources of heat and the risk of fire) ii. free of obstacles iii. with appropriate signage to provide ready identification for emergency teams.	✓		
Disposal	Inadequate seals	• Closed valves when not in use • Check all seals for leakage every 3 months.	✓		
	Mixing refrigerant types	• Clearly identify refrigerant stored in cylinders • Store reclaimed refrigerant separately.	✓		
	Lack of labeling	• Clearly label refrigerant type • Clearly label lubricant type • Store in specific locations • Training personnel.	✓		
	Equipment that cannot be repaired	• Document and keep records of reasons why • Establish a retirement plan of action.	✓		
	Recovered refrigerant	• Return refrigerant contaminated to supplier for disposal • Document and keep records of recovered refrigerant returned to supplier for disposal • Ensure quarterly recovered refrigerant returned records are kept up to date.	✓		

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Montreal Protocol Division

HCFC PHASE-OUT Management Plan Stage **II**

Market Acceptance Study **Report**

EGYPT

February 2024

UNIDO Project ID: 200006

This document showcases the Market Acceptance Study (MAS) report as a part of HCFC PHASE-OUT Management Plan Stage II EGYPT 2023 activities.

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ABSTRACT

This document outlines the results of the Market Acceptance Study (MAS), which was conducted in Egypt during the 2023 physical year as part of the HCFC PHASE-OUT Management Plan Stage II (HPMP II) activities.

The MAS was conducted to understand consumer perspectives on residential air conditioning products that contribute to reducing climate change and ozone depletion.

The report covers various topics related to the MAS, including its Background, Summary, Objectives, Methodology, Data Collection Tools, Sample Size Formula, Sample Classifications, Results, Findings, and Conclusion.

The findings of the MAS provide valuable insights into the preferences and perceptions of consumers in the Egyptian market regarding eco-friendly ACs. Manufacturers, suppliers, and policymakers can leverage these findings to develop effective marketing strategies, prioritize key attributes, and meet consumer demand for energy-efficient and cost-effective AC solutions.

Acknowledgment

We would like to express our gratitude to Dr. Fukuya Iino, the HPMP II Project Manager, for providing support and facilitating all the necessary logistics to accomplish the study objective. Furthermore, we extend our appreciation to Dr. Ezzat Lewis, the NOU director, for giving effective guidance and valuable insights. Finally, we want to express gratitude to the project team and NOU team for their contributions throughout the various phases of the study.

BACKGROUND

The HPMP II conducted a Market Acceptance Study to analyze the satisfaction levels of end-users and key distributors with current air conditioning (AC) product lineups, energy and environment-related information, and prices in the Egyptian market.

The MAS was conducted to understand consumer perspectives on residential air conditioning products that contribute to reducing climate change and ozone depletion.

SUMMARY

The study focused on the pre-production phase of ACs that uses R32. The sample consisted of 402 participants who owned residential AC units across Cairo, Alexandria, Delta, Suez Canal, and Upper Egypt, proportionate to the population of each governorate.

The Market Acceptance Study was a two-stage survey that aimed to understand consumer perspectives on AC products that contribute to reducing climate change and ozone depletion.

The first stage involved administering an online questionnaire to end-users to assess their level of awareness and knowledge about eco-friendly ACs, the features that are most important to consumers when selecting a residential AC, the willingness of respondents to pay for eco-friendly specifications and energy efficiency, and the level of satisfaction with existing AC products available in the Egyptian market.

The second stage entailed conducting in-depth interviews with AC distributors in Egypt to assess their level of knowledge regarding eco-friendly ACs, understand the key features and characteristics of eco-friendly ACs, determine the potential price increase associated with eco-friendly specifications and energy efficiency, and formulate effective marketing strategies to introduce the concept of eco-friendly ACs to the Egyptian market.

The study findings shed light on the participants' perception of eco-friendly AC, with the majority associating them with energy and electricity savings.

When it comes to essential attributes of an air conditioning system, participants ranked after-sale service as the most significant, followed closely by high performance. While some respondents also considered eco-friendly technologies and affordability important, these attributes were not as highly valued.

The study found that participants were significantly interested in the concept of eco-friendly air conditioning and willing to pay more for it. Specifically, they expressed a willingness to pay a 5% premium to obtain eco-friendly features.

Additionally, the study identified digital media as the preferred communication channel for promoting eco-friendly air conditioning units, emphasizing the importance of online platforms in reaching and engaging with consumers. Offering discounts on the price of air conditioning units was also identified as an effective incentive for encouraging adoption.

Lastly, respondents emphasized the importance of energy efficiency in air conditioning systems as a driving factor in their decision-making process, highlighting the desire for lower electricity bills.

These findings provide valuable insights into the preferences and perceptions of consumers in the Egyptian market regarding eco-friendly air conditioning units. Manufacturers, suppliers, and policymakers can leverage these insights to develop effective marketing strategies, prioritize key attributes, and meet consumer demand for energy-efficient and cost-effective air conditioning solutions.

METHODOLOGY

The end-users quantitative survey was conducted through an online questionnaire that took 20 minutes length with a total sample of **402** respondents.

The sample consisted of **60%** males and **40%** females and there was a soft quota in the respondents' age ranges between **18 – 24** years, **25 – 40** years, and **41- 60** years.

The socio-economic class of the sample was 50% from the A and B classes and 50% from the C class and was calculated based on the education, occupation, and income of respondents. The survey was conducted in three successive phases.

The first phase was a pilot phase that was conducted on a small sample to make sure that all the survey questions were clear and understandable, ensuring that we reached our research objective from each question, with no errors in the survey.

The second phase was conducted in Cairo and Alexandria with the distribution of **44%** from Greater Cairo (Cairo and Giza) and **13%** from Alexandria.

The third phase was conducted on a sample of **22%** from Upper Egypt, **18%** from Delta cities, and **3%** from Suez Canal cities.

The distributors' qualitative survey was conducted through in-depth interviews with three computer assisted telephone interviews with the distributors' of ACs in Egypt.

The study applied a quality checks process throughout the survey different phases to ensure the quality of the respondents that they are all eligible with the survey criteria, and the quality of their responses to ensure that they have a clear understanding of the survey questions.

DATA COLLECTION TOOLS

A comprehensive study was conducted on end-users, surveying a total of 402 consumers. The study used the reliable and accurate Sawtooth SSI tool for conducting online surveys. The survey collected responses on various parameters, providing a rich dataset for analysis. The collected data was then analyzed using the Statistical Package for the Social Sciences (SPSS), which provided deep insights and valuable trends and patterns.

The qualitative phase (distributors) was conducted through In-depth computer-assisted telephone interviews.

SAMPLE SIZE FORMULA

Z score (also called a standard score) gives you an idea of how far from the mean a data point is. But more technically it's a measure of how many standard deviations below or above the population.

Sample Size Formula $(Z^2 \times P(1 - P) / E^2) \div (1 + ((Z^2 \times P(1 - P)) / E^2 N))$

N = AC Annual productions size = **1,500,000** units **(estimated)**
E = Margin of error **(5%)**
Z = Desired confidence level (1.96) = **95%**
P = Standard deviation **(0.5)**
$(3.8416 \times 0.5 (0.5) / (0.05^2)) \div (1 + ((3.8416 \times 0.5 (0.5)) / 3.750))$ Total sample size = 385 participants

QUESTIONNAIRE STRUCTURE

The questionnaire has two flows and sequences based on the response to the first question:

- The first sequence is for respondents who purchased an eco-friendly AC; identified as **Yes Sample**
- The second sequence is for respondents who didn't purchase eco-friendly AC; and identified as **No Sample**

Below are the questions along with the objective of each question for the end-user survey.

1) Did you purchase Eco-friendly air conditioning before?		**Measure the awareness, knowledge, and interest of the respondents in their willingness to buy Eco-friendly air-conditioning**
☐ **Yes**	☐ **No**	

2) Concerning the current ACs of the Egyptian Market, Assess your satisfaction level towards them on the level of energy efficiency			**Assess the level of satisfaction with the current ACs (Energy efficiency& Price) in the Egyptian Market**
☐ **Extremely satisfied**	☐ **Satisfied**	☐ **Neutral**	
☐ **Unsatisfied**	☐ **Extremely unsatisfied**		

3) What is your definition when you hear that this product is "Eco-friendly"?			
☐ ……			
4) What are the features that make you say that the air conditioner is "Eco-friendly"? (From most important to least important)		**Understand the level of awareness and interest of the respondents in environment related features in air conditioners use (R32)**	
☐ **Energy efficiency**	☐ **Reduces Carbon Emissions**		
☐ **Air purification feature**	☐ **Customized AC Systems**		
5) Does the idea of eco-friendly air conditioning motivate you to buy it?		☐ **Yes**	☐ **No**
6) Did you know that air conditioning that works with Freon (R32) is eco-friendly that helps combat climate change (reducing global warming), and is more efficient in consuming electricity?		☐ **Yes**	☐ **No**

7) Scale the important factors that important to you when you buy an AC?		**Identify the respondents' priorities in selecting residential AC** • **Extremely Important** • **Important** • **Neutral** • **Unimportant** • **Extremely unimportant**
☐ **High performance**	☐ **Affordability**	
☐ **Eco-friendly technologies**	☐ **Brand credibility**	
☐ **After sale service**	☐ **Shape & Design**	

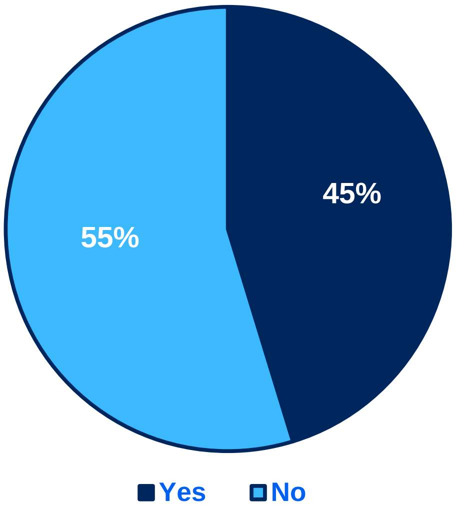
8) What is the feature that you wish/would like to have, that is not available in your current AC?	**Gather info on respondents' potential wishes in ACs.**

9) Are you willing to pay for an Eco-Friendly AC that offers less electric bill due to better Energy efficiency, Lower energy consumption, saving environmental & reducing global warming?	**Finding out the acceptable price increase percentage that respondents are willing to pay for Eco-friendly AC.** • **5%** • **10%** • **15%** • **More than 15%**
10) To what extent are you willing to pay an extra amount in the price of the air conditioner to obtain higher technical and environmentally friendly specifications?	

Finding out the acceptable price increase percentage that respondents are willing to pay for Eco-friendly AC.RESULTS AND OUTPUTS (END-USERS)

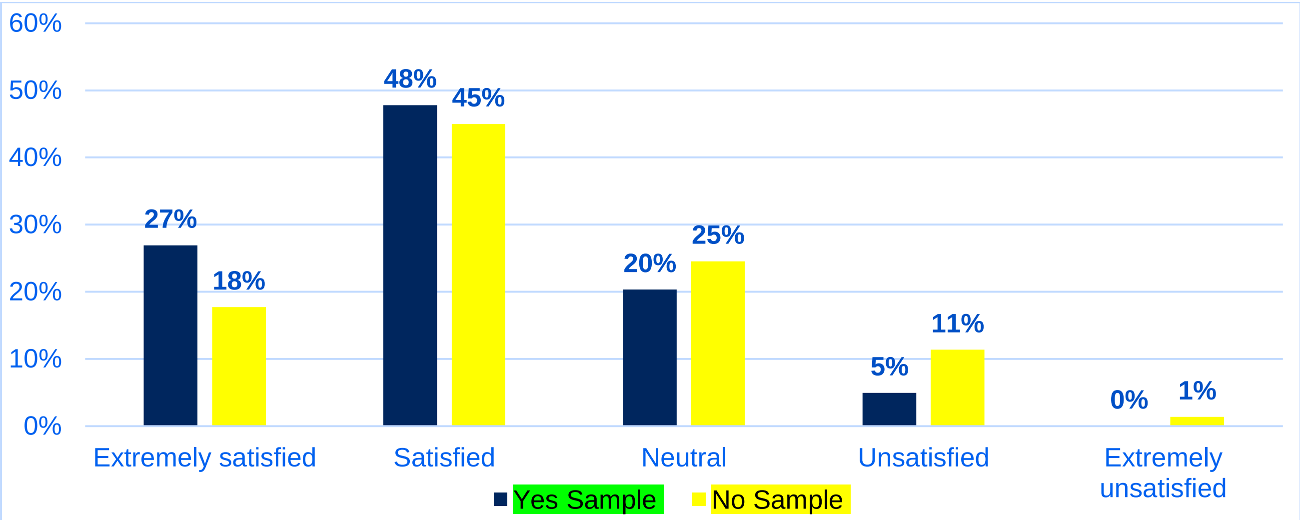
The survey was conducted with the participation of 402 individuals. 182 respondents confirmed that they had purchased eco-friendly air-conditioners (ACs) and were referred to as the **"Yes Sample"**. The remaining 220 individuals who did not buy eco-friendly ACs were referred to as the **"No Sample"**.

The survey aimed to measure the respondents' awareness, knowledge, interest, and willingness to buy eco-friendly air-conditioning. The statistical analysis showed that out of the total sample of respondents, **45%** had already purchased eco-friendly ACs, while **55%** had not bought eco-friendly ACs.



Did you purchase Eco-friendly air conditioning before?

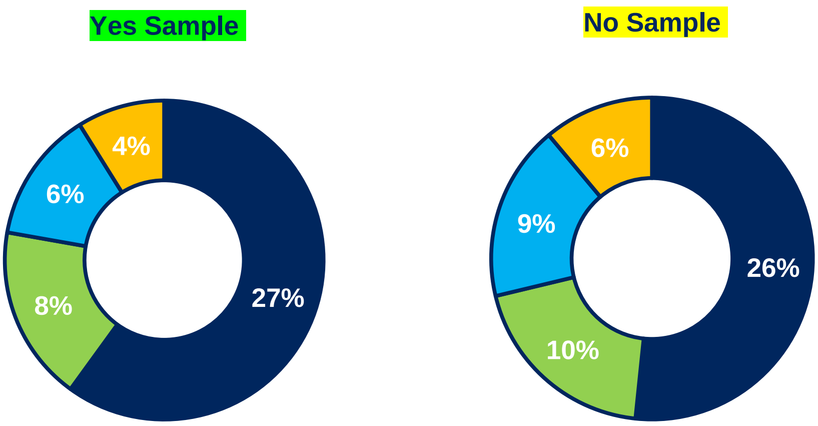
As for the assessment of the satisfaction level with the current ACs products in the Egyptian Market. The statistical analysis of the sample shows that **48%** of the **Yes Sample** and **45%** of the **No Sample** was satisfied with the ACs in the Egyptian Market.



Assess the level of satisfaction with the current ACs (Energy efficiency and Price) in the Egyptian Market

Concerning the definition of the **Eco-friendly,** the statistical analysis of the sample shows that **27%** from **Yes Sample** define Eco-Friendly as it saves electricity, **8%** define it as a protects the environment, **6%** doesn't define it as emit harmful gases or emissions into the air, and **4%** define it as purifies the air.

While **26%** of the **No Sample** define Eco-Friendly as it saves electricity, **10%** define it as it reduces air pollution, **9%** as it purifies the air, and **6%** as it doesn't emit harmful gases or emissions into the air.



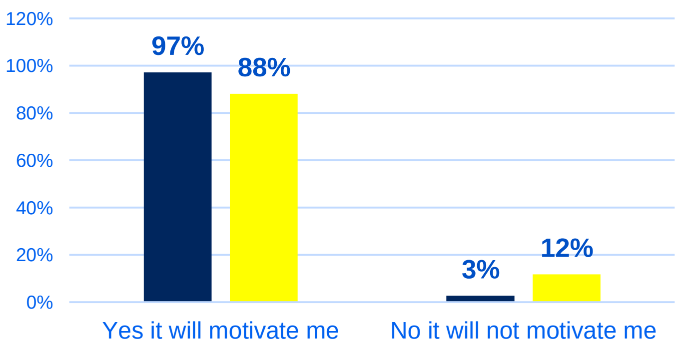
What is your definition when you hear that this product is "Eco-friendly"?

The statistical description below shows that respondents of **Yes Sample** and **No Sample** ranked the following attributes from most important to the least important Energy Efficiency comes first, followed by Reducing Carbon Emissions, then Air Purification Feature, and lastly the Customized AC Systems that suit the consumer habits.

1. Energy Efficiency
2. Reduces Carbon Emissions
3. Air purification feature
4. Customized AC Systems

What is your definition when you hear that this product is "Eco-friendly"?

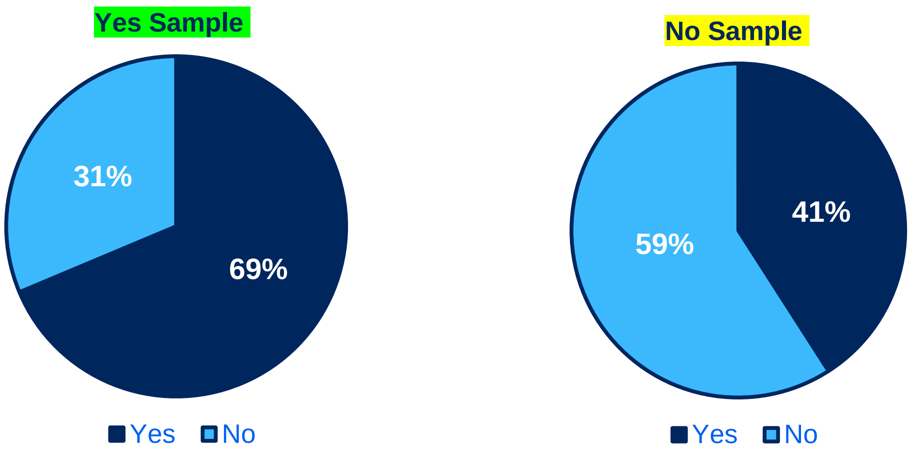
The survey also revealed that **97%** of the **Yes Sample** are motivated by the idea of the eco-friendly AC while **3%** are not motivated by the idea. While **88%** from the **No Sample** are motivated and **12%** are not motivated by the idea of Eco-friendly ACs.



Does the idea of eco-friendly air conditioning motivate you to buy it?

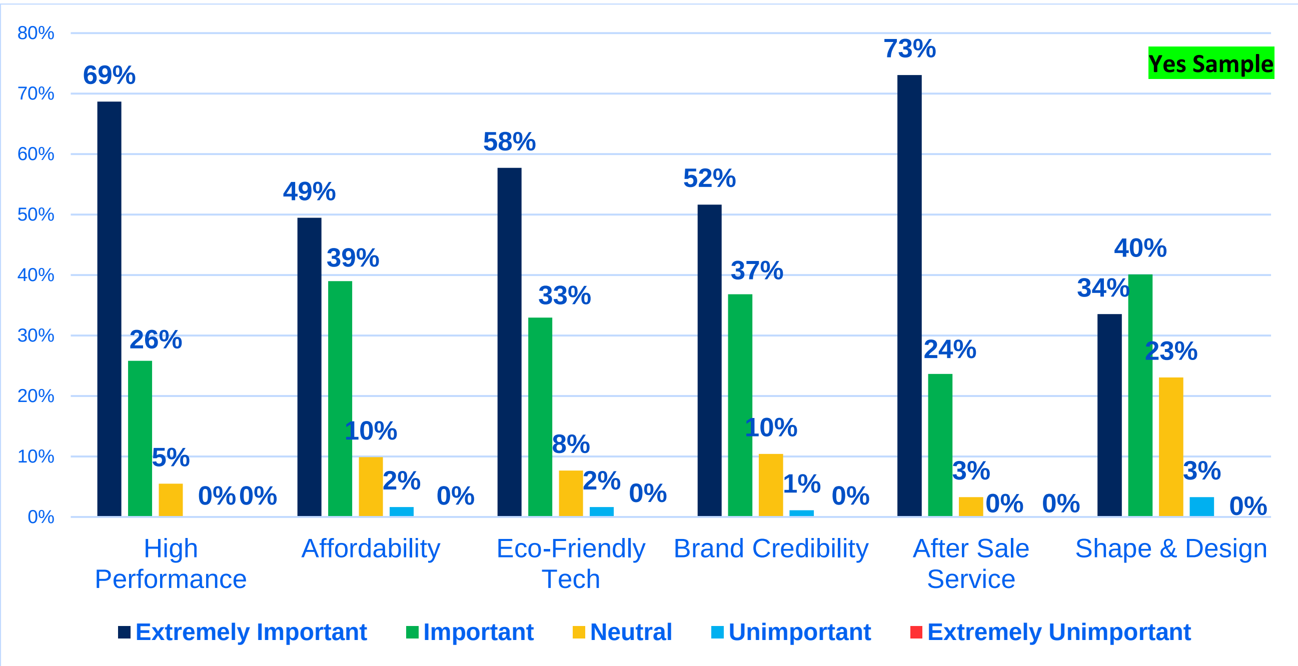
According to the statistical analysis of the sample, **69%** of the respondents who answered **"Yes"** were aware that using AC with R32 can help combat climate change and reduce global warming while being more efficient in consuming electricity, while **31%** were not aware of this.

In contrast, only **41%** of the respondents who answered **"No"** knew about the eco-friendly benefits of AC with R32, while **59%** did not know.



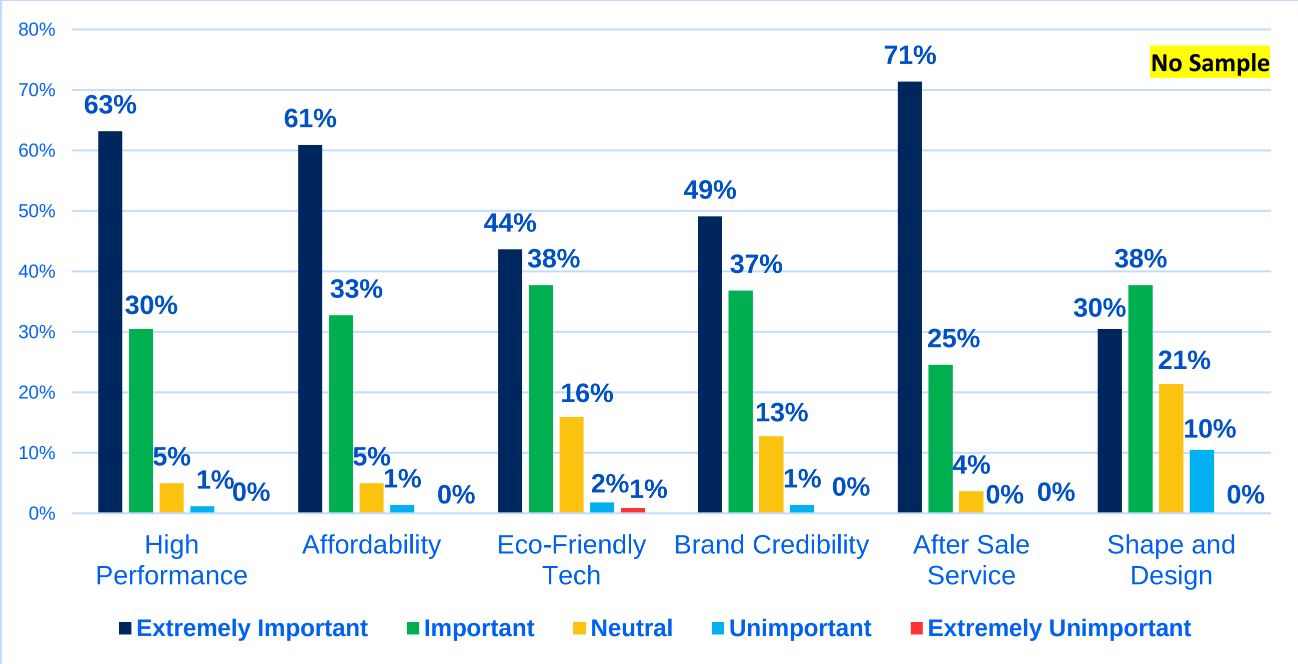
Knowledge of R32 benefits to ozone layer

According to the statistical analysis of the **Yes Sample**, the factors that most influence the decisions of AC consumers are "After Sale Service" (73%), "High Performance" (69%), "Eco-friendly Technologies" (58%), and "Brand Credibility" (52%). These factors were rated as "Extremely Important" by the majority of respondents.

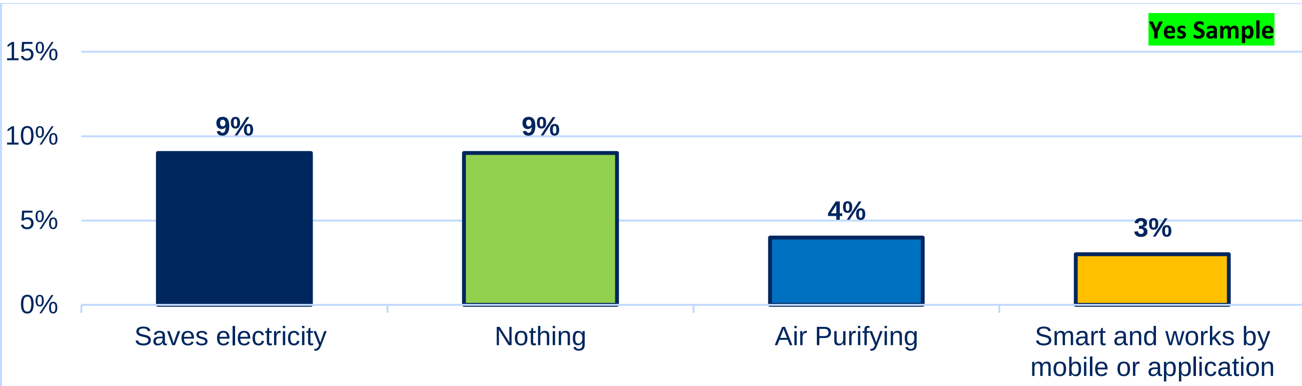


Factors that affecting AC consumers decisions

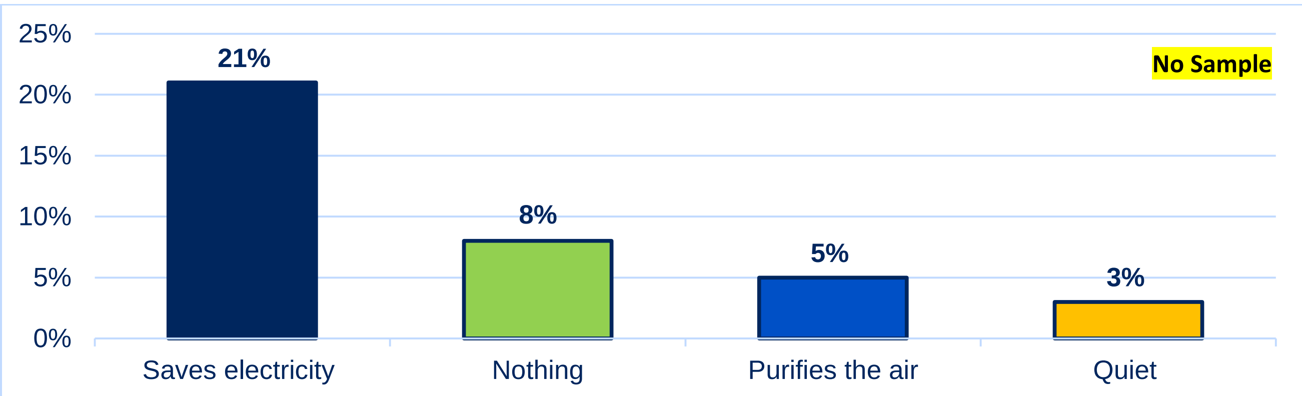
While, the respondents of **No Sample** rated 'After Sale Service' as the most important factor with an extremely high percentage of 71%, followed by 'High Performance' at 63%, 'Affordability' at 61%, and 'Brand Credibility' at 49%.



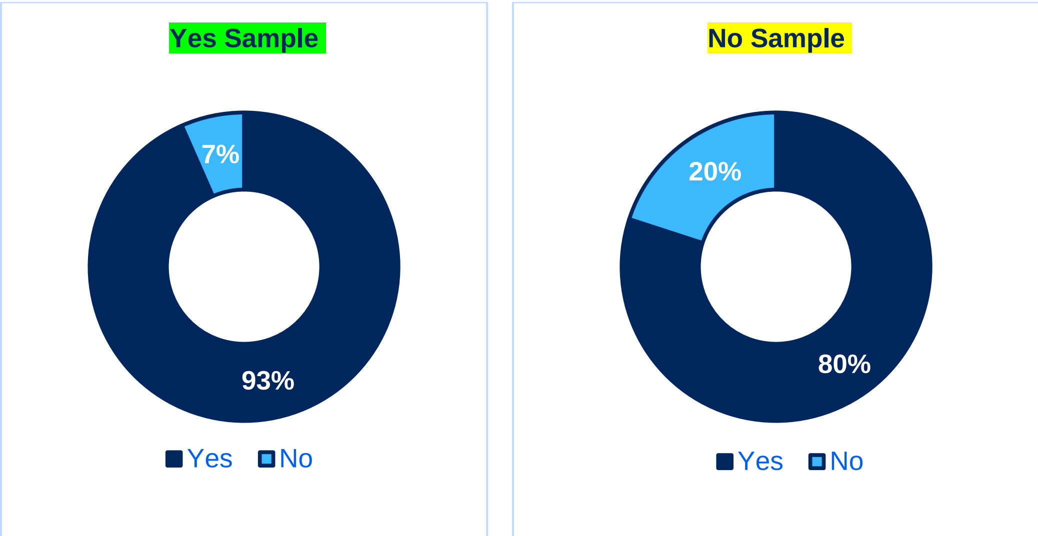
Regarding the identification of respondent preferences that are not currently available in the AC. The statistical analysis of the sample shows that **9%** of the **Yes Sample** wish to have ACs that save electricity and power, followed by **4%** that wish to have Air Purifying ACs, and **3%** wish to have smart ACs that controlled by mobile app, while **21%** of **No Sample** wish that ACs save electricity and power, followed by **5%** that wish to have ACs that purify the air and **3%** wish to have quiet ACs.



Respondents' wishes that is not available in the current ACs

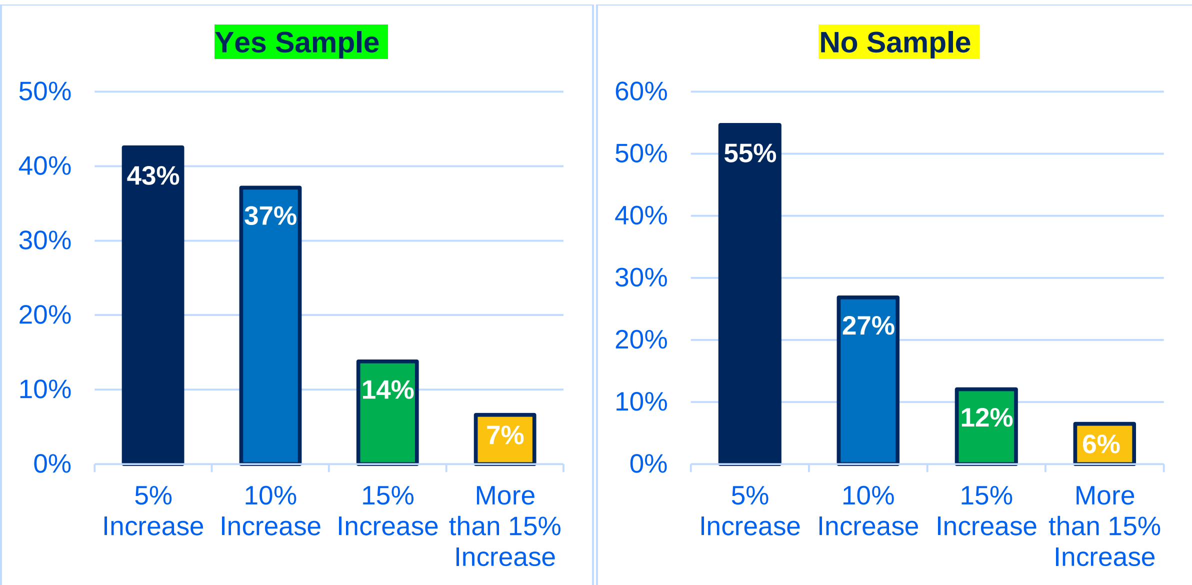


The last part of the survey is designed to investigate the respondents' willingness to pay for an Eco-Friendly AC that offers Energy efficiency, lower energy consumption, saving the environment, and reducing global warming. The statistical analysis of the sample shows that 93% of the **Yes Sample** and 80% of the **No Sample** are willing to pay an extra amount for the Eco-Friendly AC offered specifications.



Willingness to pay an extra amount for Eco-Friendly AC specifications

The concluded statistics for the acceptable price increase percentage show that the mean of the acceptable price increase is 5% as per 43% of the **Yes Sample** and 55% of the **No Sample**.



The acceptable price increase percentage that respondents are willing to pay for Eco-friendly AC.

RESULTS AND OUTPUTS (DISTRIBUTORS)

The qualitative phase comprised in-depth interviews with three AC distributors in Egypt. The questions and responses are presented below.

Question One: Amidst the current challenges, what opportunities exist in the air conditioning market?
There are various challenges faced by distributors in the air conditioning market such as short supply of all devices, suspension of imports, poor after-sale service, and scarcity of raw materials. Despite these challenges, there are still opportunities in the market such as improvements for after-sales service and the availability of air conditioners again.

Question Two: What are the factors that consumers usually consider when buying air conditioners?
The factors that consumers consider when buying air conditioners include 1) after-sale service, 2) competitive price, 3) material used, 4) brand name, 5) product quality, and 5) warranty.

Question Three: Suppliers were asked to rank the importance of various characteristics to consumers when purchasing an air conditioner?
They rated Price, Brand Credibility, and After-sale Service as Very Important. High Performance and Eco-friendly Technologies were rated as Important. Finally, the Shape and Design of the AC were rated as Neutral.

Question Four: What is the feature that the consumer wishes/ would like to have, that is not available in their current AC?
Suppliers have identified three main factors. Firstly, consumers want ACs that are energy-efficient to reduce electricity consumption. Secondly, they prefer ACs made with high-quality materials that are reasonably priced. Finally, there is a growing demand for smart ACs that can be controlled via Wi-Fi.

Question Five: Rank the characteristics that make you say that the air conditioner is “Eco-Friendly”.
This is the ranking that suppliers gave to the eco-friendly characteristics of ACs: 1) Energy Efficiency, 2) Air Purification Feature, 3) Customized AC Systems, 4) Reduce Carbon Emissions

Question Six: How would you rate the idea of an eco-friendly air conditioning unit that offers better energy efficiency, lower energy consumption, and helps in saving the environment by reducing global warming while also providing a lower electricity bill?
AC distributors were presented with this new concept, and they all rated it as excellent.

Question Seven: What is your perceived average increase in price (as a percentage) that an air conditioner with higher technical and environmentally friendly specifications can be sold for?
Distributors have different opinions on the price increase for the new concept: 10%, more than 15%, and 50%.

Question Eight: How can this concept are marketed effectively to consumers to maximize its value for them?
According to the distributors, the best way to market this concept is through digital media platforms as they are the most common channels of communication with consumers. TV ads can also be used by communicating through the brand itself. Additionally, offering discounts and promotions that encourage consumers to buy the product is another effective way to market this concept.

FINDINGS

Based on the study's findings and results, several key insights emerge:

I. A significant majority of respondents (97% from the "yes" sample and 88% from the "no" sample) express motivation and interest in the new concept of eco-friendly ACs. This indicates a strong market potential and consumer receptiveness towards environmentally eco-friendly air conditioning solutions.
II. The study reveals that a substantial proportion of respondents (93% from the "yes" sample and 80% from the "no" sample) are willing to pay an additional amount for eco-friendly ACs. This willingness to invest in eco-friendly features demonstrates a growing awareness and desire among consumers to prioritize sustainable and energy-efficient products.
III. Among the respondents who express a willingness to pay more for eco-friendly ACs, the most commonly cited percentage increase in the price is 5%. This finding suggests that pricing strategies should consider this benchmark to align with consumer expectations and maximize market acceptance.
IV. Digital media emerges as the preferred communication channel among consumers. Leveraging online platforms, such as social media, websites, and targeted digital advertising, will be effective in reaching and engaging with the target audience. Additionally, offering discounts or special promotions through these channels can further enhance the appeal and market acceptance of eco-friendly ACs.

These findings underscore the potential for successful market acceptance of eco-friendly ACs in the Egyptian market. By effectively promoting the energy-saving and environmentally conscious aspects of these ACs through digital outreach channels, and considering a reasonable price increase of around 5%, manufacturers and distributors can capitalize on the growing consumer demand for sustainable and energy-efficient air conditioning solutions.

CONCLUSION

1) One of the key benefits of eco-friendly air conditioners is their ability to save electricity and operate with high energy efficiency, which is a top priority for consumers. The eco-friendly ACs are similar to inverter ACs but also contribute to environmental preservation. Energy efficiency is a significant attribute that resonates with consumers, and it should be emphasized when introducing the concept.
2) Providing robust after-sale service is crucial to ensuring customer satisfaction when purchasing ACs. Consumers consistently rate excellent after-sale service and optimal performance of the AC units as extremely important. Delivering both will enhance customer loyalty and satisfaction.
3) Consumers are willing to accept a modest increase of 5% in the price of ACs for eco-friendly specifications. This percentage aligns with the majority of respondents and can serve as a suitable benchmark for pricing strategies.
4) Digital media platforms are recommended as the primary communication channel to effectively convey the benefits of eco-friendly ACs and engage with consumers. These platforms offer extensive reach and enable targeted marketing campaigns. Emphasizing the energy-efficient nature of the ACs and implementing discounts or special offers can create a compelling value proposition for prospective buyers.

By incorporating these key points in marketing and business strategies, manufacturers and distributors can effectively promote eco-friendly ACs in the Egyptian market, addressing consumer demands and contributing to sustainable environmental practices.

Technical and Financial Report for the Group Project for Transformation of Commercial Air Conditioning Companies (HCFC Phase-out Management Plan (HPMP) EGYPT (Stage II)), UNIDO ID:140400

2022

Report

Project supported by
MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL

UNITED NATIONS ENVIRONMENT

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Disclaimer

Acknowledgement

We would like to acknowledge the assistance given by the governmental sectors and the National Ozone Unit Officers of Egypt and 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 to the "Egyptian Russian University ERU" for providing the testing yard, facilities (Electrical feeding, water supply … etc.). In the same manner, Acknowledgement also goes to the "*Movenpick Soma Bay* Hurghada hotel" for providing the testing yard and the facilities (Electrical feeding, water supply, Wi-Fi network and so).

The project team also acknowledges the OEM manufacturers who built the IEC-H and DX system prototypes to be tested at the two definite locations.

- Delta Construction & Manufacturing DCM
- MISR Engineering Industries
- TIBA Engineering Industries Co.
- VOLTA EGYPT

Acknowledgement also goes to the OEM manufacturers who still actively working on building the IEC-H and DX system prototypes to be tested at the new expansion phase of the project.

- Egyptian German Air Treatment Company (EGAT)
- Misr Refrigeration & Air Conditioning MFG Co. (MIRACO)

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**, Program Officer – UNIDO and **Eng. Ayman El-Talouny**, International Partnership Coordinator, Ozone Action Program – UN Environment

The Coordination Consultant, Eng. Shahenaz Fouad and Eng. Ahmed El-Korashy provided logistical support and coordination for the project.

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**
Prof. Sayed Shebl Mohamed	Team Leader
Eng. Sally Aladdin Ali	Expert Testing Engineer
Eng. Aya Mohamed Zaki	Expert Testing Engineer
Eng. Nourhan Abdel Rahman Mohamed	Expert Testing Engineer
Mr. Mohamed Shebl Mohamed	Specialized Accountant Manager
Mr. Shady Gamal Abdel Aziz	Specialized Awareness and Hospitality Assistant
Mr. Farid Rashed Ibrahim	Specialized Testing Technician
Mr. Ahmed Maher Mohamed	Specialized Testing Technician
Mr. Mostafa Abdullah Hamad	Specialized Testing Technician
Mr. Ahmed Ezzat Mahmoud	Specialized IT Assistant
Mss. Hebatallah Waheed Ismail	Secretarial Work
Mr. Mohamed Hassan Ahmed	Secretarial Work
Mr. Mohamed Ibrahim Abdel Moety	Driver

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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 two of the eight climatic zones of Egypt.

The five figures below show the results of one OEM only in the two climatic zones tested. The figures below show 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 units, the wet bulb temperatures, the EERs and the unit's capacities. The tests were conducted for each OEM's IEC-H and DX units simultaneously for a 24 hours period in two climatic zones.

Figure 3: Inlet ambient temperature versus outlet temperature of IEC Hybrid and DX units for OEM2 at CZ2

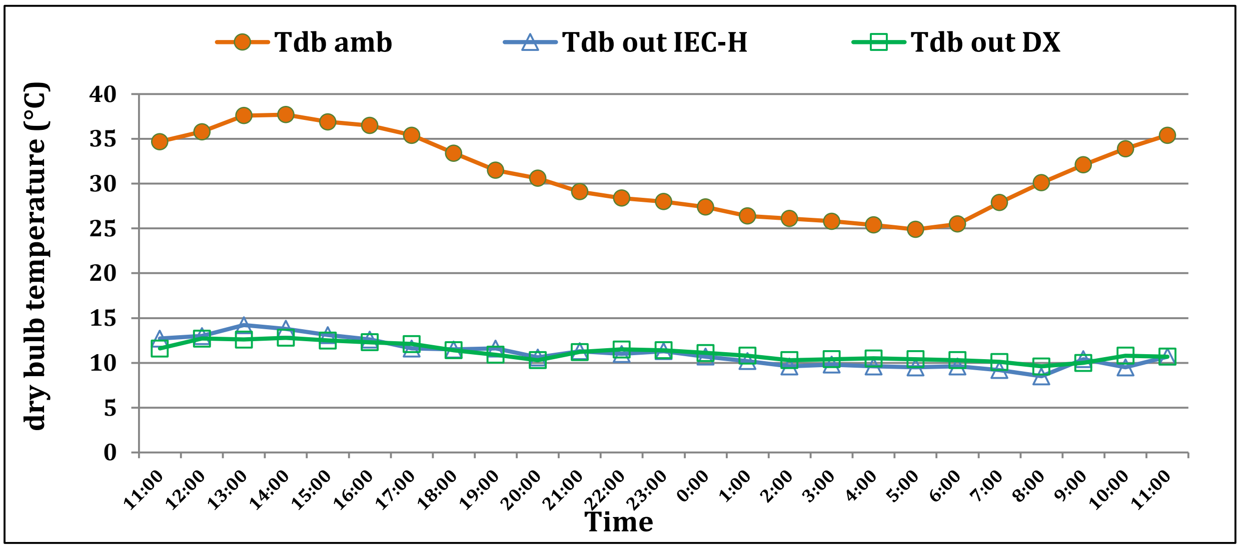


Fig 4: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM2 at CZ2

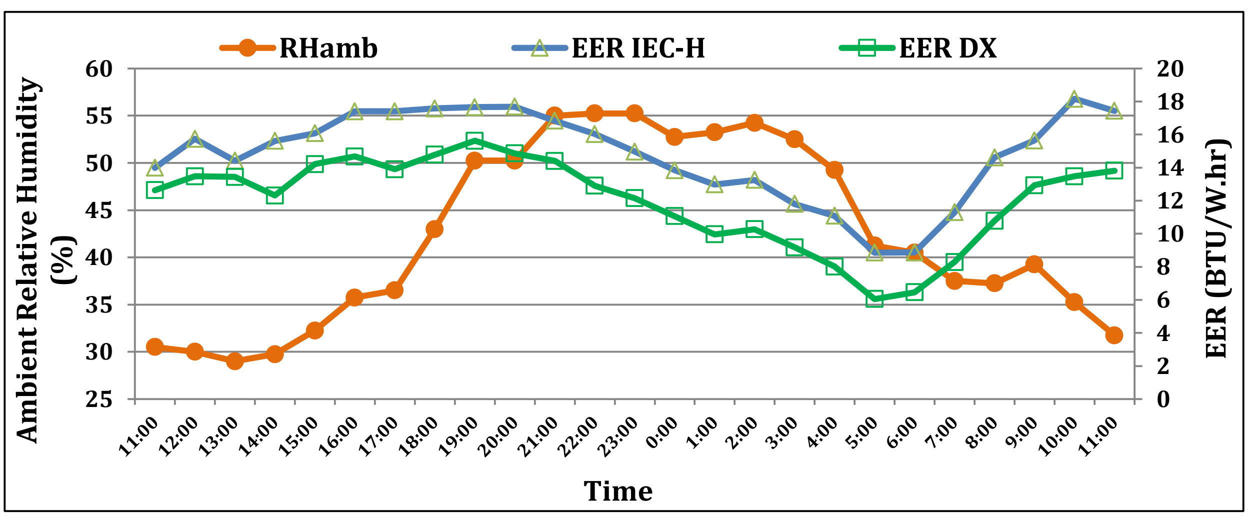


Fig 5: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM2 at CZ2

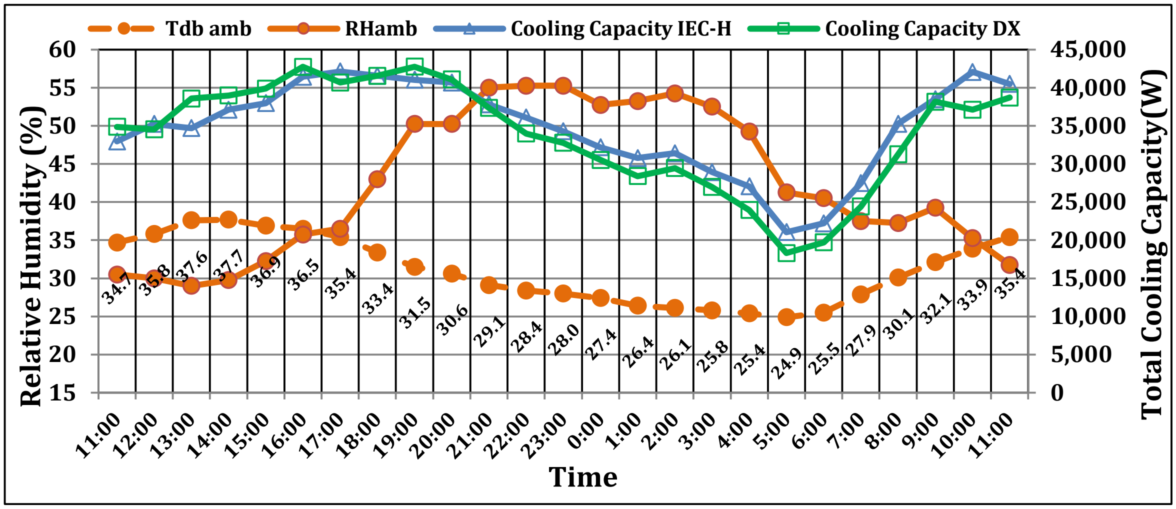


Fig 6: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM2 at CZ2

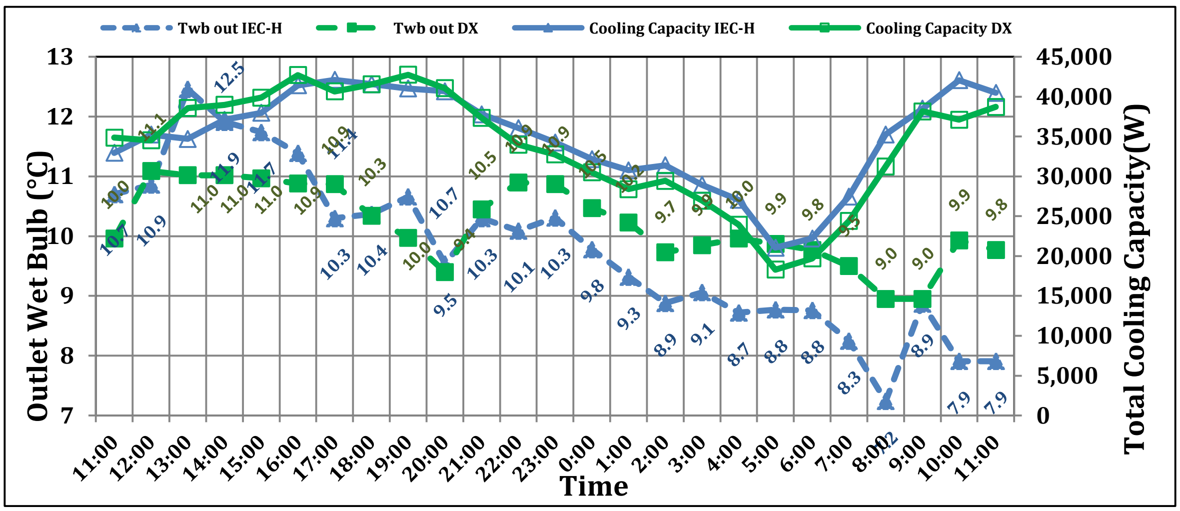
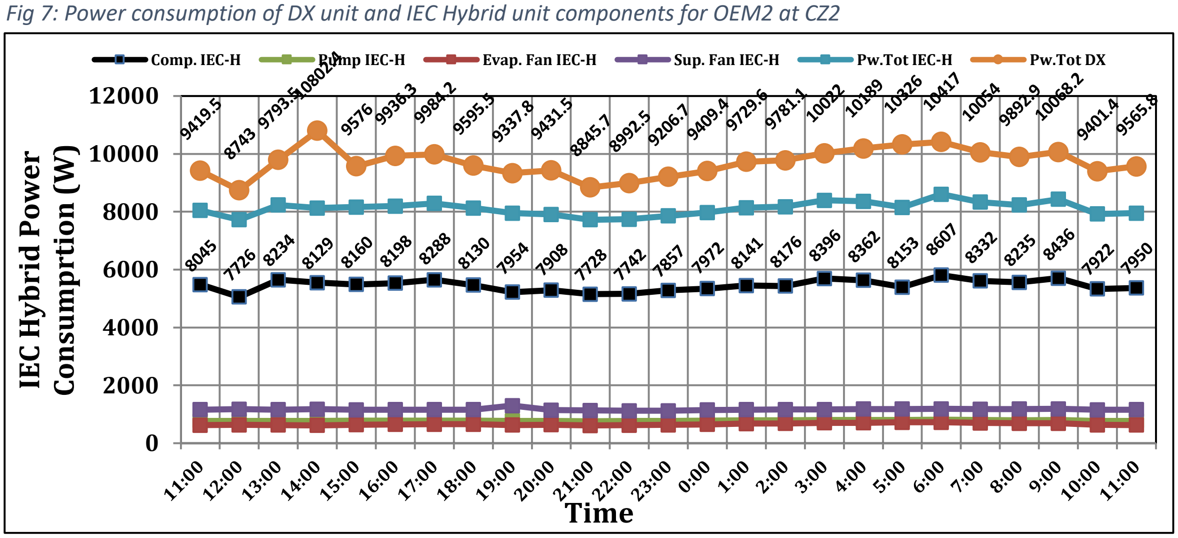


Fig 7: Power consumption of DX unit and IEC Hybrid unit components for OEM2 at CZ2



All OEMs results (see Annex 1) showed better EER for their IEC-H units compared to their respective DX unit in the two climatic zones where the tests were conducted. The highest and lowest EERs of all OEMs are shown below in the two climatic zones.

In that sense, the report showed that an IEC-H system is superior thermodynamically to a DX system because it achieves higher EERs.

Fig 13: High and Low EER (in BTU/W.hr) for Climatic Zone 2

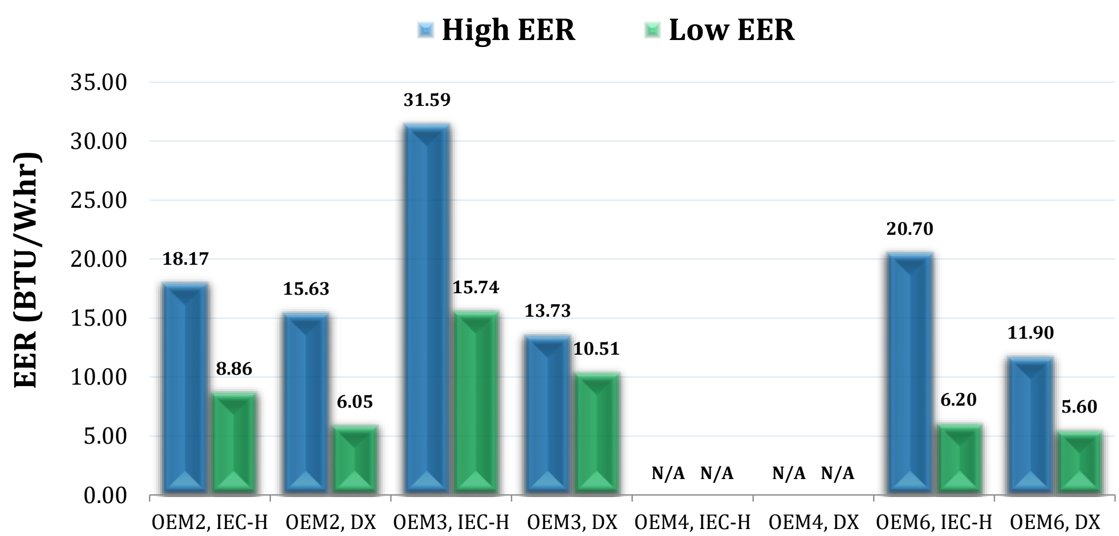
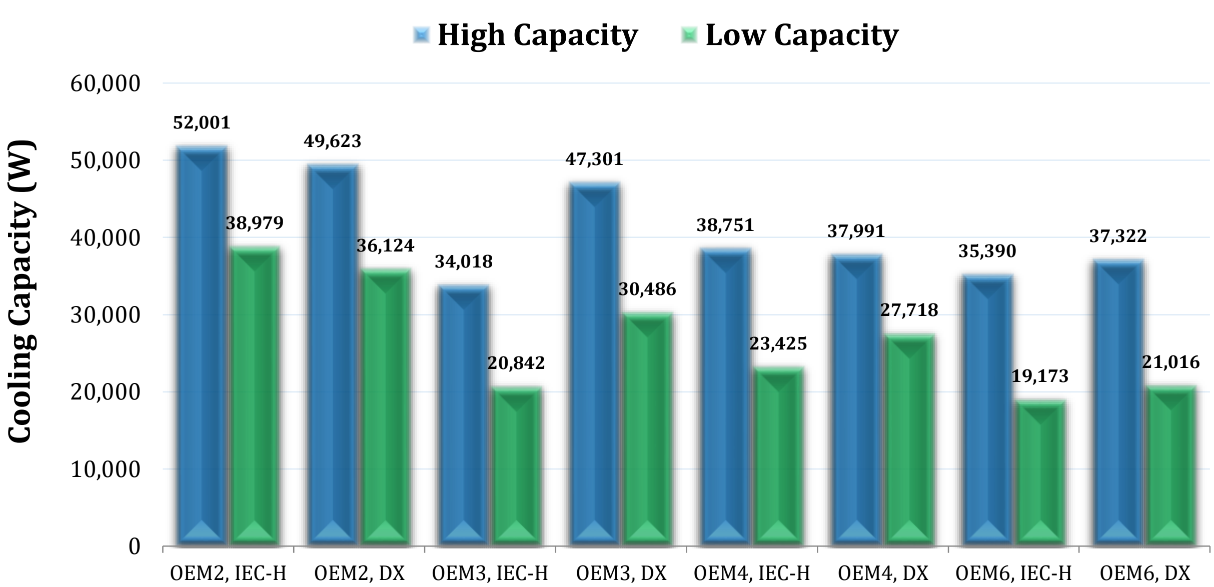


Fig 15: High and Low Capacity (in W) for Climatic Zone 5



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.

However, the report recommends further work to decide on the optimum size of compressor suitable for the IEC-H systems at all climatic zones assisted by further tests at the harshest climatic zone, CZ 8 to complete the tests needed for the writing of a code for Direct Indirect Evaporative Cooling.

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.

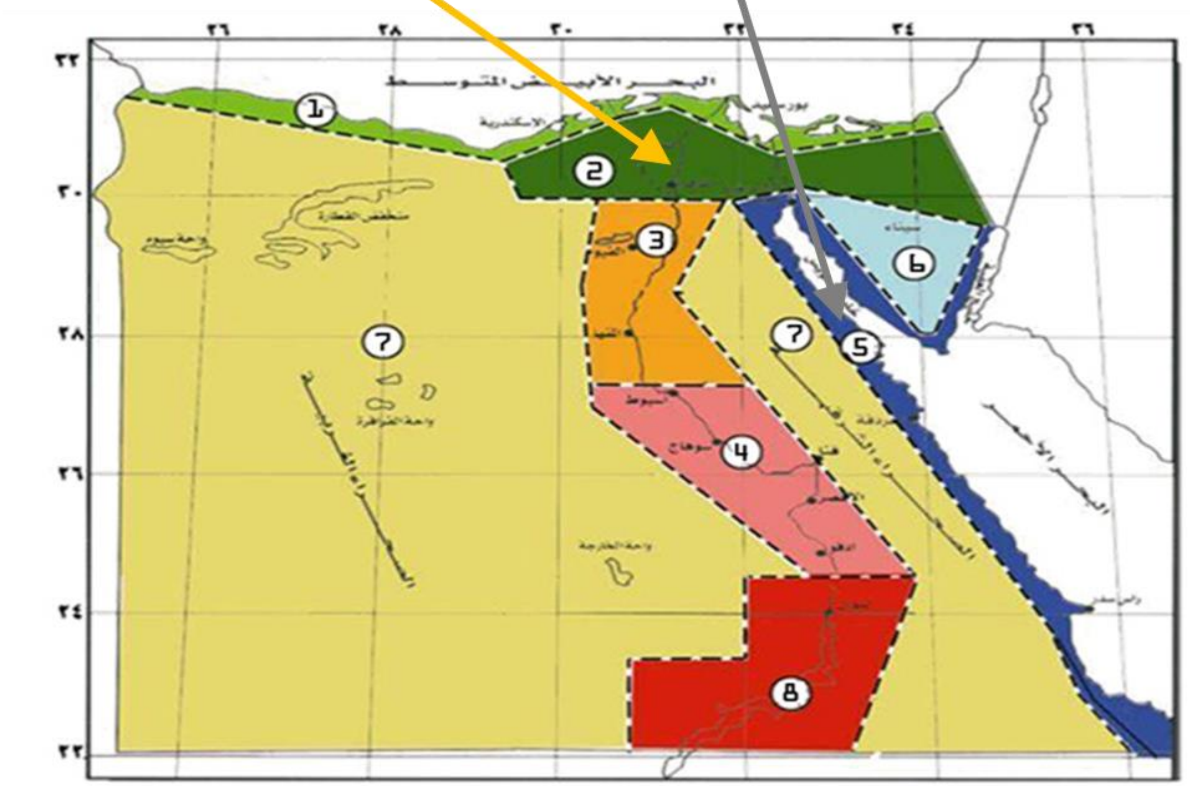
Chapter 1

1. Results and Analysis of the Testing and Measurements for the Prototypes for all OEMs in Two Locations

1.1. Selection of Climatic Zones 2 and 5

Figure 1: The Eight 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



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 repeated in two climatic zones to show the effect of dry bulb temperature increase versus relative humidity decrease on the efficiency and capacity of the prototypes. Changes in these two parameters in two diverse zones, climatic zone 2 and climatic zone 5, would indicate the viability of an IEC-H system in lower humidity/higher ambient climates when compared to a DX system.

Figure 1 shows the different climatic zones of Egypt. Climatic zone 2 encompass the capital Cairo and 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. Climatic zone 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.

Climatic zone 5 is the eco-climatic zone around the shores of the red sea north from Suez to south in Halayeb and Shalatein 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.

Climatic zone 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.

1.2. OEMs 1 and 5 did not Participate in the Tests

Although all manufacturers of central air-condition units in Egypt declared their intentions to participate in the project, in the end four out of six actively participated.

Two OEMs declined participation because of inability to allocate time or funds to manufacture IEC-H units. Both OEMs, though declared their intentions to participate in future projects in the same subject.

1.3. OEMs Active Participation in the Testing Program

Table 1: Testing in climatic zones 2 and 5

Status of Testing IEC Hybrid Prototypes and DX Units for all OEMs in August 2022				
OEM	**Both Units Ready**	**Climatic Zone 2 Testing Date in Badr City**	**Climatic Zone 5 Testing Date in Hurghada**	*Comments*
1	No	---	---	*Will not be ready this summer*
2	Yes	22- Aug	25- Aug	*Finished testing in both CZ2 and CZ5*
3	Yes	16- Jun	5- Jul	*Finished testing in both CZ2 and CZ5*
4	Yes	4- Aug	27- Aug	*Finished testing in both CZ2 and CZ5*
5	Declined Participation	---	---	*Declined testing – Needs technical assistance*
6	Yes	19- Jun	3- Jul	*Finished testing in both CZ2 and CZ5*

Although all six OEMs manufacturing central air conditioning units in Egypt consented to participate in the testing program, only four OEMs tested their units in the two climatic Zones. Not all OEMs prototypes were ready for testing during these months. Table 1 shows the status of testing of the OEMs at the end of August 2022.
The reasons some OEMs could not participate in testing are elaborated on in 1.2.

1.4. Report no. 1, the Pre-Testing Phase

In report no. 1, the Pre-testing phase was reported and its results were listed. In this Pre-testing phase, the same criteria for testing were used, together with the same unit's arrangement. Please refer to **annex 2** for the first report. The Pre-testing phase provided data and information on the problems associated with testing and also validated the selection of CZ 2 as a climatic zone with relatively higher humidity.

1.5. How the Tests were Performed?

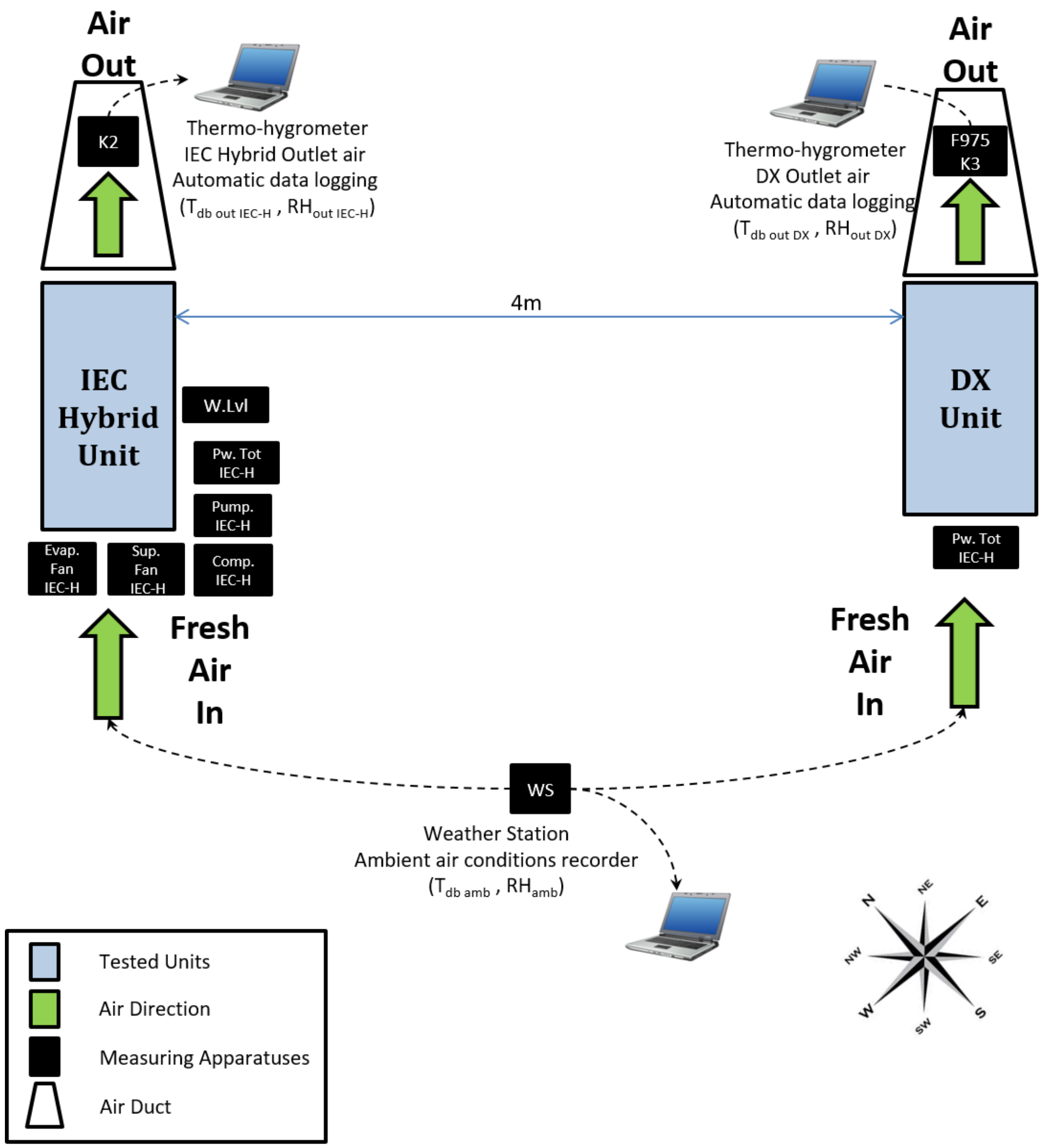
Each OEM tested two of his units in the same 24 hours, one IEC-H next to one DX unit.
Each OEM tested in the two designated climatic zones, 2 and 5.
Both units tested were full fresh air and had the same air flow rate.
Initially it was hoped the OEMs will use lower-GWP refrigerants approved to use in Egypt, R-32 and R-454 B. Unfortunately, this proved impossible because of the difficulties obtaining compressors for these refrigerants locally. To wait until compressors were sent from abroad, we would have missed the summer month’s window and delayed the project a full year.

1.6. The Testing Methodology

This is a brief description of the testing methodology. The complete testing methodology is shown in **annex 3**; 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 the Egyptian climatic zones 2 and 5.
- Both units tested simultaneously were full fresh air units with rate of air discharge of one unit regulated so that it matches the other.
- To try 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, the test results were discarded.
- The tests meteorological readings were recorded.
- The tests were performed to obtain the total cooling capacities (watts) and the energy efficiency ratios (BTU/W.hr) of both IEC-H and the DX unit for each OEM simultaneously and compare the results over a 24 hours period; see the Egyptian standard EOS 3795:2013.
- In this report, the test values are plotted and analysed to help obtaining a definite understanding of the advantages of the systems 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.
- The results of the economic study are now being calculated by the economic expert. The results of the economic analysis will be published when finished.
- Figure 2 shows the Schematic Diagram of the Test Arrangement with Instrumentation.

Fig 2: Schematic Diagram of the Test Arrangement with Instrumentation



Chapter 2

2. Tabulation Formats for Compiling and Presenting the Results of the Project (Results in CZ2 and CZ5)

The results obtained were tabulated in excel sheets tabs as follows:

- Basic information
- Used apparatus for testing
- Abbreviations
- Final results listing
- Calculations of capacities and EERs for IEC-H
- Calculations of capacities and EERs for DX
- Graphs
- Units' arrangement drawing.

The tabs of the calculations of capacities and EERs for IEC-H units were used to plot the essential graphs in the tab graphs.
The figures show the following:
Figure 3: The ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units across a whole day
Figure 4: the EERs of both the IEC-H and the DX units and ambient RH across a whole day.
Figure 5: The cooling capacities of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day
Figure 6: The cooling capacities and the outlet wet bulb temperatures and RHs of the IEC-H and DX units across a whole day
Figure 7: The power consumptions of the DX unit and the IEC-H unit and its components.
This was repeated for each OEM in the two designated climatic zones, 2 and 5.
These figures were used in the analysis that follows each OEM.
All tabulated excel sheets are included in annexes 4 and 5.

Chapter 3

3. Provision of the Technical Parameters for the Financial Model (Capital and Operating Costs of OEMs)

The financial analysis will provide us with figures that will help us decide if an IEC-H system is economically advantageous compared to a DX system.

In order to clarify how the economic study is made for all OEMs, a simplified example for OEM2 in CZ 2 is listed here. All figures used in this example are provided by the OEM2 or from the tests conducted for the OEM2 in CZ 2.

OEM2 CZ2 - Basic Assumptions:

- **Investment Cost:**

Unit Type	**DX unit**	**IEC Hybrid**
Total Price, EGP	355,000	385,000

- **Annualizing the test:**

Testing between the two units was conducted on August 22, 2022, and an EFLH (equivalent full load hours per year) is assumed to characterize the test results annually.

The annual operation is assumed based on EFLH of 50% of total annual working hours as illustrated in the following table:

Months Operating		12
Days Operating		365
Yearly working hours	hr	8,760
Equivalent Full Load Hours	%	50%
EFLH per year	hr	4,380

- **Cost of Operations:**

The main costs incurred for producing the required energy is illustrated as in below.

Maximum Power Consumption	W/hr	Annual Electricity Consumption
IEC Hybrid Unit	8,607	37,698,660
DX Unit	10,802	47,314,512
Average Cost	kW/hr	1.60 (EGP)
Electricity cost Increase	%	0.00%
Electricity Cost		
IEC Hybrid Unit	EGP	60,318
DX Unit	EGP	75,703
Difference -Saving	EGP	15,385

The main costs incurred for the required water is illustrated as in below.

Maximum Water Consumption	Litres/hour	Annual Water consumption
IEC Hybrid Unit	54	236,520
DX Unit	-	-
Average Cost per Cubic meter		5.00 (EGP)
water cost Increase	%	0.00%
Water Cost		
IEC Hybrid Unit	EGP	1,183
DX Unit	EGP	-
Difference -Saving	EGP	(1,183)

- **Total Saving and Returns:**

The test showed a favorable difference for IEC Hybrid Unit, as it achieved total saving in its operation cost amount EGP 14,203 as illustrated in the following table:

Electricity Saving	15,385
Water Expenditure	(1,183)
Net Saving	14,203

The test showed a favorable difference for IEC-H unit, as it achieved total saving in its investment cost amount EGP 30k as illustrated in the following table:

UNITS PRICES (EGP)	
IEC Hybrid Unit	385,000.00
DX Unit	355,000.00
Difference -Costs	(30,000.00)

The following table, the IEC Hybrid Unit shows favorable IRR of 46%, and NPV amount EGP 24,621 with a payback period of 3.11 years.

		Year (0)	Year (1)	Year (2)	Year (3)	Year (4)
Net Cash		(30,000)	14,203	14,203	14,203	14,203
Cumulative Cash Flows		(30,000)	(15,797)	(1,594)	12,608	26,811
Discount Rate		20%				
NPV	**EGP**	24,620.57				
IRR	**%**	46%				
Breakeven Year	**Years**	3.00				
Fraction	**Years**	0.11				

Chapter 4

4. 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 (1).

4.1. OEM2, Climatic Zone 2

Table 2: Basic Information for OEM2 at Climatic Zone 2

Basic Information			
Tested Units Name	**DX**		**Direct Expansion Unit**
	IEC hybrid		**Indirect Evaporative Cooling Hybrid Unit**
OEM No.	2		
Air Flow Rate	2000		c.f.m for DX and IEC hybrid Units
Water Bath Area	1000*900		mm^2
Climatic Zone	2 (Delta and Cairo Region)		
	Altitude	208	meter (from sea level)
	Location	30°08' 36" N 31°43' 06" E	
Test Date	22-Aug-22		
Compressor Capacity	DX	10 TR	35.2 kW
	IEC-H	10 TR	35.2 kW
		DX Unit	IEC Hybrid Unit
Compressor brand		Copeland Scroll ZP	Copeland Scroll ZP
Refrigerant		R410 A	R410 A

The figures below show the following:

- Figure 3: The ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units across a whole day for OEM2 at CZ2.
- Figure 4: The EERs of both the IEC-H and the DX units and ambient RH across a whole day for OEM2 at CZ2.
- Figure 5: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day for OEM2 at CZ2.
- Figure 6: The cooling capacities and the outlet wet bulb temperatures and RHs of the IEC-H and DX units across a whole day for OEM2 at CZ2.
- Figure 7: The power consumptions of the DX unit and the IEC-H unit and its components for OEM2 at CZ2.

Fig 3: Inlet ambient temperature versus outlet temperature of IEC Hybrid and DX units for OEM2 at CZ2

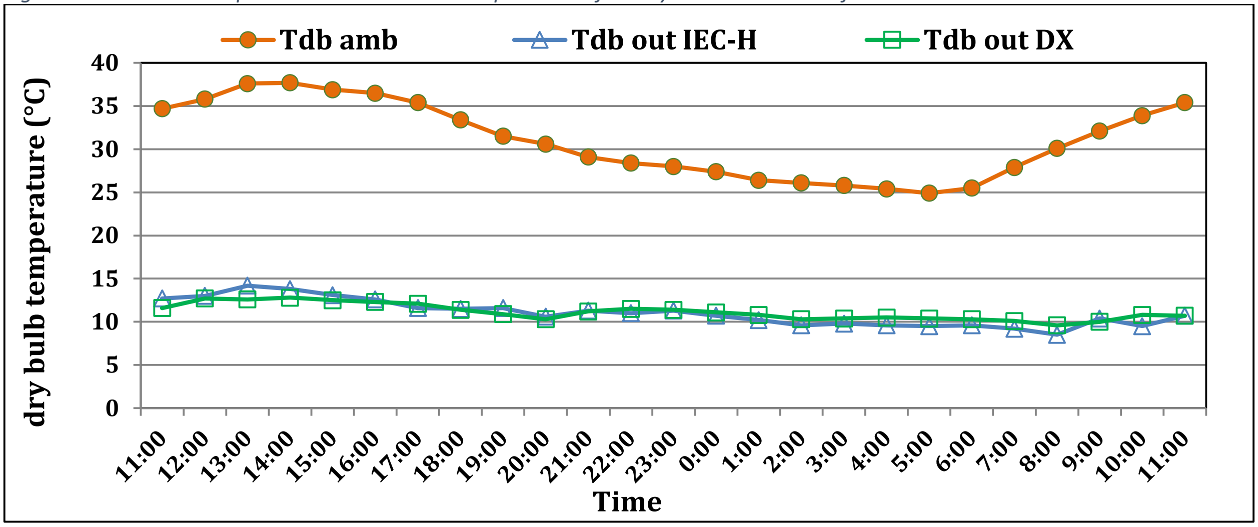


Fig 4: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM2 at CZ2

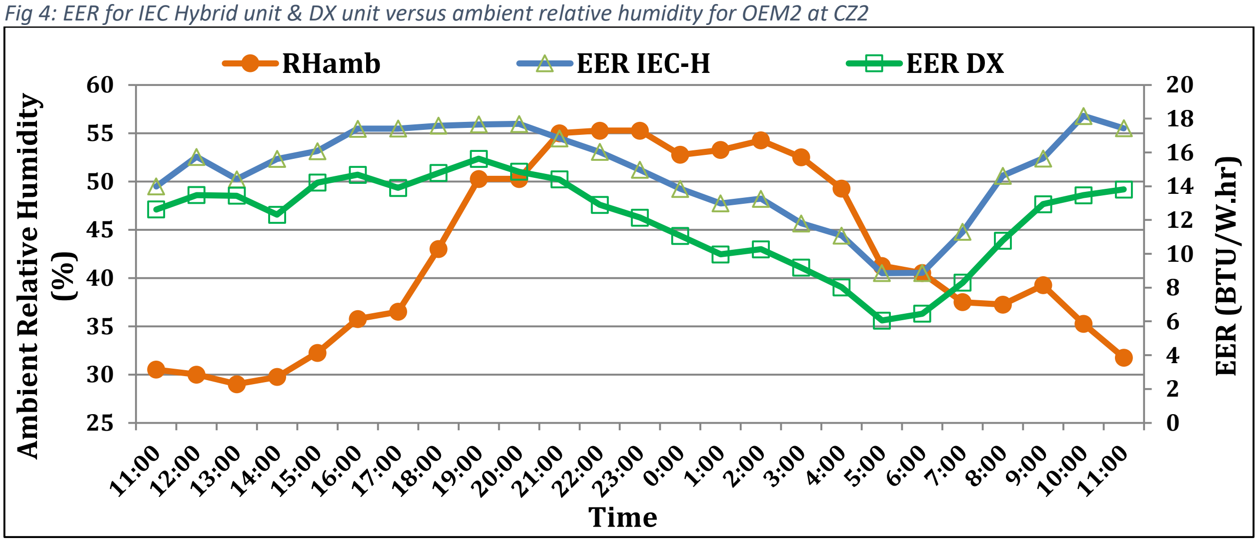


Fig 5: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM2 at CZ2

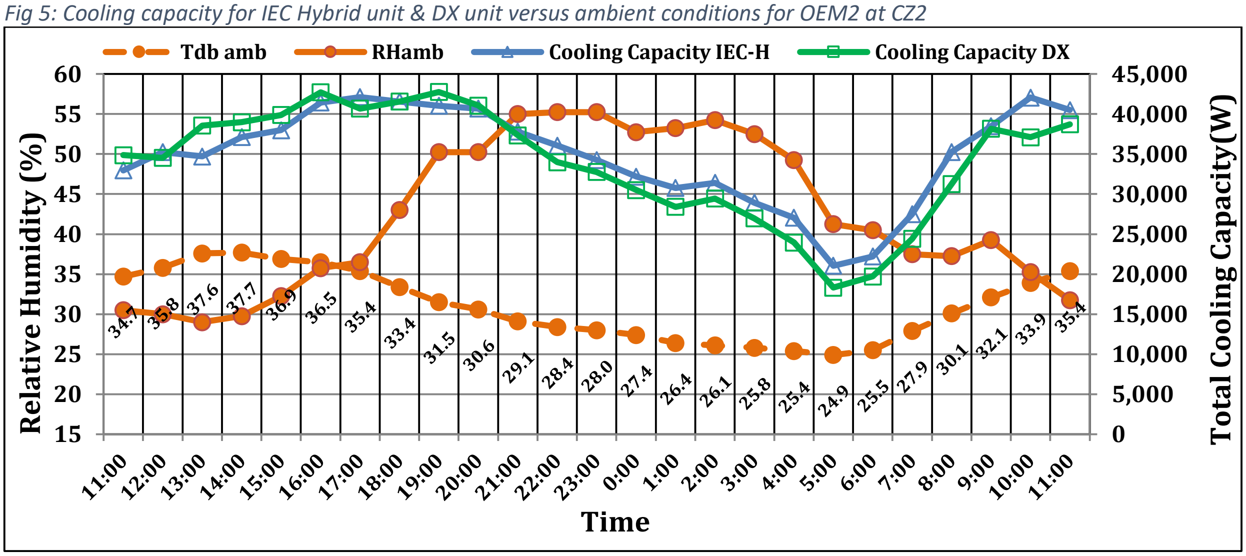


Fig 6: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM2 at CZ2

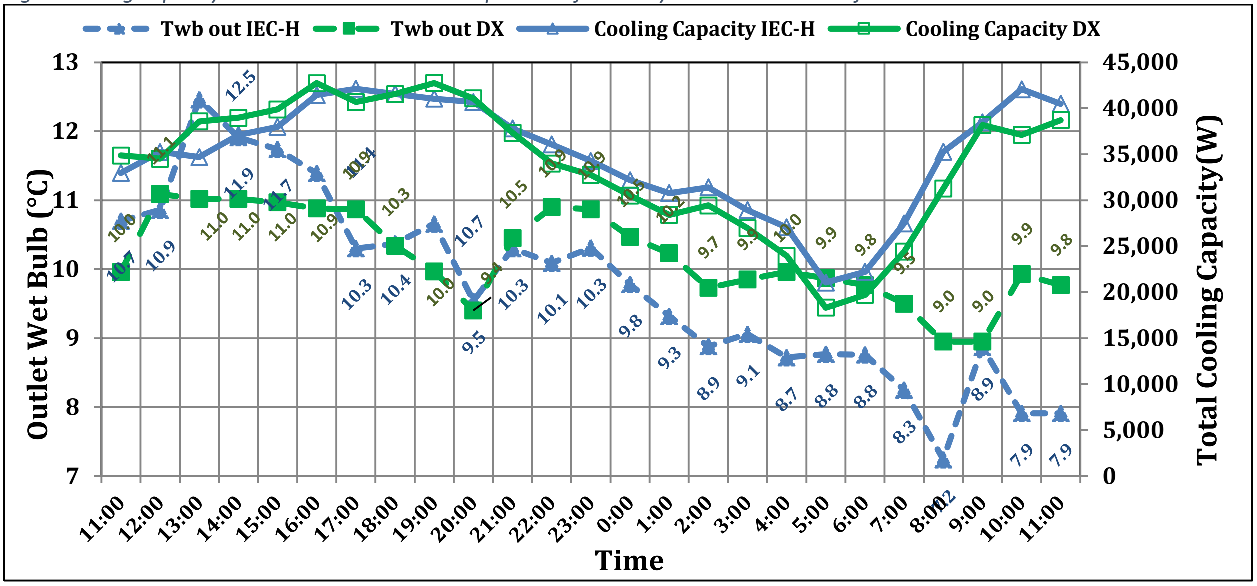
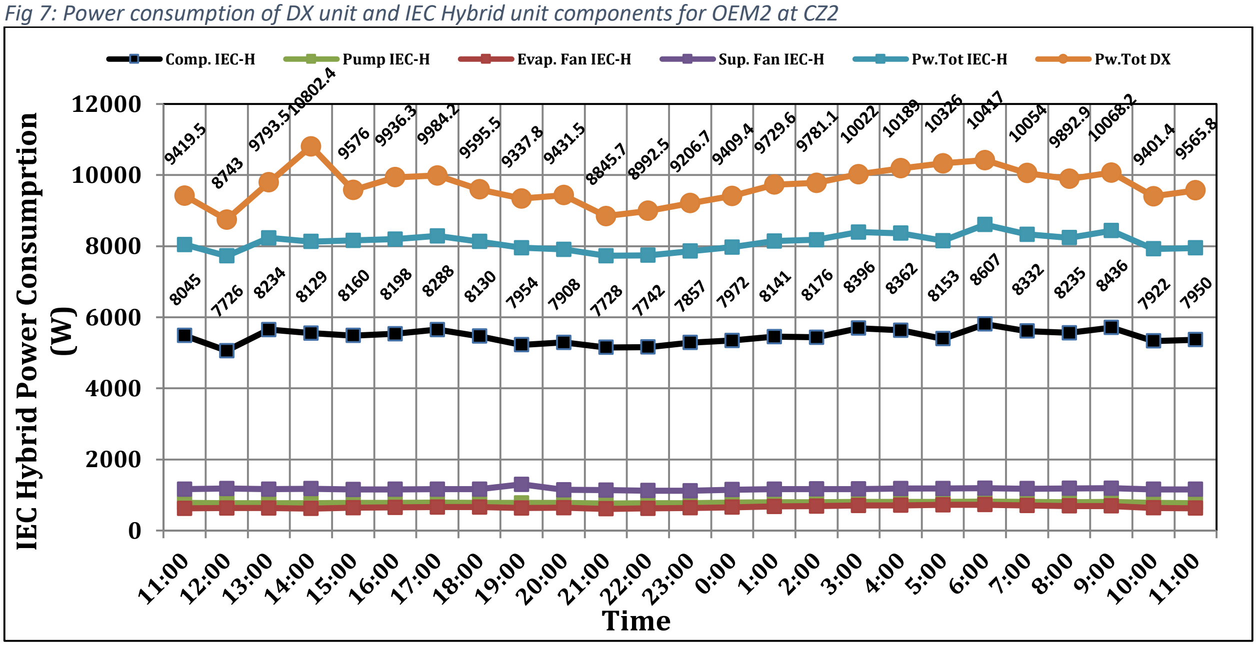


Fig 7: Power consumption of DX unit and IEC Hybrid unit components for OEM2 at CZ2



Analysis of the results of OEM2 at CZ 2:

Table 3: High and Low readings for OEM2 at Climatic Zone 2

CZ2					
High and low, ℃					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
37.7	55.3 @ 22:00	14.2	11.9	12.8	11.1
24.9	29.0 @ 13:00	8.5	7.2	9.6	8.9

- **$T_{db\ out}$ Comparison:**
  - In figure 3, the outlet dry bulb temperatures of both units are close to each other.
  - The swing in $T_{db\ out}$ of DX unit is from to 12.8 ^oC to 9.6 ^oC, 3.2 ^oC swing
  - The swing in $T_{db\ out}$ of IEC-H unit is from to 14.2 ^oC to 8.5 ^oC, 5.7 ^oC swing
  - The daily $T_{db\ amb}$ changes from 37.7 ^oC down to 24.9^oC, a swing of 12.8 ^oC.
  - The changes of $T_{db\ out}$ of IEC-H unit are consistent with the ambient dry bulb, as it goes up it increases and vice versa. The same applies for the DX unit.

- **EERs Comparison:**
  - In figure 4, the EERs of the IEC-H are consistly higher than these of the DX unit although both use the same compressor capacity.
  - The swing in the values of the EERs of both units is consistent with the relative humidity. As the RHs increases the EERs decreases and vice versa.

- **Capacities Comparison:**
  - In figure 5, the IEC-H capacities are higher than those of the DX unit consistently except in the period 12:00 to 17:00 and 18:00 to 20:00 pm due to the losses in hot gas bypass.
  - This is important to note considering that both systems are equipped with the same capacity compressors.

- **$T_{wb\ out}$ Comparison:**
  - In figure 6, the changes of $T_{wb\ out}$ of IEC-H unit were more pronounced than those of the DX unit across the day. This is understandable because during the day when RH was low more evaporation was used to achieve cooling in the IEC-H unit.
  - In the night, when humidity increases lower evaporation occurred in the IEC-H unit resulting in lower $T_{wb\ out}$ of the unit in comparison the $T_{wb\ out}$ of DX unit.
  - The swing in RHs were between 29.0 % at 13:00 to 55.3 % at 22:00

- **Power Consumptions Comparison:**
  - In figure 7, the total power consumption of the DX unit was consistently higher than that of the IEC-H unit across the whole day.
  - The compressor of the IEC-H unit constituted the largest portion of the power consumption of the unit while the evaporation fan, the supply fan and the pump constituted the remaining much lower consumptions.

4.2. OEM2, Climatic Zone 5

Table 4: Basic Information for OEM2 at Climatic Zone

Basic Information			
Tested Units Name	**DX**		**Direct Expansion Unit**
	IEC hybrid		**Indirect Evaporative Cooling Hybrid Unit**
OEM No.	2		
Air Flow Rate	2000		c.f.m for DX and IEC hybrid Units
Water Bath Area	1000*900		mm^2
Climatic Zone	5 (Eastern Coast Region)		
	Altitude	2	meter (from sea level)
	Location	26°49' 39" N 33°56' 13" E	
Test Date	25-Aug-22		
Compressor Capacity	DX	10 TR	35.2 kW
	IEC hybrid	10 TR	35.2 kW
	DX Unit		IEC Hybrid Unit
Compressor brand	Copeland Scroll ZP		Copeland Scroll ZP
Refrigerant	R410 A		R410 A

The figures below show the following:

- Figure 8: the ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units across a whole day for OEM2 at CZ5
- Figure 9: the EERs of both the IEC-H and the DX units and ambient RH across a whole day for OEM2 at CZ5.
- Figure 10: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day for OEM2 at CZ5
- Figure 11: The cooling capacities and the outlet wet bulb temperatures and RHs of the IEC-H and DX units across a whole day for OEM2 at CZ5
- Figure 12: The power consumptions of the DX unit and the IEC-H unit and its components for OEM2 at CZ5.

Fig 8: Inlet ambient temperature versus outlet temperature of IEC Hybrid unit & DX unit for OEM2 at CZ5

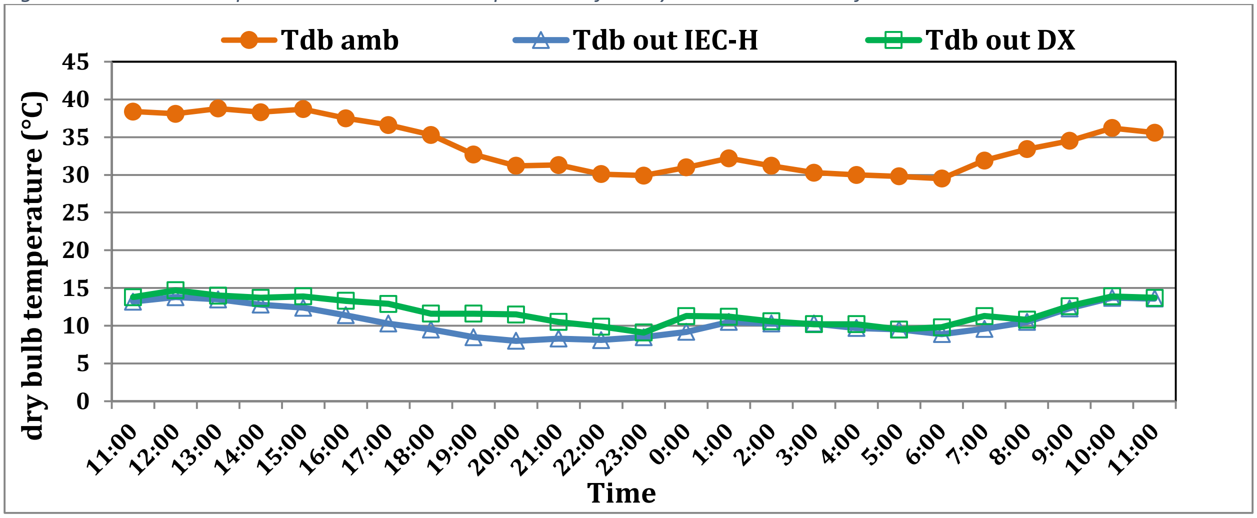


Fig 9: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM2 at CZ5

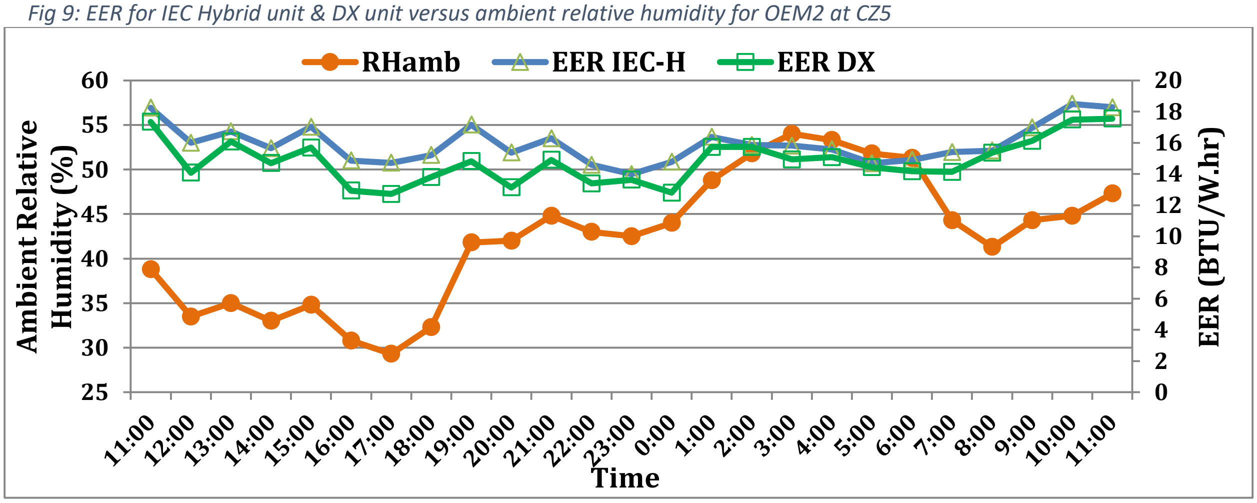


Fig 10: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM2 at CZ5

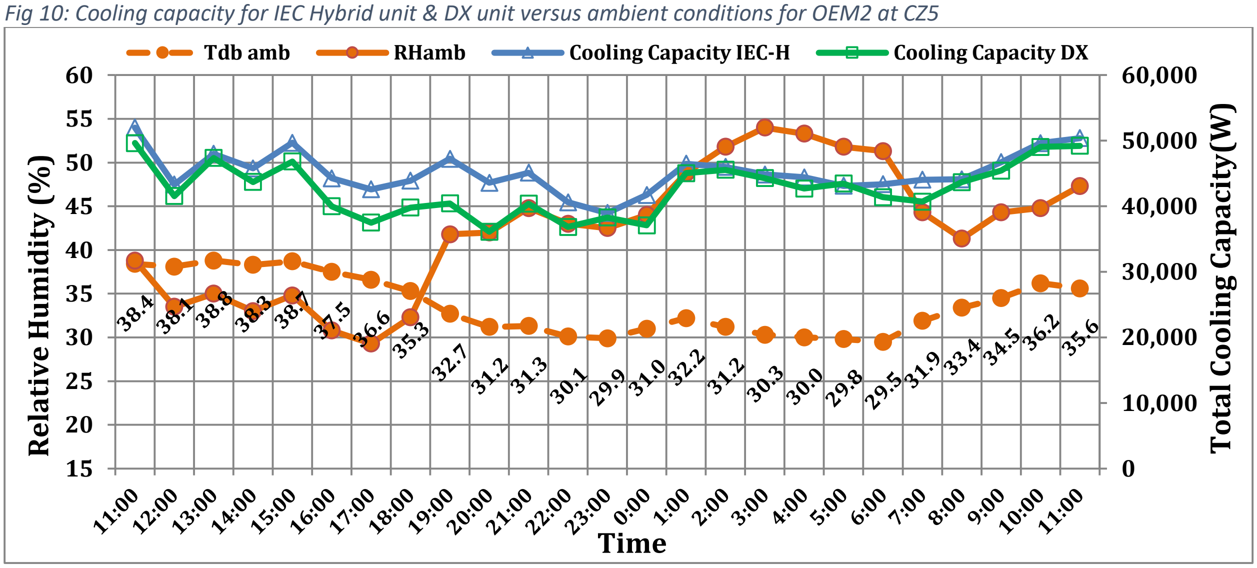


Fig 11: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM2 at CZ5

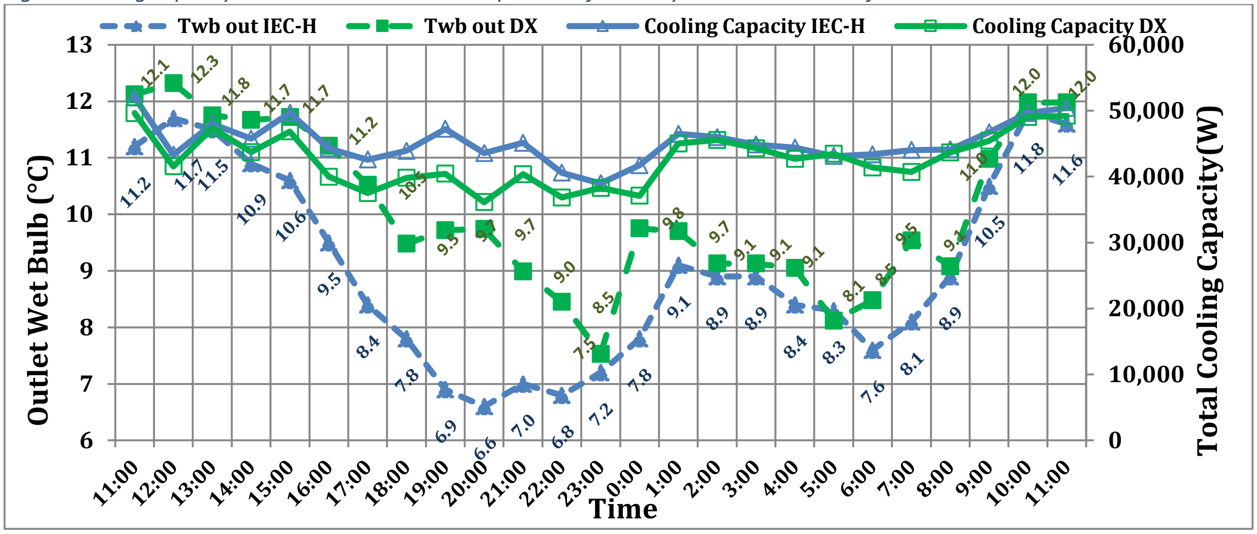
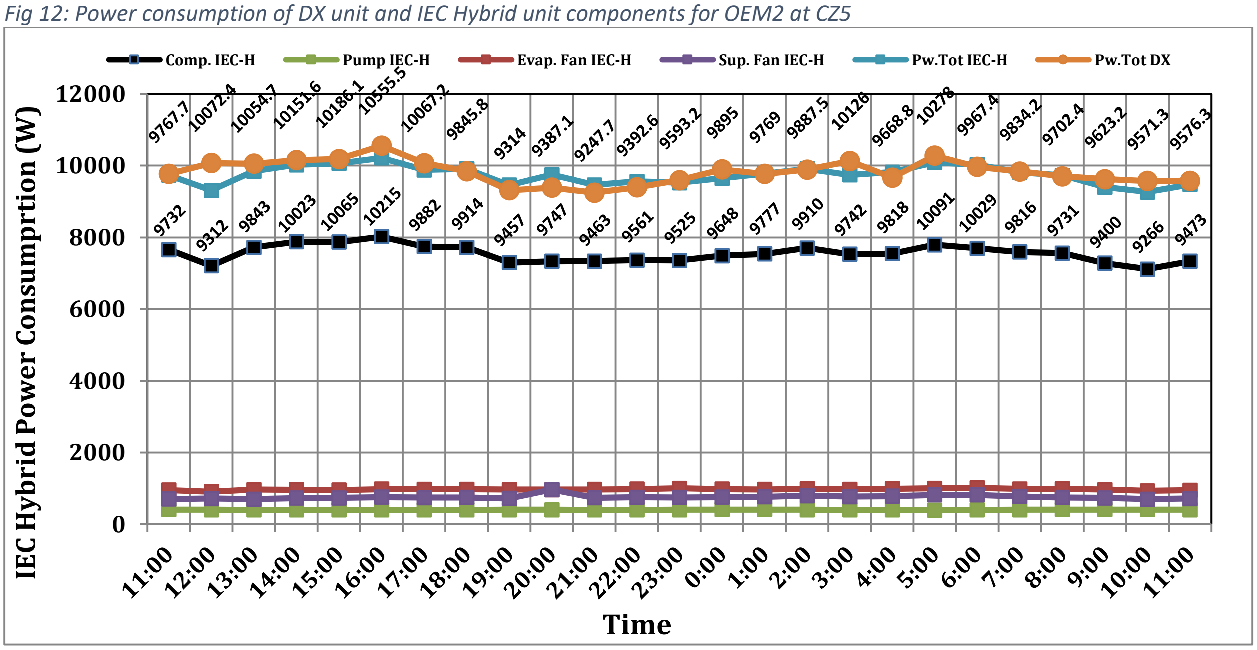


Fig 12: Power consumption of DX unit and IEC Hybrid unit components for OEM2 at CZ5



Analysis of the results of OEM2 at CZ5:

Table 5: High and Low readings for OEM2 at Climatic Zone 5

CZ5					
High and low, °C					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
38.8	54 @ 3:00	13.8	11.8	14.7	12.3
29.5	29 @ 17:00	8	6.6	9.1	7.5

- **$T_{db\ out}$ Comparison:**
  - In figure 8, the outlet dry bulb temperatures of the DX unit are generally slightly higher than those of the IEC-H except in a few readings when they are almost equal.
  - The swing in outlet dry bulb temperature of the DX unit is from to 14.7 ^{o}C to 9.1 ^{o}C, 5.6 ^{o}C swing
  - The swing in outlet dry bulb temperature of the IEC-H unit is from to 13.8 ^{o}C to 8 ^{o}C, 5.8 ^{o}C swing
  - The daily ambient dry bulb temperature changes are from 38.8 ^{o}C down to 29.5^{o}C, a swing of 9.3 ^{o}C.
  - The changes of outlet dry bulb temperature of the IEC-H unit are consistent with the ambient db. As it goes up it increases and vice versa. The same applies for the DX unit.

- **$T_{wb\ out}$ Temperature Comparison:**
  - In figure 11, the changes of outlet wet bulb temperature of the IEC-H unit were closer to those of the DX unit across the day, except between 14:00 and 23:30.
  - In the night, when humidity increases lower evaporation occurred in the IEC-H unit resulting in lower outlet wet bulb temperature out of the unit and therefore in comparison the outlet wet bulb temperature of the DX unit is higher.
  - Unusually high ambient RH occurs, 29.3 % at 17:00 to 54 % at 3:00

- **EERs Comparison:**
  - In figure 9, the EER of the IEC-H is consistly higher than that of the DX unit except at 2:30, 5:30 and 8:00 when they were almost equal. This fluctuation arose due to the voltage fluctuation between 350 to 375 volt. This is important to note although both uses the same capacity compressor.
  - The swing in the values of the EER of both units is consistent with the relative humidity. As the RH increase the EERs decreases and vice versa.

- **Capacities Comparison:**
  - In figure 11, the IEC-H capacity is higher than that of the DX unit consistently except in the period 23:30, 2:30 and 5:00 when both are almost equal.
  - Again, this is important to note although both systems are equipped with the same capacity compressors.

- **Power Consumptions Comparison:**
  - In figure 12, the total power consumption of the DX unit was close to that of the IEC-H unit across the whole day. Nevertheless, the ERs of the IEC-H unit were higher than these of the DX unit.
  - This is because of the unusually high ambient RH with consistly high ambient RH which necessitated high compressor power use in the IEC-h unit.
  - The compressor of the IEC-H unit constituted the largest portion of the power consumption of the unit while the evaporation fan, the supply fan and the pump constituted the remaining much lower consumptions.

Table 6: Concluding remarks on the performance of OEM2 IEC-H unit and the DX unit in CZ2 and CZ5

CZ2						**CZ5**					
High and Low						High and Low					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX	$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
37.7	55.3	14.2	11.9	12.8	11.1	38.8	54	13.8	11.8	14.7	12.3
24.9	29.0	8.5	7.2	9.6	8.9	29.5	29	8	6.6	9.1	7.5

CZ2				CZ5			
EER		Capacities, W		EER		Capacities, W	
IEC-H	DX	IEC-H	DX	IEC-H	DX	IEC-H	DX
18.2	15.6	42118.08	42751.24	18.5	17.5	52001.32	49622.73
8.9	6.1	21047.24	18311.86	14.0	12.7	38978.72	36124.40

- The EER of the IEC-H in CZ2 was between and 18.2 and 8.9 and that of the DX unit was between 15.6 and 6.1
- The EER of the IEC-H in CZ5 was between 18.5 and 14 and that of the DX unit was between 17.5 and 12.7
- The capacity of the IEC-H in CZ2 was between and 42,118 W and 21,047 Wand that of the DX unit was between 42,751 W and 18,311 W.
- The capacity of the IEC-H in CZ5 was between and 52,001 W and 38,978 Wand that of the DX unit was between 49,623 Wand 36,124 W.
- The smaller swing in ambient dry bulb temperature at CZ5 compared to CZ2 (38.8 ^oC to 29.5^oC compared at CZ2, to 37.7 ^oC to 24.9 ^oC) together with unusually high relative humidity in CZ5 (29 % at 17:00 to 54 % at 3:00 at CZ5 compared to 29% at 17:00 and 55% at 3:00 at CZ2) made the IEC-H unit unable to use its full potential for evaporation cooling across the day.
- The total capacities delivered by both units in CZ5 were higher than these at CZ2 (42,118 W and 42,751 W in CZ2 compared to 52,001 W and 49,622 W in CZ5).
- The Relative Humidity fluctuation also affected the performance of the IEC-H unit in CZ5.

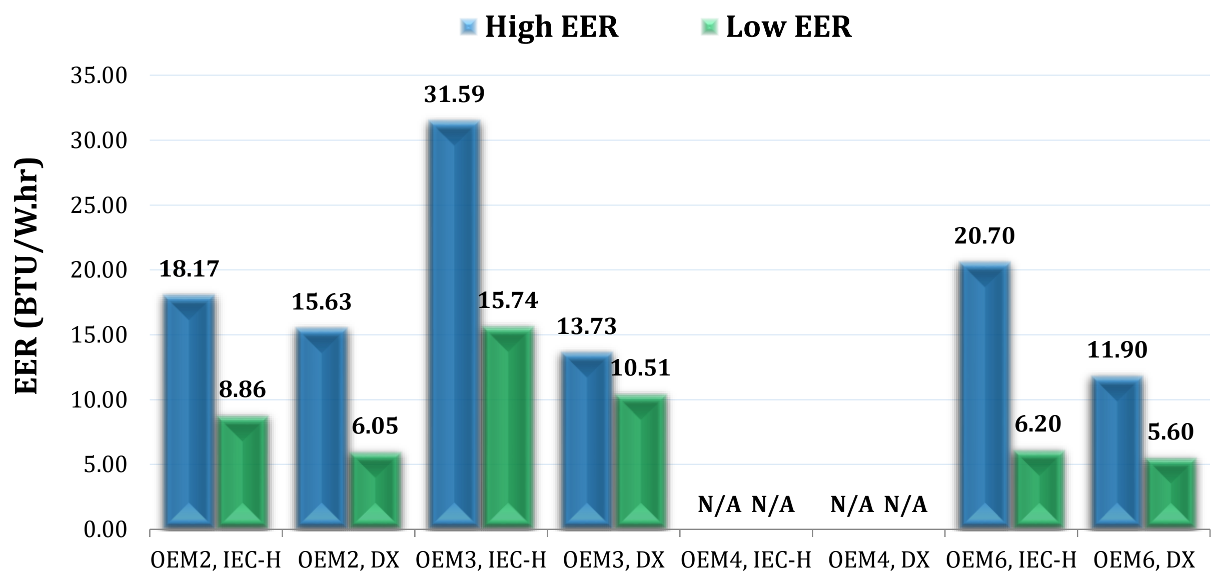
Chapter 5

5. The Final Results Analysis with Conclusion and Recommendation for Future Work

5.1. The Final Results Analysis

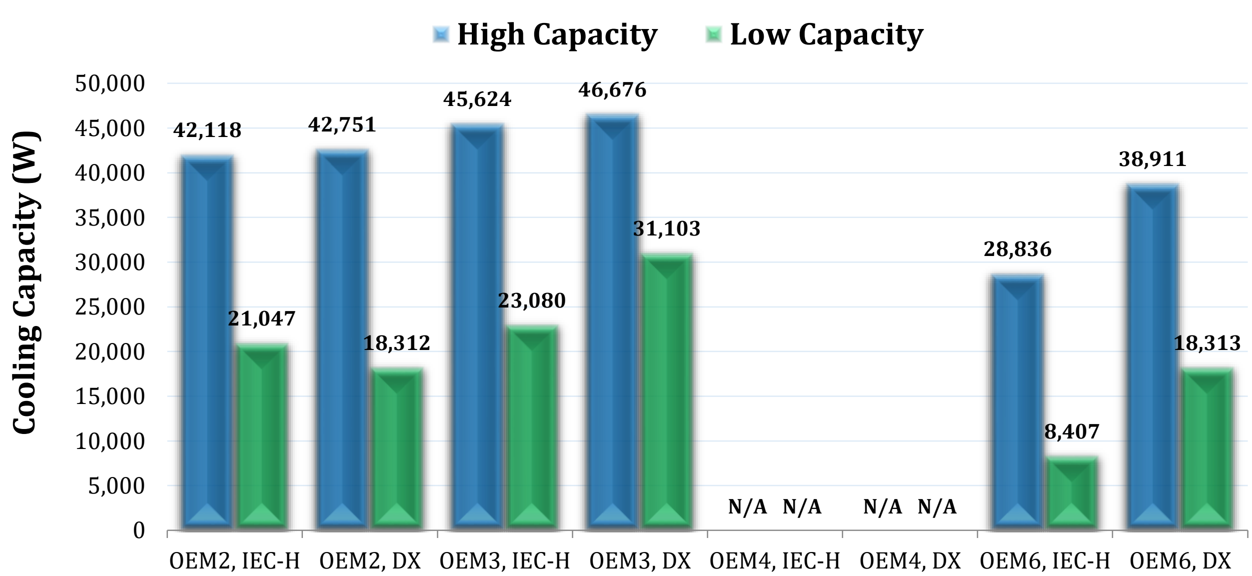
5.1.1. EER HIGH and LOW - CZ2

Fig 13: High and Low EER (in BTU/W.hr) for Climatic Zone 2



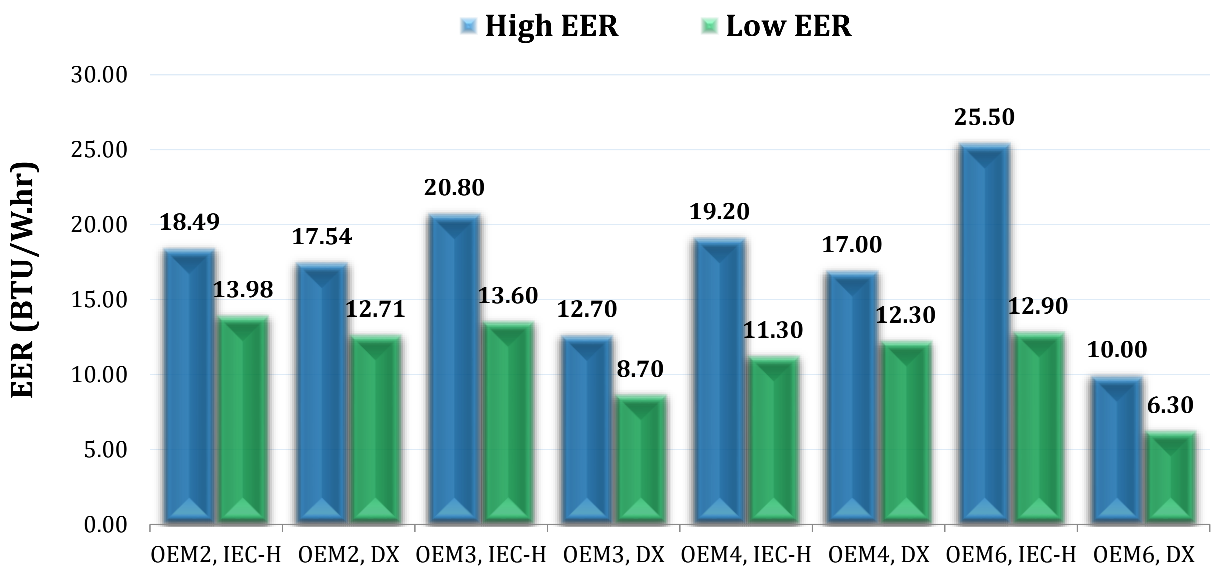
5.1.2. CAPACITY HIGH and LOW - CZ2

Fig 14: High and Low Cooling Capacity (in W) for Climatic Zone 2



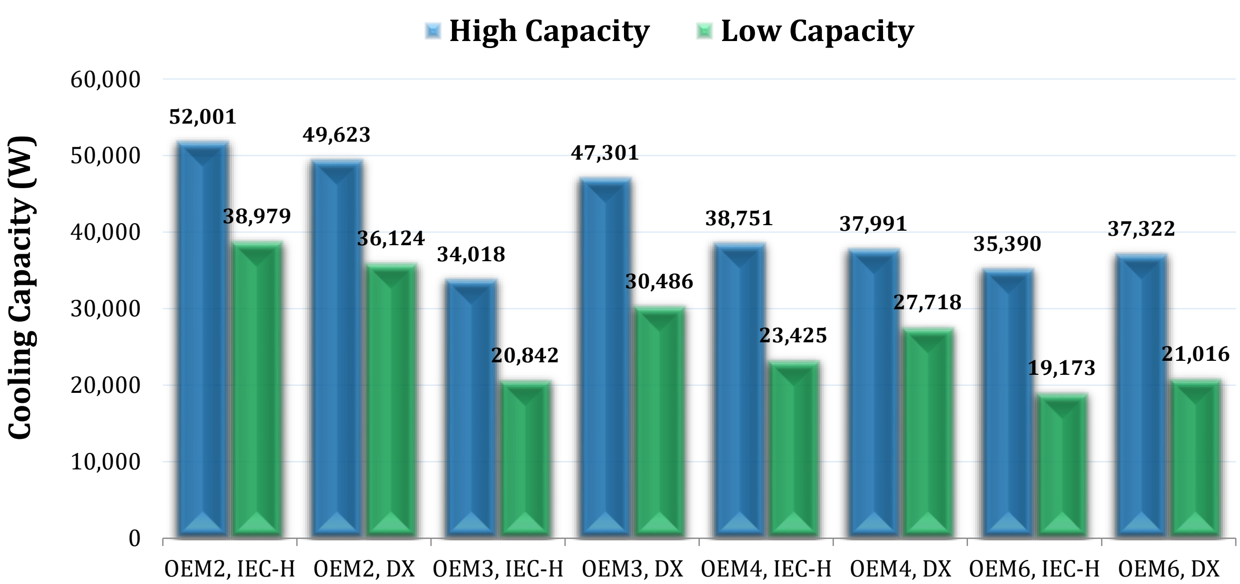
5.1.3. EER HIGH and LOW - CZ5

Fig 15: High and Low EER (in BTU/W.hr) for Climatic Zone 5



5.1.4. CAPACITY HIGH and LOW - CZ5

Fig 16: High and Low Cooling Capacity (in W) for Climatic Zone 5



5.2. Conclusion

The analysis of the final results of all OEMs shows the following:

- All OEMs show EERs of the IEC-H units that are superior to corresponding DX units.
- The IEC-H unit compressor capacity compared to DX unit is as follows:

OEM	IEC-H Compressor capacity compared to compressor capacity of DX unit	IEC-H unit capacity compared to DX capacity
4	Larger by 20 %	Almost equal unit capacities
2	Equal in capacity	Almost equal unit capacities
3	Smaller by 60%	Lower unit capacities
6	Smaller by 70 %	Lower unit capacities

- Capacities of IEC-H units varied between OEMs; some had almost equal capacities compared to DX units and others had lower capacities.
- There was no direct relationship indicating whether the capacity of the compressor of the IEC-H units had an impact on the capacity of the units and whether there was a critical capacity size defining this relationship. This is an important point that needs further investigation.
- Further tests are needed at the highest ambient dry bulb temperatures and the lowest humidity, climatic zone 8, to deduce the optimum compressor capacity for the systems at all climatic zones, thus optimizing the system through an algorithm that decides compressor capacity for all nominal sizes.
- The financial analysis will provide us with figures that will help us decide if an IEC-H system is economically advantageous compared to a DX system.
- In order to clarify how the economic study is made for all OEMs, a simplified example for OEM2 in CZ were listed. All figures used in this example are provided by the OEM2 or from the tests conducted for the OEM2 in CZ 2.
- For OEM 2 in CZ 2, the IEC Hybrid Unit shows a favorable IRR of 46%, and an NPV of LE 24,621 with a payback period of 3.11 years.
- It remains to be seen according to the results of the ongoing economic study whether the higher price of the IEC-H units justify its use for the remaining OEMs according to the return on investment calculated using the comparison of the NPVs of both systems.
- The project is successful from the point of view of the technical analysis side because of the superior EERs of the IEC-H units despite some smaller capacity compressors used. The capacities of the IEC-H units were not always larger than these of the DX units.

5.3. Recommendation for Future Work

- Defining the critical compressor capacity size that will deduce the optimal capacity of the unit is an important point that needs further investigation.
- Further testing at the highest dry-bulb ambient temperatures and lowest humidity climate zone 8, is needed to derive the optimal compressor capacity for systems in all climatic zones, thus optimizing the system through an algorithm that determines compressor capacity for all nominal sizes.
- However, further work is needed to decide the optimum capacity of compressor suitable for IEC-H systems at all climatic zones assisted by further tests at the harshest climatic zone, CZ 8 to complete the tests needed for the writing of a code for Direct Indirect Evaporative Cooling.
- Compiling a final matrix for defining the extrapolation rules for setting the final reference-testing conditions. This work is being done by EUROVENT.

- It is recommended that for future work the IEC-H prototypes use lower GWP refrigerants approved in Egypt (Promotion of Low-GWP Refrigerants for the Air Conditioning Industry in Egypt, UNEP/UNIDO 2021) refrigerants R-32 and R-454 B.

Chapter (6)

6. Reporting on the Advocacy and Outreach Campaign

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 services in this outreach campaign are to be made available to all stakeholders. The outreach campaign was designed to be person to person meeting, but because of the pandemic in Egypt, it was decided to change it to virtual meeting which was held on 21st December 2022.

OUTREACH PLAN GOAL

Characteristics of a goal statement should follow the **SMART** principle:

Specific - **M**easurable – **A**ction Oriented - **R**ealistic - **T**ime and Resource Constrained

The outreach marketing campaigns had been targeted as if it can result in the following:

- ✓ Build awareness of the HCFC Phase-out Management Plan (HPMP).
- ✓ Promote and enhance your HVAC field growth by transformation of commercial HVAC companies in Egypt.
- ✓ Generate leads of alternative refrigerants code and direct/indirect evaporative cooling code.
- ✓ Increase HVAC users' retention.
- ✓ Effect collaborations and partnerships.

The objective of the outreach campaign to benefit from the experience gain testing the IEC-H and DX units in two climatic zones in Egypt. The main discussions were of the results of the testing of IEC-H and DX units of all OEMs.

The exact structure of this campaign is flexible and defined based on the outcomes of the deliverables and it was adjusted according to the content of the framework.

We held conferences with different OEMs individually to discuss the results.	(November 2022)
Holding the outreach campaign	(December 2022)

TARGET STAKEHOLDERS ATTENDING THE OUTREACH CAMPAIGN

Provided in this section is the list of individuals/other entities having a role in the development and implementation of the Plan. The following are the stakeholder groups to receive targeted outreach:

1- The Ministry of Electricity

2- 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 and Banks
12- The General Public
13- Other

Presentation Given at the outreach Campaign held on 21st December 2022

The presentation is attached in **Annex (7)**

Question raised after the presentation

I. Question posed by Dr. Hesham Safwat (the British University in Egypt, BUC):
   a. He inquired about the electrical consumption and how it was compared with the tariff in Egypt?
   b. He inquired about the water consumption, how was it calculated and whether it was taken into consideration when doing financial analysis?
   c. He asked when the IEC-H specification code will be ready to be used by consulting engineers?

II. Question posed by Eng. Ahmed Magdy (the head of R&D in MIRACO)
   a. He inquired how the capital cost used in the financial analysis was calculated?
   b. He also inquired if the maintenance of the IEC-H units were calculated and included in the financial analysis, because of the higher costs of maintaining evaporation pads?

III. Question posed by Eng. Hossam Abdelkader (Representing DCM company)
   a. He inquired if there a plan to produce a code then legislate the usage of IEC-H for the different eight climatic zones of Egypt?
   b. He inquired why SEER (Seasonal Electric Efficiency Ratio) was not calculated in the results?

IV. Comment posed by Dr. Ezzat Lewis (the head of the Egyptian NOU)
   a. Dr. Ezzat inquired about the SEER and alluded to a program by the green fund to work on the SEER in Egypt.

Prof. Sayed Shebl and Prof. Alaa Olama answered all the posed questions.

Chapter (7)

7. Review and recommendation on how to update the national institutional technical documents of the new technologies

I. There are no Egyptian codes for evaporation cooling.
II. In view of the high response of the outreach campaign as the interest in determining specification on codes for this new technology by stakeholders, it is recommended to write a Direct-Indirect Evaporation Cooling code of practice
III. The results obtained by this testing program have made it possible to recommend writing IEC code of practice for Egypt.

How to update:

Stage 1:

1- The results obtained by IEC-H in transformation of commercial air conditioning companies project proved that there is important benefit of the IEC technology compared to existing technology
2- Although the results obtained are suitable for climatic zone 2 and climatic zone 5, more results are needed to complete the data required for other climatic zones in Egypt
3- Following the recommendation suggested by EUROVENT assessments of the results of the test campaign and compiling a final matrix for defining the extrapolation rules for setting the final reference-testing conditions.

Stage 2:

1- An empirical correlation that corrected the results in the different climatic zones will be target
2- Create guidelines that to put the basis of the Egyptian code of practice for IEC

Stage 3:

1- Create the Egyptian code of practice for IEC

Stage 4:

1- Enforcement program for the Egyptian code of practice for IEC

Annex (1) Provision of the technical parameters for the financial model (capital and operating costs of OEMs)

- **OEM3, Climatic zone 2**

Table 7: Basic Information for OEM3 at Climatic Zone 2

Basic Information			
Tested Units Name	**DX**		**Direct Expansion Unit**
	IEC hybrid		**Indirect Evaporative Cooling Hybrid Unit**
OEM No.	3		
Air Flow Rate	2025		c.f.m for DX and IEC hybrid Units
Water Bath Area	1728.5*623		mm^2
Climatic Zone	2 (Delta and Cairo Region)		
	Altitude	208	meter (from sea level)
	Location	30°08' 36" N 31°43' 06" E	
Test Date	16-Jun-22		
Compressors and Refrigerants		DX unit	IEC-H unit
Compressor Model		ZP154KCE-TFD	ZP61KCE-TFD
Compressor Manufacturer		Copeland – Hermetic Scroll Compressor	Copeland – Hermetic Scroll Compressor
Compressor Size		12.8 TR (45kW)	5 TR (17.5kW)
Refrigerant		R410 A	R410 A

The figures below show the following:

- Figure 17: the ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units across a whole day for OEM3 at CZ2
- Figure 18: the EERs of both the IEC-H and the DX units and ambient RH across a whole day for OEM3 at CZ2.
- Figure 19: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day for OEM3 at CZ2
- Figure 20: The cooling capacities and the outlet wet bulb temperatures and RHs of the IEC-H and DX units across a whole day for OEM3 at CZ2.
- Figure 21: The power consumptions of the DX unit and the IEC-H unit and its components for OEM3 at CZ2.

Fig 17: Inlet ambient temperature versus outlet temperature of IEC Hybrid unit & DX unit for OEM3 at CZ2

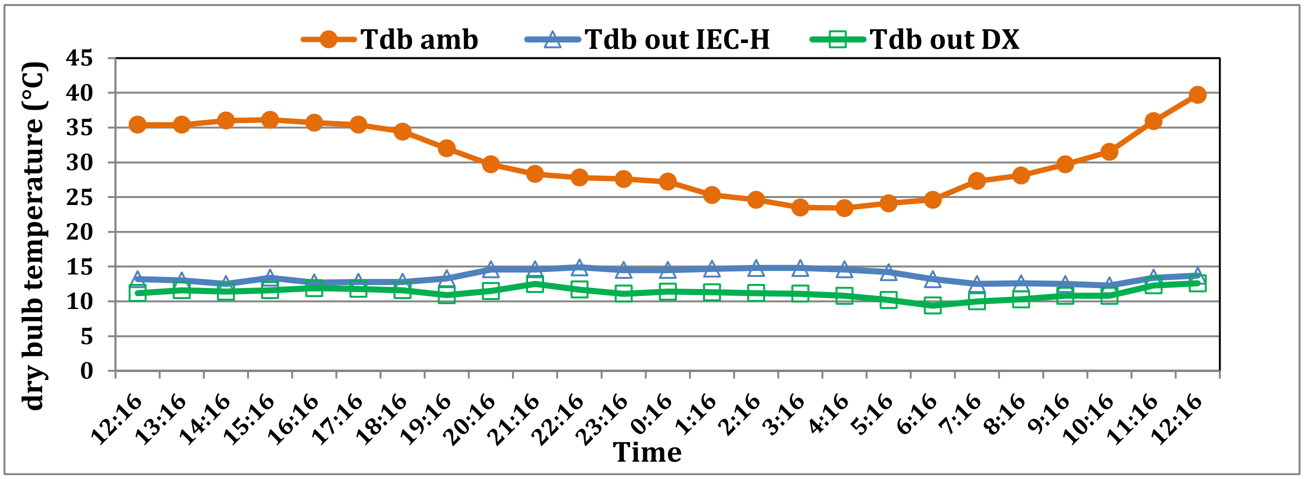


Fig 18: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM3 at CZ2

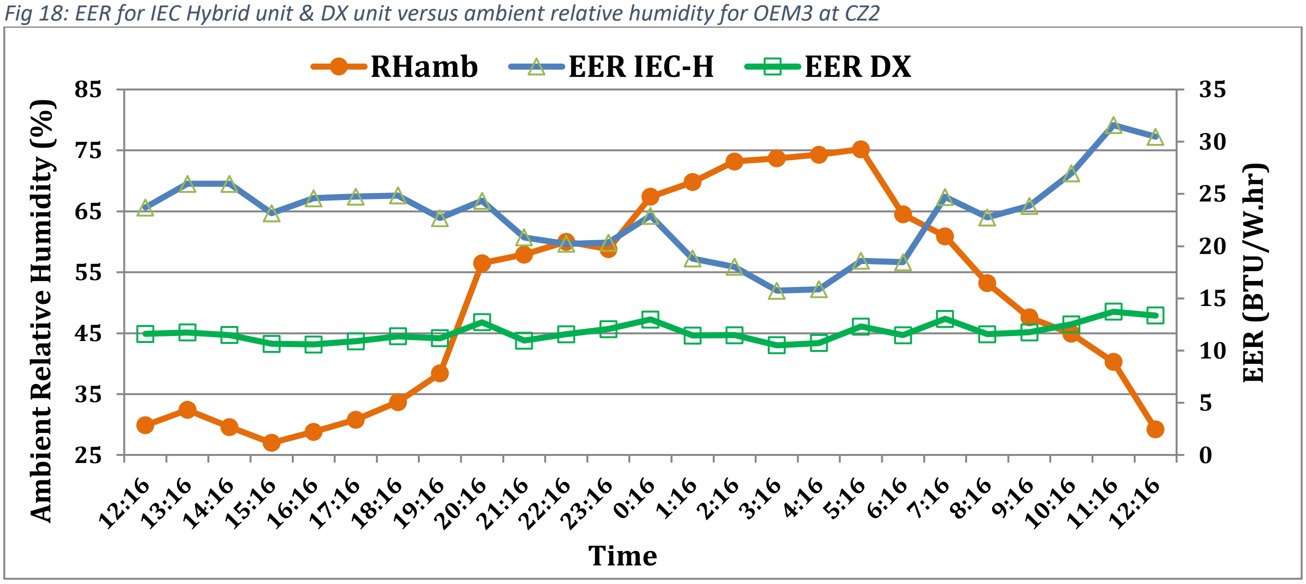


Fig 19: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM3 at CZ2

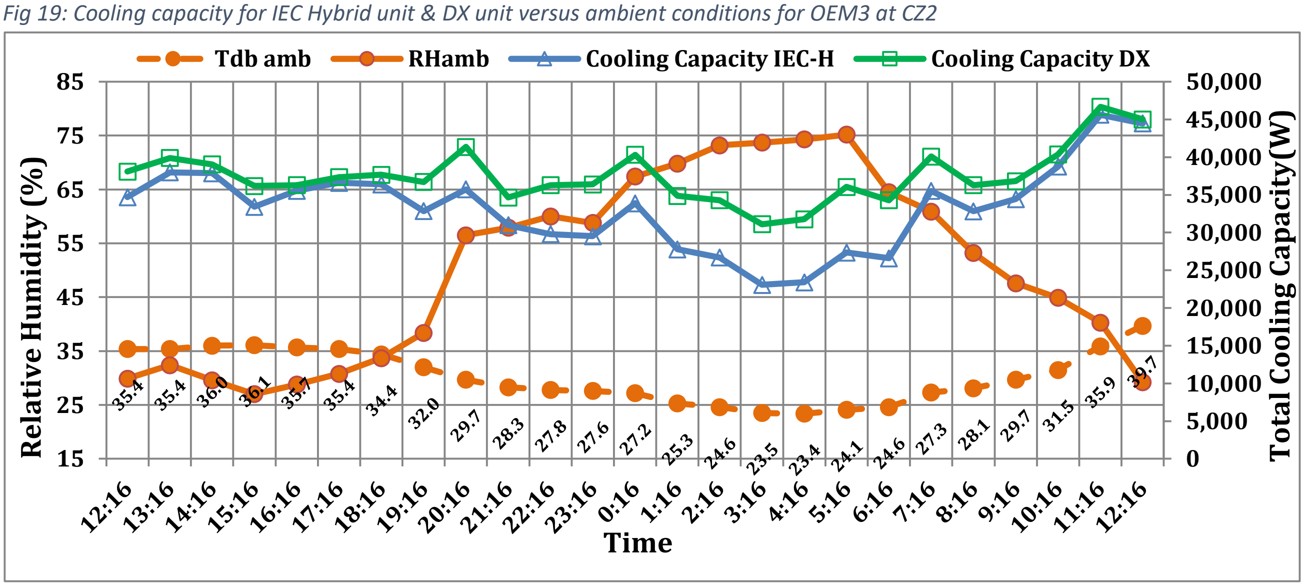


Fig 20: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM3 at CZ2

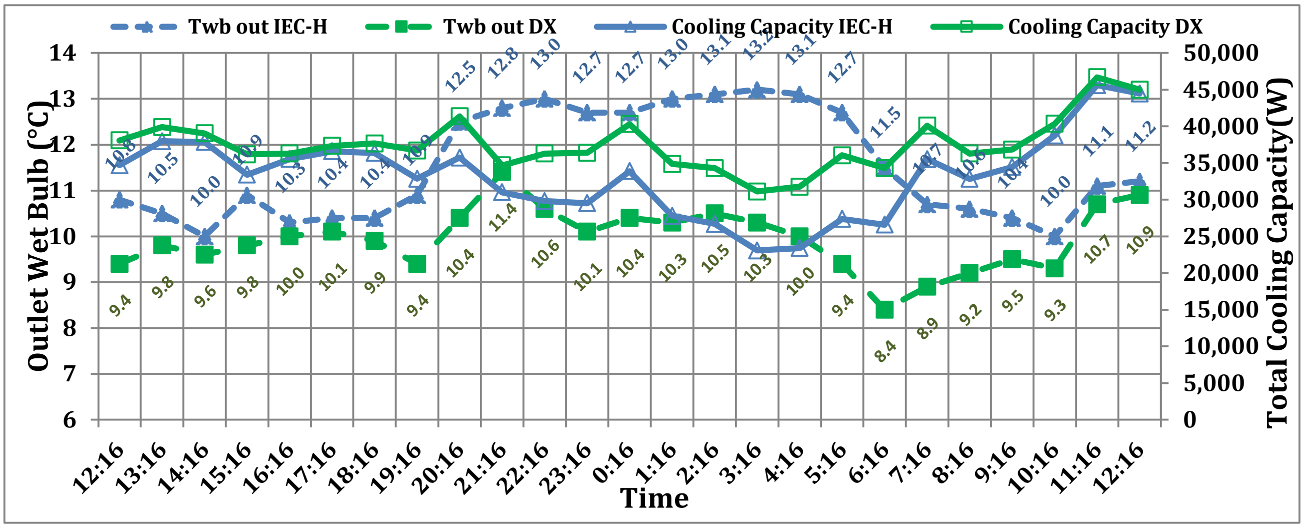
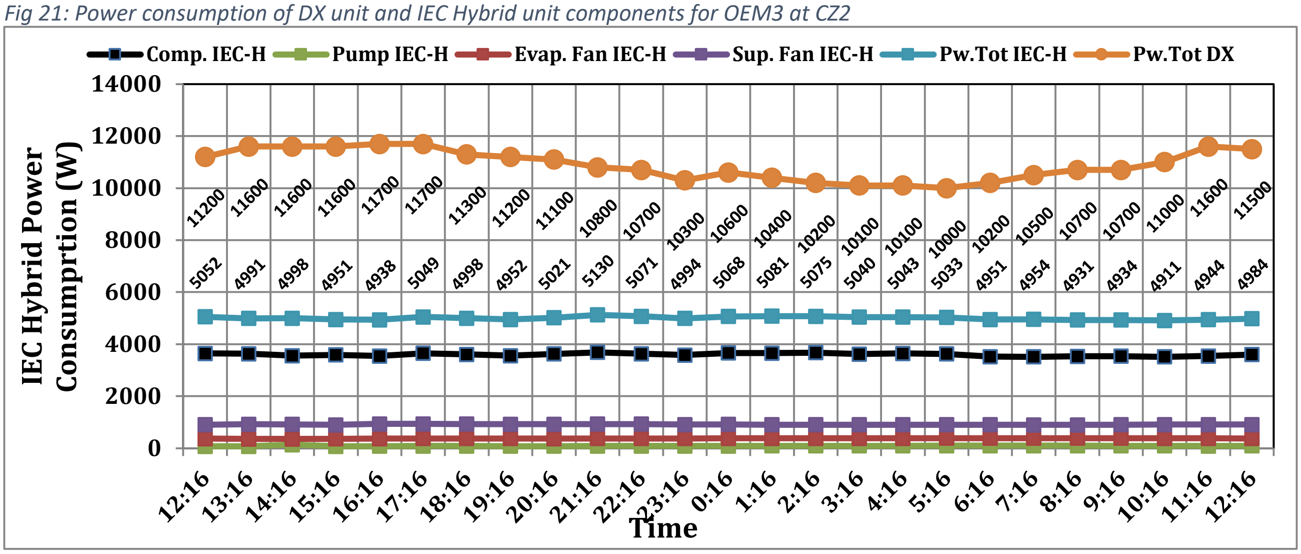


Fig 21: Power consumption of DX unit and IEC Hybrid unit components for OEM3 at CZ2



Analysis of the results of OEM 3 at CZ 2:

Table 8: High and Low readings for OEM3 at Climatic Zone 2

CZ 2					
High and low					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
39.70	75.2 @ 5:16	14.90	13.20	12.60	11.40
23.40	27.0 @ 15:16	12.30	10.00	9.40	8.40

- **$T_{db\ out}$ comparison:**
  - In figure 17, the outlet dry bulb temperatures of the IEC-H are higher than those of the DX unit.
  - The swing in $T_{db\ out}$ of DX unit is from to 12.6 °C to 9.4 °C, 3.2 °C swing
  - The swing in $T_{db\ out}$ of IEC-H unit is from to 14.9 °C to 12.3 °C, 2.6 °C swing
  - The daily $T_{db\ amb}$ changes from 39.7 °C down to 23.4°C, a swing of 16.3 °C.
  - The changes in $T_{db\ out}$ of IEC-H unit are affected by the change in $T_{db\ amb}$ and relative humidity.

- **$T_{wb\ out}$ comparison:**
  - In figure 20, the changes of $T_{wb\ out}$ of IEC-H unit were more pronounced than those of the DX unit across the day. This is understandable because during the day when RH was low more evaporation was used to achieve cooling in the IEC-H unit.
  - $T_{wb\ out}$ of IEC-H changes from 12.4 to 9.4
  - $T_{wb\ out}$ of DX changes from 11.4 to 8.4
  - In the night, when humidity increased lower evaporation occurred in the IEC-H unit resulting in lower $T_{wb\ out}$ of the unit in compared to $T_{wb\ out}$ of the DX unit.
  - The swing in RH was between 75.2 % at 5:16 to 27.0 % at 15:16

- **EERs comparison:**
  - In figure 18, the EERs of the IEC-H are consistly higher than that of the DX unit because of the IEC-H uses a smaller capacity compressor 17.6 kW (5 TR) compared to 45 kW (12.8 TR).
  - The swing in the values of the EER of IEC-H unit is consistent with the relative humidity. As the RHs increases the EER decreases and vice versa.

- **Capacities comparison:**
  - In figure 19, the IEC-H capacities are lower than those of the DX unit consistently.

- **Power consumptions comparison:**
  - In figure 21, the total power consumptions of the DX unit were consistently higher than those of the IEC-H unit across the whole day.
  - The compressor of the IEC-H unit constituted the largest portion of the power consumptions of the unit while the evaporation fan, the supply fan and the pump constituted the remaining much lower consumptions.

- **OEM3, Climatic zone 5**

Table 9: Basic Information for OEM3 at Climatic Zone 5

Basic Information			
Tested Units Name	**DX**		**Direct Expansion Unit**
	IEC hybrid		**Indirect Evaporative Cooling Hybrid Unit**
OEM No.	3		
Air Flow Rate	2025		c.f.m for DX and IEC hybrid Units
Water Bath Area	1728.5*623		mm2
Climatic Zone	5 (Eastern Coast Region)		
	Altitude	2	meter (from sea level)
	Location	26°49' 39" N 33°56' 13" E	
Test Date	5-Jul-22		
Compressors and Refrigerants		DX unit	IEC-H unit
Compressor Model		ZP154KCE-TFD	ZP61KCE-TFD
Compressor Make		Copeland – Hermetic Scroll Compressor	Copeland – Hermetic Scroll Compressor
Compressor Size		45 kW (12.8 TR)	17.5 kW (5 TR)
Refrigerant		R410 A	R410 A

The figures below show the following:

- Figure 22: the ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units across a whole day for OEM3 at CZ5
- Figure 23: the EERs of both the IEC-H and the DX units and ambient RH across a whole day for OEM3 at CZ5.
- Figure 24: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day for OEM3 at CZ5
- Figure 25: The cooling capacities and the outlet wet bulb temperatures and RHs of the IEC-H and DX units across a whole day for OEM3 at CZ5
- Figure 26: The power consumptions of the DX unit and the IEC-H unit and its components for OEM3 at CZ5.

Fig 22: Inlet ambient temperature versus outlet temperature of IEC Hybrid & DX units for OEM3 at CZ5

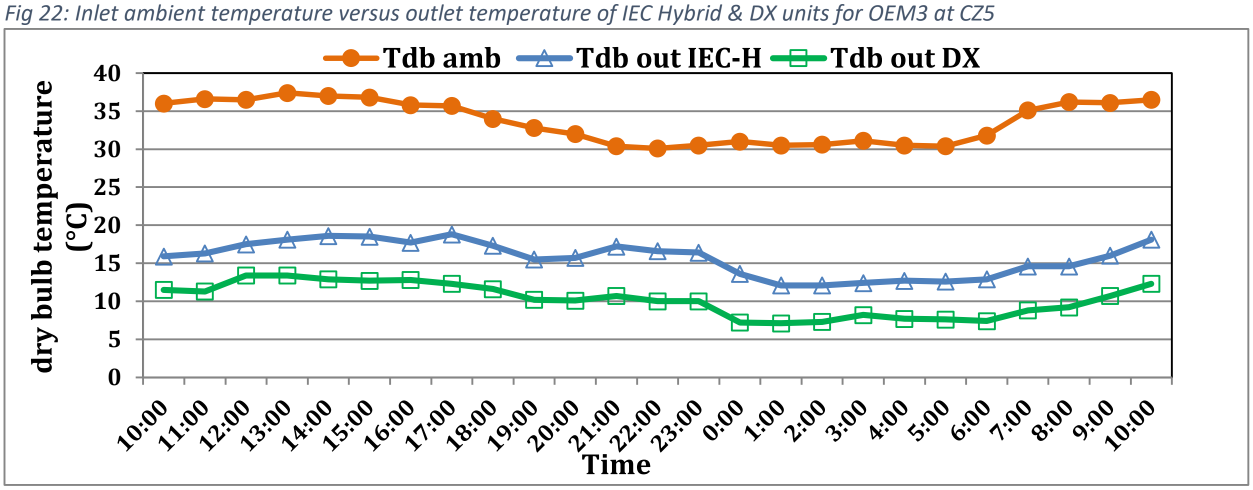


Fig 23: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM3 at CZ5

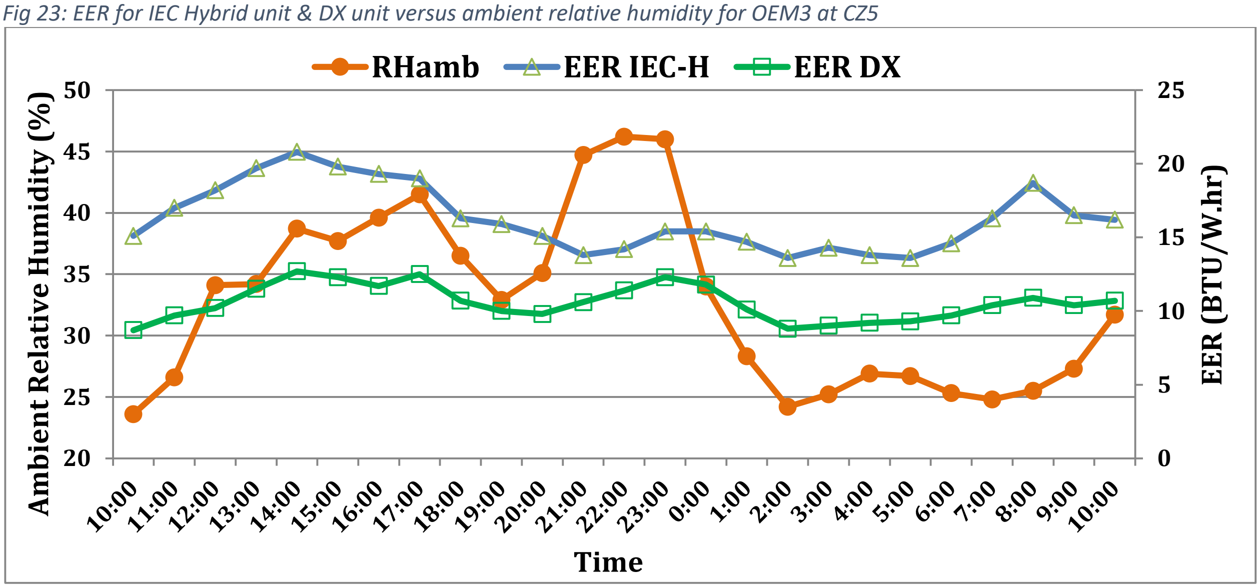


Fig 24: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM3 at CZ5

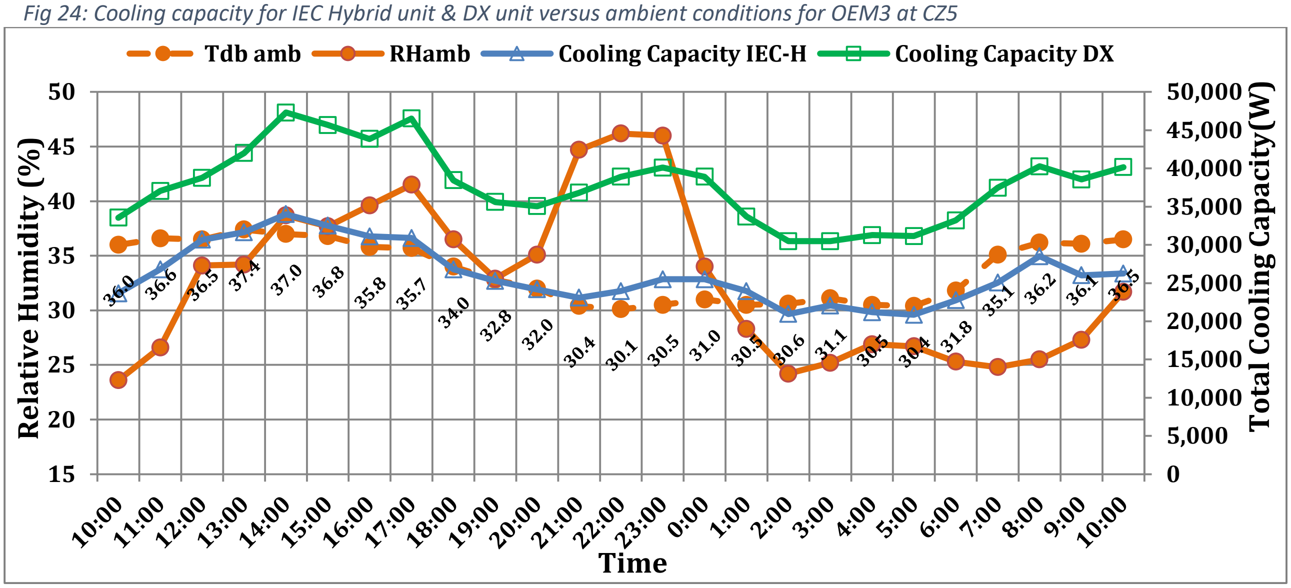


Fig 25: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid & DX units for OEM3 at CZ5

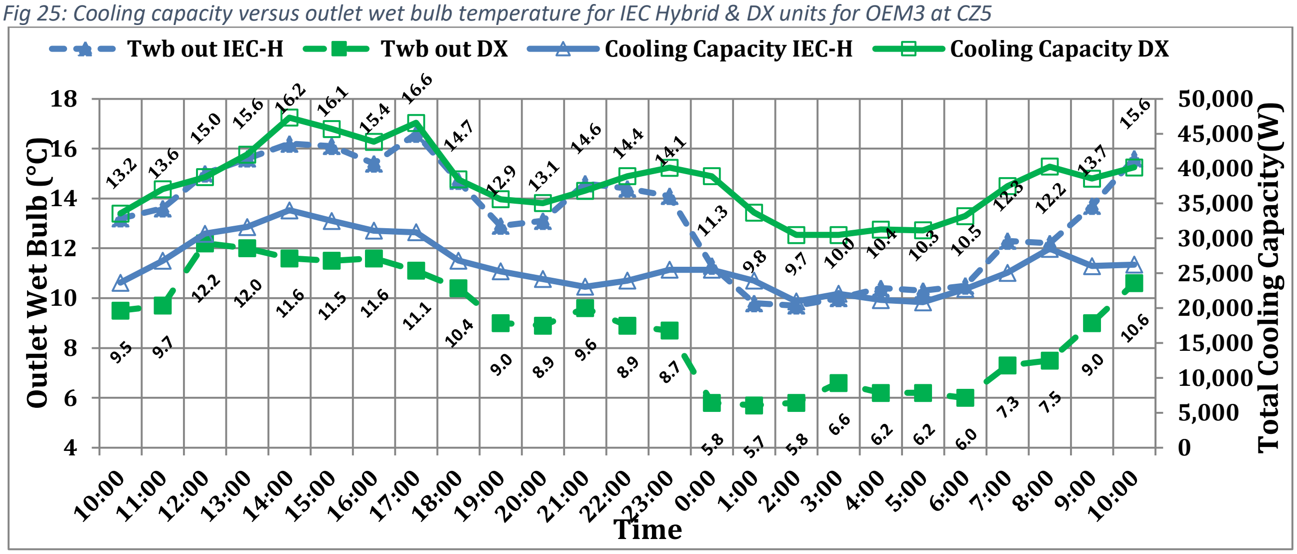
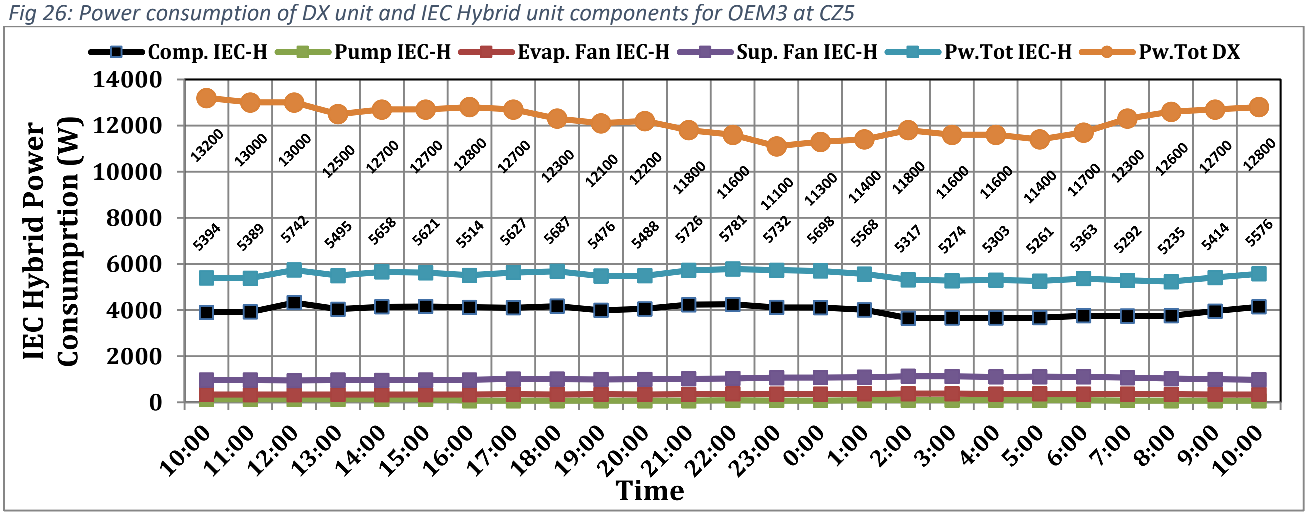


Fig 26: Power consumption of DX unit and IEC Hybrid unit components for OEM3 at CZ5



Analysis of the results of OEM3 at CZ 5:

Table 10: High and Low readings for OEM3 at Climatic Zone 5

CZ 5					
High and low					
Tdb amb	*RHamb*	*Tdb out IEC-H*	*Twb out IEC-H*	*Tdb out DX*	*Twb out DX*
37.40	*46.20 @ 22:00*	*18.80*	*16.60*	*13.40*	*12.20*
30.10	*23.60 @ 10:00*	*12.10*	*9.70*	*7.10*	*5.70*

- **$T_{db\ out}$ comparison:**
  - In figure 22, the $T_{db\ out}$ of DX unit are higher than those of the IEC-H unit.
  - The swing in $T_{db\ out}$ of DX unit is from to 13.4 ^{o}C to 7.1 ^{o}C, 6.3^{o}C swing
  - The swing in of $T_{db\ out}$ IEC-H unit is from to 18.8 ^{o}C to 12.1 ^{o}C, 6.7 ^{o}C swing
  - The daily $T_{db\ amb}$ changes are from 37.4 ^{o}C down to 30.1^{o}C, a swing of 7.3 ^{o}C.

- **$T_{wb\ out}$ temperature comparison:**
  - In figure 25, the changes of $T_{wb\ out}$ of IEC-H unit were consistently higher than those of the DX unit across the day.
  - In the night, when humidity increases lower evaporation occurred in the IEC-H unit resulting in higher $T_{wb\ out}$ of the unit.
  - Ambient RH are nearer to their expected levels in this time of the year, at 23.6 % at 10:00 to 46.2 % at 22:00

- **EERs comparison:**
  - In figure 23, the EERs of the IEC-H are consistly higher than those of the DX unit. This is important to note because its compressor's capacity is 17.5 kW (5 TR) compared to 45 kW (12.8 TR) for the DX unit.
  - The swing in the values of the EER of both units is consistent with the relative humidity. As the RH increase the EERs decreases and vice versa.

- **Capacities comparison:**
  - In figure 24, the DX unit capacities are consistently higher than those of the IEC-H unit.

- **Power consumption comparison:**
  - In figure 26, the total power consumptions of the DX unit are much higher than that of the IEC-H unit across the whole day.
  - The compressor of the IEC-H unit constituted the largest portion of the power consumption of the unit while the evaporation fan, the supply fan and the pump constituted the remaining much lower consumptions.

Table 11: Concluding remarks on the performance of OEM3 IEC-H unit and the DX unit in CZ2 and CZ5

CZ2						CZ5					
High and low °C						High and low **°C**					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX	$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
39.70	75.2 @ 5:16	14.90	13.20	12.60	11.40	37.40	46.20 @ 22:00	18.80	16.60	13.40	12.20
23.40	27.0 @ 15:16	12.30	10.00	9.40	8.40	30.10	23.60 @ 10:00	12.10	9.70	7.10	5.70

CZ2				CZ5			
EER		Capacities, W		EER		Capacities, W	
IEC-H	DX	IEC-H	DX	IEC-H	DX	IEC-H	DX
31.6	13.7	45624.38	46675.63	20.8	12.7	34017.59	47300.65
15.7	10.5	23079.78	31102.75	13.6	8.7	20841.57	30486.34

- The EER of the IEC-H in CZ2 was between and 31.6 and 15.7 and that of the DX unit was between 13.7 and 10.5
- The EER of the IEC-H in CZ5 was between 20.8 and 13.6 and that of the DX unit was between 12.7 and 8.7
- The capacity of the IEC-H in CZ2 was between and 45,624 W and 23,080 W and that of the DX unit was between 46,676 Wand 31,103 W.
- The capacity of the IEC-H in CZ5 was between and 34,018 W and 20,842 Wand that of the DX unit was between 47,300 Wand 30,486 W.

The smaller capacity compressor of the IEC-H units seems to be governing factor in understanding the results of the tests.

- EERs of the IEC- H diminish considerably in CZ5 with the higher humidity of CZ5.
- EERs of the DX unit diminish also but to a much lesser extent.
- The capacities of the IEC-H unit diminish considerably in CZ 5 at the higher humidity of CZ5.
- The capacities of the DX unit diminish also but to a much lesser extent.
- Generally, the capacities of the DX unit were higher than these of IEC-H unit.

- **OEM4, Climatic zone 2**

Table 12: Basic Information for OEM4 at Climatic Zone 2

Basic Information			
Tested Units Name	**DX**		**Direct Expansion Unit**
	IEC hybrid		**Indirect Evaporative Cooling Hybrid Unit**
OEM No.	4		
Air Flow Rate	1750		c.f.m for DX and IEC hybrid Units
Water Bath Area	2400*1600		mm^2
Compressor Capacity	DX	12 TR	42 kW
	IEC hybrid	14 TR	50 kW
Climatic Zone	2 (Delta and Cairo Region)		
	Altitude	208	meter (from sea level)
	Location	30°08' 36" N 31°43' 06" E	
Test Date	4-Aug-22		
Refrigerant	R-410 A		For both IEC-H and DX unit

The figures below show the following:

- Figure 27: the ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units across a whole day
- Figure 28: the EERs of both the IEC-H and the DX units and ambient RH across a whole day.
- Figure 29: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day
- Figure 30: The cooling capacities and the outlet wet bulb temperatures and RHs of the IEC-H and DX units across a whole day
- Figure 31: The power consumptions of the DX unit and the IEC-H unit and its components.

Fig 27: Inlet ambient temperature versus outlet temperature of IEC Hybrid unit & DX unit for OEM4 at CZ2

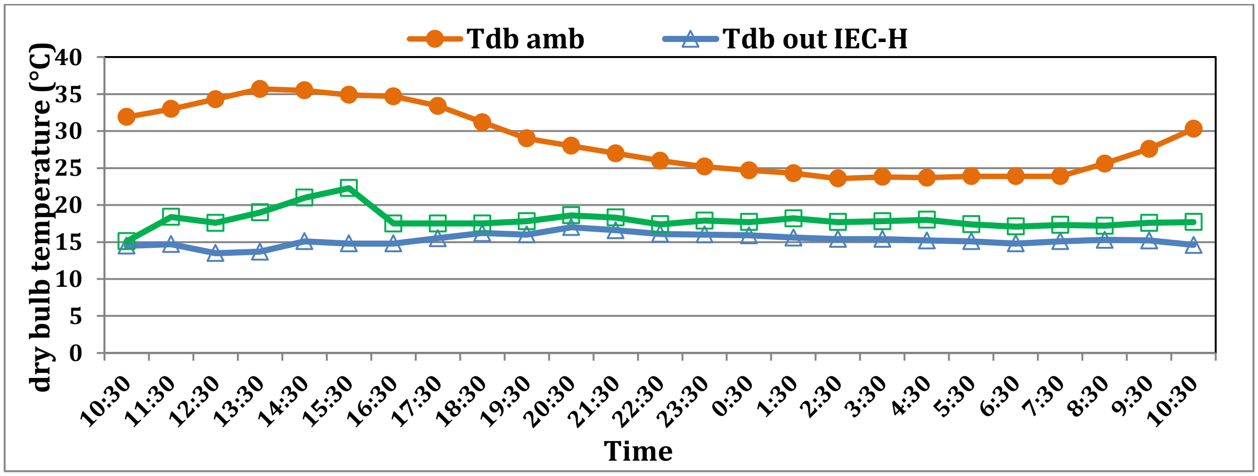


Fig 28: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM4 at CZ2

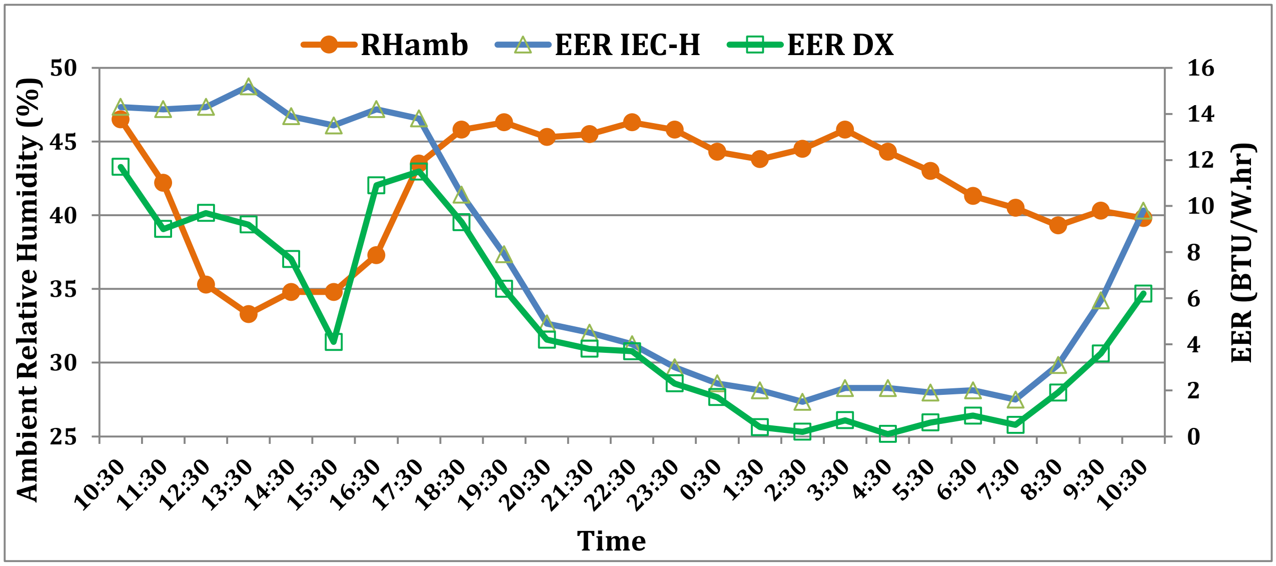


Fig 29: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM4 at CZ2

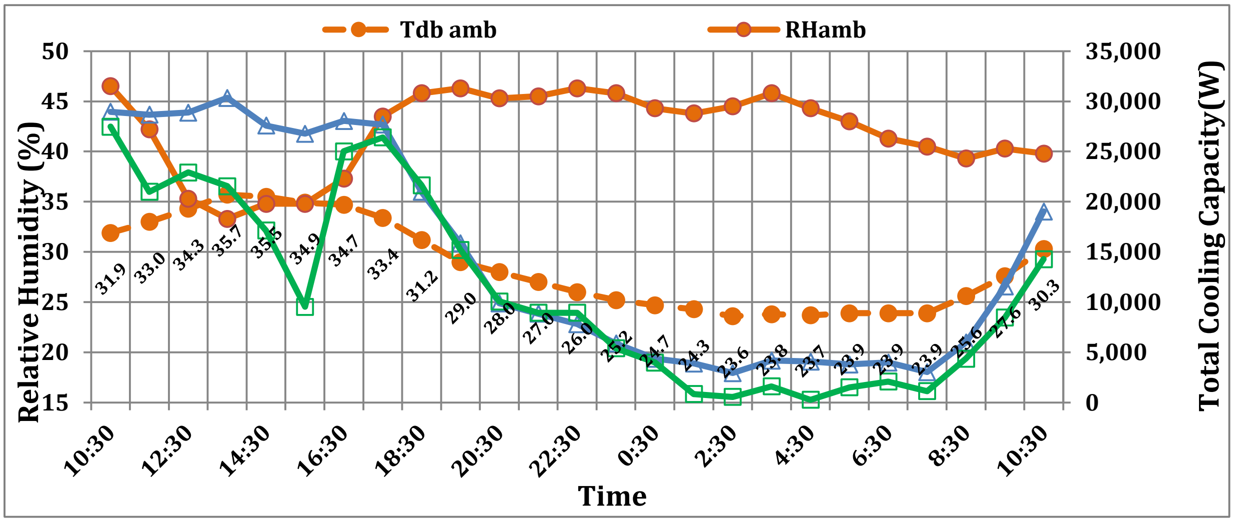


Fig 30: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM4 at CZ2

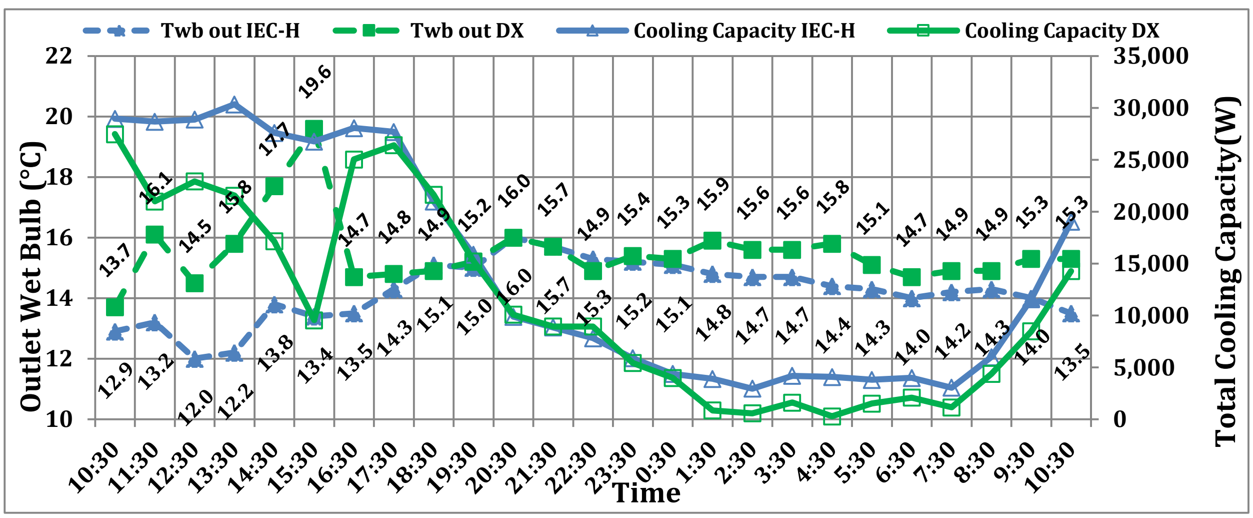
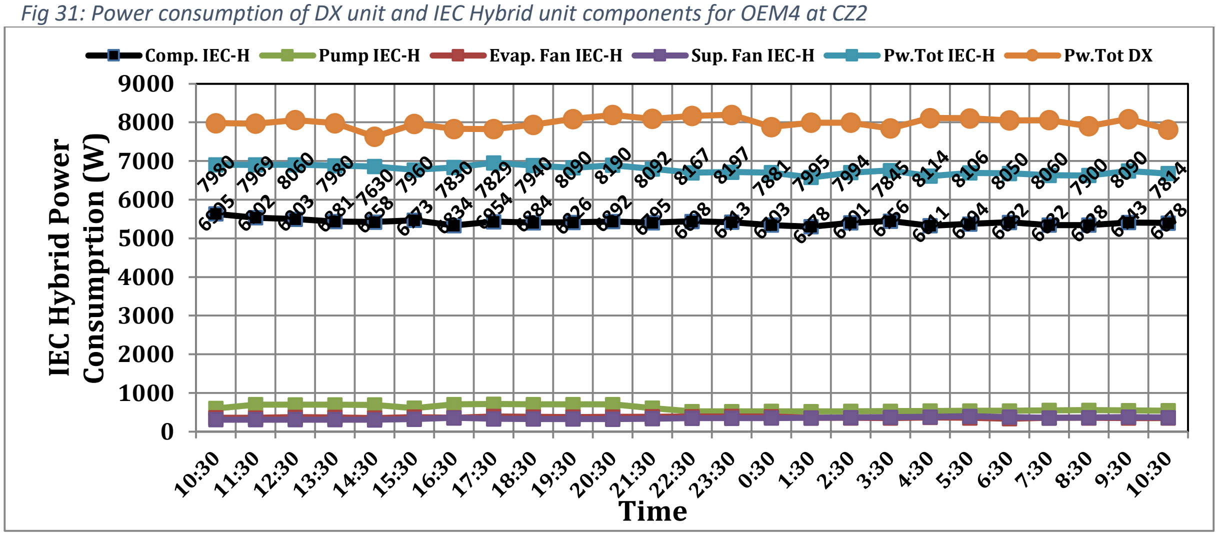


Fig 31: Power consumption of DX unit and IEC Hybrid unit components for OEM4 at CZ2



Analysis of the results of OEM4 at CZ2:

Technical problems related to the operation of the DX unit starting at 16:00 prevented analysis. See figures 27, 28 and 29.

- **OEM4, Climatic zone 5**

Table 13: Basic Information for OEM4 at Climatic Zone 5

Basic Information			
Tested Units Name	**DX**		**Direct Expansion Unit**
	IEC hybrid		**Indirect Evaporative Cooling Hybrid Unit**
OEM No.	4		
Air Flow Rate	1750		c.f.m for DX and IEC hybrid Units
Water Bath Area	2400*1600		mm^2
Climatic Zone	5 (Eastern Coast Region)		
	Altitude	2	meter (from sea level)
	Location	26°49' 39" N 33°56' 13" E	
Compressor Capacity	DX	12 TR	42 kW
	IEC hybrid	14 TR	50 kW
Test Date	27-Aug-22		For both IEC-H and DX units
Refrigerants	R-410 A		For both IEC-H and DX units

The figures below show the following:

- Figure 32: the ambient dry bulb temperature and the outlet dry bulb temperatures of the IEC-H and the DX units across a whole day
- Figure 33: the EERs of both the IEC-H and the DX units and ambient RH across a whole day.
- Figure 34: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day
- Figure 35: The cooling capacities and the outlet wet bulb temperatures and RHs of the IEC-H and DX units across a whole day
- Figure 36: The power consumptions of the DX unit and the IEC-H unit and its components.

Fig 32: Inlet ambient temperature versus outlet temperature of IEC Hybrid & DX units for OEM4 at CZ5

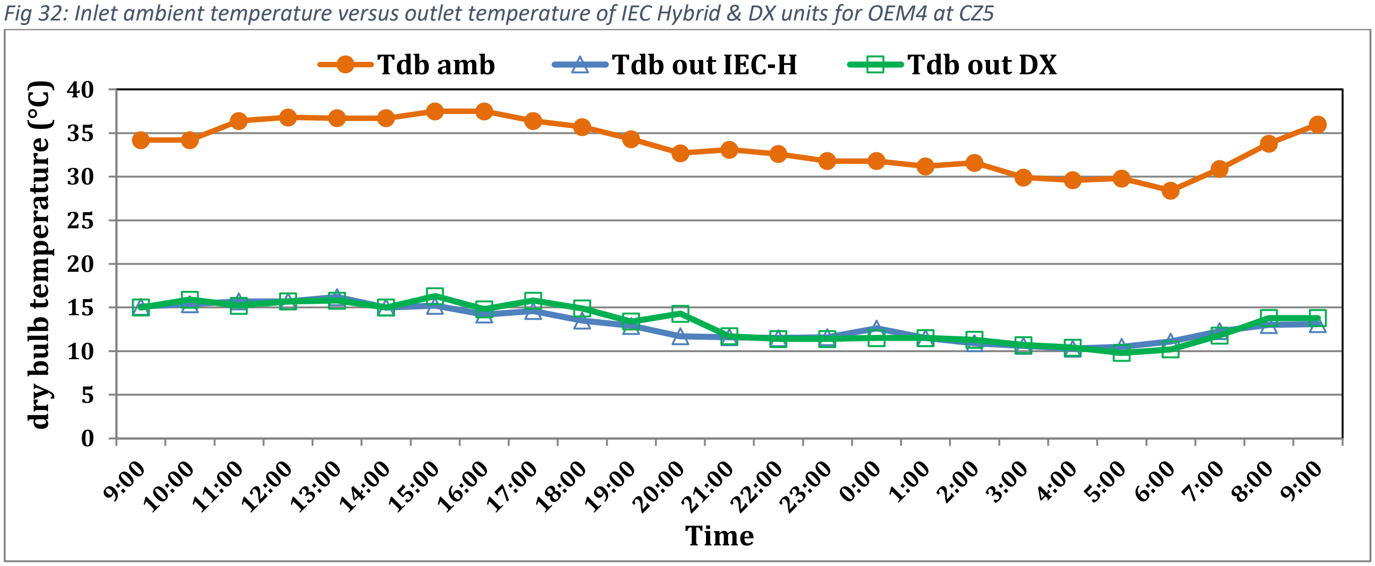


Figure 33: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM4 at CZ5

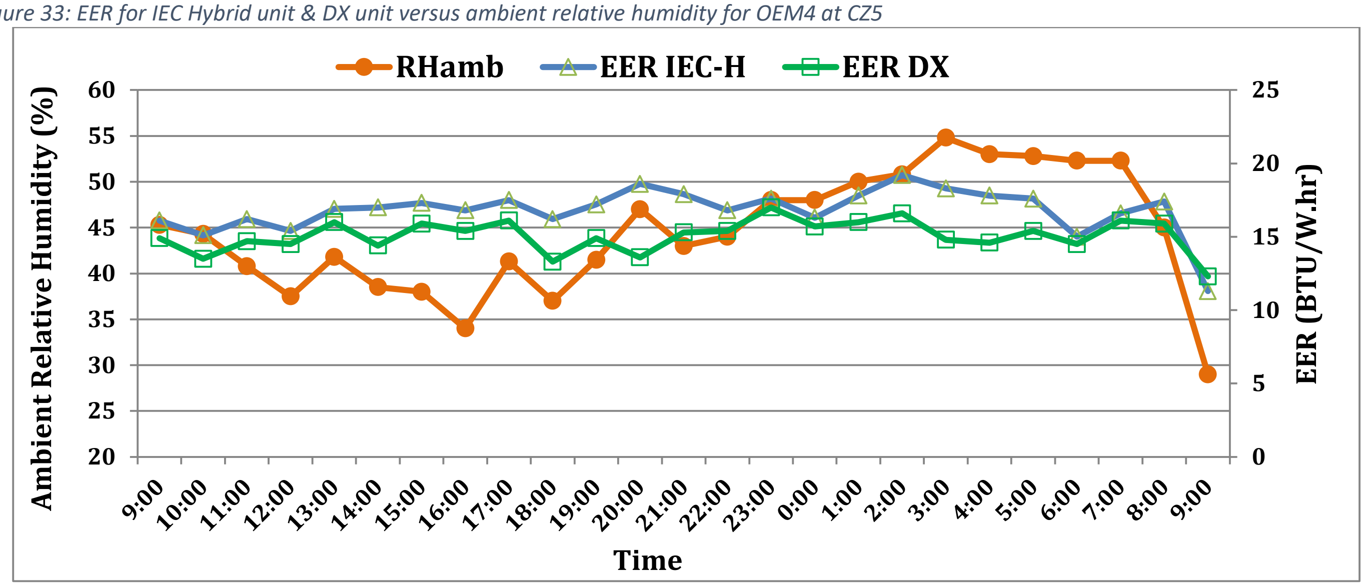


Fig 34: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM4 at CZ5

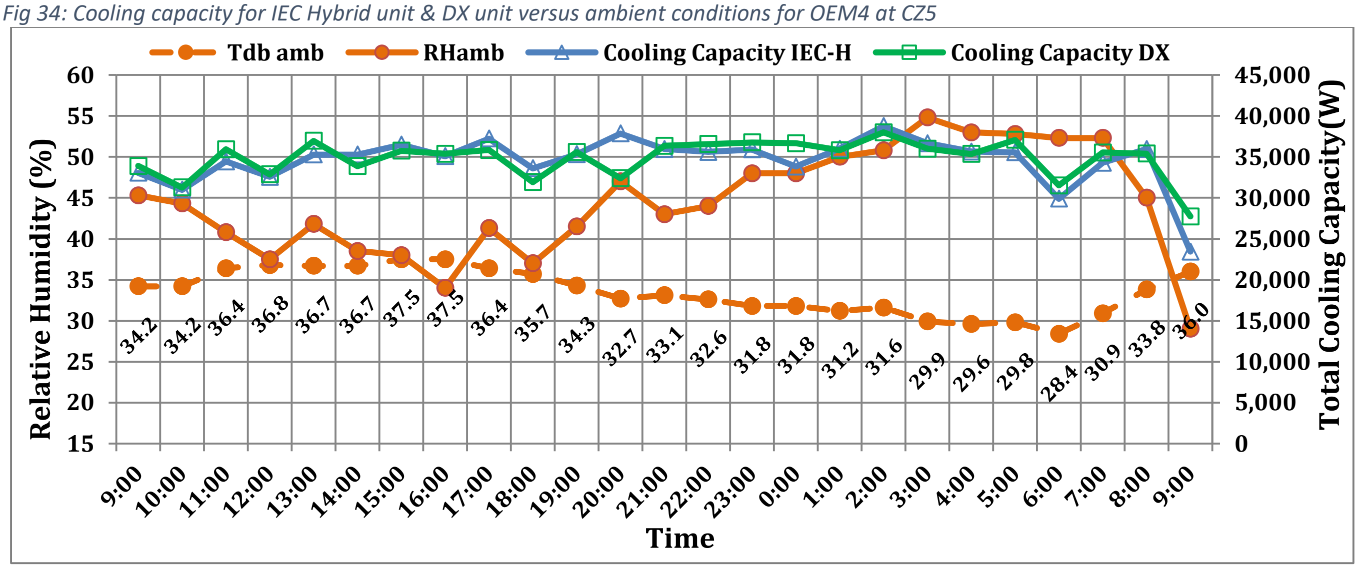


Fig 35: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid & DX units for OEM4 at CZ5

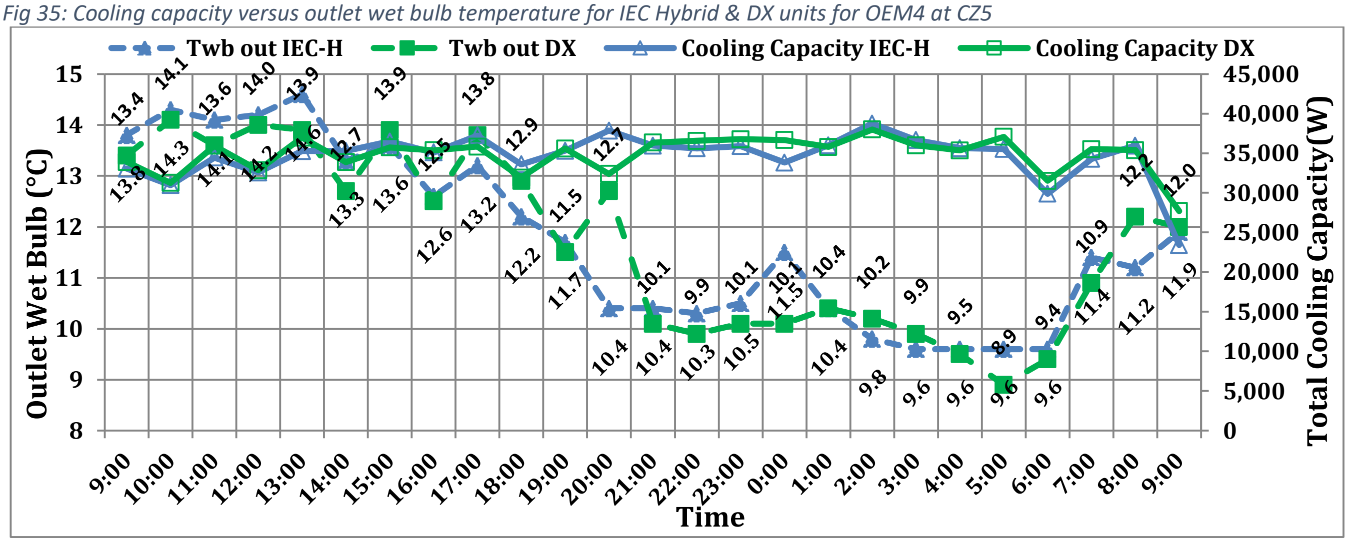
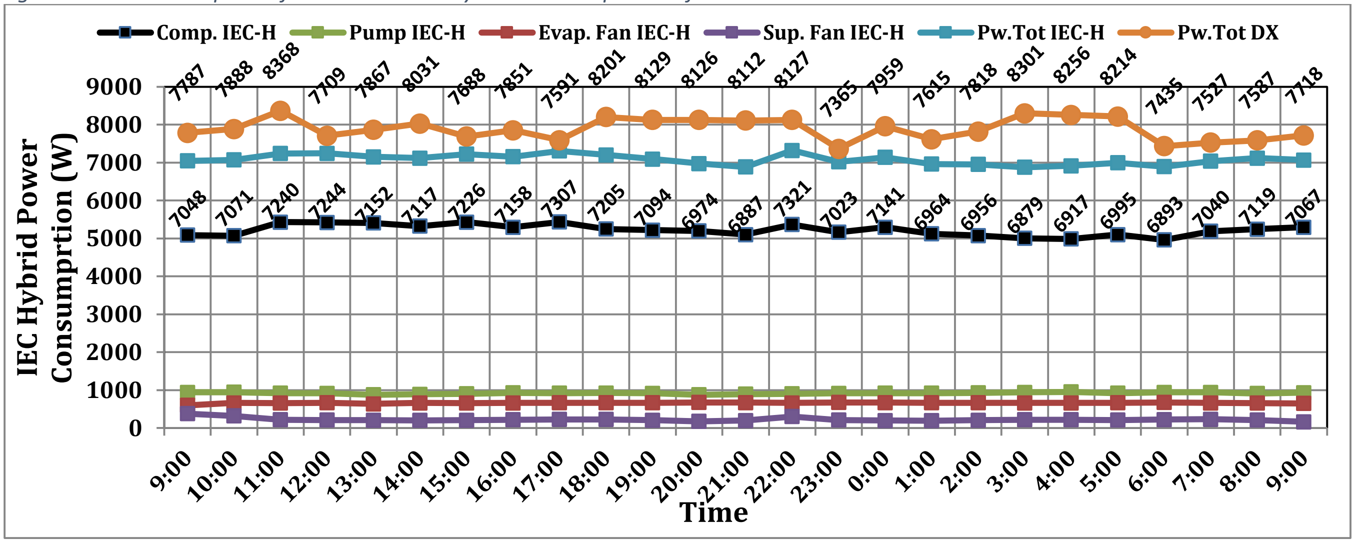


Fig 36: Power consumption of DX unit and IEC Hybrid unit components for OEM4 at CZ5



Analysis of the results of OEM 4 at CZ 5:

Table 14: High and Low readings for OEM4 at Climatic Zone 5

CZ 5					
High and low					
Tdb amb	*RHamb*	*Tdb out IEC-H*	*Twb out IEC-H*	*Tdb out DX*	*Twb out DX*
37.50	*54.80 @ 3:00*	*16.20*	*14.60*	*16.30*	*14.10*
28.40	*29.00 @ 9:00*	*10.30*	*9.60*	*9.80*	*8.90*

- **$T_{db\ out}$ comparison:**
  - In figure 32, the $T_{db\ out}$ of DX unit are nearly similar to those of the IEC-H unit.
  - The swing in $T_{db\ out}$ of DX unit is from to 16.3 ^oC to 9.8 ^oC, 6.5 ^oC swing
  - The swing in of $T_{db\ out}$ IEC-H unit is from to 16.2 ^oC to 10.3 ^oC, 5.9 ^oC swing
  - The daily $T_{db\ amb}$ changes are from 37.5 ^oC down to 28.4^oC, a swing of 9.1 ^oC.
  - The changes of $T_{db\ out}$ of IEC-H unit are consistent with the $T_{db\ amb}$, as it goes up it increases and vice versa. The same applies for the DX unit.

- **$T_{wb\ out}$ Temperature comparison:**
  - In figure 35, the $T_{wb\ out}$ of IEC-H unit and the DX unit were changing places as the higher ones across the day.
  - In the night, when humidity increases lower evaporation occurred in the IEC-H unit resulting in lower $T_{wb\ out}$ of the unit.
  - Ambient RH are nearer to their expected levels in this time of the year, at 29 % at 9:00 to 54.8 % at 3:00

- **EER comparison**
  - In figure 33, the EERs of the IEC-H were consistly higher than those of the DX unit. This is important to note. The compressor's capacity of the IEC-H unit is 50 kW (14 TR) compared to 42 kW (12 TR) for the DX unit, nominally 20% higher.

- The swing in the values of the EER of both units is consistent with the relative humidity. As the RH increase the EERs decreases and vice versa

➢ **Capacities comparison:**

- In figure 34, the IEC-H unit capacities are close to those of the DX unit.

➢ **Power consumptions comparison:**

- In figure 36, the total power consumptions of the DX unit are relatively higher than that of the IEC-H unit across the whole day.
- The compressor of the IEC-H unit constituted the largest portion of the power consumption of the unit while the evaporation fan, the supply fan and the pump constituted the remaining much lower consumptions.

Table 15: Concluding remarks on the performance of OEM4 IEC-H unit and the DX unit in CZ2 and CZ5

CZ2						**CZ5**					
High and low						High and low					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX	$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
35.70	46.50 @ 10:30	N/A	N/A	N/A	N/A	37.50	54.80 @ 3:00	16.20	14.60	16.30	14.10
23.60	33.30 @ 13:30	N/A	N/A	N/A	N/A	28.40	29.00 @ 9:00	10.30	9.60	9.80	8.90

CZ2				CZ5			
EER		Capacities, W		EER		Capacities, W	
IEC-H	DX	IEC-H	DX	IEC-H	DX	IEC-H	DX
N/A	N/A	N/A	N/A	19.2	17	38751.24	37991.41
N/A	N/A	N/A	N/A	11.3	12.3	23425.01	27718.04

The compressor nominal capacity of the IEC-H unit is higher than that of the DX unit by about 20%. This is unusual; perhaps the special design of the IEC-H unit is the reason.

- $T_{db\ out}$ achieved by the IEC-H unit are almost equal to those of the DX unit.
- EERs of the IEC- H are also superior to those of the DX unit.
- The capacities of the IEC_H unit are almost equal to these of the DX unit.
- The IEC-H unit performance, both capacity and EER, is remarkable although it uses a relatively larger compressor capacity**.**

- **OEM6, Climatic zone 2**

Table 16: Basic Information for OEM6 at Climatic Zone 2

Basic Information			
Tested Units Name	DX		Direct Expansion Unit
	IEC hybrid		Indirect Evaporative Cooling Hybrid Unit
OEM No.	6		
Air Flow Rate	2245		c.f.m for DX and IEC hybrid Units
Compressor	IEC-H	Highly	ATE 498SC3Q9RK1
	DX	Danfoss	SH161
Refrigerant	R 410 A		For both units
Water Bath Area	901108		mm2, (1308.3^2-900.3^2)
Climatic Zone	2 (Delta and Cairo Region)		
Compressor Capacity	DX	40 kW	11 TR
	IEC hybrid	12 kW	3.4 TR
	Altitude	208	meter (from sea level)
	Location	30°08' 36" N 31°43' 06" E	
Test Date	19-Jun-22		

The figures below show the following:

- Figure 37: $T_{db\ out}$ of the IEC-H and the DX units across a whole day
- Figure 38: the EERs of both the IEC-H and the DX units and ambient RH across a whole day.
- Figure 39: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day
- Figure 40: The cooling capacities and $T_{wb\ out}$ and RHs of the IEC-H and DX units across a whole day
- Figure 41: The power consumptions of the DX unit and the IEC-H unit and its components.

Fig 37: Inlet ambient temperature versus outlet temperature of IEC Hybrid & DX units for OEM6 at CZ2

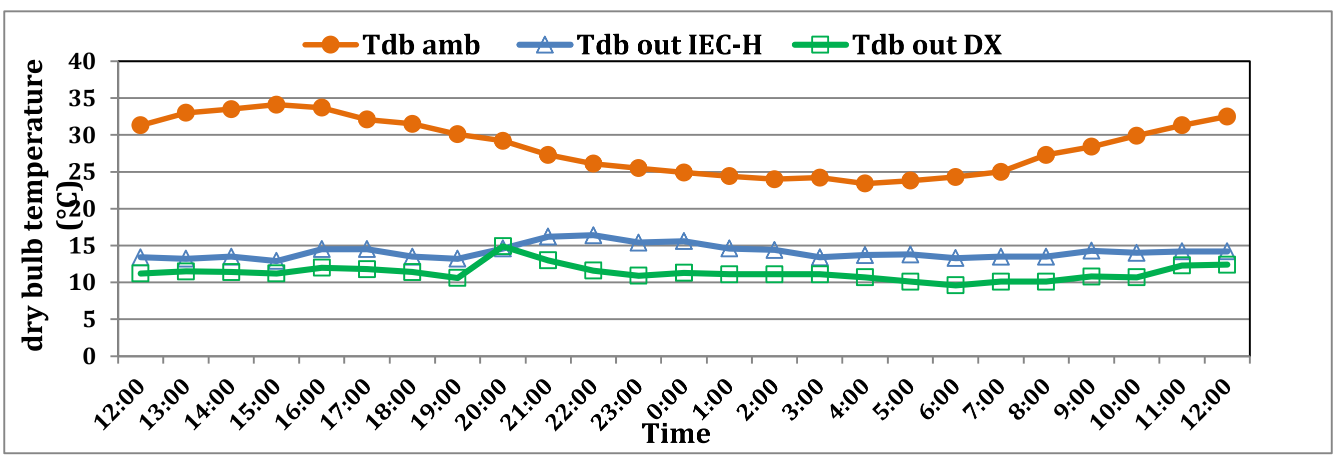


Fig 38: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM6 at CZ2

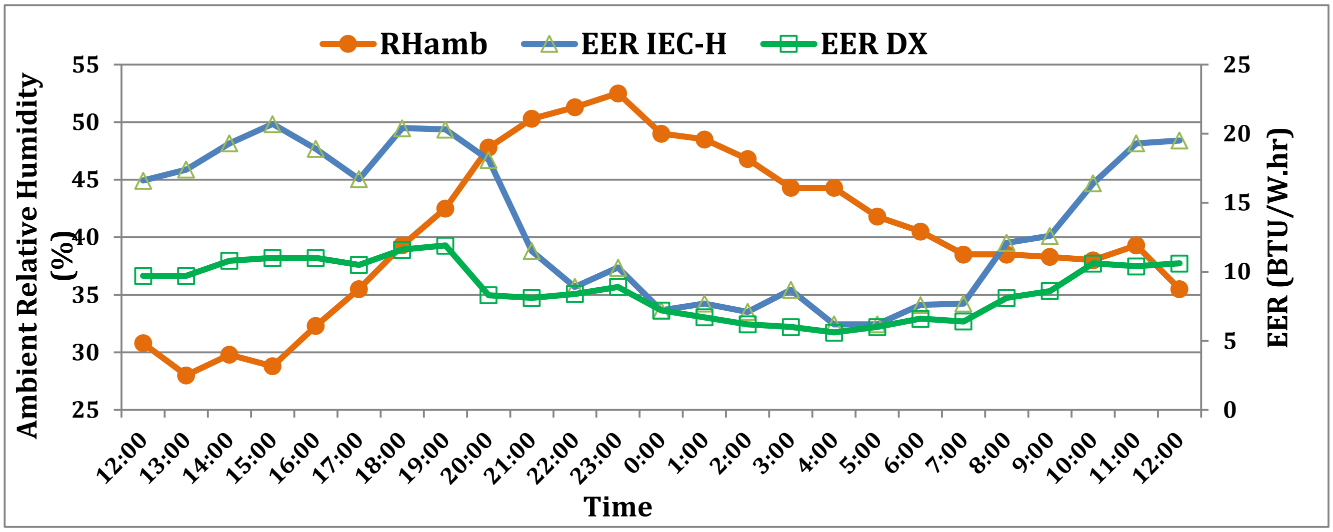


Fig 39: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM6 at CZ2

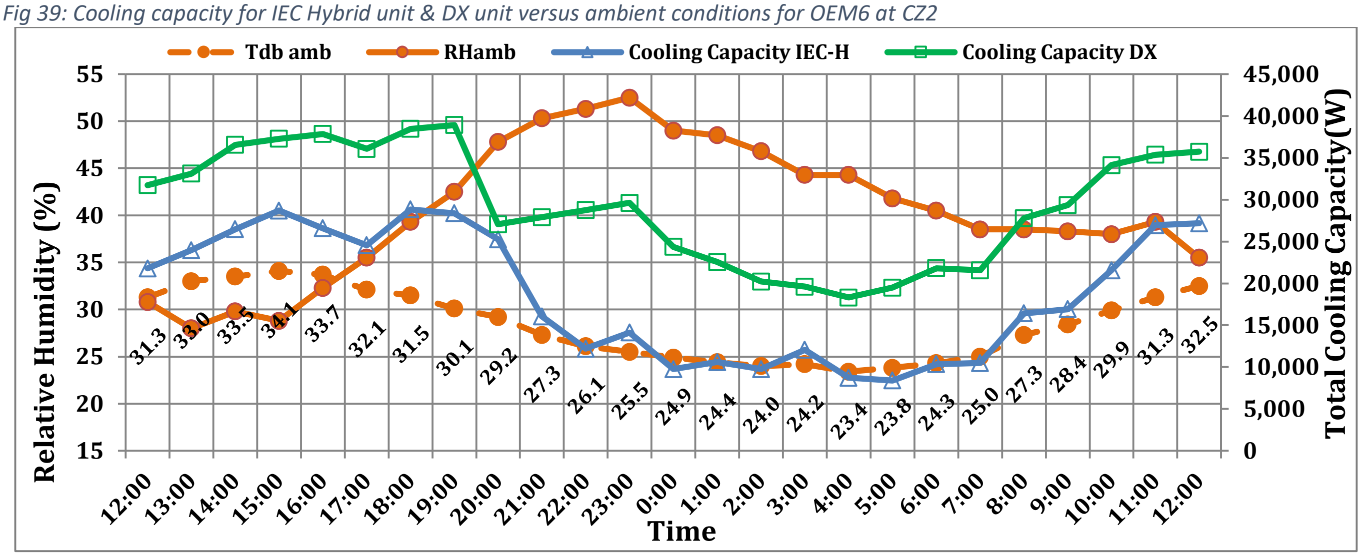


Fig 40: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid & DX units for OEM6 at CZ2

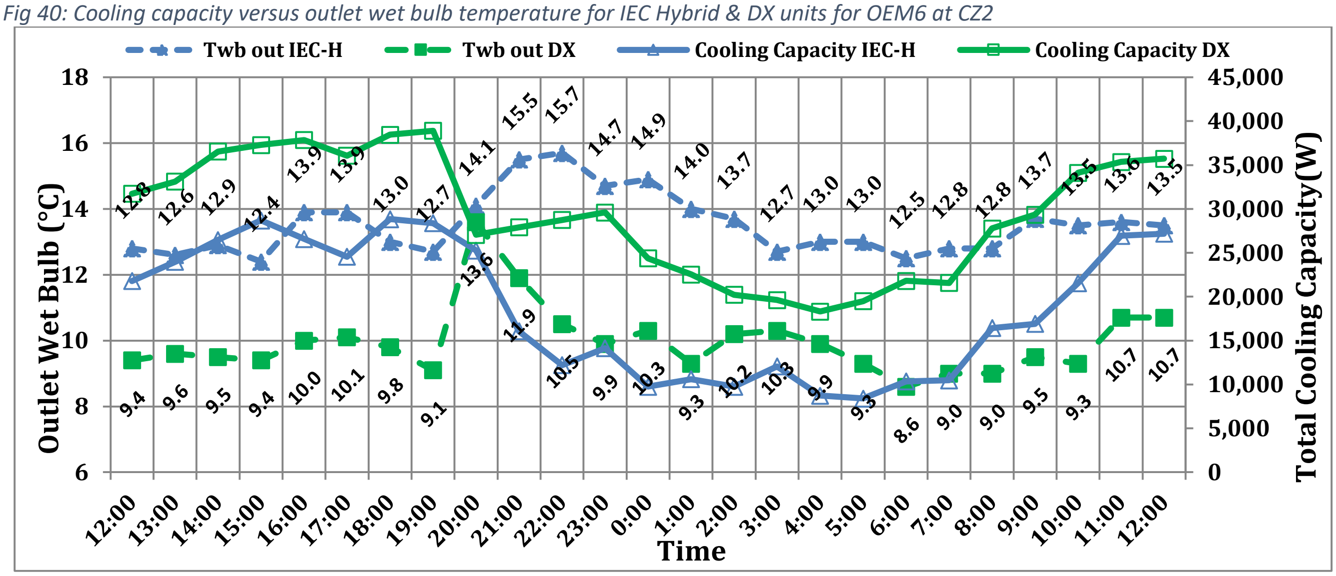
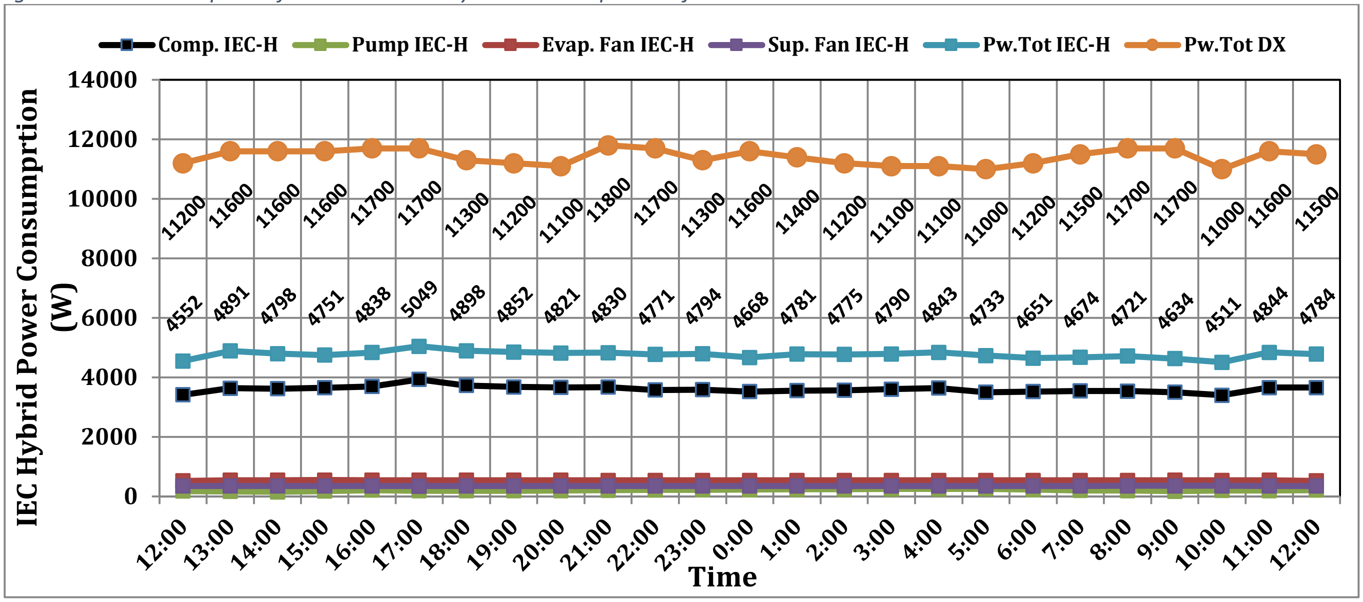


Fig 41: Power consumption of DX unit and IEC Hybrid unit components for OEM6 at CZ2



Analysis of the results of OEM 6 at CZ 2:

Table 17: High and Low readings for OEM6 at Climatic Zone 2

CZ 2					
High and low, ^oC					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
34.10	52.5 @ 23:00	16.40	15.70	14.90	13.60
23.40	28.00 @ 13:00	12.90	12.40	9.60	8.60

➢ **$T_{db\ out}$ comparison:**

- In figure 37, the $T_{db\ out}$ of the IEC-H unit are slightly higher than these of the DX unit.
- The swing in $T_{db\ out}$ of DX unit is from to 14.9 ^oC to 9.6 ^oC, 5.3^oC swing
- The swing in of $T_{db\ out}$ IEC-H unit is from to 16.4 ^oC to 12.9 ^oC, 3.5 ^oC swing
- The daily $T_{db\ amb}$ changes are from 34.1 ^oC down to 23.8^oC, a swing of 10.3 ^oC.
- The changes of $T_{db\ out}$ of IEC-H unit are consistent with the $T_{db\ amb}$, as it goes up it increases and vice versa. The same applies for the DX unit.

➢ **$T_{wb\ out}$ temperature comparison:**

- In figure 40, the changes of $T_{wb\ out}$ of IEC-H unit were higher than those of the DX unit
- Ambient RH are nearer to their expected levels in this time of the year, at 28 % at 13:00 to 52.5 % at 23.00

➢ **EER comparison:**

- In figure 38, the EERs of the IEC-H are much higher than these of the DX unit when the RH is low, 12:00 to 22:00 and 6:00 to 12:00. This is important to note.
- The compressor's capacity of the IEC-H unit is 12 kW (3.4TR) compared to 40 kW (11 TR) for the DX unit, nominally 3.4 times larger.

- The swing in the values of the EER of both units is consistent with the relative humidity. As the RH increase the EERs decreases and vice versa

➢ **Capacities comparison:**
- In figure 39, the DX unit capacities are consistently higher than these of IEC-H unit.
- This is probably because the DX unit compressor capacity is much larger than that of IEC-H unit.

➢ **Power consumptions comparison:**
- In figure 41, the total power consumptions of the DX unit are much higher than that of the IEC-H unit across the whole day. Note the larger capacity compressor of the DX unit.
- The compressor of the IEC-H unit constituted the largest portion of the power consumption of the unit while the evaporation fan, the supply fan and the pump constituted the remaining much lower consumptions

- **OEM6, Climate zone 5**

Table 18: Basic Information for OEM6 at Climatic Zone 5

Basic Information			
Tested Units Name	**DX**		**Direct Expansion Unit**
	IEC hybrid		**Indirect Evaporative Cooling Hybrid Unit**
OEM No.	6		
Air Flow Rate	2245		c.f.m for DX and IEC hybrid Units
Refrigerant	R 410 A		For both IEC-h and DX units
Test Date	3-Jul-22		
compressors	IEC-H	Highly	ATE 498SC3Q9RK1
	DX	Danfoss	SH161
Water Bath Area	901108		mm2, (1308.3^2-900.3^2)
Compressor Capacity	DX	40 kW	11 TR
	IEC hybrid	12 kW	3.4 TR
Climatic Zone	5 (Eastern Coast Region)		
	Altitude	2	meter (from sea level)
	Location	26°49' 39" N 33°56' 13" E	

The figures below show the following:

- Figure 42: $T_{db\ out}$ of the IEC-H and the DX units across a whole day
- Figure 43: the EERs of both the IEC-H and the DX units and ambient RH across a whole day.
- Figure 44: The cooling capacity of the IEC-H and DX unit and the ambient dry bulb temperature and RH across a whole day
- Figure 45: The cooling capacities and $T_{wb\ out}$ and RHs of the IEC-H and DX units across a whole day
- Figure 46: The power consumptions of the DX unit and the IEC-H unit and its components.

Fig 42: Inlet ambient temperature versus outlet temperature of IEC Hybrid & DX units for OEM6 at CZ5

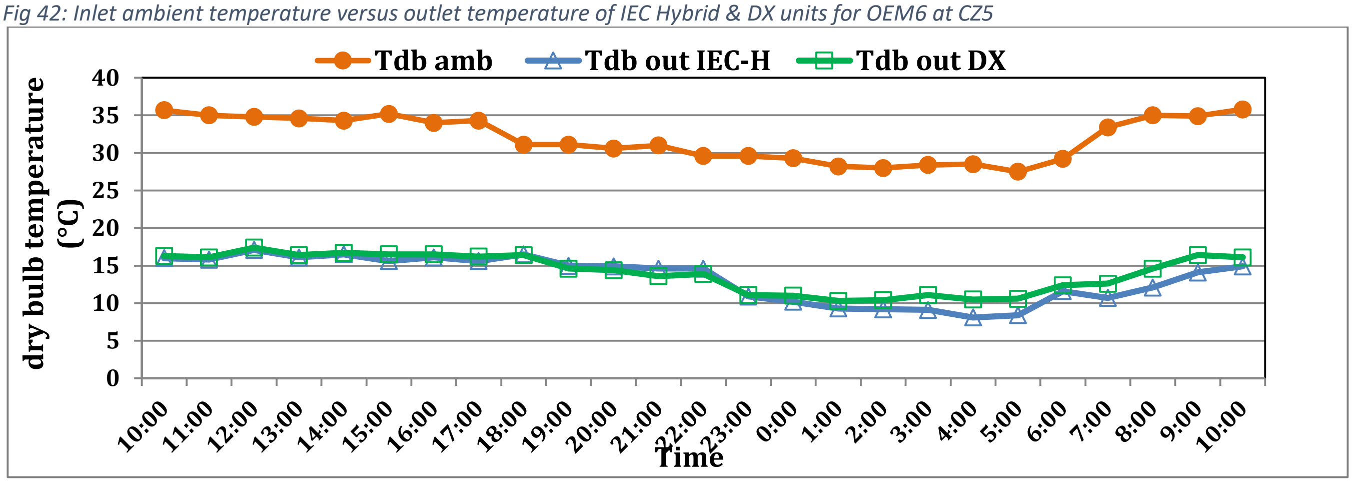


Fig 43: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM6 at CZ5

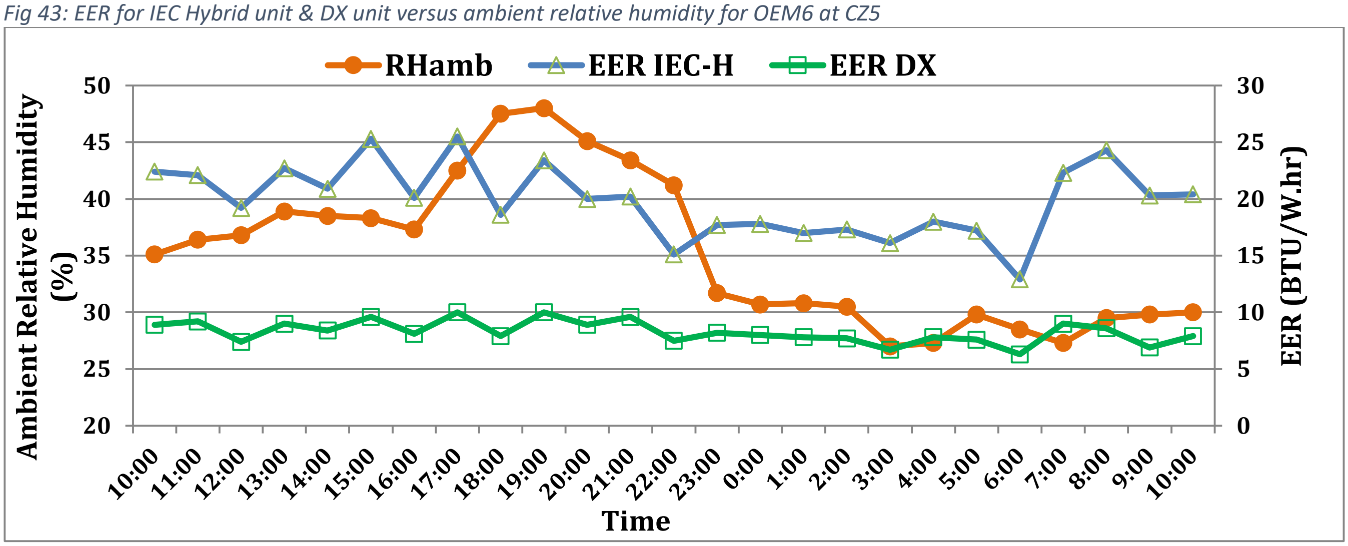


Fig 44: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM6 at CZ5

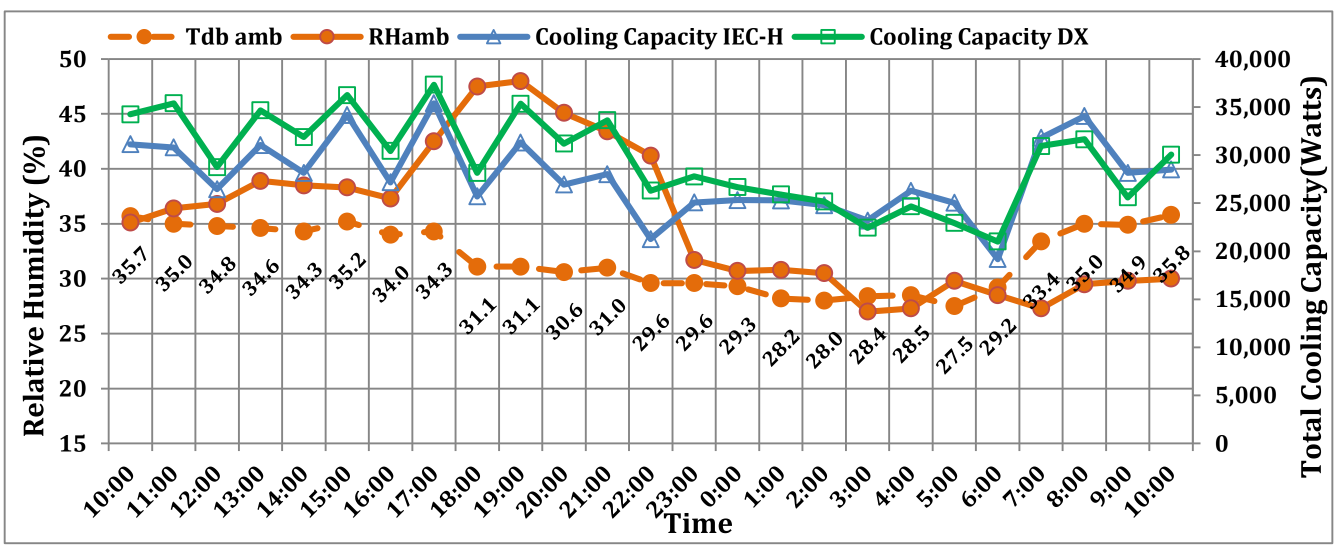


Fig 45: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM6 at CZ5

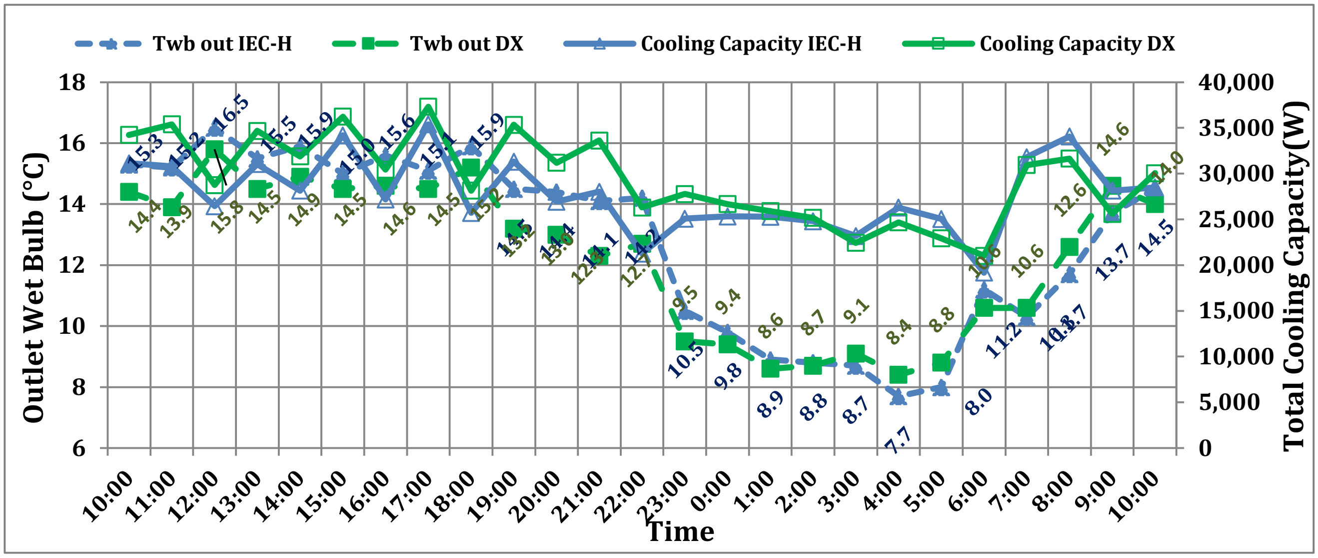
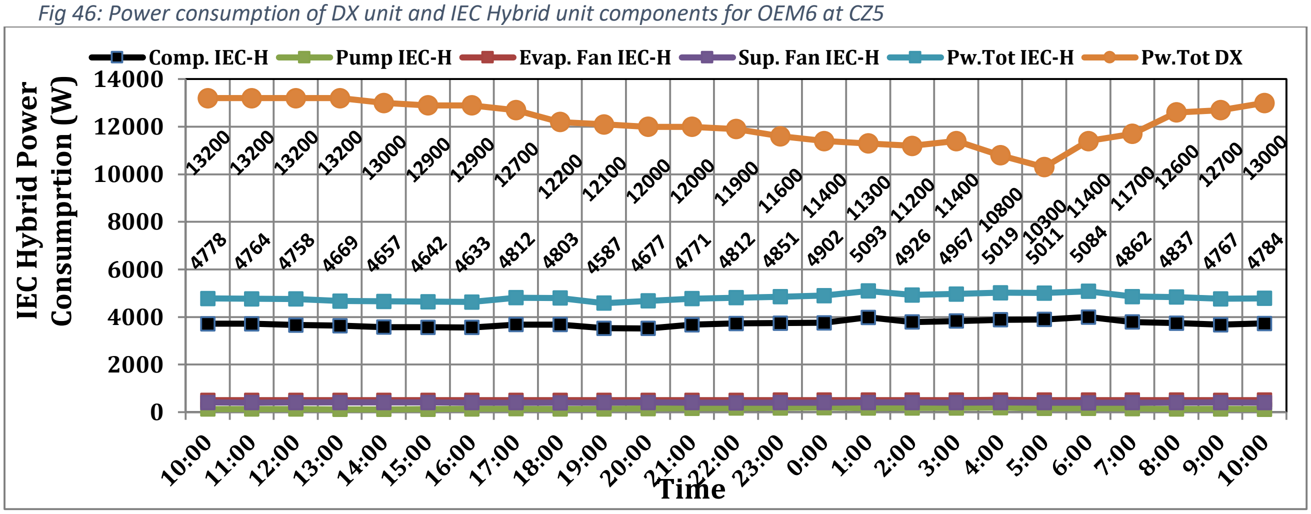


Fig 46: Power consumption of DX unit and IEC Hybrid unit components for OEM6 at CZ5



Analysis of the results of OEM6 at CZ5:

Table 19: High and Low readings for OEM6 at Climatic Zone 5

CZ5					
High and low, °C					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
35.80	48.00 @ 19:00	17.10	16.50	17.40	15.80
27.50	27.00 @ 3:00	8.10	7.70	10.30	8.40

- **$T_{db\ out}$ comparison:**
  - In figure 42, the $T_{db\ out}$ of DX unit are nearly similar to those of the IEC-H unit.
  - The swing in $T_{db\ out}$ of DX unit is from to 17.4°C to 10.3 °C, 7.1 °C swing
  - The swing in of $T_{db\ out}$ IEC-H unit is from to 17.1 °C to 8.1 °C, 9 °C swing
  - The daily $T_{db\ amb}$ changes are from 35.8 °C down to 27.5°C, a swing of 8.3 °C.
  - The changes of $T_{db\ out}$ of IEC-H unit are consistent with the $T_{db\ amb}$, as it goes up it increases and vice versa. The same applies for the DX unit.

➢ **$T_{wb\ out}$ Temperature comparison:**
- In figure 45, the changes of $T_{wb\ out}$ of IEC-H unit were higher than those of the DX unit except between 2:30 to 10:30.
- Ambient RH are nearer to their expected levels in this time of the year, at 27 % at 3:00 to 48 % at 19:00

➢ **EER comparison:**
- In figure 43, the EERs of the IEC-H are consistly higher than those of the DX unit, this is important to note the compressor's capacity of the IEC-H unit is 12 kW (3.4 TR) compared to 40 kW (11 TR) for the DX unit.

➢ **Capacities comparison:**
- In figure 44, the IEC-H unit capacities are lower than these of the DX unit except between 3:30 and 9:00.
- This is important to note the compressor's capacity of the IEC-H unit is 12 kW (3.4 TR) compared to 40 kW (11 TR) for the DX unit.

➢ **Power consumptions comparison:**
- In figure 46, the total power consumptions of the DX unit are relatively much higher than that of the IEC-H unit across the whole day.
- The compressor of the IEC-H unit constituted the largest portion of the power consumption of the unit while the evaporation fan, the supply fan and the pump constituted the remaining much lower consumptions.

Table 20: Concluding remarks on the performance of OEM6 IEC-H unit and the DX unit in CZ2 and CZ5

CZ2						**CZ5**					
High and low						High and low					
$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX	$T_{db\ amb}$	RH_{amb}	$T_{db\ out}$ IEC-H	$T_{wb\ out}$ IEC-H	$T_{db\ out}$ DX	$T_{wb\ out}$ DX
34.10	52.5	16.40	15.70	14.90	13.60	35.80	48.00	17.10	16.50	17.40	15.80
23.40	28.00	12.90	12.40	9.60	8.60	27.50	27.00	8.10	7.70	10.30	8.40

CZ2				CZ5			
EER		Capacities, W		EER		Capacities, W	
IEC-H	DX	IEC-H	DX	IEC-H	DX	IEC-H	DX
20.7	11.9	28835.68	38910.58	25.5	10	35389.82	37322.37
6.2	5.6	8407.23	18312.61	12.9	6.3	19172.93	21016.48

The compressor nominal capacity of the DX unit is much larger than that of IEC-H unit, about 3.3 times larger. This is a bold design.

- $T_{db\ out}$ achieved by the IEC-H unit are nearly similar to the DX unit in CZ5 and slightly higher than in CZ2 except in one instance where they are almost equal.
- The EERs of the IEC-H unit are consistly higher than these of the DX unit in both CZs.
- Capacities performance in CZ5 is generally almost equal to that of the DX unit In CZ2 the capacity performance of the IEC-H unit is lower than that of the DX unit.
- The IEC-H unit performance, both capacity and EER is remarkable although it uses a much smaller compressor capacity**.**

Annex (2) Pre-Testing Report No. 1

The Transformation of Commercial Air Conditioning Companies (HCFC Phase-out Management Plan (HPMP) EGYPT (Stage II))

UNIDO ID: 140400

IEC Evaluation program

Pre-Testing Technical Report

June 2022

SUBMITTED BY:

Team of AO and HBRC

Contents

Pre-Testing Technical Report

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

1. Introduction:

The project aims at providing technical assistance for the implementation of low GWP technology as well as examining the introduction of a Not-In-Kind technology, namely: Indirect Evaporative Cooling (IEC).

The project also proposes to look into the introduction of IEC in commercial air conditioning applications. The goal of the project is to secure phase out of HCFC in the commercial air conditioning manufacturing sector.

In September 2015, the world's nations agreed to adopt a set of 17 Sustainable Development Goals (SDGs). Egypt affirmed its commitment to meet the targets set by SDGs by 2030 and outlined a 15-year development strategy. The SDGs, spearheaded by the United Nations, include resilient, stable, and sustainable infrastructure as one of its goals, thus, the green building landscape is expected to soar in the upcoming years.

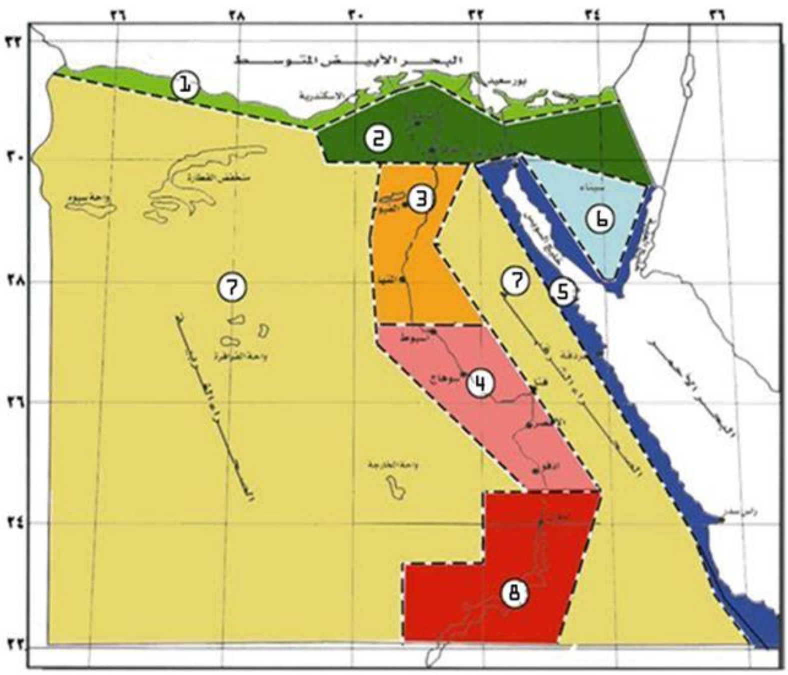
2. General Scope of Pre-tests

Pre-test the hybrid IEC Unit simultaneously with the DX Unit to find out problems during pre-test process and evaluate results to be able to refine and finalize the testing methodology to send the results to UNIDO and EUROVENT.

During the pre-testing problems arose and we were able to overcome them through certain procedures that we recommend to follow during the actual testing undertaken next year.

3. *Egypt Climatic Zones & Field Testing*

The application of any new technology, in such larger capacities of commercial air-conditioning applications, requires setting the ground to allow market acceptability noting that these are not off-the-shelf products that industry can put in markets in large quantities. Commercial air-conditioning applications are commonly specified by consultants for projects ensure reliability of the product that can justify the initial investment. The project will invite an international organization with experience in guidelines and certification programs for HVAC applications including IEC systems to provide a reference testing methodology for the IEC-hybrid units suitable for Egypt's working conditions. Egypt has 8 climatic zones out of which 7 climatic zones are suitable for IEC applications due to lower humidity conditions across the summer season, where the project is going to endorse and review the results and testing procedures during project implementation. Below figure show Egypt climatic zones:



1. North Coast Region
2. Delta and Cairo Region
3. North Upper Egypt Region
4. Southern Upper Egypt Region
5. Eastern Coast Region
6. High Heights Region
7. Desert Region
8. South of Egypt Region

It is anticipated that the tests will be done in three locations, Cairo, Hurghada and Toshka (representing Zones 2, 5 and 8). The Location's nearest Metrological Station are as per the following Table.

Weather Station Name	Weather Station Name Abbreviation	Weather Station Number	Latitude	Longitude	Altitude
Cairo Airport	HECA	623660	30.13	31.4	64
Hurghada	HEGN	624630	27.15	33.71	16
Toshka	HEBL	624190	22.36	31.61	192

The data to be collected in the three locations are temperatures (dry and wet), relative humidity. The weather in Egypt is almost always sunny and no great changes in the weather conditions occur except the large temperature swing between night and day.

4. *Prototypes and Testing Plan*

Through intensive round of discussion and consultation with local OEMs and based on formal communication and technical visits to their facilities to better understand capacities and readiness to build the needed prototypes.

Progress of Prototype Building by Local OEM

One OEM was ready with its prototype which was tested at their factory in 10th Ramadan City in Greater Cairo in Climatic Zone 2.

5. *Pre-Testing Conditions*

The pre-testing was conducted at OEM “Zone 2: Delta and Cairo Region” at altitude of 344.5 Feet above sea level. Figure 1 describes the schematic diagram of the testing site.

a. Both units were located at the entrance of OEM factory.
b. The distance between the hybrid IEC Unit and DX Unit was about 3 meters long.
c. The inlet of both units is directed to the North-East, and the outlet directed to the South-West.
d. Both units are full fresh air units.

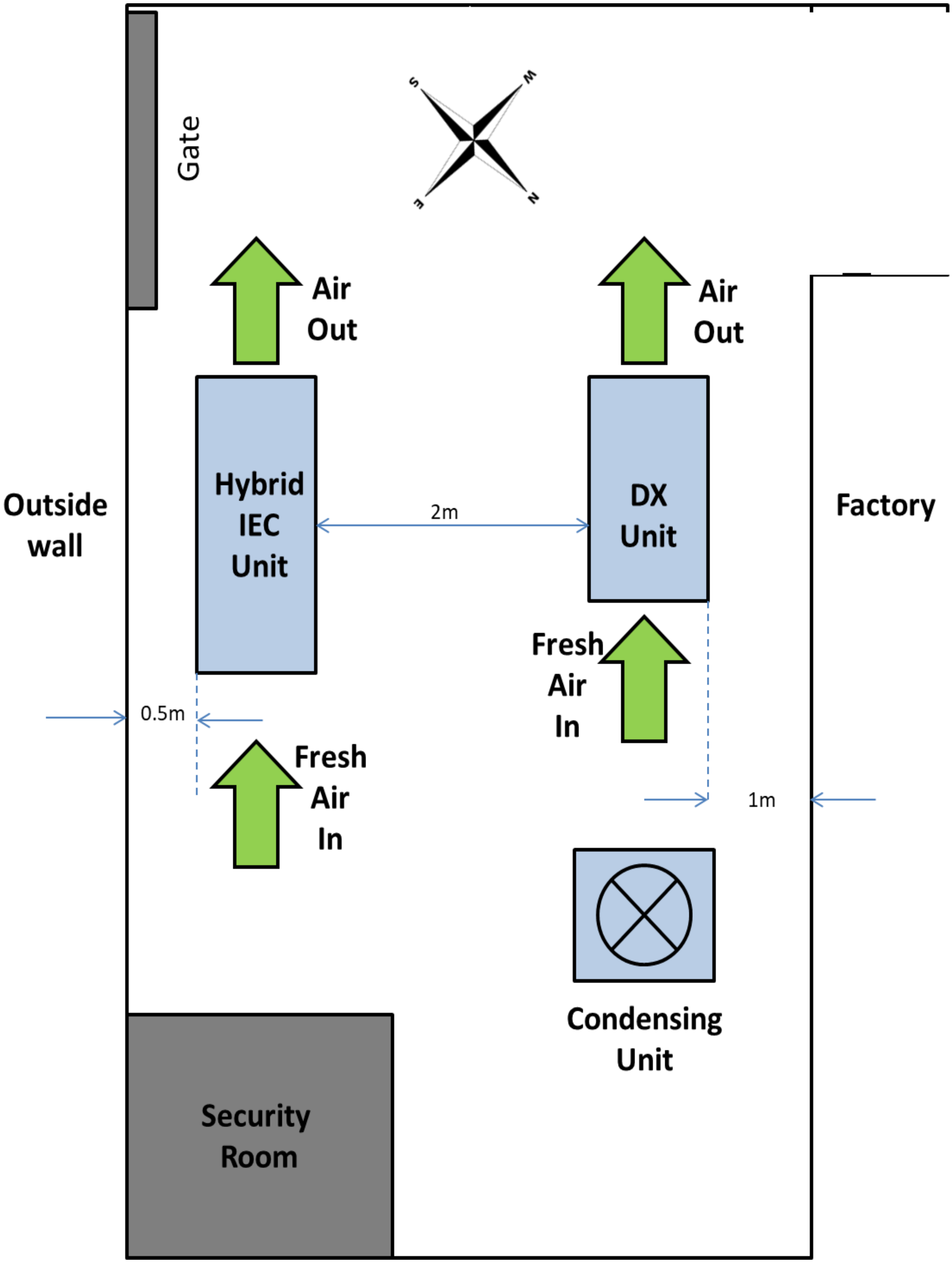


Figure (1) schematic diagram for both units

5.1 Description of Hybrid IEC Unit:

Emerson Compressor	ECU2500
Airflow	1940 cfm
Refrigerant type	R-32
Air	Full fresh air
Compressor capacity	55000 PTU/HR

5.2 Description of DX Unit:

Emerson Compressor	PAS SU/SCX 1206
Airflow	1940 cfm
Refrigerant type	R-410A
Air	Full fresh air
Compressor capacity	154000 PTU/HR

Note: An inverter was connected to the motor of the air blower of the unit to adjust the air flow rate.

6. *Measuring Instruments Used in Pre-Testing*

Code of Device	Instrument	Model	Number of Devices	Measurement Scope
1	Temperature Humidity Meter	FLUKE 971	1	Temperature & Humidity
2&3	Hygrothermometer	KIMO TH300	2	
4&5	Flow Meter	KIMO CP300	2	Air Flow
6	Power Analyzer	KYORITSU	1	Power Consumption & Energy Efficiency

***Note*:** Catalogues of measuring devices are "**attached**"

7. *Testing Methodology*

Prototypes were tested in "OEM Factory" in which the EER and cooling capacities of both (Hybrid IEC & DX) Units are calculated from measurements of inlet and outlet wet and dry bulb temperatures and associated airflow rates, which measured as below:

- The pre-testing preparations included setting the Air flow for both the Hybrid IEC Unit and the DX Unit on the same value (1940 CFM) by using a measuring Flow Meters "**code 4&5**".
- The pre-testing started at 1:00 PM on 6th October, 2021.
- The pre-testing steps included measuring the ambient conditions (Dry bulb temperature, and relative humidity), the performance of each unit by recording the outlet conditions (Dry bulb temperature, and relative humidity), in addition to the power consumption of both units.
- The recordings were taken hourly with a programmed data logging devices, and manually.
- The ambient temperature and relative humidity were measured by using measuring Temperature Humidity Meter instrument "**code 1**".
- the temperature, relative humidity, wet bulb, and enthalpy of the Hybrid IEC Unit outlet, measuring by hygrothermometer instrument "**code 2**".
- Similarly, hygrothermometer instrument "**code 3**" was used to record the temperature, relative humidity, wet bulb, and Enthalpy of the DX Unit.
- The power consumption was measured by using power analyzer "**code 6**".
- Water consumption of the hybrid IEC unit is measured by monitoring the water level in the basins.

- Measurements are done automatically by programming the aforementioned devices to log data for duration of 24 hours with a sampling time of 1 hour.
- The logged data are then transferred to a PC for tabulation and analysis.
- The pre-testing ended at 3:00 PM, on 7th October, 2021.
- The pre-testing was paused between 3:00 AM to 7:00 AM on 7th October, 2021 in sync with the reduction of the ambient temperature below 20°C.

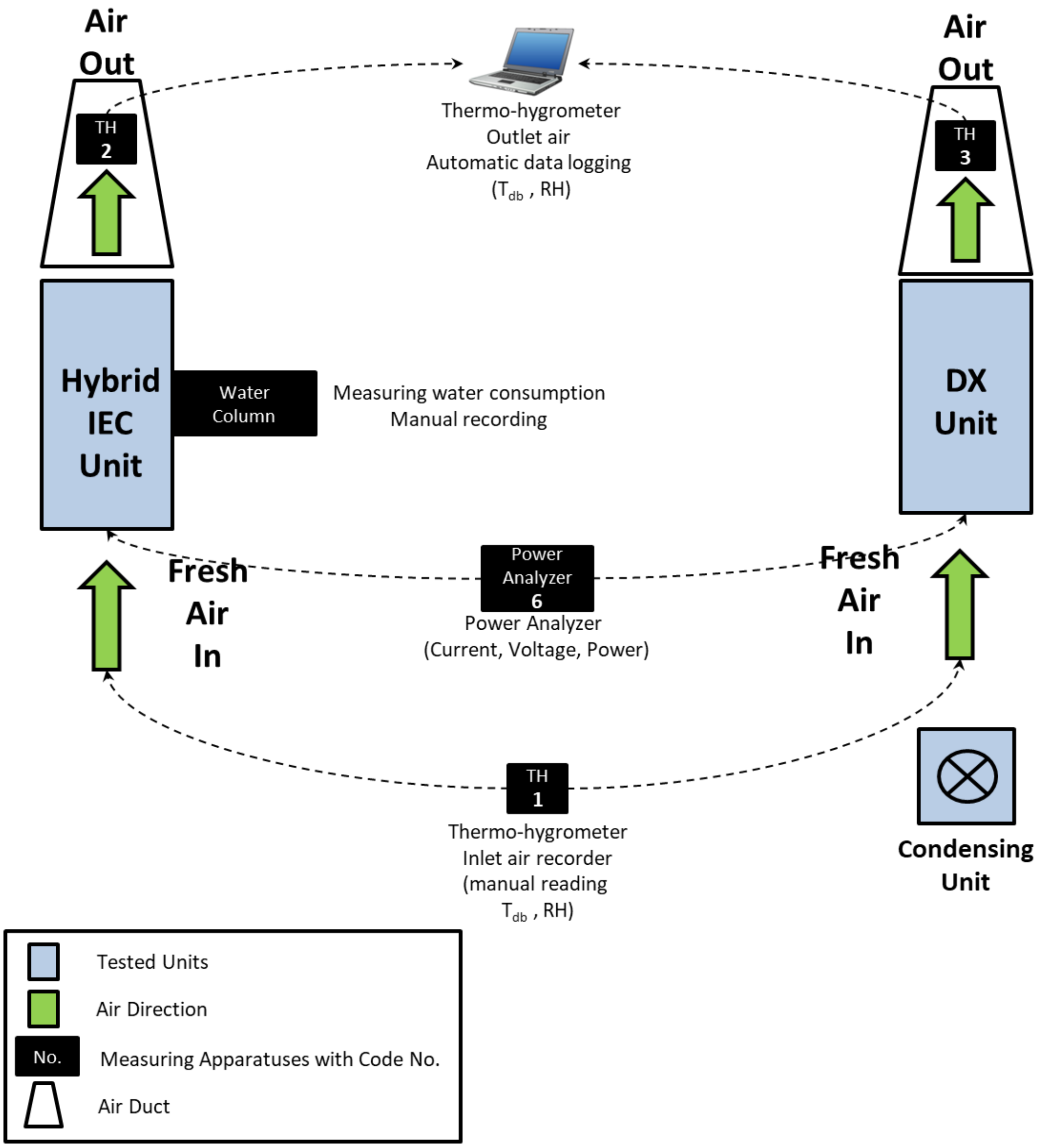


Figure 2 schematic diagram for the connection of the measuring devices on the site

7.1 Measuring Airflow Rate

- Airflow measuring apparatus (**code 4&5**) is subjected to the outlet of the two tested units in order to measure the airflow.
- The Air flow for both units is measured before starting the pre-test and is found about 1940 CFM for both units.

7.2 Measuring Wet and Dry Bulb Temperatures and Relative Humidity

- Air measuring devices for each unit (Inlet and Outlet) were used to measure average temperature.
- The Temperature Humidity Meter "**code 1**" is located in the inlet of the two tested units to measure both temperature and relative humidity.
- The two hygrothermometer instrument "**code 2&3**" are located in the outlet of the two tested units to measure both temperature and relative humidity.

7.3 Measuring Electrical Parameters:

- The Power Quality Analyzer "**code 6**" is used to measure electrical parameters such as power consumption, applied voltage, current consumption and power factor of both units.

7.4 Measuring Water consumption:

Water consumption of the hybrid IEC unit is measured by monitoring the water level in the basins.

➤ Water consumption was measured by calculating the decrease in the height of the water and multiplies it with the cross section area of the water bath:

✓ Water bath (1) Dimensions (mm) = 1728.5 × 623

✓ Water bath (2) Dimensions (mm) = 858.5 × 920

8. *Details of Performed Pre-tests*

Three pre-tests were conducted in order to construct a complete study for the performance of the hybrid IEC unit in comparison with the traditional DX unit:

The First Pre-test made by OEM, witnessed and assisted by HBRC: on 23th Sep.,2021.

Note:

- After 8 hours of starting, the hybrid IEC unit stopped because of a technical failure.
- The first pre-test did not finish due to the technical failure in the Hybrid IEC Unit, accordingly the data analysis was not completed.
- The Measuring Data was included in "**Annex 1**".

a. The second Pre-test made by the OEM after the accuracy of the measuring instruments was checked by the TAB Company.

Note:

- The calibration report, which checked by the TAB company is included in "**Annex 2**".
- Contact info. Of TAB Company: "The Engineering Company for Testing and Balancing Services" (***Site: https://www.tab.com.eg/***).

b. The third Pre-test made by OEM, witnessed and assisted by HBRC: on 6th Oct., 2021 "The testing report is included in the final results shown below".

9. *Final Results*

• **LAB**	In Site
• **Company**	OEM
• **Aims of Pre-Test :**	Comparison between the EER and Capacity of Hybrid IEC unit versus the DX Unit
• **Hybrid IEC Unit Model**	ECU2500
• **DX Unit Model**	PAS SU/SCX 1206
• **Description of Pre-Tests**	The first pre-test on 23th Sep.,2021 was discontinued after the hybrid IEC unit stopped. The second Pre-test was done to check the calibration of measuring instruments (3rd party TAB Company was invited to calibrate) on 28th Sep.,2021 . The final pre-test was the third on 6th Oct, 2021.
• **Airflow of Both Units**	1940 cfm full fresh air
• **Altitude**	344.5 ft. above sea level
• **Duct size**	(28*12 inch)

Remarks:

- Water consumption was measured by calculating the decrease in the height of the water column. The height was multiplied by the cross section area of the water bath:
  a. Water bath (1) Dimensions (mm) = 1728.5 × 623
  b. Water bath (2) Dimensions (mm) = 858.5 × 920
- Measurements started at 12:50 pm.
- Measurements were recorded hourly until 3 am, when both units stopped at inlet ambient temperature decreased below 20°C (Both hybrid IEC Unit and DX Unit were programmed to stop at 20°C).
- The measurements were restarted at 7 am next day (7th Oct., 2021) when the inlet ambient temperature exceeded 20°C.
- The pre-testing ended at 3 pm (7th Oct., 2021) after 24 records were achieved.

Readings of DX Unit

Table (1) Readings of DX Unit

DX Unit , Air flow = 1940 cfm , Altitude = 334.5 ft									
Hour	Inlet DB	Inlet RH	Outlet DB	Outlet RH	Sensible Cooling	Latent dehumidifying	Cooling Capacity	Power	EER
	Celsius	%	Celsius	%	Btu/h	Btu/h	Btu/h	kW	Btu/hr.watt
1PM	32.8	35.4	9.8	78	82,245	46,145	128,390	12.05	10.655
2PM	31.7	29.6	9.3	78.1	80,564	26,558	107,122	12.29	8.716
3PM	30.8	36.2	9.5	76.7	76,712	39,644	116,356	12.16	9.569
4PM	31.6	35.3	8.7	82.6	82,258	40,378	122,636	12.04	10.186
5PM	28.9	41	7.6	83.9	77,132	43,301	120,433	12	10.036
6PM	26.9	45.6	7.1	86.1	72,151	43,034	115,185	11.78	9.778
7PM	25.7	53	7.6	88.7	66,130	47,673	113,803	11.64	9.777
8PM	24.8	59.9	7.4	92.4	47,673	53,613	101,286	11.56	8.762
9PM	24	63.2	7.2	93.7	61,598	54,369	115,967	11.41	10.164
10PM	23.1	65.4	6.4	94.8	61,405	54,683	116,088	11.17	10.393
11PM	22.1	68.8	5.8	95.6	60,109	55,508	115,617	11.01	10.501
12AM	21.9	70.3	5.4	96.7	60,857	57,393	118,250	10.77	10.980
1AM	21.1	71.1	5	96.8	59,571	54,857	114,428	10.72	10.674
2AM	21.2	71.5	4.9	97.2	60,275	56,220	116,495	10.71	10.877
3AM	20.7	72.9	4.8	97.5	58,895	55,305	114,200	10.62	10.753
7AM	22.5	68.3	5.2	98.6	63,701	57,834	121,535	10.43	11.652
8AM	26.1	57.5	9.3	83.5	61,176	55,876	117,052	11.37	10.295
9AM	26.9	51.4	7.5	89	70,571	51,822	122,393	11.64	10.515
10AM	31.2	40.8	8.3	83.7	82,208	53,314	135,522	11.87	11.417
11AM	29.8	40.1	8.9	82.7	75,473	42,180	117,653	12.15	9.683
12PM	30.1	37.8	9.3	81.3	75,089	37,663	112,752	12.14	9.288
1PM	33	32	9.7	82.2	83,377	35,062	118,439	12.52	9.460
2PM	32	30.4	9.1	77.6	82,248	31,050	113,298	12.56	9.021
3PM	33.5	30.9	10.5	76.6	82,176	35,310	117,486	12.69	9.258

Prepared by	Checked by	Approved by
Eng. Sally Aladdin	Prof. Sayed Shebl	Prof. Alaa Olama

Eng. Nourhan Abdel Rahman

Readings of Hybrid IEC Unit

Table (2) Readings of Hybrid IEC Unit

Hybrid IEC Unit , Air flow = 1940 cfm , Altitude = 334.5 ft									
Hour	Inlet DB	Inlet RH	Outlet DB	Outlet RH	Sensible Cooling	Latent dehumidifying	Cooling Capacity	Power	EER
	Celsius	%	Celsius	%	Btu/h	Btu/h	Btu/h	kW	Btu/hr.watt
1PM	32.8	35.4	13.3	80.2	69,845	30,382	100,227	4.524	22.155
2PM	31.7	29.6	12.4	78.8	69,486	14,162	83,648	4.524	18.490
3PM	30.8	36.2	12.4	79.5	66,357	26,391	92,748	4.513	20.551
4PM	31.6	35.3	12.9	79.9	67,272	25,708	92,980	4.56	20.390
5PM	28.9	41	11.6	81.5	62,738	29,774	92,512	4.555	20.310
6PM	26.9	45.6	11.3	84.2	56,939	28,183	85,122	4.528	18.799
7PM	25.7	53	12.2	85.9	49,420	30,680	80,100	4.567	17.539
8PM	24.8	59.9	12.7	87.7	44,366	34,145	78,511	4.597	17.079
9PM	24	63.2	12.9	87.1	40,784	34,396	75,180	4.625	16.255
10PM	23.1	65.4	12.4	87.5	39,423	34,407	73,830	4.508	16.378
11PM	22.1	68.8	12.1	88.4	36,952	34,133	71,085	4.489	15.835
12AM	21.9	70.3	11.9	88.2	34,133	36,289	70,422	4.425	15.915
1AM	21.1	71.1	11.9	88.5	34,111	32,112	66,223	4.436	14.929
2AM	21.2	71.5	11.7	88.7	35,198	34,128	69,326	4.418	15.692
3AM	20.7	72.9	11.3	88.4	34,875	35,092	69,967	4.422	15.822
7AM	22.5	68.3	11.1	89	42,038	40,135	82,173	4.475	18.363
8AM	26.1	57.5	12.6	86.9	49,262	39,189	88,451	4.554	19.423
9AM	26.9	51.4	13.3	85.4	49,599	29,901	79,500	4.55	17.473
10AM	31.2	40.8	12.9	83.8	65,831	34,602	100,433	4.538	22.132
11AM	29.8	40.1	13.1	82.3	60,418	25,254	85,672	4.567	18.759
12PM	30.1	37.8	13.4	81.9	60,398	20,245	80,643	4.594	17.554
1PM	33	32	13.2	82.2	70,952	20,541	91,493	4.614	19.829
2PM	32	30.4	11.6	80.3	73,341	19,781	93,122	4.589	20.292
3PM	33.5	30.9	12.8	81.6	74,049	22,187	96,236	4.656	20.669

Prepared by	Checked by	Approved by
Eng. Sally Aladdin	Prof. Sayed Shebl	Prof. Alaa Olama

Eng. Nourhan Abdel Rahman

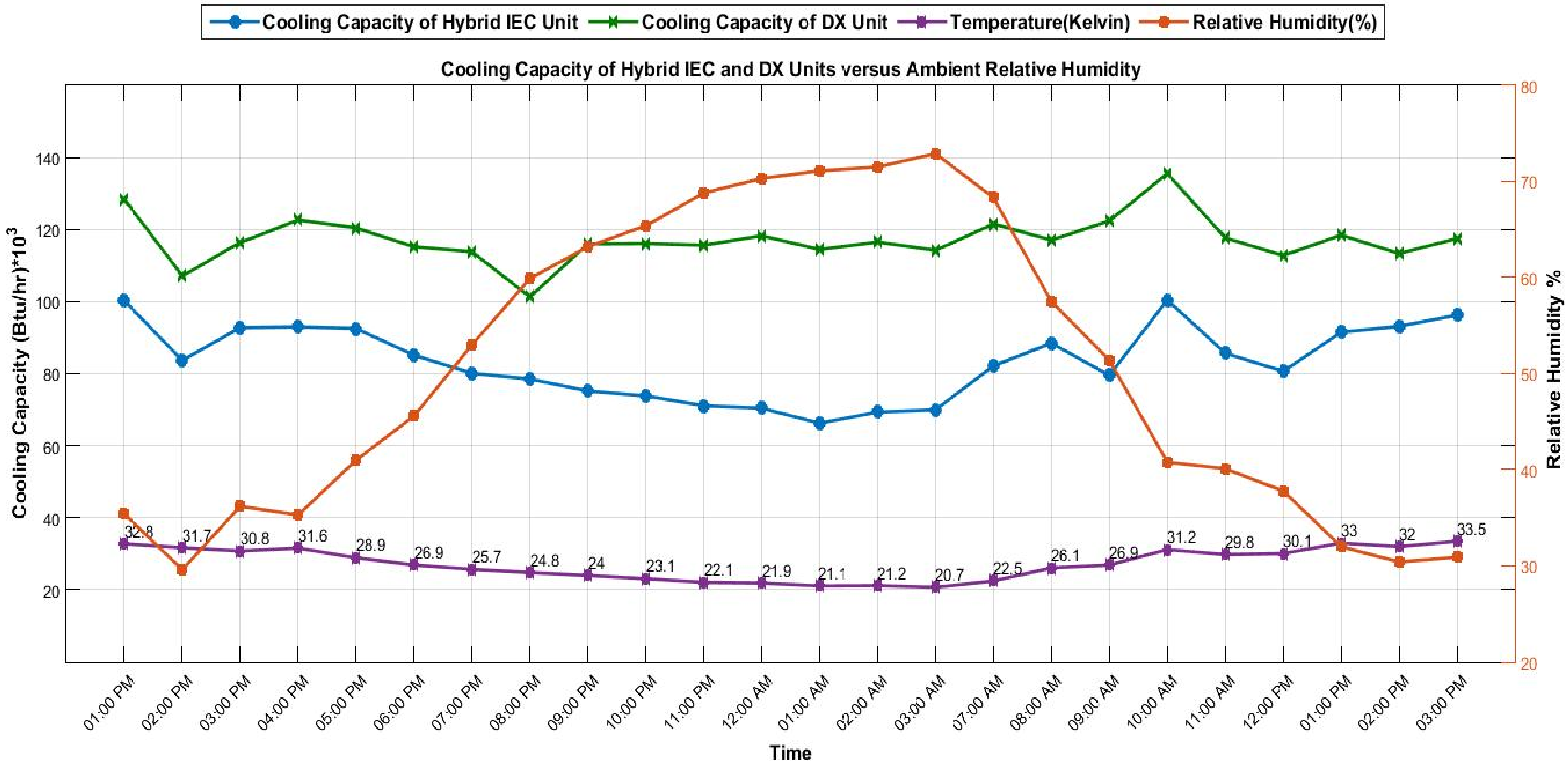


Figure (3): Cooling Capacity of (Hybrid IEC & DX) Units

Note**:** *The Plotted Cooling capacity of both units in Btu/hr(×10^3).*

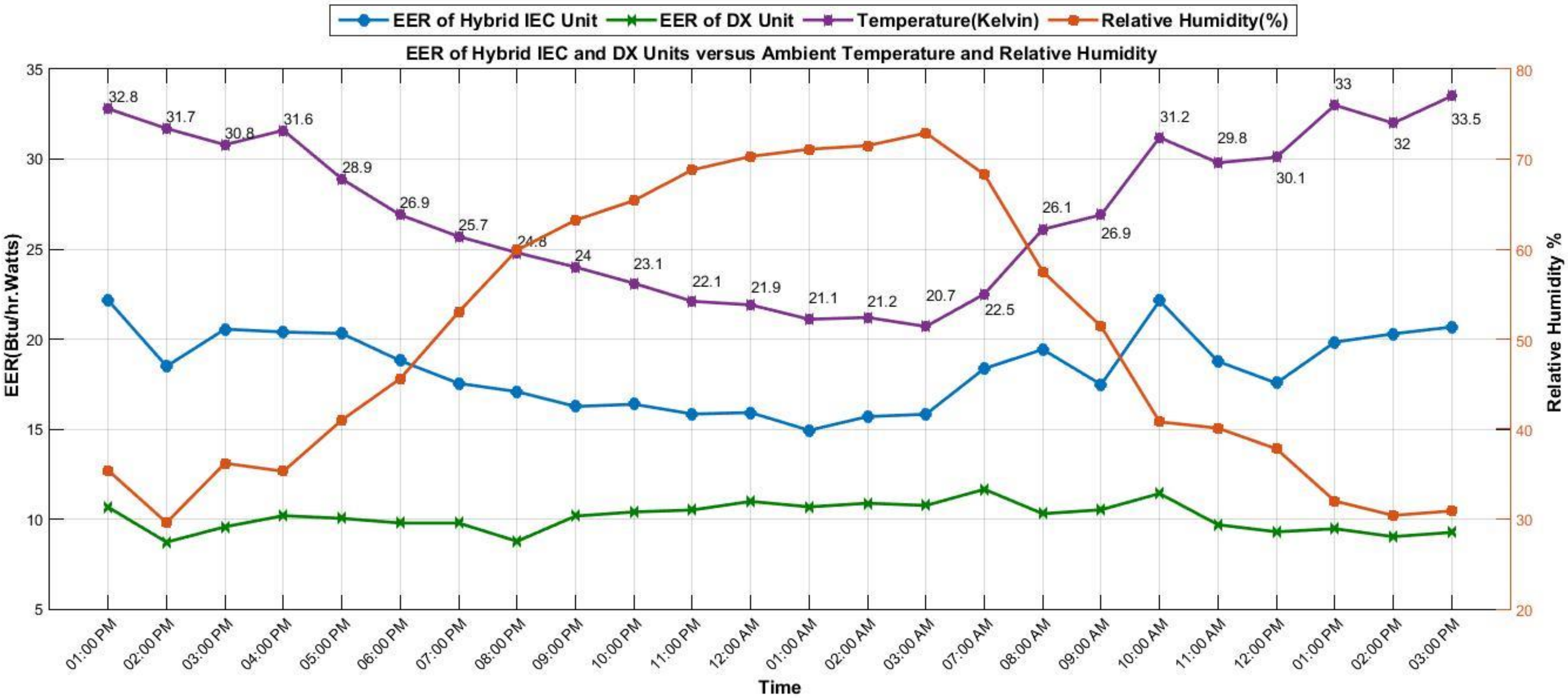


Figure (4): EER of (Hybrid IEC & DX) Units

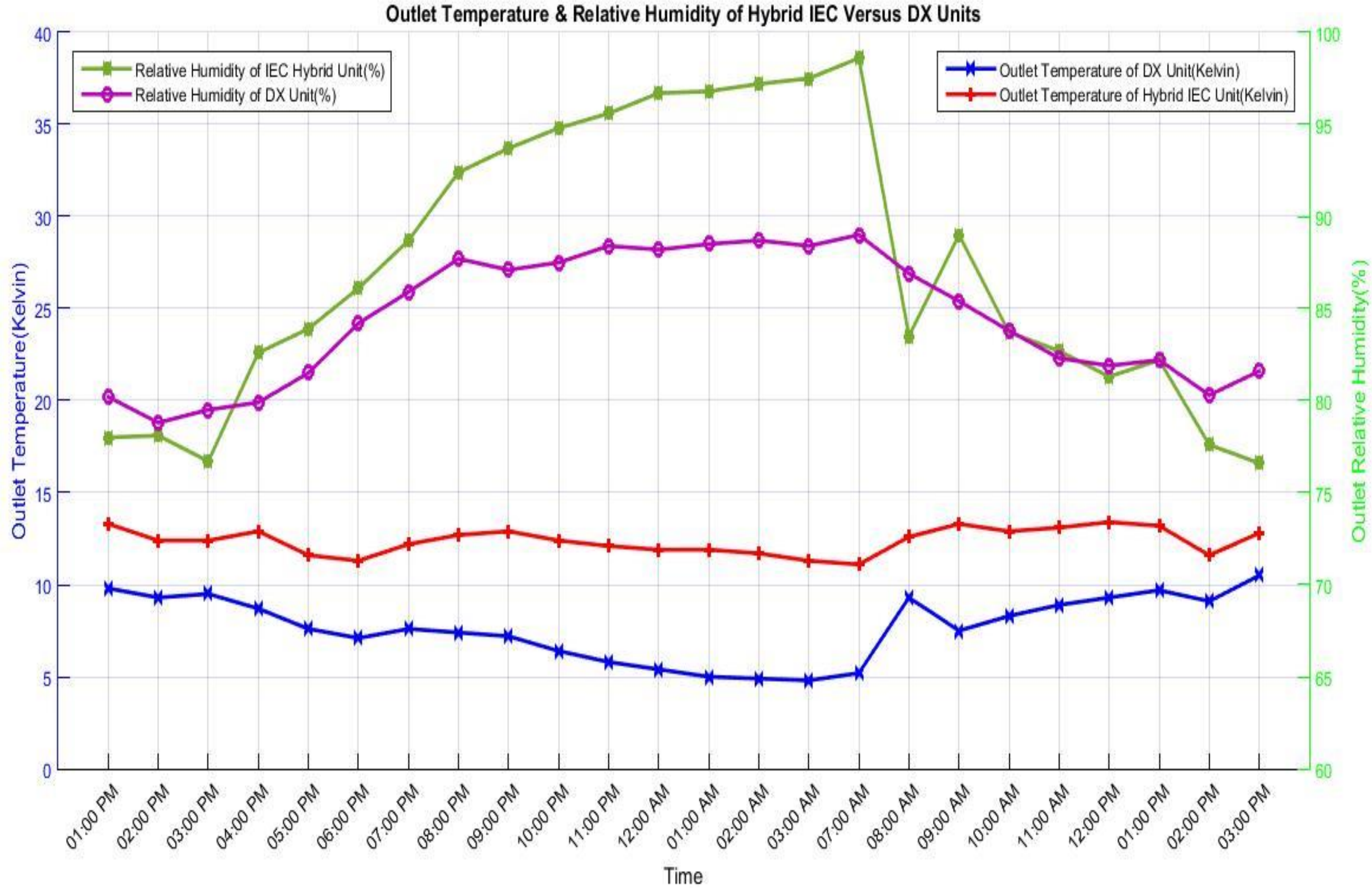


Figure (5): ambient (Relative humidity and Temperature) of (Hybrid IEC & DX) Units

10. Discussion of the results

a. The capacity of the compressor of the hybrid IEC unit is smaller than the DX unit.

b. Both units are full fresh air units with an inverter installed in the DX unit air blower to provide equality of the air flows.

c. A testing and balancing third party were invited after the first test to make sure the measuring instruments were well calibrated.

d. The hybrid IEC unit compressor was switched on continuously, as well as the DX unit compressor.

e. The pre-testing started on 6th October, 2021 and ended on 7th October, 2021.

f. In Figure 2:

- As the ambient RH increases the capacity of the IEC unit decreases and vice versa.
- The capacity of DX unit is almost constant.
- As the dry bulb temperature increases the capacity of both units decreases and vice versa**.**

g. In Figure 3:

- The EER of the DX unit is almost constant during all the testing periods.
- The EER of the hybrid IEC unit is superior that the DX unit throughout all relative humidities.
- Although the RH increased from 29.6 to 72.9 (59.4 %) the EER of the hybrid IEC unit decreased from 18.49 to 15.822 (Percentage of improvement Hybrid IEC Unit=14.43%).
- Percentage of improvement Hybrid IEC Unit= 34.0625%.
- Percentage of improvement DX Unit = 25.2623%.

h. According to table 1 and 2 we can sum up the following findings:

Type	**Min. RH %**	**Coincident T_{db} (Kelvin)**	**EER**	**Cooling Capacity**	**Max. RH %**	**Coincident T_{db} (Kelvin)**	**EER**	**Cooling Capacity**	**Diff. EER**	**Diff. Cooling Capacity**
DX	29.6	31.7	8.716	107,122	72.9	20.7	10.753	114,200	2.037	7,078
IEC			18.490	83,648			15.822	69,967	2.668	13,681

11. Conclusions

a. To make sure the testing comparison is more realistic between the hybrid IEC unit and DX unit; it is recommended that the size of compressors of both units have the same nominal capacity, or the dry bulb temperature of the outlet air for the hybrid IEC and DX unit are kept constant.

b. Although the pre-testing was conducted at the end of the summer season, the results show the EER of the IEC unit is superior to that the DX unit.

c. When testing at the height of the summer season the result is expected to be even better.

d. Climatic Zone 2 “Delta and Cairo region” is relatively high in humidity, other climatic regions except climatic region 1 will show even better results because of the lower humidity.

e. Consistent results for 24 hours took 3 days of pre-test trials.

Notes:

- The EER is calculated using equation(1)

$$\text{EER} = \frac{Total\ Cooling\ Capacity\ (\frac{Btu}{hr})}{Power\ (watt)} \qquad (1)$$

- The Total Cooling Capacity is calculated using equation (2)

$$\text{Cooling Capacity (Btu/hr)} = \frac{Enthalpy_{in} - Enthalpy_{out}}{flow * Air\ volume_{@344.5\ ft}} \qquad (2)$$

Prepared by	Checked by	Approved by
Eng. Sally Aladdin	**Prof. Sayed Shebl**	**Prof. Alaa Olama**

Eng. Nourhan Abdel Rahman

Annex 1

Results of the First Pre-Test on 23th Sep., 2021

<u>The Reading of the DX Unit:</u>

Project No.: 140400				**Air Flow (CFM): 1932**				
End Time: 11:16 AM, 23th Sep.,2021					**End Time:** 11:16 AM, 24th Sep.,2021			
Item	**INLET (fluke 971)**			**DXU (OEM1)**				
	Ambient Temp.	**Wet Bulb**	**Relative Humidity**	**Dry Bulb**	**Wet Bulb**	**Relative Humidity**	**Enthalpy**	**Power**
	°C	**°C**	**%**	**°C**	**°C**	**%**	**kJ/kg**	**kW**
1	36.2	26.7	48.7	14	11.9	76.4	33.4	7.992
2	40	24.4	29.7	13.3	11.6	79.2	32.7	8.074
3	40	24.1	24.1	13.7	11.8	77.8	33.2	8.192
4	40.1	24.4	25.4	13.7	11.7	77.4	32.9	8.108
5	36.6	23.9	34.5	14.7	12.2	73.8	31.3	8.231
6	35.1	23.5	36.9	13.2	11.6	80.8	32.8	8.239
7	33	22.8	40.9	12.5	11.1	82.1	31.4	8.231
8	30.8	22.5	50	11.7	10.8	85.7	30.6	8.051

The Reading of the Hybrid IEC Unit:

Project No.: 140400								**Air Flow (CFM):** 1934		
End Time: 11:16 AM, 23th Sep.,2021						**End Time:** 11:16 AM, 24th Sep.,2021				
Item	**INLET (fluke 971)**			**ECU-Hybrid (OEM1)**						
	Ambient Temp.	**Wet Bulb**	**Relative Humidity**	**Dry Bulb**	**Wet Bulb**	**Relative Humidity**	**Enthalpy**	**Water Level**	**Water Cons.**	**Power**
	°C	**°C**	**%**	**°C**	**°C**	**%**	**kJ/kg**	**mm**	**m3/hr**	**kW**
1	36.2	26.7	48.7	17	16.4	89.5	44.3	0	0	2.633
2	40	24.4	29.7	16.4	15.9	89.2	42.8	26	0.0485	2.741
3	40	24.1	24.1	17	16.4	89	44.2	27	0.0504	2.59
4	40.1	24.4	25.4	17	16.4	88.5	44.1	28	0.0523	2.596
5	36.6	23.9	34.5	17.5	17	89.2	45.7	27	0.0504	2.623
6	35.1	23.5	36.9	17.9	17.6	90.9	47.4	23	0.0429	2.596
7	33	22.8	40.9	17.6	17.3	91.4	46.5	24	0.0448	2.641
8	30.8	22.5	50	18.6	18.5	92.4	50	19	0.0355	2.606

Note*: *The first pre-test did not finish due to the technical failure in the Hybrid IEC Unit, accordingly the data analysis was not completed.

Annex 2

Calibration results made by the TAB Company On 28th Sep., 2021

No.	TSI Device (Air flow & Pressure)		KIMO Device (Air flow & Pressure)	
	Air flow (CFM)	Static Pressure	Air flow (CFM)	Static Pressure
1	1927	5	1930	12
2	1657	115	1650	122
3	-	208	-	218
4	-	22	-	32

UNIT DATA	PU		
Equipment Location	-		
Area Served	-		
Equipment Manufacturer	OEM		
Model	BOX BD 10/10 M4		
Serial Number	-		
FAN DATA	**DESIGN**	**MEASURED**	**%**
Total air Flow (CFM)	2003	1927	96%
Total Static Pressure (Pa)	235	-	
External Static Pressure (Pa)	-	12	
Fan RPM	1340	N.A	
MOTOR DATA	**DESIGN**	**MEASURED**	**%**
Motor Manufacturer	-		
Motor (KW)	0.59	0.5	
Phase/HZ	3PH/50Hz		
Voltage (v)	230	22 7	
Amperage (A)	4.5	3.8	
Motor RPM	1340	N. A	

Point No.	1	2	3	4	5
A	+	+	+	+	+
B	+	+	+	+	+
C	+	+	+	+	+

Design		
	Duct size (inch)	28*12
	Area (Sq. inch)	336
	Velocity (ft./min)	858
	Flow (CFM)	2003

Point No.	1	2	3	4	5
A	2154	1845	2073	1585	2024
B	2358	1705	2119	1884	1821
C	2072	1894	1753	2070	1553

Measured		
	Duct size (inch)	28*12
	Area (Sq. inch)	336
	Velocity (ft./min)	826
	Flow (CFM)	1927

Temperature & RH Calibration

No.	AQM (Reference Device)		KIMO2		KIMO3	
	Temp. (°C)	RH %	Temp. (°C)	RH %	Temp. (°C)	RH %
1	26.8	43.4	27.5	44.6	27.9	39
2	27.3	42.9	27.9	44.4	28.4	38.8
3	26.8	43.4	27.5	44.6	27.9	39
4	27.5	42.6	28.2	44.8	28.7	38.5
5	27.8	42.4	28.6	43.8	29.1	38.3
6	27.8	42.4	28.7	43.8	29.1	38.2
7	28.3	42	29.4	43.3	29.7	38.3
8	28.4	42	29.4	43.1	29.7	38.3
9	28.4	42.7	30.3	43.2	30.5	37.3
10	29	42.4	30.5	42.3	30.6	37.6
11	29.2	43	30.9	42.7	31.1	37.5
12	29.2	43.3	30.9	42.6	31.2	37.4
13	33.7	32	34	35.3	34.2	30.2
14	33.7	31.4	34.1	34.9	34.3	29.9
15	33.4	30.8	34.1	34.5	34.4	29.6
16	34.1	31.7	34.5	34.4	34.7	29.7
17	34	31.6	34.5	34.5	34.8	29.7
18	33.4	32	34.7	34.3	34.9	29.5
19	33.7	31.9	34.7	34.3	34.9	29.4
20	33.5	31.8	34.9	33.7	28.8	35.1
21	33.6	32	35	33.8	35.1	29
22	33.5	32.1	35	33.8	35.2	28.9
Average	**30.6**	**37.7**	**31.6**	**39.4**	**31.6**	**34.5**
Deviation from AQM	**-**	**-**	**1.0**	**1.7**	**1.0**	**-4.9**
Deviation %	**-**	**-**	**3.3%**	**4.4%**	**3.3%**	**13.0%**

Temperature & RH Calibration

No.	AQM (Reference Device)		FLUKE	
	Temp. (°C)	RH %	Temp. (°C)	RH %
1	25.3	44.8	24.9	46.6
2	25.5	44.7	25.6	46.9
3	25.7	44.5	25.8	46.7
4	26	44.1	25.9	47.2
5	26.6	43.2	26.1	47.3
6	26.9	43.1	26.4	48
7	26.8	43.4	25.2	47.5
8	27.3	42.9	25.6	46.6
9	26.8	43.4	25.2	47.5
10	27.5	42.6	26.7	46.1
11	27.8	42.4	26.9	46.1
12	28.3	42	27.2	46
13	28.4	42	27	46.1
14	28.4	42.7	27.6	46.4
15	29.2	43	27.4	47.7
16	33.7	32	33.4	35.6
17	34.1	31.7	34.8	33.5
18	34	31.6	34.7	33.5
19	33.4	32	35.3	33.4
20	33.7	31.9	35.5	33.6
21	33.5	31.8	35	33.9
22	33.6	32	34.9	34.4
23	33.5	32.1	34.6	34.6
Average	**29.39**	**39.3**	**29.2**	**42.4**
Deviation From AQM %	**-**	**-**	**-0.2**	**3.1**
Deviation %	-	-	**0.6%**	**7.9%**

Attachment

Measuring Instrument - Code 1

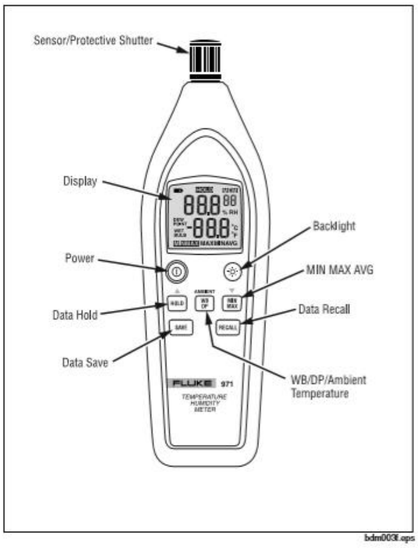
FLUKE.

971

Temperature Humidity Meter

Users Manual

PN 2441047
September 2005 Rev.1, 5/06



Introduction

⚠ Caution

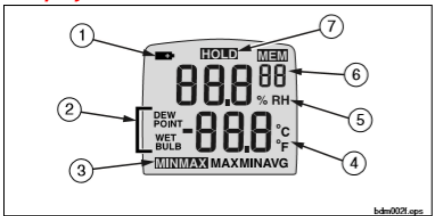
To extend sensor life, keep the sensor's protective shutter closed whenever the meter is not in use.

The Fluke Model 971 (hereafter referred to as "the Meter" is a battery powered meter that measures relative humidity and temperature. Through a few easy to use controls, the Meter displays three different temperature points of the air surrounding the meter's sensor: ambient, wet bulb, and dew point.

Electrical and Safety Symbols

⚠	Important information. See manual	(low battery symbol)	Low battery when shown in the display.
CE	Conforms to European Union requirements	(C-tick symbol)	Conforms to Australian standards.
CSA	Conforms to Canadian standards	ⓞ	Power ON / OFF

Display



No.	Symbol	Meaning
1	(battery symbol)	Low battery.
2		Wet bulb or dew point temperature displayed.
3	MIN MAX MAX, MIN, AVG	Min Max Record enabled. Maximum, minimum, or average reading displayed.
4	°F, °C	Temperature measurement units.
5	% RH	Relative humidity measurement unit.
6	MEM 88	Displayed reading is from memory. Memory location number.
7	HOLD	HOLD enabled. Display freezes present reading.

Operation

Note

When moving from one temperature/humidity extreme to another, allow time for the Meter to stabilize.

After opening the sensor's protective shutter, press ⓞ to turn on the Meter and start taking measurements.

Temperature readings are displayed in either the Celcius (°C) or Fahrenheit (°F) scale. To switch between °C and °F, remove the battery compartment door and position the temperature scale switch to the desired scale. See Figure 1.

Dew Point and Wet Bulb Temperature

The Meter displays ambient temperature when first turned on. To display dew point (DP) temperature, press WB DP once. Press WB DP again to switch to wet bulb (WB) temperature. Pressing WB DP a third time returns the Meter to ambient temperature. The display indicates when dew point and wet bulb temperatures are selected.

HOLD

Pressing HOLD causes the meter to freeze the displayed readings. It also causes the meter to stop taking measurements. HOLD is displayed when HOLD is enabled. To continue taking measurements, press HOLD again.

Min Max Record

When enabled, Min Max Record stores a new measurement when it is either higher or lower than a previously stored maximum or minimum measurement. Press MIN MAX to start Min Max Record. MIN MAX appears in the display to indicate Min Max Record mode is enabled.

Note

The temperature scale switch (°C/°F), Save, Recall, and Hold buttons, as well as the Automatic Power Off (APO) switch are all disabled when Min Max Record is enabled.

To view the stored Minimum, Maximum and Average readings, press MIN MAX repeatedly to cycle through all three stored sets of measurements. You must select wet bulb, dew point, or ambient before reading their respective Min Max Avg values. The display indicates which stored set of readings is displayed. Pressing MIN MAX a fourth time displays the present measurement.

To exit Min Max Record mode and resume normal operation, press and hold MIN MAX for two seconds.

Saving and Recalling Measurements

The Meter stores up to 99 readings for later recall. Each memory location stores relative humidity as well as ambient, dew point and wet bulb temperatures.

Pressing SAVE saves the present readings to a memory location. MEM and the memory location number appear in the display to indicate the readings have been stored. Press WB DP to return the display to the present reading. After all 99 memory locations are filled, each subsequent save overwrites a memory location starting with the first.

To recall the readings from memory, press RECALL. If the memory location you are looking for is not already displayed, press ▲ or ▼ until the desired memory location is displayed. To return the Meter to normal operation, press RECALL for two seconds.

By default, relative humidity and ambient temperature are displayed when a memory location is recalled. Pressing WB DP cycles through the Wet Bulb, Dew Point, and Ambient temperatures stored in the memory location displayed.

To erase all 99 memory locations, simultaneously press SAVE and RECALL for five seconds.

Automatic Power Off

To save battery life, the Automatic Power Off (APO) feature can be used to turn the meter off after 20 minutes of no activity. To enable or disable the APO feature, remove the battery cover and position the APO switch to the desired position. See Figure 1.

Maintenance

Battery Replacement

Meter power is supplied by four 1.5 V (AAA size) batteries. When ▮+ appears in the display, replace the batteries as soon as possible. To replace the batteries:

1. Back out the screw at the top of the battery door and lift the door away from the Meter.
2. Remove the four AAA batteries from the compartment.
3. Replace with four new AAA batteries, observing proper polarity as depicted on the bottom of the battery compartment.
4. Replace the battery door and tighten the screw to lock it in place.

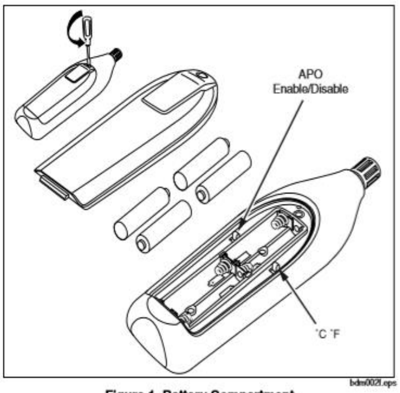


Figure 1. Battery Compartment

Cleaning

⚠ Caution

To avoid damage to the case, do NOT use abrasives or solvents for cleaning the meter.

Periodically wipe the case with Fluke Meter Cleaner or a damp cloth and detergent.

Specifications

Temperature	
Range:	-20 to 60 °C (-4 to 140 °F)
Accuracy:	±0.5 °C on 0 to 45 °C ±1.0 °C on -20 to 0 °C, 45 to 60 °C ±1.0 °F on 32 to 113 °F ±2.0 °F on -4 to 32 °F, 113 to 140 °F
Resolution:	0.1 °C /°F
Update rate:	500 ms
Sensor type:	NTC
Relative Humidity	
Range:	5 to 95 % RH
Accuracy:	±2.5 % RH (10 to 90 % RH) @23 °C (73.4 °F) ±5.0 % RH (<10, >90 % RH) @23 °C (73.4 °F)
Resolution:	0.1 % RH
Response time:	60 seconds max.
Sensor hysteresis:	±1 % RH with excursion of 90 % to 10 % to 90 %
Sensor type:	Electronic–capacitance polymer film
Temperature Coefficient:	0.1 x (specified accuracy)/°C (< 23 °C or > 23 °C)
Wet Bulb Temperature	
Range:	-20 to 60 °C (-4 to 140 °F)
Dew Point Temperature	
Range:	-50 to 60 °C (-58 to 140 °F)

Memory:	99 data points
Power:	4 each AAA batteries, 24A, LR03
Battery Life:	200 hours
Environment	
Storage:	-20 to 60 °C at <80 % R.H. (Batteries removed)
Operating:	Temperature: -20 to 60 °C Humidity: 0 to 55 °C
Weight/Dimensions:	190 g with batteries 194 mm x 60 mm x 34 mm
Safety Approvals/ Certifications:	Meets Australian requirements Meets CSA requirements CE Meets European requirements Meets EN61326-1, Schedule B Electromagnetic Emissions and Susceptibility

Specifications subject to change without notice

LIMITED WARRANTY AND LIMITATION OF LIABILITY

This Fluke product will be free from defects in material and workmanship for one year from the date of purchase. This warranty does not cover fuses, disposable batteries, or damage from accident, neglect, misuse, alteration, contamination, or abnormal conditions of operation or handling. Resellers are not authorized to extend any other warranty on Fluke's behalf. To obtain service during the warranty period, contact your nearest Fluke authorized service center to obtain return authorization information, then send the product to that Service Center with a description of the problem.

THIS WARRANTY IS YOUR ONLY REMEDY. NO OTHER WARRANTIES, SUCH AS FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSED OR IMPLIED. FLUKE IS NOT LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OR LOSSES, ARISING FROM ANY CAUSE OR THEORY. Since some states or countries do not allow the exclusion or limitation of an implied warranty or of incidental or consequential damages, this limitation of liability may not apply to you.

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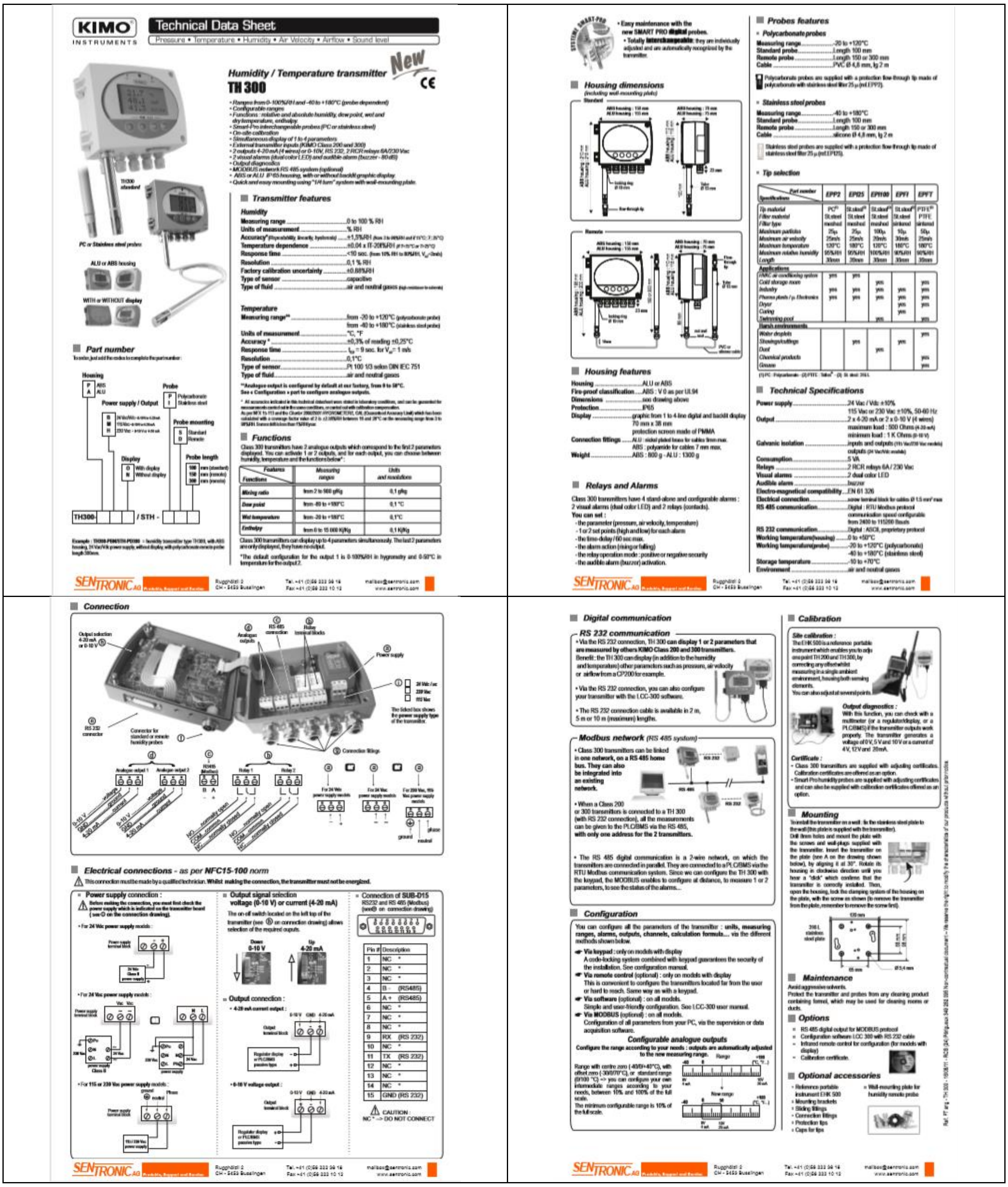
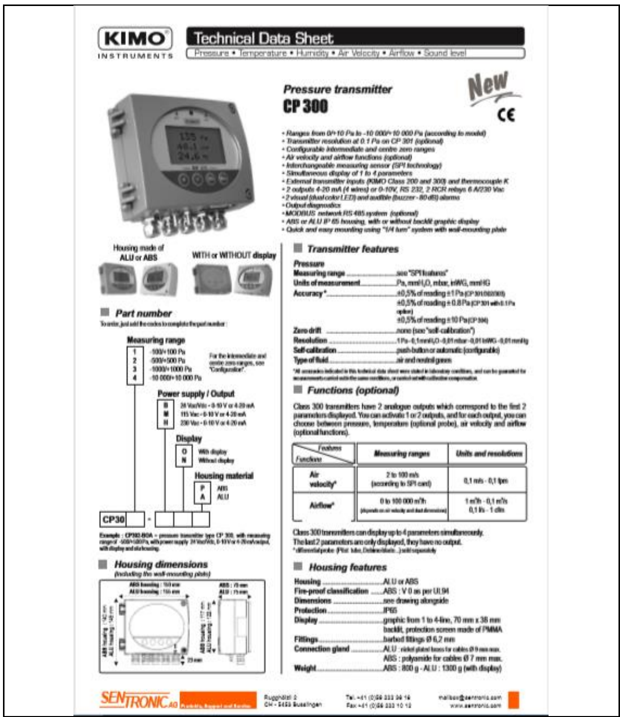
11/99

Measuring Instruments - Code 2 & 3



Measuring Instruments - Code 4 & 5



KIMO INSTRUMENTS — Technical Data Sheet
Pressure • Temperature • Humidity • Air Velocity • Airflow • Sound level

Pressure transmitter
CP 300

New

- Ranges from 0/+10 Pa to -10 000/+10 000 Pa (according to model)
- Transmitter resolution at 0.1 Pa on CP 301 (optional)
- Configurable intermediate and centre zero ranges
- Air velocity and airflow functions (optional)
- Interchangeable measuring sensor (SPI technology)
- Simultaneous display of 1 to 4 parameters
- External transmitter inputs (KIMO Class 200 and 300) and thermocouple K
- 2 outputs 4-20 mA (4 wires) or 0-10V, RS 232, 2 RCR relays 6 A/230 Vac
- 2 visual (dual color LED) and audible (buzzer - 80 dB) alarms
- Output diagnostics
- MODBUS network RS 485 system (optional)
- ABS or ALU IP 65 housing, with or without backlit graphic display
- Quick and easy mounting using "1/4 turn" system with wall-mounting plate

Housing made of ALU or ABS — WITH or WITHOUT display

Part number

Measuring range: 1 -100/+100 Pa; 2 -500/+500 Pa; 3 -1000/+1000 Pa; 4 -10 000/+10 000 Pa

Power supply / Output: B 24 Vac/Vdc - 0-10 V or 4-20 mA; M 115 Vac - 0-10 V or 4-20 mA; H 230 Vac - 0-10 V or 4-20 mA

Display: O With display; N Without display

Housing material

Transmitter features

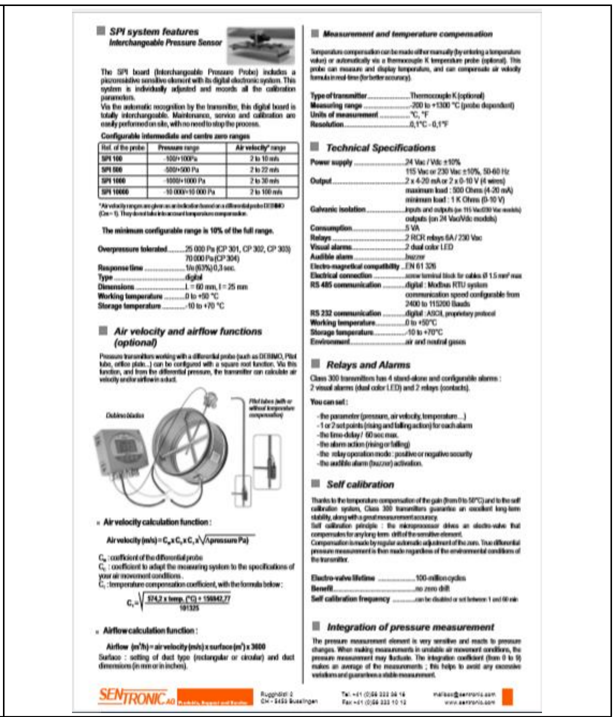
Pressure
Measuring range: see "SPI features"
Units of measurement: Pa, mmH2O, mbar, inWG, mmHG
Accuracy*: ±0,5% of reading ±1 Pa; ±0,5% of reading ±0.8 Pa; ±0,5% of reading ±10 Pa
Zero drift: none (see "self-calibration")
Self-calibration: push-button or automatic (configurable)
Type of fluid: air and neutral gases

Functions (optional)

Class 300 transmitters have 2 analogue outputs which correspond to the first 2 parameters displayed. You can activate 1 or 2 outputs, and for each output, you can choose between pressure, temperature (optional probe), air velocity and airflow (optional functions).

Housing dimensions

Housing features



SPI system features — Interchangeable Pressure Sensor

Measurement and temperature compensation

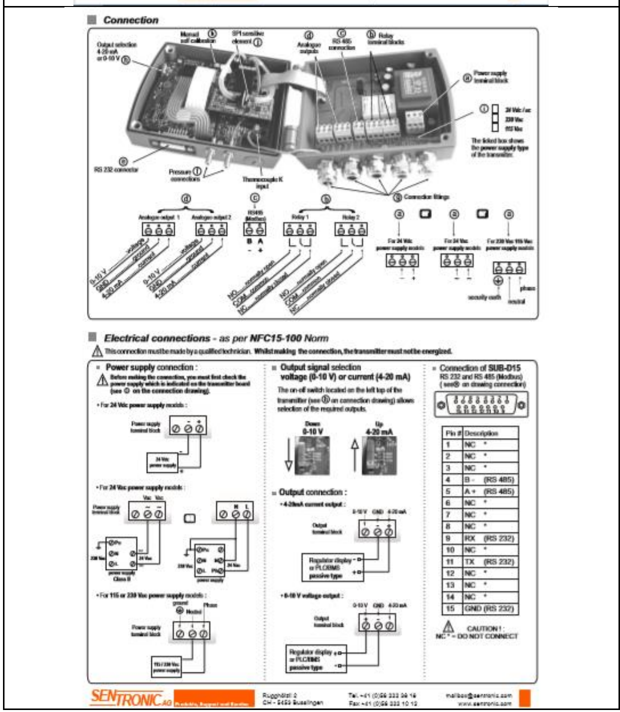
Technical Specifications

Air velocity and airflow functions (optional)

Relays and Alarms

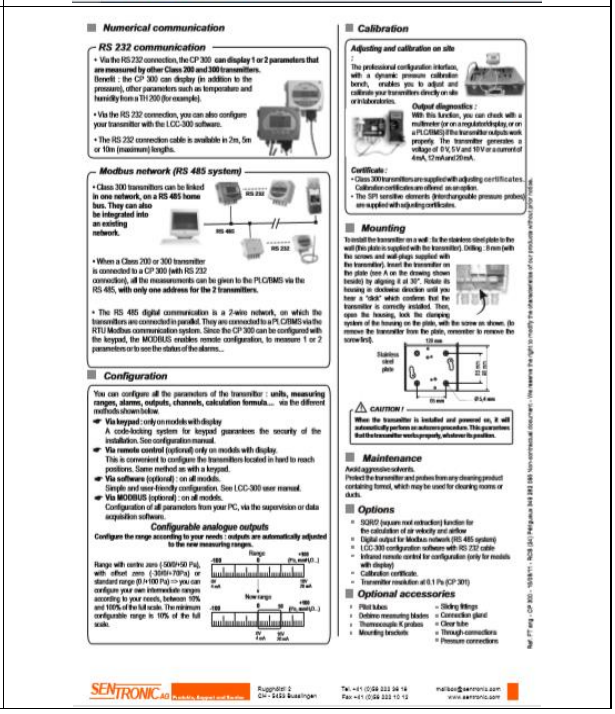
Self calibration

Integration of pressure measurement



Connection

Electrical connections - as per NFC15-100 Norm



Numerical communication

RS 232 communication

Modbus network (RS 485 system)

Configuration

Calibration

Mounting

Maintenance

Options

Optional accessories

Measuring Instrument - Code 6

Quick manual

POWER QUALITY ANALYZER

KEW 6310

KYORITSU ELECTRICAL INSTRUMENTS WORKS, LTD.

●Preface

This Quick manual is a simplified version of the full instruction manual which can be found in the supplied CD-ROM. **This manual is intended only as a handy reference guide and should only be used after having read the full instruction manual which contains full details on each function of this instrument and the items contained in the package.**

●Safety Warning!

The instruction manual contains warnings and safety procedures which have to be observed to ensure safe operation of the instrument and maintain it in a safe condition. Thus, these operating instructions have to be read prior to using the instrument.

Contents

The latest software can be downloaded from our web site.
http://www.kew-ltd.co.jp

1. Instrument Overview

Feature

This is a Clamp-type Power Quality Analyzer that can be used for various wiring systems. It can be used for simple measurements of instantaneous/ integration/ demand values, and also for monitoring waveforms and vectors, analyzing harmonics and measuring fluctuations in supply voltages and for the simulation of power factor correction with capacitor banks. Data can be saved either in the internal memory or a CF card, and can be transferred to a PC either via an USB lead or a CF Card reader.

Safety construction

Designed to meet the international safety standard IEC 61010-1 CAT.III 600V/ CAT.II 1000V

Wiring configuration

KEW6310 supports : Single-phase 2-wire, Single-phase 3-wire, Three-phase 3-wire, Three-phase 4-wire.

Measurement and calculation

KEW6310 measures voltage (RMS), current (RMS), and calculates active/reactive/apparent power, power factor, phase angle, frequency, neutral current and active/ reactive/ apparent electric energy. (RMS)

Demand measurment

Electricity consumption can be easily monitored so as not to exceed the target maximum demand values.

Waveform / Vector display

Voltage and current can be displayed by waveform or vector.

Harmonic analysis

Harmonic components of voltage and current can be measured and analyzed.

Power quality analysis

Measuring Swell/ Dip/ Int, Transient, Inrush current, Unbalance ratio and flicker*, moreover, simulating power factor correction with capacitor banks.

* Flicker measurement function is only available with ver.2.00 or later.

Saving data

KEW6310 is endowed with a logging function with a preset recording interval. Data can be saved by manual operation or at pre-set time & date. Screen data can be saved by using Print Screen function.

Dual power supply system

KEW6310 operates either with an AC power supply or with batteries. Both dry-cell batteries (alkaline) and rechargeable batteries (Ni-MH) can be used. Battery charge while rechargeable batteries installed in the instrument is possible. In the event of interruption, while operating with AC power supply, power to the instrument is automatically restored by the batteries in the instrument.

Large display

Color display with large screen

Light & compact design

Clamp sensor type, compact and light weight design

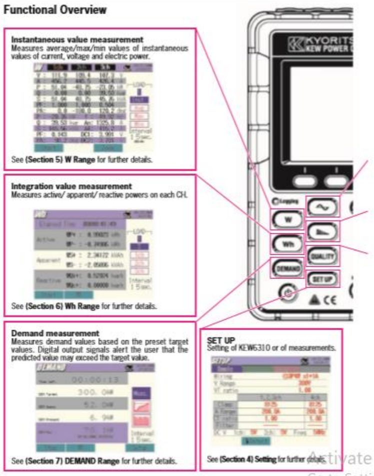
Application

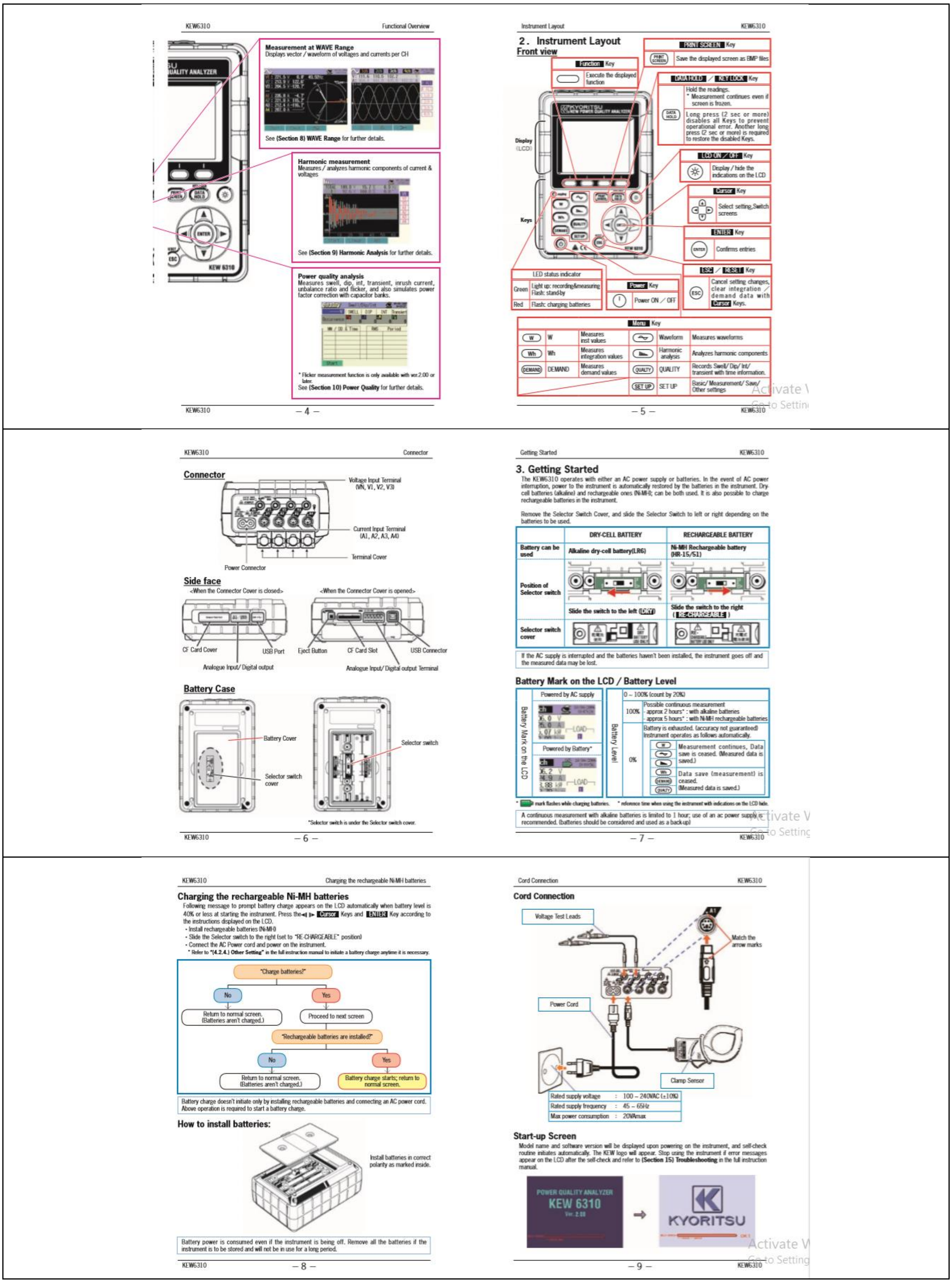
Data in the internal memory or CF card can be saved in a PC via a USB lead or a CF Card reader. As well supplied software facilitates setting, optional analysis software facilitates data analysis.

Input/output function

Analogue signals from thermometers or light sensors can be measured simultaneously with electrical power data via 2 analogue inputs (DC voltage); signals exceeding a preset threshold values at each range can be transmitted to alarms devices via 1 digital output.

Functional Overview





KEW6310 Functional Overview

Measurement at WAVE Range
Displays vector / waveform of voltages and currents per CH
See (Section 8) WAVE Range for further details.

Harmonic measurement
Measures / analyzes harmonic components of current & voltages
See (Section 9) Harmonic Analysis for further details.

Power quality analysis
Measures swell, dip, int, transient, inrush current, unbalance ratio and flicker, and also simulates power factor correction with capacitor banks.
* Flicker measurement function is only available with ver.2.00 or later.
See (Section 10) Power Quality for further details.

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Instrument Layout KEW6310

2. Instrument Layout
Front view

Key	Function
PRINT SCREEN Key	Save the displayed screen as BMP files
Function Key	Execute the displayed function
DATA HOLD / KEY LOCK Key	Hold the readings. * Measurement continues even if screen is frozen. Long press (2 sec or more) disables all Keys to prevent operational error. Another long press (2 sec or more) is required to restore the disabled Keys.
LCD ON / OFF Key	Display / hide the indications on the LCD
Cursor Key	Select setting, Switch screens
ENTER Key	Confirms entries
ESC / RESET Key	Cancel setting changes, clear integration / demand data with Cursor Keys.
Power Key	Power ON / OFF

LED status indicator	
Green	Light up: recording&measuring; Flash: stand-by
Red	Flash: charging batteries

Menu Key

Key	Name	Function	Key	Name	Function
W	W	Measures inst values	Waveform	Waveform	Measures waveforms
Wh	Wh	Measures integration values	Harmonic	Harmonic analysis	Analyzes harmonic components
DEMAND	DEMAND	Measures demand values	QUALITY	QUALITY	Records Swell/ Dip/ Int/ transient with time information.
			SET UP	SET UP	Basic/ Measurement/ Save/ Other settings

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KEW6310 Connector

Connector
Voltage Input Terminal (VN, V1, V2, V3)
Current Input Terminal (A1, A2, A3, A4)
Terminal Cover
Power Connector

Side face
<When the Connector Cover is closed> <When the Connector Cover is opened>
CF Card Cover, USB Port, Analogue Input/ Digital output, Eject Button, CF Card Slot, USB Connector, Analogue Input/ Digital output Terminal

Battery Case
Battery Cover, Selector switch cover, Selector switch
*Selector switch is under the Selector switch cover.

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Getting Started KEW6310

3. Getting Started
The KEW6310 operates with either an AC power supply or batteries. In the event of AC power interruption, power to the instrument is automatically restored by the batteries in the instrument. Dry-cell batteries (alkaline) and rechargeable ones (Ni-MH); can be both used. It is also possible to charge rechargeable batteries in the instrument.

Remove the Selector Switch Cover, and slide the Selector Switch to left or right depending on the batteries to be used.

	DRY-CELL BATTERY	RECHARGEABLE BATTERY
Battery can be used	Alkaline dry-cell battery(LR6)	Ni-MH Rechargeable battery (HR-15/51)
Position of Selector switch	Slide the switch to the left (DRY)	Slide the switch to the right (RE-CHARGEABLE)
Selector switch cover		

If the AC supply is interrupted and the batteries haven't been installed, the instrument goes off and the measured data may be lost.

Battery Mark on the LCD / Battery Level

Battery Mark on the LCD: Powered by AC supply; Powered by Battery*

Battery Level	
0 – 100% (count by 20%)	
100%	Possible continuous measurement - approx 2 hours* : with alkaline batteries - approx 5 hours* : with Ni-MH rechargeable batteries
0%	Battery is exhausted. (accuracy not guaranteed) Instrument operates as follows automatically. W / Waveform / Harmonic: Measurement continues, Data save is ceased. (Measured data is saved.) Wh / DEMAND / QUALITY: Data save (measurement) is ceased. (Measured data is saved.)

* mark flashes while charging batteries. * reference time when using the instrument with indications on the LCD fade.

A continuous measurement with alkaline batteries is limited to 1 hour; use of an ac power supply is recommended. (Batteries should be considered and used as a back-up)

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KEW6310 Charging the rechargeable Ni-MH batteries

Charging the rechargeable Ni-MH batteries
Following message to prompt battery charge appears on the LCD automatically when battery level is 40% or less at starting the instrument. Press the ◀ ▶ Cursor Keys and ENTER Key according to the instructions displayed on the LCD.
- Install rechargeable batteries (Ni-MH)
- Slide the Selector switch to the right (set to "RE-CHARGEABLE" position)
- Connect the AC Power cord and power on the instrument.

* Refer to "(4.2.4.) Other Setting" in the full instruction manual to initiate a battery charge anytime it is necessary.

"Charge batteries?" → No: Return to normal screen. (Batteries aren't charged.) / Yes: Proceed to next screen → "Rechargeable batteries are installed?" → No: Return to normal screen. (Batteries aren't charged.) / Yes: Battery charge starts; return to normal screen.

Battery charge doesn't initiate only by installing rechargeable batteries and connecting an AC power cord. Above operation is required to start a battery charge.

How to install batteries:
Install batteries in correct polarity as marked inside.

Battery power is consumed even if the instrument is being off. Remove all the batteries if the instrument is to be stored and will not be in use for a long period.

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Cord Connection KEW6310

Cord Connection
Voltage Test Leads; Match the arrow marks; Power Cord; Clamp Sensor

Rated supply voltage	: 100 – 240VAC (±10%)
Rated supply frequency	: 45 – 65Hz
Max power consumption	: 20VAmax

Start-up Screen
Model name and software version will be displayed upon powering on the instrument, and self-check routine initiates automatically. The KEW logo will appear. Stop using the instrument if error messages appear on the LCD after the self-check and refer to **(Section 15) Troubleshooting** in the full instruction manual.

POWER QUALITY ANALYZER KEW 6310 Ver.2.00 → KYORITSU

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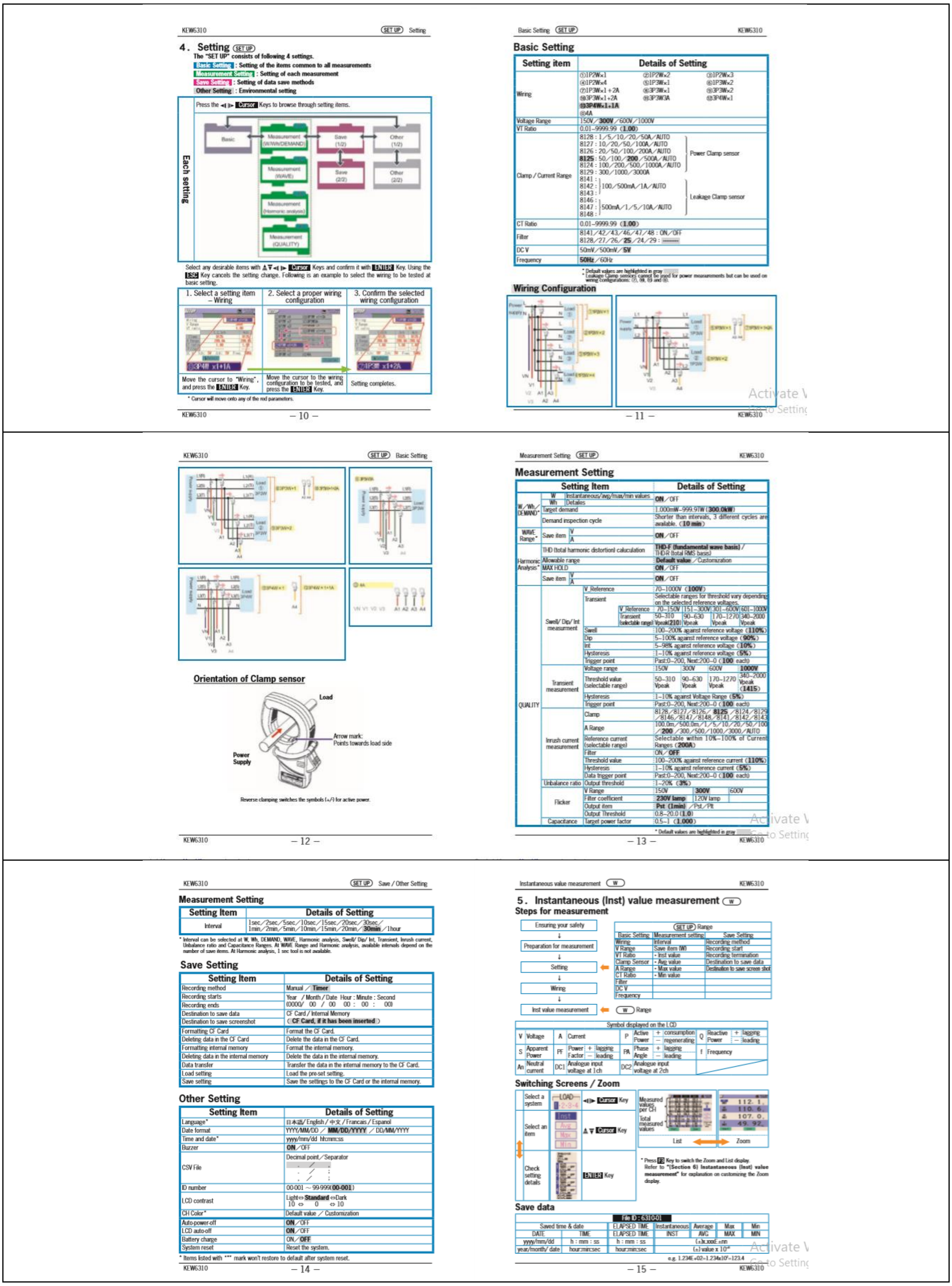
KEW6310 SET UP Setting

4. Setting SET UP

The "SET UP" consists of following 4 settings.

Basic Setting : Setting of the items common to all measurements

Measurement Setting : Setting of each measurement

Save Setting : Setting of data save methods

Other Setting : Environmental setting

Press the ◄ ► Cursor Keys to browse through setting items.

Select any desirable items with ▲▼◄► Cursor Keys and confirm it with ENTER Key. Using the ESC Key cancels the setting change. Following is an example to select the wiring to be tested at basic setting.

1. Select a setting item – Wiring / 2. Select a proper wiring configuration / 3. Confirm the selected wiring configuration

Move the cursor to "Wiring", and press the ENTER Key. / Move the cursor to the wiring configuration to be tested, and press the ENTER Key. / Setting completes.

* Cursor will move onto any of the red parameters.

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Basic Setting SET UP KEW6310

Basic Setting

Setting item	Details of Setting
Wiring	①1P2W×1 ②1P2W×2 ③1P2W×3 ④1P2W×4 ⑤1P3W×1 ⑥1P3W×2 ⑦1P3W×1+2A ⑧3P3W×1 ⑨3P3W×2 ⑩3P3W×1+2A ⑪3P3W3A ⑫3P4W×1 ⑬3P4W×1+1A ⑭4A
Voltage Range	150V／300V／600V／1000V
VT Ratio	0.01～9999.99 (1.00)
Clamp / Current Range	8128 : 1／5／10／20／50A／AUTO; 8127 : 10／20／50／100A／AUTO; 8126 : 20／50／100／200A／AUTO; 8125 : 50／100／200／500A／AUTO; 8124 : 100／200／500／1000A／AUTO; 8129 : 300／1000／3000A (Power Clamp sensor); 8141–8143 : 100／500mA／1A／AUTO; 8146–8148 : 500mA／1／5／10A／AUTO (Leakage Clamp sensor)
CT Ratio	0.01～9999.99 (1.00)
Filter	8141／42／43／46／47／48 : ON／OFF; 8128／27／26／25／24／29 : ——
DC V	50mV／500mV／5V
Frequency	50Hz／60Hz

* Default values are highlighted in gray.

Wiring Configuration

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KEW6310 SET UP Basic Setting

Orientation of Clamp sensor

Load / Arrow mark: Points towards load side / Power Supply

Reverse clamping switches the symbols (+/-) for active power.

KEW6310 – 12 –

Measurement Setting SET UP KEW6310

Measurement Setting

Setting Item	Details of Setting
W／Wh／DEMAND: Instantaneous/avg/max/min values	ON／OFF
Target demand	1.000mW～999.9TW (300.0kW)
Demand inspection cycle	Shorter than intervals, 3 different cycles are available. (10 min)
WAVE Range: Save item V, A	ON／OFF
Harmonic Analysis: THD (total harmonic distortion) calculation	THD-F (fundamental wave basis)／THD-R (total RMS basis)
Allowable range	Default value／Customization
MAX HOLD	ON／OFF
Save item V, A	ON／OFF
QUALITY: Swell/Dip/Int measurement – Transient V Reference	70～1000V (100V)
Swell	100～200% against reference voltage (110%)
Dip	5～100% against reference voltage (90%)
Int	5～98% against reference voltage (10%)
Hysteresis	1～10% against reference voltage (5%)
Trigger point	Past:0～200, Next:200～0 (100 each)
Transient measurement: Voltage range	150V / 300V / 600V / 1000V
Threshold value	50～310 Vpeak / 90～630 Vpeak / 170～1270 Vpeak / 340～2000 Vpeak (1415)
Hysteresis	1～10% against Voltage Range (5%)
Trigger point	Past:0～200, Next:200～0 (100 each)
Inrush current measurement: Clamp	8128／8127／8126／8125／8124／8129／8146／8147／8148／8141／8142／8143
A Range	100.0m／500.0m／1／5／10／20／50／100／200／300／500／1000／3000／AUTO
Reference current	Selectable within 10%～100% of Current Ranges (200A)
Filter	ON／OFF
Threshold value	100～200% against reference current (110%)
Hysteresis	1～10% against reference current (5%)
Data trigger point	Past:0～200, Next:200～0 (100 each)
Unbalance ratio: Output threshold	1～20% (3%)
Flicker: V Range	150V / 300V / 600V
Filter coefficient	230V lamp / 120V lamp
Output item	Pst (1min)／Pst／Plt
Output Threshold	0.8～20.0 (1.0)
Capacitance: Target power factor	0.5～1 (1.000)

* Default values are highlighted in gray.

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KEW6310 SET UP Save / Other Setting

Measurement Setting

Setting Item	Details of Setting
Interval	1sec／2sec／5sec／10sec／15sec／20sec／30sec／1min／2min／5min／10min／15min／20min／30min／1hour

* Interval can be selected at W, Wh, DEMAND, WAVE, Harmonic analysis, Swell/ Dip/ Int, Transient, Inrush current, Unbalance ratio and Capacitance Ranges. At WAVE Range and Harmonic analysis, available intervals depend on the number of save items. At Harmonic analysis, 1 sec tool is not available.

Save Setting

Setting Item	Details of Setting
Recording method	Manual／Timer
Recording starts	Year／Month／Date Hour : Minute : Second
Recording ends	(0000／00／00 00 : 00 : 00)
Destination to save data	CF Card／Internal Memory
Destination to save screenshot	(CF Card, if it has been inserted)
Formatting CF Card	Format the CF Card.
Deleting data in the CF Card	Delete the data in the CF Card.
Formatting internal memory	Format the internal memory.
Deleting data in the internal memory	Delete the data in the internal memory.
Data transfer	Transfer the data in the internal memory to the CF Card.
Load setting	Load the pre-set setting.
Save setting	Save the settings to the CF Card or the internal memory.

Other Setting

Setting Item	Details of Setting
Language*	日本語／English／中文／Francais／Espanol
Date format	YYYY/MM/DD／MM/DD/YYYY／DD/MM/YYYY
Time and date*	yyyy/mm/dd hh:mm:ss
Buzzer	ON／OFF
CSV File	Decimal point／Separator
ID number	00-001～99-999 (00-001)
LCD contrast	Light⇔Standard⇔Dark
CH Color*	Default value／Customization
Auto-power-off	ON／OFF
LCD auto-off	ON／OFF
Battery charge	ON／OFF
System reset	Reset the system.

* Items listed with "*" mark won't restore to default after system reset.

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Instantaneous value measurement W KEW6310

5. Instantaneous (Inst) value measurement W

Steps for measurement

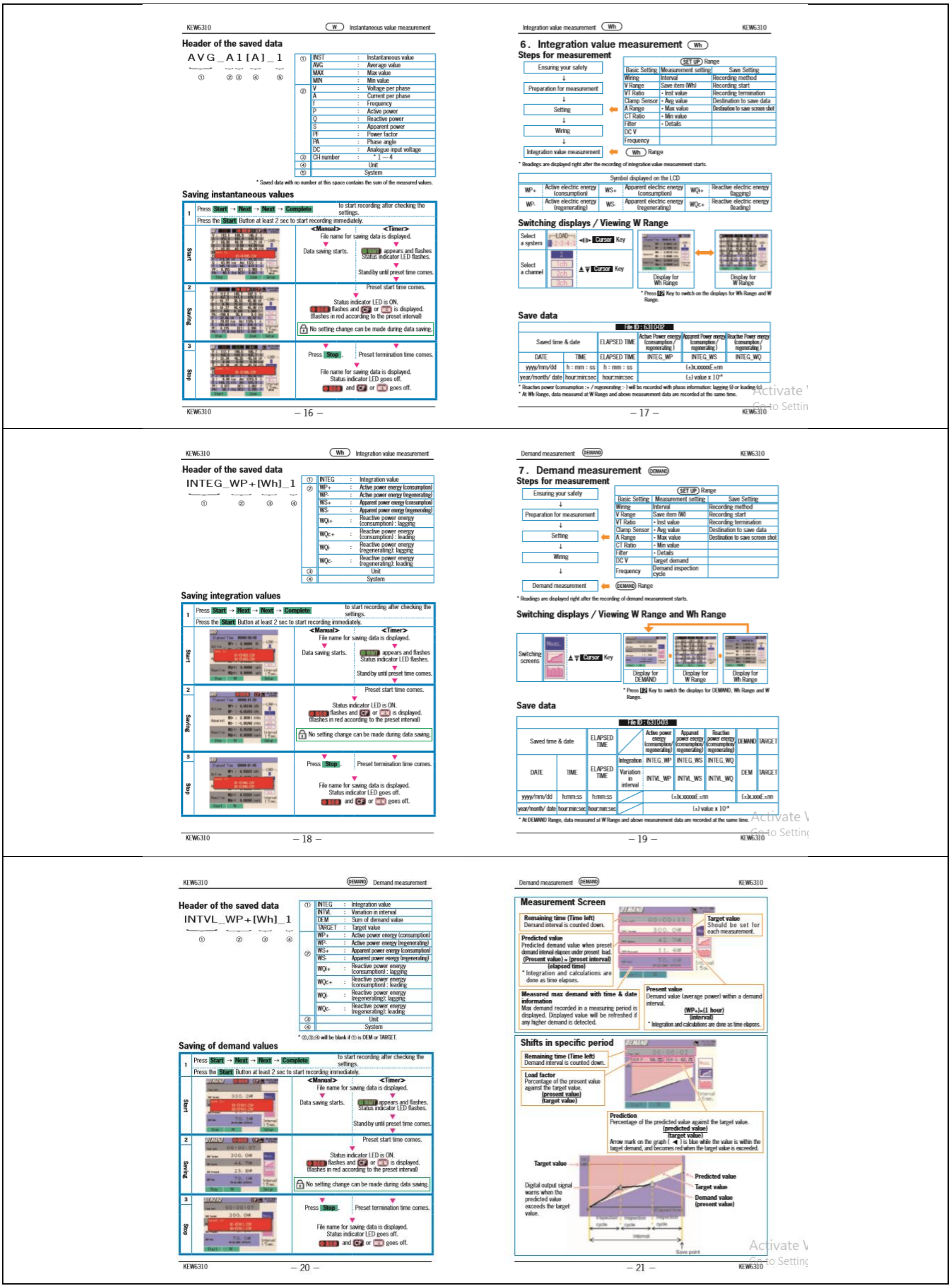
Ensuring your safety → Preparation for measurement → Setting → Wiring → Inst value measurement

Symbol displayed on the LCD

Switching Screens / Zoom

Save data

KEW6310 – 15 –



Header of the saved data

AVG_A1[A]_1

① ②③ ④ ⑤

①	INST	:	Instantaneous value
	AVG	:	Average value
	MAX	:	Max value
	MIN	:	Min value
②	V	:	Voltage per phase
	A	:	Current per phase
	f	:	Frequency
	P	:	Active power
	Q	:	Reactive power
	S	:	Apparent power
	PF	:	Power factor
	PA	:	Phase angle
	DC	:	Analogue input voltage
③	CH number	:	*1 ~ 4
④			Unit
⑤			System

* Saved data with no number at this space contains the sum of the measured values.

Saving instantaneous values

1. Press Start → Next → Next → Complete to start recording after checking the settings.
Press the Start Button at least 2 sec to start recording immediately.

Start: <Manual> File name for saving data is displayed. Data saving starts. <Timer> File name for saving data is displayed. appears and flashes. Status indicator LED flashes. Standby until preset time comes.

2. Saving: Preset start time comes. Status indicator LED is ON. flashes and or is displayed. (flashes in red according to the preset interval) No setting change can be made during data saving.

3. Stop: Press Stop. Preset termination time comes. File name for saving data is displayed. Status indicator LED goes off. and or goes off.

6. Integration value measurement (Wh)

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Integration value measurement

Basic Setting	Measurement setting	Save Setting
Wiring	Interval	Recording method
V Range	Save item (Wh)	Recording start
VT Ratio	- Inst value	Recording termination
Clamp Sensor	- Avg value	Destination to save data
A Range	- Max value	Destination to save screen shot
CT Ratio	- Min value	
Filter	- Details	
DC V		
Frequency		

* Readings are displayed right after the recording of integration value measurement starts.

Symbol displayed on the LCD					
WP+	Active electric energy (consumption)	WS+	Apparent electric energy (consumption)	WQi+	Reactive electric energy (lagging)
WP-	Active electric energy (regenerating)	WS-	Apparent electric energy (regenerating)	WQc+	Reactive electric energy (leading)

Switching displays / Viewing W Range

Select a system — LOAD Cursor Key. Select a channel — ▲▼ Cursor Key. Display for Wh Range / Display for W Range.

* Press F2 Key to switch on the displays for Wh Range and W Range.

Save data

File ID: 6310-02

Saved time & date		ELAPSED TIME	Active Power energy (consumption / regenerating)	Apparent Power energy (consumption / regenerating)	Reactive Power energy (consumption / regenerating)
DATE	TIME	ELAPSED TIME	INTEG_WP	INTEG_WS	INTEG_WQ
yyyy/mm/dd	h : mm : ss	h : mm : ss	(±)x.xxxxxE±nn		
year/month/date	hour:min:sec	hour:min:sec	(±) value x 10^n		

* Reactive power (consumption : + / regenerating : -) will be recorded with phase information: lagging (i) or leading (c).
* At Wh Range, data measured at W Range and above measurement data are recorded at the same time.

Header of the saved data

INTEG_WP+[Wh]_1

① ② ③ ④

①	INTEG	:	Integration value
②	WP+	:	Active power energy (consumption)
	WP-	:	Active power energy (regenerating)
	WS+	:	Apparent power energy (consumption)
	WS-	:	Apparent power energy (regenerating)
	WQi+	:	Reactive power energy (consumption) : lagging
	WQc+	:	Reactive power energy (consumption) : leading
	WQi-	:	Reactive power energy (regenerating): lagging
	WQc-	:	Reactive power energy (regenerating): leading
③			Unit
④			System

Saving integration values

1. Press Start → Next → Next → Complete to start recording after checking the settings.
Press the Start Button at least 2 sec to start recording immediately.

Start: <Manual> File name for saving data is displayed. Data saving starts. <Timer> File name for saving data is displayed. appears and flashes. Status indicator LED flashes. Standby until preset time comes.

2. Saving: Preset start time comes. Status indicator LED is ON. flashes and or is displayed. (flashes in red according to the preset interval) No setting change can be made during data saving.

3. Stop: Press Stop. Preset termination time comes. File name for saving data is displayed. Status indicator LED goes off. and or goes off.

7. Demand measurement (DEMAND)

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Demand measurement

Basic Setting	Measurement setting	Save Setting
Wiring	Interval	Recording method
V Range	Save item (W)	Recording start
VT Ratio	- Inst value	Recording termination
Clamp Sensor	- Avg value	Destination to save data
A Range	- Max value	Destination to save screen shot
CT Ratio	- Min value	
Filter	- Details	
DC V	Target demand	
Frequency	Demand inspection cycle	

* Readings are displayed right after the recording of demand measurement starts.

Switching displays / Viewing W Range and Wh Range

Switching screens — ▲▼ Cursor Key. Display for DEMAND / Display for W Range / Display for Wh Range.

* Press F2 Key to switch the displays for DEMAND, Wh Range and W Range.

Save data

File ID: 6310-03

Saved time & date		ELAPSED TIME		Active power energy (consumption / regenerating)	Apparent power energy (consumption / regenerating)	Reactive power energy (consumption / regenerating)	DEMAND	TARGET
			Integration	INTEG_WP	INTEG_WS	INTEG_WQ		
DATE	TIME	ELAPSED TIME	Variation in interval	INTVL_WP	INTVL_WS	INTVL_WQ	DEM	TARGET
yyyy/mm/dd	h:mm:ss	h:mm:ss		(±)x.xxxxxE±nn			(±)x.xxxE±nn	
year/month/ date	hour:min:sec	hour:min:sec		(±) value x 10^n				

* At DEMAND Range, data measured at W Range and above measurement data are recorded at the same time.

Header of the saved data

INTVL_WP+[Wh]_1

① ② ③ ④

①	INTEG	:	Integration value
	INTVL	:	Variation in interval
	DEM	:	Sum of demand value
	TARGET	:	Target value
②	WP+	:	Active power energy (consumption)
	WP-	:	Active power energy (regenerating)
	WS+	:	Apparent power energy (consumption)
	WS-	:	Apparent power energy (regenerating)
	WQi+	:	Reactive power energy (consumption) : lagging
	WQc+	:	Reactive power energy (consumption) : leading
	WQi-	:	Reactive power energy (regenerating): lagging
	WQc-	:	Reactive power energy (regenerating): leading
③			Unit
④			System

* ②,③,④ will be blank if ① is DEM or TARGET.

Saving of demand values

1. Press Start → Next → Next → Complete to start recording after checking the settings.
Press the Start Button at least 2 sec to start recording immediately.

Start: <Manual> File name for saving data is displayed. Data saving starts. <Timer> File name for saving data is displayed. appears and flashes. Status indicator LED flashes. Standby until preset time comes.

2. Saving: Preset start time comes. Status indicator LED is ON. flashes and or is displayed. (flashes in red according to the preset interval) No setting change can be made during data saving.

3. Stop: Press Stop. Preset termination time comes. File name for saving data is displayed. Status indicator LED goes off. and or goes off.

Measurement Screen

Remaining time (Time left) Demand interval is counted down.

Target value Should be set for each measurement.

Predicted value Predicted demand value when preset demand interval elapses under present load. (Present value) × (preset interval) / (elapsed time)
* Integration and calculations are done as time elapses.

Measured max demand with time & date information Max demand recorded in a measuring period is displayed. Displayed value will be refreshed if any higher demand is detected.

Present value Demand value (average power) within a demand interval. (WP+)×(1 hour) / (interval)
* Integration and calculations are done as time elapses.

Shifts in specific period

Remaining time (Time left) Demand interval is counted down.

Load factor Percentage of the present value against the target value. (present value) / (target value)

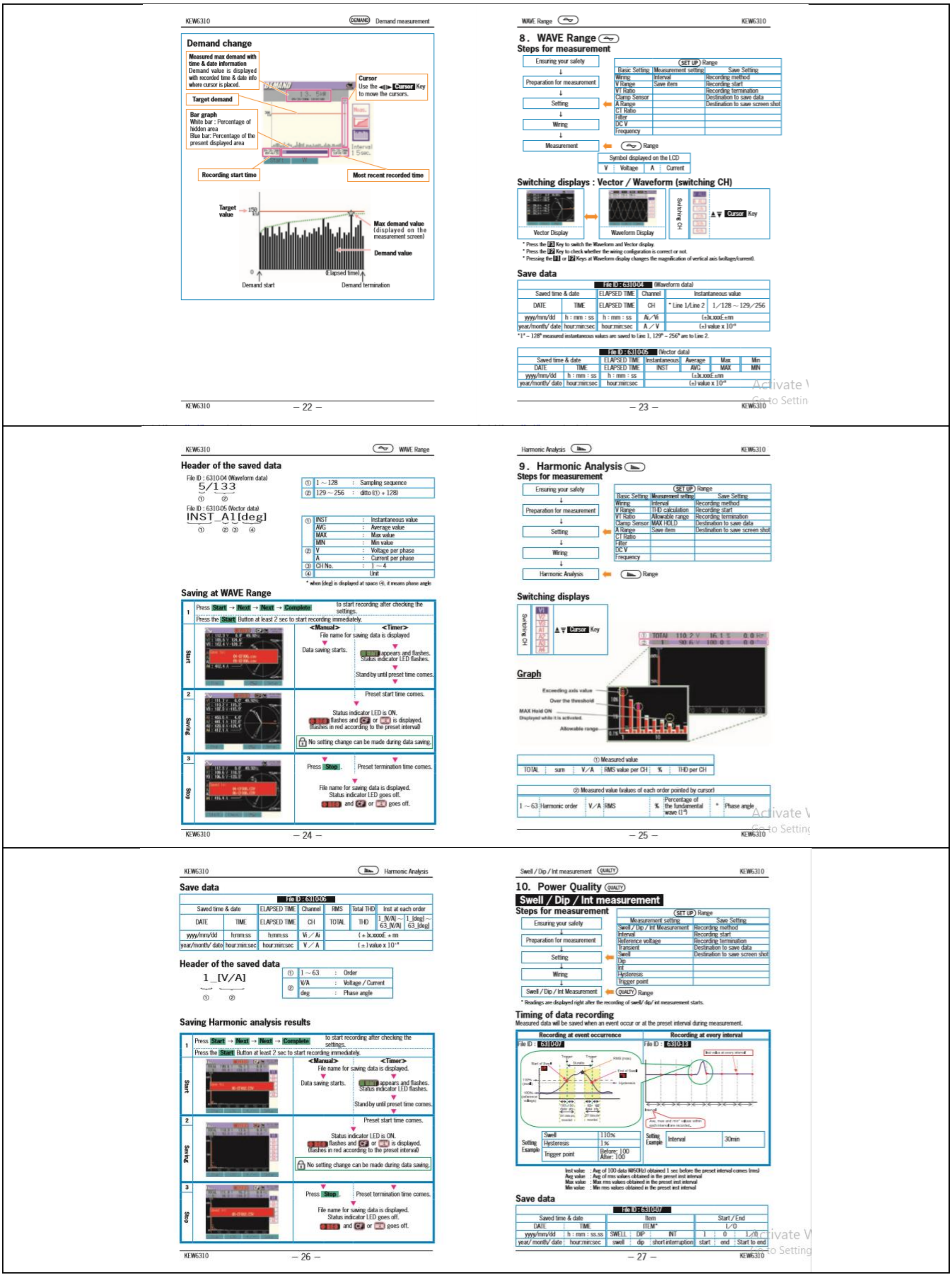
Prediction Percentage of the predicted value against the target value. (predicted value) / (target value)
Arrow mark on the graph (◄) is blue while the value is within the target demand, and becomes red when the target value is exceeded.

Target value

Digital output signal warns when the predicted value exceeds the target value.

Predicted value / Target value / Demand value (present value)

Inspection cycle / Interval / Save point



KEW6310 — DEMAND Demand measurement

Demand change

Measured max demand with time & date information
Demand value is displayed with recorded time & date info where cursor is placed.

Target demand

Bar graph
White bar : Percentage of hidden area
Blue bar: Percentage of the present displayed area

Cursor
Use the ◀|▶ Cursor Key to move the cursors.

Recording start time

Most recent recorded time

KEW6310 — 22 —

WAVE Range — KEW6310

8. WAVE Range

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Measurement (WAVE Range)

Basic Setting	Measurement setting	Save Setting
Wiring	Interval	Recording method
V Range	Save item	Recording start
VT Ratio		Recording termination
Clamp Sensor		Destination to save data
A Range		Destination to save screen shot
CT Ratio		
Filter		
DC V		
Frequency		

Symbol displayed on the LCD			
V	Voltage	A	Current

Switching displays : Vector / Waveform (switching CH)

Vector Display ↔ Waveform Display; Switching CH ▲▼ Cursor Key

* Press the F3 Key to switch the Waveform and Vector display.
* Press the F2 Key to check whether the wiring configuration is correct or not.
* Pressing the F1 or F2 Keys at Waveform display changes the magnification of vertical axis (voltage/current).

Save data

File ID : 6310-04 (Waveform data)

Saved time & date		ELAPSED TIME	Channel	Instantaneous value	
DATE	TIME	ELAPSED TIME	CH	* Line 1/Line 2	1/128 ~ 129/256
yyyy/mm/dd	h : mm : ss	h : mm : ss	Ai/Vi	(±)x.xxxE±nn	
year/month/ date	hour:min:sec	hour:min:sec	A / V	(±) value x 10^±n	

*1st – 128th measured instantaneous values are saved to Line 1, 129th – 256th are to Line 2.

File ID : 6310-05 (Vector data)

Saved time & date		ELAPSED TIME	Instantaneous	Average	Max	Min
DATE	TIME	ELAPSED TIME	INST	AVG	MAX	MIN
yyyy/mm/dd	h : mm : ss	h : mm : ss	(±)x.xxxE±nn			
year/month/ date	hour:min:sec	hour:min:sec	(±) value x 10^±n			

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KEW6310 — WAVE Range

Header of the saved data

File ID : 6310-04 (Waveform data)
5/133 (① ②)

①	1 ~ 128	Sampling sequence
②	129 ~ 256	ditto (① + 128)

File ID : 6310-05 (Vector data)
INST_A1[deg] (① ② ③ ④)

①	INST	Instantaneous value
	AVG	Average value
	MAX	Max value
	MIN	Min value
②	V	Voltage per phase
	A	Current per phase
③	CH No.	1 ~ 4
④		Unit

* when [deg] is displayed at space ④, it means phase angle

Saving at WAVE Range

1. Press Start → Next → Next → Complete to start recording after checking the settings. Press the Start Button at least 2 sec to start recording immediately.

Start: <Manual> File name for saving data is displayed → Data saving starts. <Timer> appears and flashes. Status indicator LED flashes. → Stand-by until preset time comes.

2. Saving: Preset start time comes. → Status indicator LED is ON. flashes and CF or USB is displayed. (flashes in red according to the preset interval) No setting change can be made during data saving.

3. Stop: Press Stop. / Preset termination time comes. → File name for saving data is displayed. Status indicator LED goes off. and CF or USB goes off.

KEW6310 — 24 —

Harmonic Analysis — KEW6310

9. Harmonic Analysis

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Harmonic Analysis (Range)

Basic Setting	Measurement setting	Save Setting
Wiring	Interval	Recording method
V Range	THD calculation	Recording start
VT Ratio	Allowable range	Recording termination
Clamp Sensor	MAX HOLD	Destination to save data
A Range	Save item	Destination to save screen shot
CT Ratio		
Filter		
DC V		
Frequency		

Switching displays

Switching CH: V1 V2 V3 A1 A2 A3 A4 ▲▼ Cursor Key

Graph

① Measured value					
TOTAL	sum	V/A	RMS value per CH	%	THD per CH

② Measured value (values of each order pointed by cursor)							
1 ~ 63	Harmonic order	V/A	RMS	%	Percentage of the fundamental wave (1st)	°	Phase angle

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KEW6310 — Harmonic Analysis

Save data

File ID : 6310-06

Saved time & date		ELAPSED TIME	Channel	RMS	Total THD	Inst at each order	
DATE	TIME	ELAPSED TIME	CH	TOTAL	THD	1_[V/A] ~ 63_[V/A]	1_[deg] ~ 63_[deg]
yyyy/mm/dd	h:mm:ss	h:mm:ss	Vi / Ai	(±)x.xxxE±nn			
year/month/ date	hour:min:sec	hour:min:sec	V / A	(±) value x 10^±n			

Header of the saved data

1_[V/A] (① ②)

①	1 ~ 63	Order
②	V/A	Voltage / Current
	deg	Phase angle

Saving Harmonic analysis results

1. Press Start → Next → Next → Complete to start recording after checking the settings. Press the Start Button at least 2 sec to start recording immediately.

Start: <Manual> File name for saving data is displayed. → Data saving starts. <Timer> appears and flashes. Status indicator LED flashes. → Stand-by until preset time comes.

2. Saving: Preset start time comes. → Status indicator LED is ON. flashes and CF or USB is displayed. (flashes in red according to the preset interval) No setting change can be made during data saving.

3. Stop: Press Stop. / Preset termination time comes. → File name for saving data is displayed. Status indicator LED goes off. and CF or USB goes off.

KEW6310 — 26 —

Swell / Dip / Int measurement — KEW6310

10. Power Quality

Swell / Dip / Int measurement

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Swell / Dip / Int Measurement (QUALITY Range)

Measurement setting	Save Setting
Swell / Dip / Int Measurement	Recording method
Interval	Recording start
Reference voltage	Recording termination
Transient	Destination to save data
Swell	Destination to save screen shot
Dip	
Int	
Hysteresis	
Trigger point	

* Readings are displayed right after the recording of swell/ dip/ int measurement starts.

Timing of data recording

Measured data will be saved when an event occur or at the preset interval during measurement.

Recording at event occurrence — File ID : 6310-07

Setting Example	
Swell	110%
Hysteresis	1%
Trigger point	Before: 100 After: 100

Recording at every interval — File ID : 6310-13

Setting Example	
Interval	30min

Inst value : Avg of 100 data (@50Hz) obtained 1 sec before the preset interval comes (rms)
Avg value : Avg of rms values obtained in the preset inst interval
Max value : Max rms values obtained in the preset inst interval
Min value : Min rms values obtained in the preset inst interval

Save data

File ID : 6310-07

Saved time & date		Item			Start / End		
DATE	TIME	ITEM*			I/O		
yyyy/mm/dd	h : mm : ss.ss	SWELL	DIP	INT	1	0	1/0
year/ month/ date	hour:min:sec	swell	dip	short-interruption	start	end	Start to end

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Duration		Max / Min		Data
DURATION		MAX/MIN		201
-:-:-.-	h : mm : ss.ss	(±)x.xxxE±nn		
start	end	max(Swell)	min(Dip/Int)	(±) value x 10^nn

File ID : 6310-13						
Saved time & date		ELAPSED TIME	Instantaneous	Average	Max	Min
DATE	TIME	ELAPSED TIME	INST	AVG	MAX	MIN
yyyy/mm/dd	h:mm:ss	h:mm:ss	(±)x.xxxE±nn			
year/month/ date	hour:min:sec	hour:min:sec	(±) value x 10^nn			

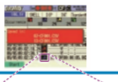
Header of the saved data

50 ～ 1_1 ～ 150 (①)

①	201 data in total	:	Data No.

e.g. Trigger point is set to Past: 50 / Next: 150.

Saving Swell / Dip / Int

1	Press Start → Next → Next → Complete to start recording after checking the settings. Press the Start Button at least 2 sec to start recording immediately.	
Start		<Manual> / <Timer> File name for saving data is displayed. <Manual>: Data saving starts. <Timer>: appears and flashes. Status indicator LED flashes. Stand-by until preset time comes.
2 Saving		Preset start time comes. Status indicator LED is ON. REC flashes and CF or USB is displayed. No setting change can be made during data saving.
3 Stop		Press Stop. / Preset termination time comes. File name for saving data is displayed. Status indicator LED goes off. REC and CF or USB goes off.

	Start to End	Start	End	
Swell				(Red)
Dip				(Blue)
Int				(Yellow)
Transient				(Green)

Transient measurement

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Transient Measurement

SET UP Range	
Measurement setting	Save Setting
Transient measurement	Recording method
Interval	Recording start
V Range	Recording termination
Threshold value	Destination to save data
Hysteresis	Destination to save screen shot
Trigger point	

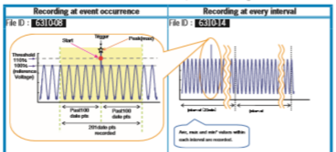
Transient Measurement ← QUALITY Range

* Readings are displayed right after the recording of Transient measurement starts.

Timing of data recording

Measured data will be saved when an event occur or at the preset interval during measurement.

Recording at event occurrence	Recording at every interval
File ID : 6310-08	File ID : 6310-14



Setting Example (Recording at event occurrence):

Threshold Value	110%
Hysteresis	1%
Trigger point	Before: 100 After: 100

Setting Example (Recording at every interval):

Interval	30min

Inst value : max value of 10,000 data obtained at 100us 1sec before the preset interval comes
Avg value : Avg of inst values obtained in the preset inst interval
Max value : Max inst values obtained in the preset inst interval
Min value : Min inst values obtained in the preset inst interval

Save data

File ID : 6310-08			
Saved time & date		Max	Data
DATE	TIME	MAX	201 data
yyyy/mm/dd	h : mm : ss.ss	(±)x.xxxE±nn	
year/month/ date	hour:min:sec	Max (Peak)	(±) value x 10^nn

File ID : 6310-14						
Saved time & date		ELAPSED TIME	Instantaneous	Average	Max	Min
DATE	TIME	ELAPSED TIME	INST	AVG	MAX	MIN
yyyy/mm/dd	h:mm:ss	h:mm:ss	(±)x.xxxE±nn			
year/month/ date	hour:min:sec	hour:min:sec	(±) value x 10^nn			

Header of the saved data

50 ～ 1_1 ～ 150 (①)

①	201 data in total	:	Data No.

e.g. Trigger point is set to Past: 50 / Next: 150.

Saving Transient Measurement

1	Press Start → Next → Next → Complete to start recording after checking the settings. Press the Start Button at least 2 sec to start recording immediately.	
Start		<Manual> / <Timer> File name for saving data is displayed. <Manual>: Data saving starts. <Timer>: appears and flashes. Status indicator LED flashes. Stand-by until preset time comes.
2 Saving		Preset start time comes. Status indicator LED is ON. REC flashes and CF or USB is displayed. No setting change can be made during data saving.
3 Stop		Press Stop. / Preset termination time comes. File name for saving data is displayed. Status indicator LED goes off. REC and CF or USB goes off.

Inrush Current Measurement

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Inrush Current Measurement

SET UP Range	
Measurement setting	Save Setting
Inrush Current Measurement	Recording method
Interval	Recording start
Clamp sensor	Recording termination
A Range	Destination to save data
Reference current	Destination to save screen shot
Filter	
Threshold value	
Hysteresis	
Trigger point	

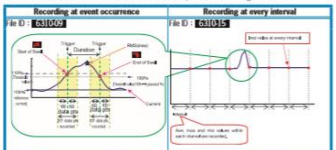
Inrush Current Measurement ← QUALITY Range

* Readings are displayed right after the inrush current measurement starts.

Timing of data recording

Measured data will be saved when an event occur or at the preset interval during measurement.

Recording at event occurrence	Recording at every interval
File ID : 6310-09	File ID : 6310-15



Setting Example (Recording at event occurrence):

Reference current	100A
Threshold value	110%
Hysteresis	1%
Trigger point	Before: 100 After: 100

Setting Example (Recording at every interval):

Interval	30min

Inst value : Avg of 100 data (@50Hz) obtained 1 sec before the preset interval comes (rms)
Avg value : Avg of rms values obtained in the preset inst interval
Max value : Max rms values obtained in the preset inst interval
Min value : Min rms values obtained in the preset inst interval

Save data

File ID : 6310-09										
Saved time & date		Start / End			Duration		Max / Min		Data	
DATE	TIME	I/O			DURATION		MAX/MIN		201 data	
yyyy/mm/dd	h:mm:ss.ss	1	0	1/0	-:-:-.-	h:mm:ss.ss	(±)x.xxxE±nn			
year/month/ date	hour:min:sec	Start	End	Start to End	Start	End	Max	Min	(±) value x 10^nn	

File ID : 6310-15						
Saved time & date		ELAPSED TIME	Instantaneous	Average	Max	Min
DATE	TIME	ELAPSED TIME	INST	AVG	MAX	MIN
yyyy/mm/dd	h:mm:ss	h:mm:ss	(±)x.xxxE±nn			
year/month/ date	hour:min:sec	hour:min:sec	(±) value x 10^nn			

Header of the saved data

50 ～ 1_1 ～ 150 (①)

①	201 data in total	:	Data No.

e.g. Trigger point is set to Past: 50 / Next: 150.

Saving Inrush Current Measurement

1	Press Start → Next → Next → Complete to start recording after checking the settings. Press the Start Button at least 2 sec to start recording immediately.	
Start		<Manual> / <Timer> File name for saving data is displayed. <Manual>: Data saving starts. <Timer>: appears and flashes. Status indicator LED flashes. Stand-by until preset time comes.
2 Saving		Preset start time comes. Status indicator LED is ON. REC flashes and CF or USB is displayed. No setting change can be made during data saving.
3 Stop		Press Stop. / Preset termination time comes. File name for saving data is displayed. Status indicator LED goes off. REC and CF or USB goes off.

Start to End	Start	End

Unbalance Ratio

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Unbalance Ratio

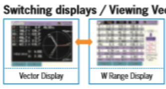
SET UP Range		
Basic Setting	Measurement setting	Save Setting
Wiring	Unbalance Ratio	Recording method
V Range	Interval	Recording start
VT Ratio	Output threshold	Recording termination
Clamp		Destination to save data
A Range		Destination to save screen shot
CT Ratio		
Filter		
DC V		
Frequency		

* Measurements can be made with any of wiring configurations: ①, ②, ③.

Unbalance Ratio ← QUALITY Range

Symbol displayed on the LCD							
V	Voltage	A	Current	P	Active Power (+ consumption, – regenerating)	Q	Reactive Power (+ lagging, – leading)
S	Apparent Power	PF	Power Factor (+ lagging, – leading)	PA	Phase angle	f	Frequency
An	Neutral current	DC1	Analogue input Voltage at 1ch	DC2	Analogue input Voltage at 2ch		

Switching displays / Viewing Vector W Range display



Vector Display ← W Range Display

Select a system: ◄► Cursor Key
Select an item: ▲▼ Cursor Key

Press the F2 Key to switch the Vector and W Range displays.

Save data

File ID : 6310-10						
Saved time & date		ELAPSED TIME	Instantaneous	Average	Max	Min
DATE	TIME	ELAPSED TIME	INST	AVG	MAX	MIN
yyyy/mm/dd	h : mm : ss	h : mm : ss	(±)x.xxxE±nn			
year/month/ date	hour:min:sec	hour:min:sec	(±) value x 10^nn			

Header of the saved data

AVG_A1[A]_1
① ②③ ④ ⑤

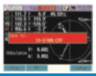
①	INST	:	Instantaneous value
	AVG	:	Average value
	MAX	:	Max value
	MIN	:	Min value
②	UV	:	Voltage unbalance ratio
	UA	:	Current unbalance ratio
	V	:	Voltage of each phase
	A	:	Current of each phase
	f	:	Frequency
	P	:	Active power
	Q	:	Reactive power
	S	:	Apparent power
	PF	:	Power factor
	PA	:	Phase angle
	DC	:	Analogue input voltage
③	CH number	:	*1 ~ 4
④	Unit		
⑤	System		

*Saved data with no number at this space contains the sum of the measured values.

Saving PFC calculation results

1. Press Start → Next → Next → Complete to start recording after checking the settings.
Press the Start Button at least 2 sec to start recording immediately.

Start



<Manual> / <Timer>
File name for saving data is displayed.
<Manual>: Data saving starts.
<Timer>: START appears and flashes. Status indicator LED flashes. → Stand-by until preset time comes.

2 **Saving**

Preset start time comes.
Status indicator LED is ON.
REC flashes and CF or MEM is displayed.
(flashes in red according to the preset interval)
No setting change can be made during data saving.

3 **Stop**

Press Stop. / Preset termination time comes.
File name for saving data is displayed.
Status indicator LED goes off.
REC and CF or MEM goes off.

Flicker

* An optional voltage sensor KEW8325F is required for Flicker measurement.

Steps for measurement

Ensuring your safety
↓
Preparation for measurement
↓
Setting ← (SET UP) Range
↓
Wiring
↓
Flicker ← (QUALTY) Range

(SET UP) Range	
Measurement setting	Save Setting
Flicker	Recording method
V Range	Recording start
Filter	Recording termination
Output item	Destination to save data
Output Threshold	Destination to save screen shot

* Preliminary measurement (for 10 sec) will be done automatically prior to Flicker measurement.

Save data

File ID : 6310-12									
Saved time & date		ELAPSED TIME	Frequency	Voltage Average	Voltage Max	Voltage Min	Short time intensity (for 1 min)	Short time intensity	Long time intensity
DATE	TIME	ELAPSED TIME	f	AVG_V	MAX_V	MIN_V	Pst (1min)	Pst	Plt
yyyy/mm/dd	h:mm:ss	h:mm:ss	(+)x.xxxE+nn	(+)x.xxxxxE+nn			(+)x.xxxE+nn		
year/month/date	hour:min:sec	hour:min:sec	(±) value x 10^{nn}						

* Data is saved at every 1 min, but Pst is saved at every 10 min and Plt is at every 10 min in 2 hours later.

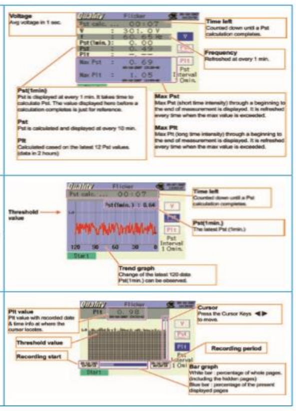
Saving Flicker data

The saving procedure is same to the one for the other measurements. See the previous corresponding pages.

V

Pst (1min)

Plt



Capacitance Calculation - Sizing of capacitor banks for Power factor correction (PFC)

Steps for measurement

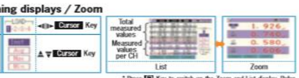
Ensuring your safety
↓
Preparation for measurement
↓
Setting ← (SET UP) Range
↓
Wiring
↓
Capacitance calculation ← (QUALTY) Range

(SET UP) Range		
Basic Setting	Measurement setting	Save Setting
Wiring	Capacitance	Recording method
V Range	Interval	Recording start
VT Ratio	Target power factor	Recording termination
Clamp sensor		Destination to save data
A Range		Destination to save screen shot
CT Ratio		
Filter		
DC V		
Frequency		

Symbol displayed on the LCD							
V	Voltage	A	Current	P	Active Power + consumption − regenerating	Q	Reactive Power + lagging − leading
S	Apparent Power	PF	Power Factor + lagging − leading	C	Capacitance	f	Frequency
An	Neutral current	DC1	Analogue input Voltage at 1ch	DC2	Analogue input Voltage at 2ch		

Switching displays / Zoom

Select a system — Cursor Key
Select an item — Cursor Key
Total measured values / Measured values per CH



* Press F2 Key to switch on the Zoom and List display. Refer to "[Section 6] Instantaneous measurement" for an explanation on customizing the Zoom display.

Save data

File ID : 6310-11						
Saved time & date		ELAPSED TIME	Instantaneous	Average	Max	Min
DATE	TIME	ELAPSED TIME	INST	AVG	MAX	MIN
yyyy/mm/dd	h : mm : ss	h : mm : ss	(+)x.xxxE+nn			
year/month/ date	hour:minute:second	hour:minute:second	(±) value x 10^{nn}			

Header of the saved data

AVG_A1[A]_1
① ②③ ④ ⑤

①	INST	:	Instantaneous value
	AVG	:	Average value
	MAX	:	Max value
	MIN	:	Min value
②	V	:	Voltage of each phase
	A	:	Current of each phase
	f	:	Frequency
	P	:	Active power
	Q	:	Reactive power
	S	:	Apparent power
	PF	:	Power factor
	C	:	Capacitance
	DC	:	Analogue input voltage
③	CH number		* 1 ~ 4
④	Unit		
⑤	System		

* Saved data with no number at this space contains the sum of the measured values.

Saving PFC calculation results

1. Press Start → Next → Next → Complete to start recording after checking the settings.
Press the Start Button at least 2 sec to start recording immediately.

Start

<Manual> / <Timer>
File name for saving data is displayed.
<Manual>: Data saving starts.
<Timer>: START appears and flashes. Status indicator LED flashes. → Stand-by until preset time comes.

2 **Saving**

Preset start time comes.
Status indicator LED is ON.
REC flashes and CF or MEM is displayed.
(flashes in red according to the preset interval)
No setting change can be made during data saving.

3 **Stop**

Press Stop. / Preset termination time comes.
File name for saving data is displayed.
Status indicator LED goes off.
REC and CF or MEM goes off.

11. CF Card / Saved data

CF Card (operation check has completed)

Capacity	32MB	64MB	128MB	256MB	512MB	1GB
SanDisk Corp.*	SDCFB-32	SDCFB-64	SDCFB-128	SDCFB-256	SDCFB-512	SDCFG-1
Adtec co., Ltd.	AD-CFG32	AD-CFG64	AD-CFG128	AD-CFG256	—	AD-CFX 40T1G
BUFFALO INC.	—	—	RCF-X128MY	RCF-X256MY	—	RCF-X1GY

* CF Card with more or less capacity other than listed above cannot be used with this instrument.
* Company name and model name are the trademark or the registered trademark.
A CF Card may not operate properly even if any of the following cards are used due to manufacture's specification change, etc. Please be aware above issue when purchasing commercially available CF Cards. We can offer following CF Cards (proper operation has been verified) as optional parts. Please feel free to inquire.

Max number of saved data / Possible recoding time

Destination to save data		CF Card						Internal Memory
Caacity		32MB	64MB	128MB	256MB	512MB	1GB	1.8MB
Instantaneous value measurement	1sec	15H	1D	2D	5D	10D	20D	7min
	1min	10D	20D	1M	2M	5M	10M	2H
	30min	10M	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	2D
Integration value Measurement	1sec	6H	13H	1D	2D	4D	8D	3min
	1min	7D	15D	1M	2M	4M	8M	1H
	30min	7M	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	1D
DEMAND measurement	1sec	4H	8H	17H	1D	2D	5D	2min
	1min	6D	12D	24D	1M	3M	6M	1H
	30min	6M	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	1D
WAVE Range	10sec	1D	3D	7D	14D	28D	1M	20min
	1min	10D	21D	1M	2M	5M	11M	2H
	30min	10M	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	2D
Harmonic anaysis	15sec	3D	7D	15D	1M	2M	4M	44min
	1min	15D	1M	2M	4M	8M	1Y	2H
	30min	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	3D
Swell / Dip / Int measurement*1	1sec	2D	5D	11D	22D	1M	2M	32min
	1min	5M	11M	1Y	Over 1Y	Over 1Y	Over 1Y	1D
	30min	Over 1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	1M
Transient measurement*1	1sec	3D	6D	12D	24D	1M	3M	35min
	1min	6M	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	1D
	30min	Over 1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	1M
Inrush Current measurement*1	1sec	2D	5D	11D	22D	1M	2M	32min
	1min	5M	11M	1Y	Over 1Y	Over 1Y	Over 1Y	1D
	30min	Over 1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	1M
Unbalance Ratio	1sec	21H	1D	3D	7D	14D	27D	10min
	1min	14D	29D	1M	3M	7M	1Y	2H
	30min	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	3D
Flicker*1	1min	7M	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	1D
Capacitance	1sec	15H	1D	2D	5D	10D	19D	7min
	1min	10D	20D	1M	2M	5M	10M	1H
	30min	10M	1Y	Over 1Y	Over 1Y	Over 1Y	Over 1Y	2D
Max number of file	Measurement data file (CSV)	512						6
	Graphics file (BMP)							7
	Configuration file (KAS)							20

*In case that no file exist in the CF card or the Internal memory.
where : H– hour(s), D–day(s), M–month(s), Y–year(s)
Numbers and time listed above are the minimum ones.
*1 Assumed one event occur per minute and calculated.

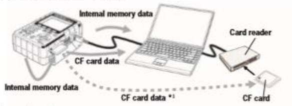
Data transfer

Data in the CF card or internal memory can be transferred to a PC via USB connection or CF card reader.

	Transfer to PC via:	
	USB	Card reader
CF card data (file)	△*1	○
Internal memory data (file)	○	—*2

*1 It is reccomended to transfer the data with big size by a use of CF card reader since trasfer of such data via USB takes time. (transfer time : approx 4MB/ hour)
*2 Data in the internal memory can be tranferred to a CF card.

*As to the manipulation of the CF card, please refer to the instruction manual attached to the card.
*In order to save the data without any problem, make sure to delete the file other than the data measured with this instrument in the CF card.



File format and name

Measurement data

File Name : 01 – CF 001 .CSV
① ② ③ ④

①	Measuring Items	01 : Data measured at W Range
		02 : Data measured at Wh Range
		03 : Data measured at DEMAND Range
		04 : Waveform data
		05 : Vector data
		06 : Harmonic data
		07 : Swell / Dip / Int data
		08 : Transient data
		09 : Inrush current data
		10 : Unbalance ratio
		11 : Capacitance
		12 : Flicker date
		13 : Voltage Interval data
		14 : Voltage Interval data
		15 : Current Interval data
②	Save in	CF : CF Card
		ME : Internal memory
③	File No	001 ~ 999
④	Format	CSV

Configuration file

File Name : ME 000123 .KAS
① ② ③

①	Save in	CF : CF card
		ME : Internal memory
②	File No	000000 ~ 999999
③	Extension	KAS

Bitmap file

File Name : PS – CF 001 .BMP
① ② ③ ④

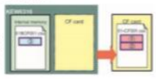
①	Save item	PS : Print screen
②	Save in	CF : CF card
		ME : Internal memory
③	File No	001 ~ 999
④	Extension	BMP

Backup Memory

In case one CF card is removed and inserted while saving data:

Saving

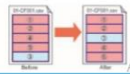
①. A file is created in the CF card, when CF card is selected as a destination for saving data, and measurement data is saved to the CF card.



②. A backup file is created in the internal memory when a CF card is removed at saving data.
Further data is saved to the internal memory.

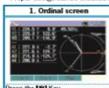
③. When inserting the CF card again during a data saving, further data will be saved to the last available space in CF card ①or ②.

Saving completes	Download completes
Backup files in the internal memory are automatically transferred to the last available space in a CF card. (Time-series is as follows.)	Use of supplied software [KEW PQA MASTER] enables to sort files in time-series.



12. Wiring check

Proper wirings can be checked at (WAVE key) WAVE Range.

1. Ordinal screen	2. Checking wiring	3. Check completes
		
Press the F2 Key.	Wiring check starts.  [Checking status] & [Proper vector] are displayed.	Wiring check completes. In case of NG, Error message appears. (Press the ENTER Key when OK is displayed.) 

* Check results may by affected if great power factors exist at the measurement sites.

Criteria of Judgment and cause

Check	Criteria of Judgment	Cause
Frequency	Frequency of V1 is between 42 and 68Hz.	• Voltage clip is firmly connected to the DUT? • Measuring too high harmonic components?
Voltage input	Voltage input is 10% or more of (Voltage Range x VT).	• Voltage clip is firmly connected to the DUT? • Voltage test leads are firmly connected to the Voltage input terminals on the instrument?
Voltage balance	Voltage input is within ±30° of reference voltage (V1) * (not judged by single-phase wiring)	• Setting against the wiring under test are matched? • Voltage clip is firmly connected to the DUT? • Voltage test leads are firmly connected to the Voltage input terminals on the instrument?
Voltage phase	Phase of voltage input is within ±10° of reference value (proper vector).	• Voltage test leads are properly connected? (Connected to proper channels?)
Current input	Current input is 5% or more of (Current Range x CT).	• Clamp sensors are firmly connected to the Power input terminals on the instrument? • Setting for Current Range is appropriate for input levels?
Current phase	Current input is within ±60° of reference value (proper vector).	• Arrow mark on a Clamp sensor and the orientation of flowing current is matched? (Power supply to Load) • Clamp sensors are connected properly?

Annex (3) Testing Methodology

The Transformation of Commercial Air Conditioning Companies (HCFC Phase-out Management Plan (HPMP) EGYPT (Stage II))

UNIDO ID: 140400

IEC Evaluation program

Guiding Principles for on-site Testing (Testing Methodology)

June 2022

SUBMITTED BY:

Team of AO and HBRC

Contents

TESTING METHODOLOGY OF THE PROJECT OF THE TRANSFORMATION OF COMMERCIAL AIR CONDITIONING COMPANIES (HCFC PHASE-OUT MANAGEMENT PLAN (HPMP) EGYPT (STAGE II)),

UNIDO ID: 140400

1. *Introduction:*

The project aims to provide technical assistance for the implementation of low GWP technology as well as examining the introduction of a Not-In-Kind technology, namely: Indirect Evaporative Cooling (IEC).

The project also proposes to look into the introduction of IEC in commercial air conditioning applications. The goal of the project is to secure phase out of HCFC in the commercial air conditioning manufacturing sector.

In September 2015, the world's nations agreed to adopt a set of 17 Sustainable Development Goals (SDGs). Egypt affirmed its commitment to meet the targets set by SDGs by 2030 and outlined a 15-year development strategy. The SDGs, spearheaded by the United Nations, include resilient, stable, and sustainable infrastructure as one of its goals, thus, the green building landscape is expected to soar in the upcoming years.

2. *General Scope of tests*

To test hybrid IEC Unit simultaneously with the DX Unit to find out the performance of the hybrid IEC unit compared to the DX unit, in particular its total cooling capacity and the energy efficiency ratio EER at various ambient operating conditions. The tabulation, evaluation and plotting of the results will be included in the program final report and will include an economic evaluation of the IEC hybrid system to help establish its commercial feasibility in the local market.

3. EUROVENT role, Egypt Climatic Zones and Field Testing

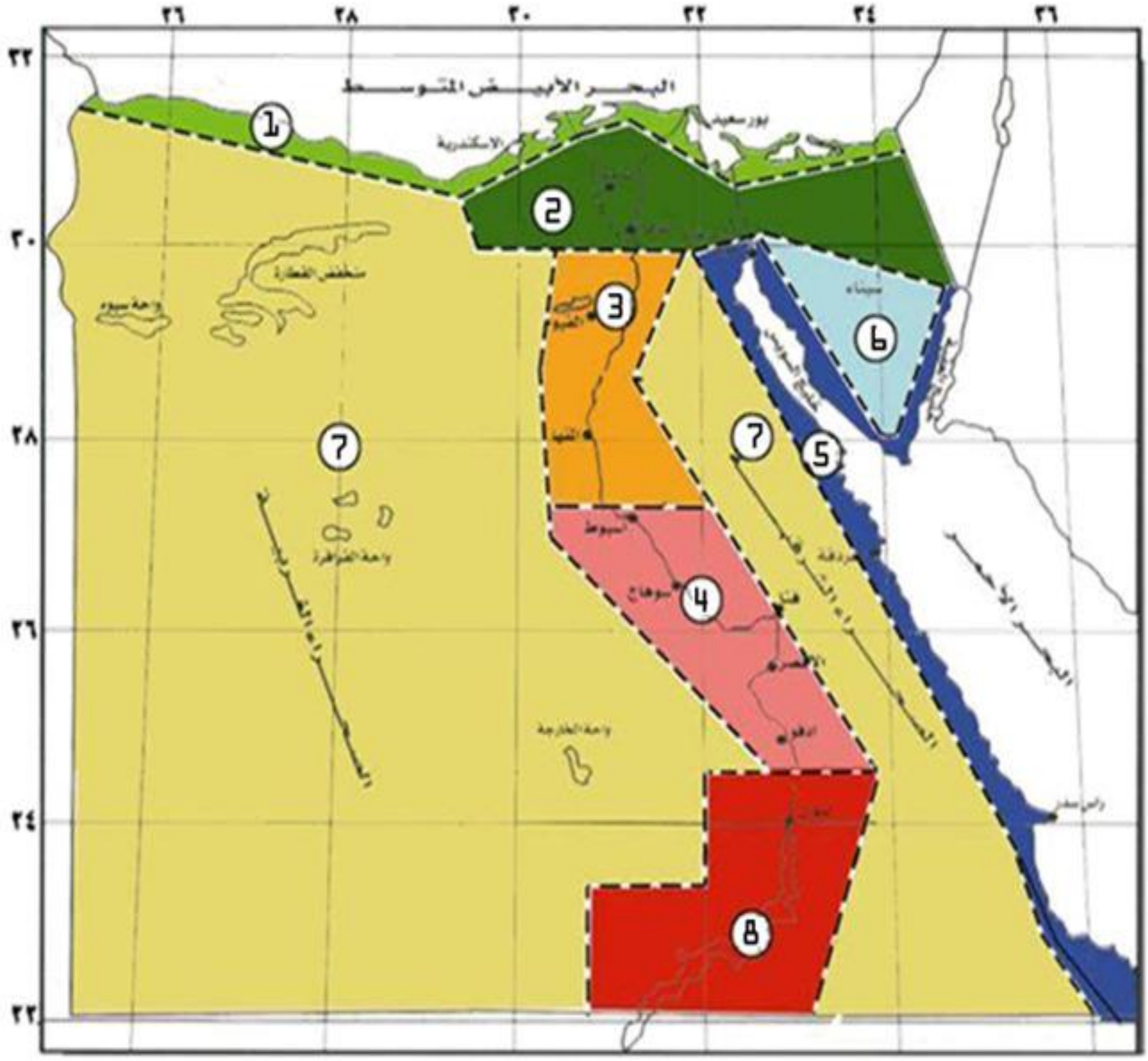
EUROVENT:

The application of any new technology, in larger capacities of commercial air-conditioning applications, requires setting the ground to allow market acceptability noting that these are not off-the-shelf products that industry can put in markets in substantial quantities. Commercial air-conditioning applications are commonly specified by consultants for projects to ensure reliability of the product that can justify the initial investment.

The project invited EUROVENT, the internationally renowned organization with experience in guidelines and certification programs for HVAC applications including IEC systems, to provide a reference testing methodology for the IEC hybrid units suitable for Egypt's working conditions. EUROVENT provided testing procedures (see EUROVENT XX/1- 2022 Hybrid Indirect Evaporative Cooling Equipment: Requirement and Test Method), will review and endorse the results of the project.

Egypt has 8 climatic zones out of which 7 are suitable for IEC applications due to lower humidity conditions across the summer season. Below figure shows:

Egypt climatic zones:



1	North Coast Region	5	Eastern Coast Region
2	Delta Cairo and middle Sinai Region	6	High Heights Region
3	North Upper Egypt Region	7	Desert Region
4	Southern Upper Egypt Region	8	South of Egypt Region

Field Testing:

Field Testing will be done in the open air throughout a whole day, for both the IEC hybrid unit and the DX unit.

4. Testing Plan

Testing plans were developed after intensive rounds of discussion and consultation with local OEMs and formal communication. Technical visits were made to manufacturing facilities to better understand capacities and readiness to build prototypes.

It was decided to start the tests in Climatic Zone 2 (Delta, Cairo Region and middle Sinai) at an altitude of 344.5 feet above sea level.

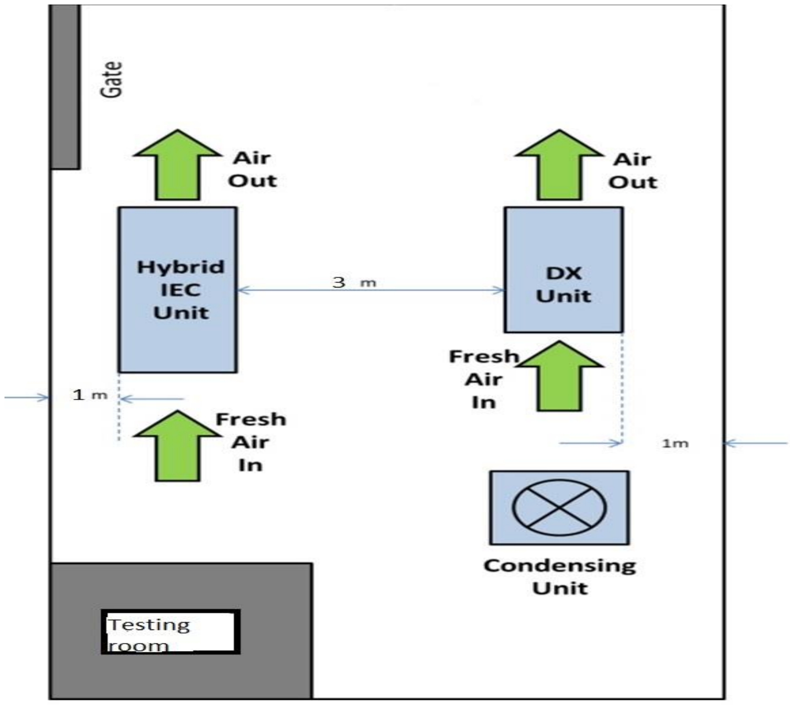
The first testing batch will start on the 15^{th} of June 2022 in Climate Zone 2 (Delta Cairo and middle Sinai Region) followed by a second testing batch starting in the second half of July 2022 at Climatic Zone 5 or 8.

5. General Testing Conditions

The testing will be conducted for all OEMs that indicated the readiness of their units by the time the start date indicated for in Climatic Zone 2 (Delta, Sinai central and Cairo Region).

a. There are 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.
b. The purpose of the tests is to make sure there are energy efficiency advantages obtained by adopting a hybrid IEC system when compared to a DX or Chilled Water system for the Egyptian Climate Zones 2 and 5 or 8.
c. The schematic diagram below shows the position of the units during testing. Both DX and hybrid units are to be located at the same site, with a distance in between to guard against short cycling.
d. Both units to be full fresh air with air discharge of one unit regulated so that it matches the other.
e. The primary air outlet dry bulb temperature will try to maintain 15 °C.
f. For each OEM, testing will be performed over a 24hr period for both units simultaneously.
g. The tests will be performed for all OEMs, one after the other.
h. The tests will be considered completed once a 24 hrs cycle is recorded for both IEC hybrid and DX units.

i. The tests meteorological readings will be recorded.
j. The tests are be performed to obtain the total cooling capacities and the energy efficiency ratios of both IEC hybrid and the DX unit for each OEM simultaneously and compare the results over a 24 hours period.
k. In the final report, the test values will be plotted and analysed to help in obtaining a definite understanding of the advantages of the systems at various Climatic Zones.
l. An economic comparison will be made comparing the Net Present Value (NPV) of the IEC hybrid compared to a DX unit over its lifetime to check its economic feasibility.



Schematic diagram of testing unit's emplacement at the test site.

6. Testing Methodology

6.1 EUROVENT

The testing methodology is based on:

"Eurovent XX/1 — 2022 Hybrid Indirect Evaporative Cooling Equipment: Requirements and Test Method"

Recorded Individual data for each OEM

- Date of test
- Test identification number
- Latitude of the location where the test is done
- Longitude of the location where the test is done
- Altitude of the location where the test is done
- Indication of the Egypt climate zone
- Serial number
- Model dimensions

6.2 Calculation of total cooling capacity (q_{tot})

The Total Cooling Capacity (kW) of the Indirect Evaporative Cooling Units is calculated as follows:

$$\boldsymbol{q_{tot} = 1.21\ Qp\ (h1 - h2)}$$

Where:

q_{tot} = *Total Cooling Capacity, kW*

h1= Primary air inlet enthalpy (from psychrometric chart and calculation), [kj/kg]

*h*2= Primary air outlet enthalpy (from psychrometric chart and calculation), [kj/kg]

Qp= Primary air flow rate, [kg/s]

6.3 Calculation of Energy Efficiency ratio (EER)

The Energy Efficiency Ratios the ratio of the total cooling capacity to the power input:

$$\boldsymbol{EER = \frac{q_{tot}}{W}}$$

Where:

EER = Energy Efficiency Ratio, B.t.u/hr. W and in W/W

q_{tot}= Total cooling capacity, kW

W= Total Power input [kW] = W_p+W_s+W_c+W_{DX}

W_p= Power of the fans for primary air

W_s= Power of the fans for secondary air

W_c= Power of the recirculating pump

W_{DX}= Power of the direct expansion coils/system

6.4 Measurements:

The tests will record the following values, on the hour, every hour for a 24 hours period:

- the Primary air inlet dry bulb temperature
- the Primary air outlet dry bulb temperature
- the Secondary air inlet wet bulb
- the Secondary air inlet dry bulb
- the Primary air flow rate
- the Total Power input
- the EER
- the total cooling Capacity
- the power of fans for primary air

- the power of fans for secondary air
- the power of the recirculating pump
- the power of direct expansion coils/system
- the water consumption

7. The Final Report

The final report will include the following:

- Individual data for each OEM.
    - Hourly readings of the IEC hybrid unit
    - Hourly readings of the DX unit
    - Calculation of total cooling capacity
    - Calculation of Energy Efficiency ratio
    - Graph showing the total cooling capacity of the IEC hybrid and the DX unit versus the hours for 24 hours cycle, and including the ambient dry bulb and ambient relative humidity
    - Graph showing the total energy efficiency ratio of the IEC hybrid and the DX unit versus the hours for 24 hours cycle, and including the ambient dry bulb and ambient relative humidity
    - Cooling Effectiveness of the IEC hybrid unit versus the hours for 24 hours cycle
    - Discussion of the results
    - Economic Net Present value comparison of the IEC hybrid versus the DX system to help establish its commercial feasibility to local market.

8. Standards used in the tests

- ANSI/ASHRAE Standard 133-2015 - Method of Testing Direct Evaporative Coolers, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta.
- EN 14511-3: 2013. – Air-conditioner, Liquid Chiller packages & Heat Pumps with electrically driven compressor for space heating & cooling – Part 3 - Tolerance for reading temperature measurement.
- ANSI/ASHRAE Standard 143-2015 - Method of Test for Rating Indirect Evaporative Coolers, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta.
- ASHRAE Standard 41.2-2018 - Standard Methods for Air Velocity and Airflow Measurement
- ISO 5801-2017 - Fans Performance testing using standardised airways
- ECP-24 EC:2021 - Technical certification rules of the Eurovent Certified Performance Mark-Evaporative Cooling-

Annex (4) Results in CZ2

Results and Calculations for OEM2 - CZ2

IEC Hybrid Unit , Air flow = 2000 cfm (3398 m3/hr), Altitude = 208 m, , water bath area = (1000*900) mm2, size of duct for air balancing = 0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out IEC-H	RH out IEC-H	Twb out IEC-H	h amb	ρ amb	h out IEC-H	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
11:00	34.7	30.5	12.7	78.7	10.7	62.94	1.11	31.48	1.05	32961.06	8043.4	4.098	14.0
12:00	35.8	30	13	77.5	10.9	65.36	1.11	31.72	1.05	35245.08	7642.8	4.612	15.7
13:00	37.6	29	14.2	82.4	12.5	69.32	1.10	35.9	1.04	34699.14	8215.3	4.224	14.4
14:00	37.7	29.75	13.8	80.7	11.9	70.27	1.10	34.52	1.04	37118.32	8113.2	4.575	15.6
15:00	36.9	32.25	13.1	85.7	11.7	70.58	1.10	34	1.04	37980.08	8060.9	4.712	16.1
16:00	36.5	35.75	12.6	87	11.4	73.12	1.10	33.21	1.04	41437.54	8124.6	5.100	17.4
17:00	35.4	36.5	11.6	85.6	10.3	70.68	1.11	30.48	1.05	42118.08	8257.1	5.101	17.4
18:00	33.4	43	11.5	87.4	10.4	70.32	1.11	30.65	1.05	41562.79	8067.1	5.152	17.6
19:00	31.5	50.25	11.6	89.5	10.7	70.08	1.12	31.26	1.06	41038.65	7930.1	5.175	17.7
20:00	30.6	50.25	10.6	87.9	9.5	67.21	1.12	28.73	1.06	40679.22	7849.7	5.182	17.7
21:00	29.1	55	11.3	88.8	10.3	65.93	1.13	30.49	1.07	37799.99	7661.7	4.934	16.8
22:00	28.4	55.25	11	89.7	10.1	63.88	1.13	30.06	1.07	36072.11	7678.4	4.698	16.0
23:00	28	55.25	11.3	88.9	10.3	62.64	1.13	30.51	1.07	34269.57	7812.4	4.387	15.0
0:00	27.4	52.75	10.7	89.5	9.8	59.17	1.14	29.26	1.08	32184.06	7932.5	4.057	13.8
1:00	26.4	53.25	10.2	89.7	9.3	56.8	1.14	28.2	1.08	30774.46	8087.1	3.805	13.0
2:00	26.1	54.25	9.6	91.4	8.9	56.44	1.14	27.26	1.08	31398.56	8084	3.884	13.3
3:00	25.8	52.5	9.8	91.2	9.1	54.56	1.14	27.67	1.08	28934.45	8368.8	3.457	11.8
4:00	25.4	49.25	9.6	89.5	8.7	51.66	1.15	26.74	1.09	27049.88	8331.4	3.247	11.1
5:00	24.9	41.25	9.5	91.3	8.8	46.33	1.15	26.94	1.09	21047.24	8109.5	2.595	8.9
6:00	25.5	40.5	9.6	90	8.8	47.31	1.15	26.85	1.09	22208.69	8542.1	2.600	8.9
7:00	27.9	37.5	9.2	88.5	8.3	51.38	1.14	25.84	1.08	27481.81	8298	3.312	11.3
8:00	30.1	37.25	8.5	84.5	7.2	56.64	1.13	23.57	1.07	35272.17	8232.2	4.285	14.6
9:00	32.1	39.25	10.4	82.5	8.9	63.52	1.12	27.11	1.06	38490.92	8395	4.585	15.6
10:00	33.9	35.25	9.5	81.3	7.9	65.13	1.11	24.98	1.05	42065.69	7903.5	5.322	18.2
11:00	35.4	31.75	10.7	81	7.9	66.1	1.11	27.45	1.05	40494.12	7928.3	5.108	17.4

Results and Calculations for OEM2 - CZ2

DX Unit , Air flow = 2000 cfm (3398 m3/h), Altitude = 208 m, duct size =0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out DX	RH out DX	Twb out DX	h amb	ρ amb	h out DX	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
11:00	34.7	30.5	11.6	82	10.0	62.94	1.11	29.67	1.05	34857.43	9419.5	3.701	12.6
12:00	35.8	30	12.7	82.9	11.1	65.36	1.11	32.41	1.05	34522.16	8743	3.949	13.5
13:00	37.6	29	12.6	83.2	11.0	69.32	1.10	32.17	1.04	38571.90	9793.5	3.939	13.4
14:00	37.7	29.75	12.8	83	11.0	70.27	1.10	32.73	1.04	38976.83	10802.4	3.608	12.3
15:00	36.9	32.25	12.5	83.6	11.0	70.58	1.10	32.17	1.04	39880.13	9576	4.165	14.2
16:00	36.5	35.75	12.3	84.7	10.9	73.12	1.10	31.97	1.04	42725.00	9936.3	4.300	14.7
17:00	35.4	36.5	12.1	86.6	10.9	70.68	1.11	31.86	1.05	40672.24	9984.2	4.074	13.9
18:00	33.4	43	11.4	88.2	10.3	70.32	1.11	30.66	1.05	41552.31	9595.5	4.330	14.8
19:00	31.5	50.25	10.9	89.4	10.0	70.08	1.12	29.64	1.06	42751.24	9337.8	4.578	15.6
20:00	30.6	50.25	10.3	89.5	9.4	67.21	1.12	28.36	1.06	41070.37	9431.5	4.355	14.9
21:00	29.1	55	11.2	91.5	10.5	65.93	1.13	30.92	1.07	37341.36	8845.7	4.221	14.4
22:00	28.4	55.25	11.5	93.3	10.9	63.88	1.13	32.01	1.07	33992.26	8992.5	3.780	12.9
23:00	28	55.25	11.4	94	10.9	62.64	1.13	31.92	1.07	32765.68	9206.7	3.559	12.1
0:00	27.4	52.75	11.1	92.8	10.5	59.17	1.14	30.81	1.08	30516.21	9409.4	3.243	11.1
1:00	26.4	53.25	10.8	93.5	10.2	56.8	1.14	30.4	1.08	28407.19	9729.6	2.920	10.0
2:00	26.1	54.25	10.3	93.4	9.7	56.44	1.14	29.08	1.08	29440.18	9781.1	3.010	10.3
3:00	25.8	52.5	10.4	93.6	9.9	54.56	1.14	29.5	1.08	26965.31	10022	2.691	9.2
4:00	25.4	49.25	10.5	93.7	10.0	51.66	1.15	29.6	1.09	23945.44	10189	2.350	8.0
5:00	24.9	41.25	10.4	93.8	9.9	46.33	1.15	29.46	1.09	18311.86	10326	1.773	6.1
6:00	25.5	40.5	10.3	93.8	9.8	47.31	1.15	29.15	1.09	19712.11	10417	1.892	6.5
7:00	27.9	37.5	10.1	93	9.5	51.38	1.14	28.69	1.08	24415.12	10054	2.428	8.3
8:00	30.1	37.25	9.6	92.2	9.0	56.64	1.13	27.33	1.07	31261.79	9892.9	3.160	10.8
9:00	32.1	39.25	10	87.7	9.0	63.52	1.12	27.42	1.06	38163.20	10068.2	3.790	12.9
10:00	33.9	35.25	10.8	90.1	9.9	65.13	1.11	29.71	1.05	37110.01	9401.4	3.947	13.5
11:00	35.4	31.75	10.7	89.3	9.8	66.1	1.11	29.15	1.05	38713.01	9565.8	4.047	13.8

Results and Calculations for OEM3 - CZ2

IEC Hybrid Unit , Air flow = 2025 cfm , Altitude = 208 m, , water bath area = (1728.5*623) mm2, size of duct for air balancing = 0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out IEC-H	RH out IEC-H	Twb out IEC-H	h amb	ρ amb	h out IEC-H	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
12:16	35.4	29.9	13.2	75	10.8	64.3	1.11	31.6	1.06	34688.48	4996.3	6.943	23.7
13:16	35.4	32.4	13	74.2	10.5	66.7	1.11	30.9	1.06	37976.99	4989.8	7.611	26.0
14:16	36	29.6	12.5	73.7	10.0	65.5	1.11	29.8	1.06	37870.91	4978.4	7.607	26.0
15:16	36.1	27	13.4	73.9	10.9	63.3	1.11	31.8	1.06	33415.51	4926.4	6.783	23.2
16:16	35.7	28.8	12.7	74.5	10.3	63.9	1.11	30.4	1.06	35537.13	4932.7	7.204	24.6
17:16	35.4	30.8	12.8	74.6	10.4	65.1	1.11	30.6	1.06	36597.94	5048.6	7.249	24.7
18:16	34.4	33.7	12.8	75	10.4	65.1	1.11	30.8	1.06	36385.78	4996.9	7.282	24.9
19:16	32	38.4	13.3	75.2	10.9	62.5	1.12	31.8	1.07	32860.26	4944	6.646	22.7
20:16	29.7	56.5	14.6	79.5	12.5	69	1.13	35.9	1.08	35745.47	5012	7.132	24.3
21:16	28.3	57.9	14.6	81.6	12.8	65.2	1.13	36.5	1.08	30993.81	5076.1	6.106	20.8
22:16	27.8	60	14.9	81.3	13.0	64.9	1.13	37.3	1.08	29805.89	5028.4	5.928	20.2
23:16	27.6	58.8	14.5	82	12.7	63.4	1.14	36.3	1.09	29524.92	4955.8	5.958	20.3
0:16	27.2	67.4	14.5	82.2	12.7	67.6	1.14	36.5	1.09	33882.84	5048.1	6.712	22.9
1:16	25.3	69.8	14.7	82.6	13.0	62.4	1.14	36.9	1.09	27781.75	5038.9	5.513	18.8
2:16	24.6	73.2	14.8	83.4	13.1	61.9	1.15	37.6	1.10	26706.60	5059	5.279	18.0
3:16	23.5	73.7	14.8	84.4	13.2	58.7	1.15	37.7	1.10	23079.78	5005.2	4.611	15.7
4:16	23.4	74.3	14.6	84.7	13.1	58.7	1.15	37.4	1.10	23409.49	5030.9	4.653	15.9
5:16	24.1	75.2	14.2	84.3	12.7	61.2	1.15	36.3	1.10	27366.03	5022.6	5.449	18.6
6:16	24.6	64.5	13.2	81.9	11.5	57.4	1.15	33.2	1.10	26596.70	4916.3	5.410	18.5
7:16	27.3	60.9	12.5	80.8	10.7	63.9	1.14	31.3	1.09	35517.06	4903.4	7.243	24.7
8:16	28.1	53.2	12.6	78.7	10.6	61.4	1.13	31	1.08	32829.68	4926.1	6.664	22.7
9:16	29.7	47.6	12.5	77.8	10.4	62.6	1.13	30.7	1.08	34449.56	4928.4	6.990	23.9
10:16	31.5	44.9	12.3	75.3	10.0	65.9	1.12	29.7	1.07	38747.27	4900.2	7.907	27.0
11:16	35.9	40.3	13.4	76.1	11.1	75.6	1.10	32.2	1.05	45624.38	4929	9.256	31.6
12:16	39.7	29.2	13.7	74.4	11.2	75.1	1.09	32.4	1.04	44480.43	4982.6	8.927	30.5

Results and Calculations for OEM3 - CZ2

DX Unit , Air flow = 2025 cfm , Altitude = 208 m, duct size =0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out DX	RH out DX	Twb out DX	h amb	ρ amb	h out DX	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
12:16	35.4	29.9	11.2	80.2	9.4	64.3	1.11	28.4	1.06	38083.07	11200	3.400	11.6
13:16	35.4	32.4	11.6	79.7	9.8	66.7	1.11	29.1	1.06	39886.45	11600	3.438	11.7
14:16	36	29.6	11.4	79.7	9.6	65.5	1.11	28.7	1.06	39037.80	11600	3.365	11.5
15:16	36.1	27	11.6	80.5	9.8	63.3	1.11	29.2	1.06	36173.62	11600	3.118	10.6
16:16	35.7	28.8	11.9	79.1	10.0	63.9	1.11	29.7	1.06	36279.70	11700	3.101	10.6
17:16	35.4	30.8	11.8	81.3	10.1	65.1	1.11	29.9	1.06	37340.51	11700	3.191	10.9
18:16	34.4	33.7	11.6	81.7	9.9	65.1	1.11	29.6	1.06	37658.75	11300	3.333	11.4
19:16	32	38.4	10.9	82.5	9.4	62.5	1.12	28.2	1.07	36713.58	11200	3.278	11.2
20:16	29.7	56.5	11.5	87.7	10.4	69	1.13	30.7	1.08	41361.07	11100	3.726	12.7
21:16	28.3	57.9	12.5	88.2	11.4	65.2	1.13	33.1	1.08	34665.55	10800	3.210	11.0
22:16	27.8	60	11.7	88.3	10.6	64.9	1.13	31.3	1.08	36285.43	10700	3.391	11.6
23:16	27.6	58.8	11.1	88.6	10.1	63.4	1.14	30	1.09	36388.65	10300	3.533	12.1
0:16	27.2	67.4	11.4	88.8	10.4	67.6	1.14	30.6	1.09	40310.77	10600	3.803	13.0
1:16	25.3	69.8	11.3	89.2	10.3	62.4	1.14	30.4	1.09	34863.37	10400	3.352	11.4
2:16	24.6	73.2	11.2	90.4	10.5	61.9	1.15	30.7	1.10	34289.96	10200	3.362	11.5
3:16	23.5	73.7	11.1	90.7	10.3	58.7	1.15	30.4	1.10	31102.75	10100	3.079	10.5
4:16	23.4	74.3	10.8	91	10.0	58.7	1.15	29.8	1.10	31762.18	10100	3.145	10.7
5:16	24.1	75.2	10.2	90.5	9.4	61.2	1.15	28.4	1.10	36048.42	10000	3.605	12.3
6:16	24.6	64.5	9.4	88.4	8.4	57.4	1.15	26.2	1.10	34289.96	10200	3.362	11.5
7:16	27.3	60.9	10	87.1	8.9	63.9	1.14	27.1	1.09	40092.88	10500	3.818	13.0
8:16	28.1	53.2	10.3	87	9.2	61.4	1.13	27.8	1.08	36285.43	10700	3.391	11.6
9:16	29.7	47.6	10.8	84.9	9.5	62.6	1.13	28.5	1.08	36825.39	10700	3.442	11.7
10:16	31.5	44.9	10.8	83.2	9.3	65.9	1.12	28.2	1.07	40352.82	11000	3.668	12.5
11:16	35.9	40.3	12.3	82.5	10.7	75.6	1.10	31.2	1.05	46675.63	11600	4.024	13.7
12:16	39.7	29.2	12.6	81.6	10.9	75.1	1.09	31.9	1.04	45001.27	11500	3.913	13.4

Results and Calculation for OEM4 - CZ2

IEC Hybrid Unit , Air flow = 1750 cfm , Altitude = 208 m, , water bath area = (2400*1600) mm2, size of duct for air balancing = 0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out IEC-H	RH out IEC-H	Twb out IEC-H	h amb	ρ amb	h out IEC-H	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
10:30	31.9	46.5	14.5	84.3	12.9	68.5	1.12	37.2	0.93	28952.76	6899	4.197	14.3
11:30	33	42.2	14.7	84.7	13.2	68.6	1.12	37.6	0.93	28675.26	6898	4.157	14.2
12:30	34.3	35.3	13.5	84.8	12.0	66.2	1.11	34.7	0.92	28877.60	6879.9	4.197	14.3
13:30	35.7	33.3	13.7	84.7	12.2	68.4	1.11	35.3	0.92	30344.40	6812.1	4.454	15.2
14:30	35.5	34.8	15.1	86.7	13.8	69.3	1.11	39.2	0.92	27594.15	6777.1	4.072	13.9
15:30	34.9	34.8	14.8	86.2	13.4	67.5	1.11	38.3	0.92	26769.08	6771.1	3.953	13.5
16:30	34.7	37.3	14.8	86.7	13.5	69.2	1.11	38.6	0.92	28052.53	6752.3	4.155	14.2
17:30	33.4	43.5	15.5	88	14.3	70.9	1.11	40.7	0.92	27685.83	6866.3	4.032	13.8
18:30	31.2	45.8	16.2	89.4	15.1	65.7	1.12	43	0.93	20997.69	6817.8	3.080	10.5
19:30	29	46.3	16	90.4	15.0	59.7	1.13	42.7	0.93	15865.54	6819.3	2.327	7.9
20:30	28	45.3	17	90.8	16.0	56.2	1.14	45.7	0.94	9886.03	6844.9	1.444	4.9
21:30	27	45.5	16.6	91	15.7	54	1.14	44.6	0.94	8850.35	6730	1.315	4.5
22:30	26	46.3	16.1	91.9	15.3	51.8	1.14	43.5	0.94	7814.67	6693.8	1.167	4
23:30	25.2	45.8	16	91.9	15.2	49.4	1.15	43.2	0.95	5888.67	6679.8	0.882	3
0:30	24.7	44.3	15.9	92.2	15.1	47.5	1.15	42.9	0.95	4369.01	6610.6	0.661	2.3
1:30	24.3	43.8	15.6	92	14.8	46.3	1.15	42.2	0.95	3894.12	6535.2	0.596	2
2:30	23.6	44.5	15.4	92.6	14.7	44.9	1.15	41.8	0.95	2944.33	6644.7	0.443	1.5
3:30	23.8	45.8	15.4	92.6	14.7	46	1.15	41.6	0.95	4179.06	6705.3	0.623	2.1
4:30	23.7	44.3	15.2	91.5	14.4	45.1	1.15	40.8	0.95	4084.08	6609.4	0.618	2.1
5:30	23.9	43	15.1	92	14.3	44.8	1.15	40.8	0.95	3799.14	6661.3	0.570	1.9
6:30	23.9	41.3	14.8	91.5	14.0	44.1	1.15	39.9	0.95	3989.10	6668.1	0.598	2
7:30	23.9	40.5	15.1	91.4	14.2	43.7	1.15	40.5	0.95	3039.31	6602.4	0.460	1.6
8:30	25.6	39.3	15.3	89.7	14.3	46.9	1.15	40.6	0.95	5983.65	6612.9	0.905	3.1
9:30	27.6	40.3	15.2	88.5	14.0	52.3	1.14	40	0.94	11580.77	6686.7	1.732	5.9
10:30	30.3	39.8	14.6	88.5	13.5	58.8	1.13	38.4	0.93	19038.65	6655.9	2.860	9.8

Results and Calculation for OEM4 - CZ2

DX Unit , Air flow = 1750 cfm , Altitude = 208 m, duct size =0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out DX	RH out DX	Twb out DX	h amb	ρ amb	h out DX	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
10:30	31.9	46.5	15.1	85.5	13.7	68.5	1.12	38.8	0.93	27472.75	7980	3.443	11.7
11:30	33	42.2	18.4	79.4	16.1	68.6	1.12	45.9	0.93	20997.69	7969	2.635	9
12:30	34.3	35.3	17.6	71.9	14.5	66.2	1.11	41.2	0.92	22918.73	8060	2.844	9.7
13:30	35.7	33.3	19	72.2	15.8	68.4	1.11	44.9	0.92	21543.61	7980	2.700	9.2
14:30	35.5	34.8	21	72.7	17.7	69.3	1.11	50.6	0.92	17143.21	7630	2.247	7.7
15:30	34.9	34.8	22.3	78.5	19.6	67.5	1.11	57.1	0.92	9534.19	7960	1.198	4.1
16:30	34.7	37.3	17.5	75	14.7	69.2	1.11	41.9	0.92	25027.25	7830	3.196	10.9
17:30	33.4	43.5	17.5	75.6	14.8	70.9	1.11	42.1	0.92	26402.38	7829	3.372	11.5
18:30	31.2	45.8	17.5	76.3	14.9	65.7	1.12	42.3	0.93	21645.19	7940	2.726	9.3
19:30	29	46.3	17.8	76.8	15.2	59.7	1.13	43.4	0.93	15212.26	8090	1.880	6.4
20:30	28	45.3	18.6	76.7	16.0	56.2	1.14	45.5	0.94	10074.33	8190	1.230	4.2
21:30	27	45.5	18.3	76.7	15.7	54	1.14	44.5	0.94	8944.50	8092	1.105	3.8
22:30	26	46.3	17.4	77	14.9	51.8	1.14	42.3	0.94	8944.50	8167	1.095	3.7
23:30	25.2	45.8	17.9	77.4	15.4	49.4	1.15	43.7	0.95	5413.78	8197	0.660	2.3
0:30	24.7	44.3	17.7	77.8	15.3	47.5	1.15	43.3	0.95	3989.10	7881	0.506	1.7
1:30	24.3	43.8	18.2	79.6	15.9	46.3	1.15	45.4	0.95	854.81	7995	0.107	0.4
2:30	23.6	44.5	17.7	80.5	15.6	44.9	1.15	44.3	0.95	569.87	7994	0.071	0.2
3:30	23.8	45.8	17.8	80	15.6	46	1.15	44.3	0.95	1614.63	7845	0.206	0.7
4:30	23.7	44.3	18	79.8	15.8	45.1	1.15	44.8	0.95	284.94	8114	0.035	0.1
5:30	23.9	43	17.4	79.2	15.1	44.8	1.15	43.2	0.95	1519.66	8106	0.187	0.6
6:30	23.9	41.3	17.1	78.2	14.7	44.1	1.15	41.9	0.95	2089.53	8050	0.260	0.9
7:30	23.9	40.5	17.3	78.2	14.9	43.7	1.15	42.5	0.95	1139.74	8060	0.141	0.5
8:30	25.6	39.3	17.2	78.6	14.9	46.9	1.15	42.3	0.95	4369.01	7900	0.553	1.9
9:30	27.6	40.3	17.6	78.7	15.3	52.3	1.14	43.3	0.94	8473.74	8090	1.047	3.6
10:30	30.3	39.8	17.7	77.9	15.3	58.8	1.13	43.5	0.93	14278.99	7814	1.827	6.2

Results and Calculations for OEM6 - CZ2

IEC Hybrid Unit , Air flow = 2245 cfm , Altitude = 208 m, , water bath area = (1308.3^2-900.3^2) mm2, size of duct for air balancing = 0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out IEC-H	RH out IEC-H	Twb out IEC-H	h amb	ρ amb	h out IEC-H	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
12:00	31.3	30.8	13.4	93.4	12.8	54.8	1.13	36.6	1.20	21789.92	4478.4	4.866	16.6
13:00	33	28	13.2	93.9	12.6	56.6	1.12	36.4	1.19	23970.40	4709.1	5.090	17.4
14:00	33.5	29.8	13.5	93.8	12.9	59.4	1.12	37.1	1.19	26462.37	4672	5.664	19.3
15:00	34.1	28.8	12.9	94.1	12.4	60	1.11	35.6	1.18	28695.82	4733.1	6.063	20.7
16:00	33.7	32.3	14.5	93.4	13.9	61.8	1.12	39.4	1.19	26581.04	4807.1	5.530	18.9
17:00	32.1	35.5	14.5	94.2	13.9	60.5	1.12	39.8	1.19	24563.73	5021.3	4.892	16.7
18:00	31.5	39.3	13.5	95	13.0	61.6	1.12	37.3	1.19	28835.68	4820	5.983	20.4
19:00	30.1	42.5	13.2	94.9	12.7	60.2	1.13	36.5	1.20	28374.79	4772.4	5.946	20.3
20:00	29.2	47.8	14.6	94.9	14.1	61.4	1.13	40.3	1.20	25261.94	4755.6	5.312	18.1
21:00	27.3	50.3	16.2	93.4	15.5	57.5	1.14	44.2	1.21	16064.32	4772.7	3.366	11.5
22:00	26.1	51.3	16.4	93.3	15.7	54.9	1.14	44.8	1.21	12199.22	4687.2	2.603	8.9
23:00	25.5	52.5	15.4	93.4	14.7	53.7	1.15	42.1	1.22	14133.89	4702.7	3.005	10.3
0:00	24.9	49	15.6	92.6	14.9	50.4	1.15	42.4	1.22	9747.51	4643.6	2.099	7.2
1:00	24.4	48.5	14.6	93.4	14.0	48.6	1.15	39.9	1.22	10600.42	4686.9	2.262	7.7
2:00	24	46.8	14.4	92.6	13.7	47	1.15	39	1.22	9747.51	4700.3	2.074	7.1
3:00	24.2	44.3	13.4	92.7	12.7	46.4	1.15	36.5	1.22	12062.54	4740.6	2.545	8.7
4:00	23.4	44.3	13.7	92.5	13.0	44.4	1.16	37.3	1.23	8726.14	4787.8	1.823	6.2
5:00	23.8	41.8	13.8	91.7	13.0	44.2	1.15	37.3	1.22	8407.23	4654.8	1.806	6.2
6:00	24.3	40.5	13.3	91.6	12.5	44.6	1.15	36.1	1.22	10356.73	4641.7	2.231	7.6
7:00	25	38.5	13.5	92.6	12.8	45.3	1.15	36.7	1.22	10478.57	4641.7	2.257	7.7
8:00	27.3	38.5	13.5	92.8	12.8	50.4	1.14	36.8	1.21	16426.67	4631.1	3.547	12.1
9:00	28.4	38.3	14.3	93.4	13.7	52.9	1.14	38.9	1.21	16909.81	4578.1	3.694	12.6
10:00	29.9	38	14	94.4	13.5	56.6	1.13	38.6	1.20	21550.47	4498	4.791	16.4
11:00	31.3	39.3	14.2	93.3	13.6	61.3	1.12	38.6	1.19	26937.03	4756.8	5.663	19.3
12:00	32.5	35.5	14.2	93.2	13.5	61.6	1.12	38.7	1.19	27174.36	4750.4	5.720	19.5

Results and Calculations for OEM6 - CZ2

DX Unit , Air flow = 2245 cfm , Altitude = 208 m, duct size =0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out DX	RH out DX	Twb out DX	h amb	ρ amb	h out DX	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
12:00	31.3	30.8	11.2	79.5	9.4	54.8	1.13	28.3	1.20	31727.09	11200	2.833	9.7
13:00	33	28	11.5	78.6	9.6	56.6	1.12	28.7	1.19	33107.63	11600	2.854	9.7
14:00	33.5	29.8	11.4	78.8	9.5	59.4	1.12	28.6	1.19	36548.93	11600	3.151	10.8
15:00	34.1	28.8	11.2	79.9	9.4	60	1.11	28.3	1.18	37281.05	11600	3.214	11
16:00	33.7	32.3	12	78.5	10.0	61.8	1.12	29.9	1.19	37854.25	11700	3.235	11
17:00	32.1	35.5	11.8	81.6	10.1	60.5	1.12	30.1	1.19	36074.26	11700	3.083	10.5
18:00	31.5	39.3	11.4	81.8	9.8	61.6	1.12	29.2	1.19	38447.57	11300	3.402	11.6
19:00	30.1	42.5	10.6	83	9.1	60.2	1.13	27.7	1.20	38910.58	11200	3.474	11.9
20:00	29.2	47.8	14.9	87	13.6	61.4	1.13	38.8	1.20	27057.82	11100	2.438	8.3
21:00	27.3	50.3	13	88.1	11.9	57.5	1.14	34.4	1.21	27901.19	11800	2.365	8.1
22:00	26.1	51.3	11.6	88.1	10.5	54.9	1.14	31.1	1.21	28746.68	11700	2.457	8.4
23:00	25.5	52.5	10.9	88.1	9.9	53.7	1.15	29.4	1.22	29608.06	11300	2.620	8.9
0:00	24.9	49	11.3	88.5	10.3	50.4	1.15	30.4	1.22	24368.78	11600	2.101	7.2
1:00	24.4	48.5	11.1	89	9.3	48.6	1.15	30.1	1.22	22541.12	11400	1.977	6.7
2:00	24	46.8	11.1	90.1	10.2	47	1.15	30.4	1.22	20226.08	11200	1.806	6.2
3:00	24.2	44.3	11.1	90.4	10.3	46.4	1.15	30.3	1.22	19616.86	11100	1.767	6
4:00	23.4	44.3	10.7	90.8	9.9	44.4	1.16	29.5	1.23	18312.61	11100	1.650	5.6
5:00	23.8	41.8	10.1	90.7	9.3	44.2	1.15	28.2	1.22	19495.02	11000	1.772	6
6:00	24.3	40.5	9.6	88.6	8.6	44.6	1.15	26.7	1.22	21810.05	11200	1.947	6.6
7:00	25	38.5	10.1	87.5	9.0	45.3	1.15	27.6	1.22	21566.37	11500	1.875	6.4
8:00	27.3	38.5	10.1	87	9.0	50.4	1.14	27.4	1.21	27780.40	11700	2.374	8.1
9:00	28.4	38.3	10.8	85.3	9.5	52.9	1.14	28.6	1.21	29350.60	11700	2.509	8.6
10:00	29.9	38	10.7	83.7	9.3	56.6	1.13	28.1	1.20	34121.58	11000	3.102	10.6
11:00	31.3	39.3	12.3	83.2	10.7	61.3	1.12	31.5	1.19	35362.27	11600	3.048	10.4
12:00	32.5	35.5	12.4	82.2	10.7	61.6	1.12	31.5	1.19	35718.27	11500	3.106	10.6

Annex (5) Results in CZ5

Results and Calculations for OEM 2 - CZ5

IEC Hybrid Unit , Air flow = 2000 cfm (3398 m3/hr), Altitude = 208 m, , water bath area = (1000*900) mm2, size of duct for air balancing = 0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out IEC-H	RH out IEC-H	Twb out IEC-H	h amb	ρ amb	h out IEC-H	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
11:00	38.4	38.8	13.2	79.4	11.2	81.31	1.12	32.12	1.06	52001.32	9726.4	5.346	18.2
12:00	38.1	33.5	13.8	78.6	11.7	74.24	1.12	33.27	1.06	43311.53	9243	4.686	16.0
13:00	38.8	35	13.5	79.4	11.5	78.18	1.12	32.78	1.06	47994.71	9795.3	4.900	16.7
14:00	38.3	33	12.8	79.5	10.9	74.52	1.12	31.23	1.06	45764.12	9979.7	4.586	15.7
15:00	38.7	34.8	12.4	80.3	10.6	77.67	1.12	30.67	1.06	49686.16	9963	4.987	17.0
16:00	37.5	30.8	11.4	79.2	9.5	69.61	1.13	28.11	1.07	44263.53	10164.4	4.355	14.9
17:00	36.6	29.3	10.3	78.4	8.4	65.56	1.13	25.64	1.07	42578.32	9872.4	4.313	14.7
18:00	35.3	32.3	9.5	79.3	7.8	65.12	1.14	24.32	1.08	43902.02	9855.8	4.454	15.2
19:00	32.7	41.8	8.5	79.8	6.9	65.94	1.15	22.43	1.09	47228.75	9394.8	5.027	17.2
20:00	31.2	42	8	81.7	6.6	61.92	1.15	21.77	1.09	43581.58	9677.9	4.503	15.4
21:00	31.3	44.8	8.3	83.1	7.0	64.16	1.15	22.6	1.09	45112.09	9457.2	4.770	16.3
22:00	30.1	43	8.1	83.9	6.8	59.61	1.15	22.21	1.09	40596.54	9502.8	4.272	14.6
23:00	29.9	42.5	8.5	83.9	7.2	58.67	1.16	23.07	1.09	38978.72	9514.3	4.097	14.0
0:00	31	44	9.2	83.1	7.8	62.8	1.15	24.35	1.09	41736.28	9641.4	4.329	14.8
1:00	32.2	48.8	10.5	83.6	9.1	69.99	1.15	27.16	1.09	46490.63	9687.2	4.799	16.4
2:00	31.2	51.8	10.3	83.9	8.9	69.24	1.15	26.87	1.09	45991.32	9898.9	4.646	15.9
3:00	30.3	54	10.3	84	8.9	68.06	1.15	26.74	1.09	44851.57	9682.8	4.632	15.8
4:00	30	53.3	9.7	84.5	8.4	66.5	1.15	25.59	1.09	44406.53	9729.3	4.564	15.6
5:00	29.8	51.8	9.5	85.1	8.3	64.66	1.16	25.28	1.09	43117.47	10019	4.304	14.7
6:00	29.5	51.3	8.9	84.3	7.6	63.63	1.16	24.02	1.09	43369.30	9935.5	4.365	14.9
7:00	31.9	44.3	9.6	82.1	8.1	65.63	1.15	25.06	1.09	44037.47	9761.4	4.511	15.4
8:00	33.4	41.3	10.5	81.9	8.9	67.82	1.14	26.82	1.08	44117.23	9714.6	4.541	15.5
9:00	34.5	44.3	12.3	80.7	10.5	73.81	1.14	30.38	1.08	46731.98	9395.4	4.974	17.0
10:00	36.2	44.8	13.7	80	11.8	80	1.13	33.47	1.07	49628.49	9161.1	5.417	18.5
11:00	35.6	47.3	13.6	79	11.6	80.25	1.13	33	1.07	50396.43	9411.9	5.355	18.3

Results and Calculations for OEM 2 - CZ5

DX Unit , Air flow = 2000 cfm (3398 m3/h), Altitude = 208 m, duct size =0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out DX	RH out DX	Twb out DX	h amb	ρ amb	h out DX	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
11:00	38.4	38.8	13.8	82.6	12.1	81.31	1.12	34.37	1.06	49622.73	9767.7	5.080	17.3
12:00	38.1	33.5	14.7	76.3	12.3	74.24	1.12	34.93	1.06	41556.66	10072.4	4.126	14.1
13:00	38.8	35	14	77.1	11.8	78.18	1.12	33.37	1.06	47370.99	10054.7	4.711	16.1
14:00	38.3	33	13.7	79.1	11.7	74.52	1.12	33.17	1.06	43713.25	10151.6	4.306	14.7
15:00	38.7	34.8	13.9	77.7	11.7	77.67	1.12	33.37	1.06	46831.85	10186.1	4.598	15.7
16:00	37.5	30.8	13.3	78.2	11.2	69.61	1.13	32.12	1.07	39986.50	10555.5	3.788	12.9
17:00	36.6	29.3	12.9	75	10.5	65.56	1.13	30.4	1.07	37501.35	10067.2	3.725	12.7
18:00	35.3	32.3	11.6	76.7	9.5	65.12	1.14	28.13	1.08	39802.35	9845.8	4.043	13.8
19:00	32.7	41.8	11.6	79.2	9.7	65.94	1.15	28.68	1.09	40444.57	9314	4.342	14.8
20:00	31.2	42	11.5	80.4	9.7	61.92	1.15	28.64	1.09	36124.40	9387.1	3.848	13.1
21:00	31.3	44.8	10.5	82.6	9.0	64.16	1.15	26.96	1.09	40379.44	9247.7	4.366	14.9
22:00	30.1	43	9.9	82.9	8.5	59.61	1.15	25.67	1.09	36840.81	9392.6	3.922	13.4
23:00	29.9	42.5	9.1	81	7.5	58.67	1.16	23.7	1.09	38288.92	9593.2	3.991	13.6
0:00	31	44	11.3	82.6	9.8	62.8	1.15	28.62	1.09	37101.33	9895	3.750	12.8
1:00	32.2	48.8	11.2	83.1	9.7	69.99	1.15	28.5	1.09	45036.10	9769	4.610	15.7
2:00	31.2	51.8	10.6	83.1	9.1	69.24	1.15	27.27	1.09	45557.13	9887.5	4.608	15.7
3:00	30.3	54	10.2	87.4	9.1	68.06	1.15	27.26	1.09	44287.13	10126	4.374	14.9
4:00	30	53.3	10.2	86.5	9.1	66.5	1.15	27.17	1.09	42691.49	9668.8	4.415	15.1
5:00	29.8	51.8	9.5	83.5	8.1	64.66	1.16	24.97	1.09	43456.89	10278	4.228	14.4
6:00	29.5	51.3	9.8	84.4	8.5	63.63	1.16	25.83	1.09	41387.51	9967.4	4.152	14.2
7:00	31.9	44.3	11.3	80.3	9.5	65.63	1.15	28.13	1.09	40705.08	9834.2	4.139	14.1
8:00	33.4	41.3	10.8	80.4	9.1	67.82	1.14	27.23	1.08	43676.06	9702.4	4.502	15.4
9:00	34.5	44.3	12.6	82.6	11.0	73.81	1.14	31.58	1.08	45440.75	9623.2	4.722	16.1
10:00	36.2	44.8	13.9	80.3	12.0	80	1.13	34.02	1.07	49041.86	9571.3	5.124	17.5
11:00	35.6	47.3	13.7	82.2	12.0	80.25	1.13	34.1	1.07	49223.18	9576.3	5.140	17.5

Results and Calculations for OEM 3 - CZ5

IEC Hybrid Unit , Air flow = 2025 cfm , Altitude = 2 m, , water bath area = (1728.5*623) mm2, size of duct for air balancing = 0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out IEC-H	RH out IEC-H	Twb out IEC-H	h amb	ρ amb	h out IEC-H	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
10:00	36	23.6	15.9	74	13.2	58.7	1.14	37	1.09	23641.72	5341.3	4.426	15.1
11:00	36.6	26.6	16.3	74.5	13.6	63	1.13	38.2	1.08	26782.10	5363.6	4.993	17.0
12:00	36.5	34.1	17.5	76.7	15.0	70.3	1.13	41.9	1.08	30669.83	5735.8	5.347	18.2
13:00	37.4	34.2	18.1	77.8	15.6	73	1.13	43.7	1.08	31641.76	5489.1	5.764	19.7
14:00	37	38.7	18.6	78.2	16.2	76.7	1.13	45.2	1.08	34017.59	5581.4	6.095	20.8
15:00	36.8	37.7	18.5	78.1	16.1	75	1.13	44.9	1.08	32505.70	5601	5.804	19.8
16:00	35.8	39.6	17.7	78.6	15.4	73.7	1.13	44.9	1.08	31101.80	5510.9	5.644	19.3
17:00	35.7	41.5	18.8	80.6	16.6	75.1	1.13	46.5	1.08	30885.81	5544.6	5.570	19.0
18:00	34	36.5	17.3	75.8	14.7	65.5	1.14	40.9	1.09	26801.22	5605.3	4.781	16.3
19:00	32.8	32.9	15.5	74.8	12.9	59.3	1.15	36.3	1.10	25277.86	5411.1	4.671	15.9
20:00	32	35.1	15.7	75.1	13.1	58.8	1.15	36.8	1.10	24178.82	5479	4.413	15.1
21:00	30.4	44.7	17.2	75.8	14.6	61.7	1.15	40.7	1.10	23079.78	5692.1	4.055	13.8
22:00	30.1	46.2	16.6	78.8	14.4	61.9	1.16	40.3	1.11	23945.63	5752.7	4.163	14.2
23:00	30.5	46	16.4	78.2	14.1	62.8	1.15	39.6	1.10	25497.66	5640.5	4.520	15.4
0:00	31	34	13.6	76.6	11.3	55.6	1.15	32.4	1.10	25497.66	5642.1	4.519	15.4
1:00	30.5	28.3	12.1	75	9.8	50.4	1.16	28.8	1.11	23945.63	5559	4.308	14.7
2:00	30.6	24.2	12.1	74.5	9.7	47.6	1.16	28.7	1.11	20952.43	5262.4	3.982	13.6
3:00	31.1	25.2	12.4	74.7	10.0	49.3	1.16	29.4	1.11	22061.02	5255.1	4.198	14.3
4:00	30.5	26.9	12.7	75.6	10.4	49.3	1.16	30.2	1.11	21174.15	5218.1	4.058	13.8
5:00	30.4	26.7	12.6	75.8	10.3	48.9	1.16	30.1	1.11	20841.57	5243.3	3.975	13.6
6:00	31.8	25.3	12.9	74.3	10.5	50.9	1.15	30.2	1.10	22750.07	5322.5	4.274	14.6
7:00	35.1	24.8	14.6	76.8	12.3	57.7	1.14	34.7	1.09	25058.05	5259.1	4.765	16.3
8:00	36.2	25.5	14.6	76.4	12.2	61	1.13	34.6	1.08	28509.98	5208.6	5.474	18.7
9:00	36.1	27.3	16	77.5	13.7	62.5	1.13	38.4	1.08	26026.16	5381.1	4.837	16.5
10:00	36.5	31.7	18.1	77.1	15.6	67.8	1.13	43.5	1.08	26242.14	5541.9	4.735	16.2

Results and Calculations for OEM 3 - CZ5

DX Unit , Air flow = 2025 cfm , Altitude = 2 m, duct size =0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out DX	RH out DX	Twb out DX	h amb	ρ amb	h out DX	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
10:00	36	23.6	11.5	77.7	9.5	58.7	1.14	27.9	1.09	33556.00	13200	2.542	8.7
11:00	36.6	26.6	11.3	82.5	9.7	63	1.13	28.7	1.08	37041.38	13000	2.849	9.7
12:00	36.5	34.1	13.4	87	12.2	70.3	1.13	34.4	1.08	38769.26	13000	2.982	10.2
13:00	37.4	34.2	13.4	85.6	12.0	73	1.13	34.1	1.08	42009.03	12500	3.361	11.5
14:00	37	38.7	12.9	85.7	11.6	76.7	1.13	32.9	1.08	47300.65	12700	3.724	12.7
15:00	36.8	37.7	12.7	86.5	11.5	75	1.13	32.7	1.08	45680.77	12700	3.597	12.3
16:00	35.8	39.6	12.8	87.1	11.6	73.7	1.13	33.1	1.08	43844.90	12800	3.425	11.7
17:00	35.7	41.5	12.3	87.3	11.1	75.1	1.13	32	1.08	46544.70	12700	3.665	12.5
18:00	34	36.5	11.6	86.9	10.4	65.5	1.14	30.2	1.09	38458.66	12300	3.127	10.7
19:00	32.8	32.9	10.2	85.9	9.0	59.3	1.15	26.9	1.10	35608.81	12100	2.943	10
20:00	32	35.1	10.1	86.3	8.9	58.8	1.15	26.9	1.10	35059.29	12200	2.874	9.8
21:00	30.4	44.7	10.7	87.3	9.6	61.7	1.15	28.2	1.10	36817.75	11800	3.120	10.6
22:00	30.1	46.2	10	87.2	8.9	61.9	1.16	26.8	1.11	38911.65	11600	3.354	11.4
23:00	30.5	46	10	85.1	8.7	62.8	1.15	26.3	1.10	40114.86	11100	3.614	12.3
0:00	31	34	7.2	82	5.8	55.6	1.15	20.2	1.10	38905.92	11300	3.443	11.8
1:00	30.5	28.3	7.1	82.1	5.7	50.4	1.16	20	1.11	33701.26	11400	2.956	10.1
2:00	30.6	24.2	7.3	80.5	5.8	47.6	1.16	20.1	1.11	30486.34	11800	2.584	8.8
3:00	31.1	25.2	8.2	80.4	6.6	49.3	1.16	21.8	1.11	30486.34	11600	2.628	9
4:00	30.5	26.9	7.7	81.1	6.2	49.3	1.16	21.1	1.11	31262.35	11600	2.695	9.2
5:00	30.4	26.7	7.6	81.5	6.2	48.9	1.16	20.8	1.11	31151.49	11400	2.733	9.3
6:00	31.8	25.3	7.4	82.3	6.0	50.9	1.15	20.7	1.10	33190.92	11700	2.837	9.7
7:00	35.1	24.8	8.8	81.6	7.3	57.7	1.14	23.3	1.09	37478.13	12300	3.047	10.4
8:00	36.2	25.5	9.2	79.9	7.5	61	1.13	23.7	1.08	40281.15	12600	3.197	10.9
9:00	36.1	27.3	10.7	80	9.0	62.5	1.13	26.8	1.08	38553.27	12700	3.036	10.4
10:00	36.5	31.7	12.3	81.4	10.6	67.8	1.13	30.6	1.08	40173.16	12800	3.139	10.7

Results and Calculations for OEM4 - CZ5

IEC Hybrid Unit , Air flow = 1750 cfm , Altitude = 2 m, , water bath area = (2400*1600) mm2, size of duct for air balancing = 0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out IEC-H	RH out IEC-H	Twb out IEC-H	h amb	ρ amb	h out IEC-H	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
9:00	34.2	45.3	15.1	87.2	13.8	73.8	1.14	38.7	0.94	33047.57	7015	4.711	16.1
10:00	34.2	44.3	15.4	88.6	14.3	72.8	1.14	39.9	0.94	30976.21	7005	4.422	15.1
11:00	36.4	40.8	15.7	84.3	14.1	76.5	1.13	39.6	0.93	34437.56	7233	4.761	16.2
12:00	36.8	37.5	15.7	85.3	14.2	74.6	1.13	39.7	0.93	32571.03	7218	4.512	15.4
13:00	36.7	41.8	16.2	84.4	14.6	78.5	1.13	40.7	0.93	35277.50	7135	4.944	16.9
14:00	36.7	38.5	15	83.4	13.3	75.3	1.13	37.5	0.93	35277.50	7083	4.981	17
15:00	37.5	38	15.2	83.7	13.6	77.3	1.13	38.2	0.93	36490.75	7206	5.064	17.3
16:00	37.5	34	14.2	83.4	12.6	73.1	1.13	35.5	0.93	35090.85	7110	4.935	16.8
17:00	36.4	41.3	14.6	85.6	13.2	77.1	1.13	37.2	0.93	37237.36	7253	5.134	17.5
18:00	35.7	37	13.5	86.3	12.2	70.6	1.13	34.6	0.93	33597.62	7073	4.750	16.2
19:00	34.3	41.5	12.9	86.6	11.7	70.7	1.14	33.2	0.94	35307.23	7014	5.034	17.2
20:00	32.7	47	11.7	85.3	10.4	70.3	1.14	30.1	0.94	37849.36	6929	5.462	18.6
21:00	33.1	43	11.6	86.3	10.4	68.3	1.14	30.1	0.94	35966.30	6865	5.239	17.9
22:00	32.6	44	11.5	86.3	10.3	67.5	1.15	30	0.95	35616.95	7242	4.918	16.8
23:00	31.8	48	11.6	87.5	10.5	68.3	1.15	30.5	0.95	35901.88	6970	5.151	17.6
0:00	31.8	48	12.6	87.5	11.5	68.3	1.15	32.7	0.95	33812.36	7092	4.768	16.3
1:00	31.2	50	11.5	87.2	10.4	67.9	1.15	30	0.95	35996.86	6907	5.212	17.8
2:00	31.6	50.8	10.9	87.6	9.8	69.6	1.15	28.8	0.95	38751.24	6880	5.632	19.2
3:00	29.9	54.8	10.6	88.8	9.6	67	1.15	28.4	0.95	36661.71	6831	5.367	18.3
4:00	29.6	53	10.3	89	9.6	65	1.16	27.8	0.96	35639.25	6827	5.220	17.8
5:00	29.8	52.8	10.5	89.2	9.6	65.5	1.16	28.4	0.96	35543.44	6907	5.146	17.6
6:00	28.4	52.3	11.1	89	9.6	60.9	1.16	29.7	0.96	29890.98	6806	4.392	15
7:00	30.9	52.3	12.3	89.6	11.4	68.7	1.15	32.6	0.95	34287.25	7032	4.876	16.6
8:00	33.8	45	13	88.3	11.2	72	1.14	33.8	0.94	35966.30	7035	5.112	17.4
9:00	36	29	13.1	87	11.9	63.8	1.13	38.7	0.93	23425.01	7045	3.325	11.3

Results and Calculations for OEM4 - CZ5

DX Unit , Air flow = 1750 cfm , Altitude = 2 m, duct size =0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out DX	RH out DX	Twb out DX		h amb	ρ amb	h out DX	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C		kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
9:00	34.2	45.3	15	84.1	13.4		73.8	1.14	37.8	0.94	33894.95	7787	4.353	14.9
10:00	34.2	44.3	15.9	82.8	14.1		72.8	1.14	39.6	0.94	31258.67	7888	3.963	13.5
11:00	36.4	40.8	15.2	83.6	13.6		76.5	1.13	38	0.93	35930.79	8368	4.294	14.7
12:00	36.8	37.5	15.7	83.8	14.0		74.6	1.13	39.4	0.93	32851.01	7709	4.261	14.5
13:00	36.7	41.8	15.8	81.5	13.9		78.5	1.13	38.9	0.93	36957.38	7867	4.698	16
14:00	36.7	38.5	15	77.7	12.7		75.3	1.13	39	0.93	33877.60	8031	4.218	14.4
15:00	37.5	38	16.3	77.5	13.9		77.3	1.13	39	0.93	35744.14	7688	4.649	15.9
16:00	37.5	34	14.8	76.8	12.5		73.1	1.13	35.2	0.93	35370.83	7851	4.505	15.4
17:00	36.4	41.3	15.8	81	13.8		77.1	1.13	38.7	0.93	35837.46	7591	4.721	16.1
18:00	35.7	37	14.9	80.3	12.9		70.6	1.13	36.4	0.93	31917.74	8201	3.892	13.3
19:00	34.3	41.5	13.4	80.2	11.5		70.7	1.14	32.9	0.94	35589.69	8129	4.378	14.9
20:00	32.7	47	14.3	83.5	12.7		70.3	1.14	35.9	0.94	32388.50	8126	3.986	13.6
21:00	33.1	43	11.7	82.7	10.1		68.3	1.14	29.7	0.94	36342.91	8112	4.480	15.3
22:00	32.6	44	11.4	82.8	9.9		67.5	1.15	29	0.95	36566.73	8127	4.499	15.4
23:00	31.8	48	11.4	85.3	10.1		68.3	1.15	29.6	0.95	36756.69	7365	4.991	17
0:00	31.8	48	11.5	84.8	10.1		68.3	1.15	29.7	0.95	36661.71	7959	4.606	15.7
1:00	31.2	50	11.5	87.7	10.4		67.9	1.15	30.2	0.95	35806.90	7615	4.702	16
2:00	31.6	50.8	11.3	87.3	10.2		69.6	1.15	29.6	0.95	37991.41	7818	4.859	16.6
3:00	29.9	54.8	10.7	90.5	9.9		67	1.15	29.1	0.95	35996.86	8301	4.336	14.8
4:00	29.6	53	10.4	89.5	9.5		65	1.16	28.1	0.96	35351.83	8256	4.282	14.6
5:00	29.8	52.8	9.8	88.9	8.9		65.5	1.16	26.8	0.96	37076.31	8214	4.514	15.4
6:00	28.4	52.3	10.2	90.9	9.4		60.9	1.16	28	0.96	31519.66	7435	4.239	14.5
7:00	30.9	52.3	11.8	89.5	10.9		68.7	1.15	31.3	0.95	35521.97	7527	4.719	16.1
8:00	33.8	45	13.8	82.9	12.2		72	1.14	34.4	0.94	35401.39	7587	4.666	15.9
9:00	36	29	13.8	81.8	12.0		63.8	1.13	34.1	0.93	27718.04	7718	3.591	12.3

Results and Calculations for OEM6 - CZ5

IEC Hybrid Unit , Air flow = 1750 cfm , Altitude = 2 m, , water bath area = (2400*1600) mm2, size of duct for air balancing = 0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out IEC-H	RH out IEC-H	Twb out IEC-H	h amb	ρ amb	h out IEC-H	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
10:00	35.7	35.1	16	93.3	15.3	68.8	1.13	42.8	1.20	31128.46	4752	6.551	22.4
11:00	35	36.4	15.8	94.1	15.2	68.2	1.14	42.7	1.21	30800.01	4754.5	6.478	22.1
12:00	34.8	36.8	17.1	93.8	16.5	68	1.14	46.1	1.21	26451.78	4706	5.621	19.2
13:00	34.6	38.9	16.1	94.4	15.5	69.1	1.14	43.4	1.21	31041.58	4666.5	6.652	22.7
14:00	34.3	38.5	16.5	94.3	15.9	68	1.14	44.7	1.21	28142.76	4600.1	6.118	20.9
15:00	35.2	38.3	15.6	94.3	15.0	70.5	1.14	42.2	1.21	34181.98	4607.4	7.419	25.3
16:00	34	37.3	16.1	94.8	15.6	66	1.14	43.5	1.21	27176.48	4605.5	5.901	20.1
17:00	34.3	42.5	15.6	94.9	15.1	71.6	1.14	42.3	1.21	35389.82	4735.8	7.473	25.5
18:00	31.1	47.5	16.5	94.5	15.9	65.7	1.15	44.6	1.22	25709.06	4714.4	5.453	18.6
19:00	31.1	48	15	94.4	14.5	66.2	1.15	40.5	1.22	31313.88	4576.9	6.842	23.4
20:00	30.6	45.1	14.9	94.5	14.4	62.4	1.15	40.3	1.22	26927.50	4587.1	5.870	20
21:00	31	43.4	14.6	95	14.1	62.5	1.15	39.5	1.22	28024.09	4740.1	5.912	20.2
22:00	29.6	41.2	14.6	95.8	14.2	57	1.16	39.7	1.23	21262.29	4795.1	4.434	15.1
23:00	29.6	31.7	10.9	95.1	10.5	50.8	1.16	30.4	1.23	25072.29	4839.7	5.181	17.7
0:00	29.3	30.7	10.2	95.2	9.8	49.4	1.16	28.8	1.23	25318.10	4858.6	5.211	17.8
1:00	28.2	30.8	9.3	95	8.9	47.1	1.17	26.7	1.24	25288.43	5067	4.991	17
2:00	28	30.5	9.2	95.1	8.8	46.5	1.17	26.5	1.24	24792.58	4881.8	5.079	17.3
3:00	28.4	27	9.1	95	8.7	45.1	1.17	26.4	1.24	23181.06	4924	4.708	16.1
4:00	28.5	27.3	8.1	95.1	7.7	45.5	1.17	24.3	1.24	26280.14	4993.5	5.263	18
5:00	27.5	29.8	8.4	95.2	8.0	45	1.17	24.8	1.24	25040.51	4970.6	5.038	17.2
6:00	29.2	28.5	11.6	95.6	11.2	47.8	1.16	32.2	1.23	19172.93	5068.6	3.783	12.9
7:00	33.4	27.3	10.7	95.5	10.3	56.1	1.15	30	1.22	31801.25	4859	6.545	22.3
8:00	35	29.5	12.1	95.8	11.7	61.7	1.14	33.5	1.21	34061.19	4784.4	7.119	24.3
9:00	34.9	29.8	14.1	96.1	13.7	61.9	1.14	38.6	1.21	28142.76	4723.5	5.958	20.3
10:00	35.8	30	14.9	95.8	14.5	64.4	1.13	40.6	1.20	28494.52	4765.4	5.979	20.4

Results and Calculations for OEM6 - CZ5

DX Unit , Air flow = 1750 cfm , Altitude = 2 m, duct size =0.3 m * 0.7 m

Hour	Tdb amb	RH amb	Tdb out DX	RH out DX	Twb out DX	h amb	ρ amb	h out DX	Air mass Flow rate (Qp)	Total Cooling Capacity (q_tot)	Total Power Input (W)	COP	EER
	°C	%	°C	%	°C	kJ/kg	kg/m3	kJ/kg	kg/s	W	W	w/w	Btu/W.hr
10:00	35.7	35.1	16.3	81.7	14.4	68.8	1.13	40.2	1.20	34241.31	13200	2.594	8.9
11:00	35	36.4	16.1	78.6	13.9	68.2	1.14	38.9	1.21	35389.82	13200	2.681	9.2
12:00	34.8	36.8	17.4	85.2	15.8	68	1.14	44.2	1.21	28746.68	13200	2.178	7.4
13:00	34.6	38.9	16.4	81.6	14.5	69.1	1.14	40.4	1.21	34665.11	13200	2.626	9
14:00	34.3	38.5	16.7	82.5	14.9	68	1.14	41.6	1.21	31887.07	13000	2.453	8.4
15:00	35.2	38.3	16.5	80.9	14.5	70.5	1.14	40.5	1.21	36235.31	12900	2.809	9.6
16:00	34	37.3	16.5	81.8	14.6	66	1.14	40.8	1.21	30437.66	12900	2.360	8.1
17:00	34.3	42.5	16.2	83.7	14.5	71.6	1.14	40.7	1.21	37322.37	12700	2.939	10
18:00	31.1	47.5	16.4	88.4	15.2	65.7	1.15	42.6	1.22	28145.94	12200	2.307	7.9
19:00	31.1	48	14.6	86	13.2	66.2	1.15	37.2	1.22	35334.73	12100	2.920	10
20:00	30.6	45.1	14.4	85.9	13.0	62.4	1.15	36.8	1.22	31192.03	12000	2.599	8.9
21:00	31	43.4	13.6	86.5	12.3	62.5	1.15	34.9	1.22	33628.91	12000	2.802	9.6
22:00	29.6	41.2	13.9	87.1	12.7	57	1.16	35.6	1.23	26301.33	11900	2.210	7.5
23:00	29.6	31.7	11.1	82.2	9.5	50.8	1.16	28.2	1.23	27776.17	11600	2.394	8.2
0:00	29.3	30.7	11	81.4	9.4	49.4	1.16	27.7	1.23	26670.04	11400	2.339	8
1:00	28.2	30.8	10.3	80.8	8.6	47.1	1.17	26.2	1.24	25908.25	11300	2.293	7.8
2:00	28	30.5	10.4	80.4	8.7	46.5	1.17	26.2	1.24	25164.47	11200	2.247	7.7
3:00	28.4	27	11.1	77	9.1	45.1	1.17	27	1.24	22437.29	11400	1.968	6.7
4:00	28.5	27.3	10.5	75.6	8.4	45.5	1.17	25.6	1.24	24668.62	10800	2.284	7.8
5:00	27.5	29.8	10.6	79	8.8	45	1.17	26.5	1.24	22933.14	10300	2.227	7.6
6:00	29.2	28.5	12.4	80.5	10.6	47.8	1.16	30.7	1.23	21016.48	11400	1.844	6.3
7:00	33.4	27.3	12.6	78.7	10.6	56.1	1.15	30.7	1.22	30948.35	11700	2.645	9
8:00	35	29.5	14.6	79.6	12.6	61.7	1.14	35.5	1.21	31645.50	12600	2.512	8.6
9:00	34.9	29.8	16.4	82.4	14.6	61.9	1.14	40.7	1.21	25606.29	12700	2.016	6.9
10:00	35.8	30	16.1	80.2	14.0	64.4	1.13	39.3	1.20	30050.94	13000	2.312	7.9

Annex (6) Accuracy and Sensitivity of Measurements:

In order to ensure reliable results, all measurements were carried out using instruments that have been calibrated at internationally accredited laboratories. The accuracy of the measurements was scrutinized to determine the degree of how close a calculated or measured value is to the actual value. One factor that can determine the accuracy of results is the measurement tool used, as it can only record as many digits as it allows.

Accuracy of measurements is guaranteed by following the posterior steps:

1- Collecting data: records for all measurements were electronically saved using the equipment's software programs to tools such as spreadsheets.
2- Values were sorted to help determining the range of data collected.
3- The average value of the data, gives a measurement of accuracy.
4- Each individual measurement was subtracted from the average value to give a set of absolute deviations. The absolute deviation of each measurement show how close the value is to the average value.
5- Precision was measured as the average value plus or minus the average deviation.
6- The uncertainty is calculated by defining the sources of uncertainty in the measurement.
7- The uncertainty from each source is estimated then combined to give an overall estimation.
8- There are two approaches to estimate Uncertainty:
    a. Type A evaluations: uncertainty estimated using statistics (repeated readings)
    b. Type B evaluations: uncertainty estimated from any other information (resolution, annual drift in errors, manufacture's specifications, and environmental conditions).

The following Table shows the names, model numbers, serial numbers, scale ranges, accuracy and expanded uncertainty of each instrument used during the tests performed.

Used Apparatus	Code of Used Apparatus	Measured Property	Model	Serial Number	Scale Range	Accuracy	Expanded Uncertainty	Item Photo
Air Flow Meter	**K; CFM**	**Air flow**	**KIMO CP300**	**06072114**	**0 to 100000 m3/h**	**±1 cfm**	**0.24%**	
Weather Station,	**WS; T_{amb}**	**Inlet dry bulb temperature for both Units**	**HOBO U30 ONSET**	**10221018**	**0:50°C 0:100%RH**	**±0.1°C ±0.7%RH**	**1.7%, 0.4°C**	
	WS; RH_{amb}	**Inlet Relative humidity for both Units**						
Thermo-Hygrometer	**K2; T_{out}**	**Outlet dry bulb temperature for IEC Hybrid Unit**	**KIMO TH300**	**MEH1000821**	**-40:180°C, 0:100%**	**±0,3%°C ±1,5%RH**	**1.7%, 0.4°C**	
	K2; RH_{out}	**Outlet Relative humidity for IEC Hybrid Unit**						

Used Apparatus	Code of Used Apparatus	Measured Property	Model	Serial Number	Scale Range	Accuracy	Expanded Uncertainty	Item Photo
Compressor power meter - IEC hybrid unit	**Comp.; IEC-H**	**Power consumption of the Compressor of the IEC hybrid Unit**	**ENTES**	**---**	**Max V: 690V Current: 1/5A Freq.: 45:65Hz**	**±1.5%**	**0.08 kW**	
Pump power meter - IEC hybrid unit	**Pump; IEC-H**	**Power consumption of the Pump of the IEC hybrid Unit**	**ENTES**	**---**	**Max V: 690V Current: 1/5A Freq.: 45:65Hz**	**±1.5%**	**0.08 kW**	
Evaporative Fan power meter - IEC hybrid unit	**Evap. Fan; IEC-H**	**Power consumption of the Evaporator Fan of the IEC hybrid Unit**	**ENTES**	**---**	**Max V: 690V Current: 1/5A Freq.: 45:65Hz**	**±1.5%**	**0.08 kW**	
Supply fan power meter - IEC hybrid unit	**Sup. Fan; IEC-H**	**Power consumption of the Supply Fan of the IEC hybrid Unit**	**ENTES**	**---**	**Max V: 690V Current: 1/5A Freq.: 45:65Hz**	**±1.5%**	**0.08 kW**	

Used Apparatus	Code of Used Apparatus	Measured Property	Model	Serial Number	Scale Range	Accuracy	Expanded Uncertainty	Item Photo
Power Analyzer of total power consumption of IEC hybrid Unit	**Pw_{Tot}; IEC-H**	**Total Input power of IEC Hybrid Unit**	**Fluke 435-II**	**19673107**	**Max 6000 MW**	**±1%**	**0.06 kW**	
Air meter	**F975; T_{out}**	**Outlet dry bulb temperature for DX Unit**	**Fluke 975**	**2149015**	**-20:50°C, 0:100%**	**±0.5°C**	**1.7 %, 0.4 °C**	
Thermo-Hygrometer	**K3; T_{out}**	**Outlet Relative humidity for DX Unit**	**KIMO TH300**	**MEH1000820**	**-40:180°C, 0:100%**	**±0,3%°C ±1,5%RH**	**1.7 %, 0.4 °C**	
Power meter of total power consumption of DX Unit	**Pw_{Tot}; DX**	**Total Input power of DX Unit**	**6300 - Kyoritsu KEW**	**---**	**Max 200 MW**	**±0.2%f.s**	**0.06 kW**	

Annex (7) The presentation of the outreach campaign:

Dear Invitee,

UNIDO, UN environment and HBRC are pleased to invite you to attend a workshop on output of:

"Project of The Transformation of Commercial Air Conditioning Companies"

HCFC Phase-out Management Plan (HPMP II- EGYPT)

Date: Wednesday 21st December 2022.

The meeting will be held at HBRC, Address: 87 El-Tahrir ST. Dokki - Giza.

Kindly note that the meeting starts at 10:30 a.m. and is planned to end at 2:00 p.m. (Cairo time).

Prof. Sayed Shebl

Team Leader, Director of
Electro – Mechanical Institute, HBRC

Prof. Alaa Olama

Project Manager and Technical Consultant

Project of the Transformation of Commercial Air Conditioning Companies (HCFC Phase-out Management Plan (HPMP) EGYPT (Stage UNIDO project: No.140400)

HBRC – Wednesday 21 December 2022, 10:30 AM– 14:00 PM

Abstract

The project aims at providing technical assistance for the implementation of low GWP technology as well as examining the introduction of a Not-In-Kind technology, namely: Indirect Evaporative Cooling (IEC).The project also proposes to look into the introduction of IEC in commercial air conditioning applications. The goal of the project is to secure phase out of HCFC in the commercial air conditioning manufacturing sector.

Program

- 10:30 – 11:00 am **Registration**
- 11:00 – 11:45 am **First Lecture**

  -Testing Methodology and Instrumentation

  Prof. Sayed Shebl
  Director of Electro- Mechanical Institute HBRC
- 11:45 – 12:15 pm **Coffee Break**
- 12:15 – 13:00 pm **Second Lecture**

  - Discussion OF Findings and Conclusion

  Prof. Alaa Olama
  International Expert and UN RTOC member
- 13:00 – 14:00 pm **Open Discussion**

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

Workshop

SPEAKERS

Prof.Sayed Shebl
Director of Electro- Mechanical Institute HBRC

Prof. Alaa Olma
International Expert and UN RTOC member

21 Wednesday 2022 11:00 AM - 14:00 PM

LIVE

Zoom Meeting ID: 8360149880
Passcode: hbrc2021

HBRC
87 El-Tahreer ST. Dokki - Giza

Annex(7): The presentation of the outreach campaign:

Transformation of Commercial Air Conditioning Companies

HCFC Phase-out Management Plan (HPMP) EGYPT (Stage II), UNIDO ID:140400

Direct Indirect Evaporative Cooling in Egypt

Presented by:

Prof. Alaa Olama;

The Project general Manager and Technical Consultant

Prof. Sayed Shebl;

Director of Electro-Mechanical Research Institute EMI, HBRC, Egypt

Phase-out & Phase-down Strategies

Presented by:

Eng. Ayman Eltalouny;
International Partnerships Coordinator
OzonAction, Law Division
UN Environment Programme (UNEP)

Why Refrigeration and Air-Conditioning Sector is of high importance

Economics

- One of the fastest Growing sectors globally
- Protecting Capital Expenditures (CAPEX) & Minimizing Operating Expenditures (OPEX)
- Competent workforce and employment opportunities

Environment

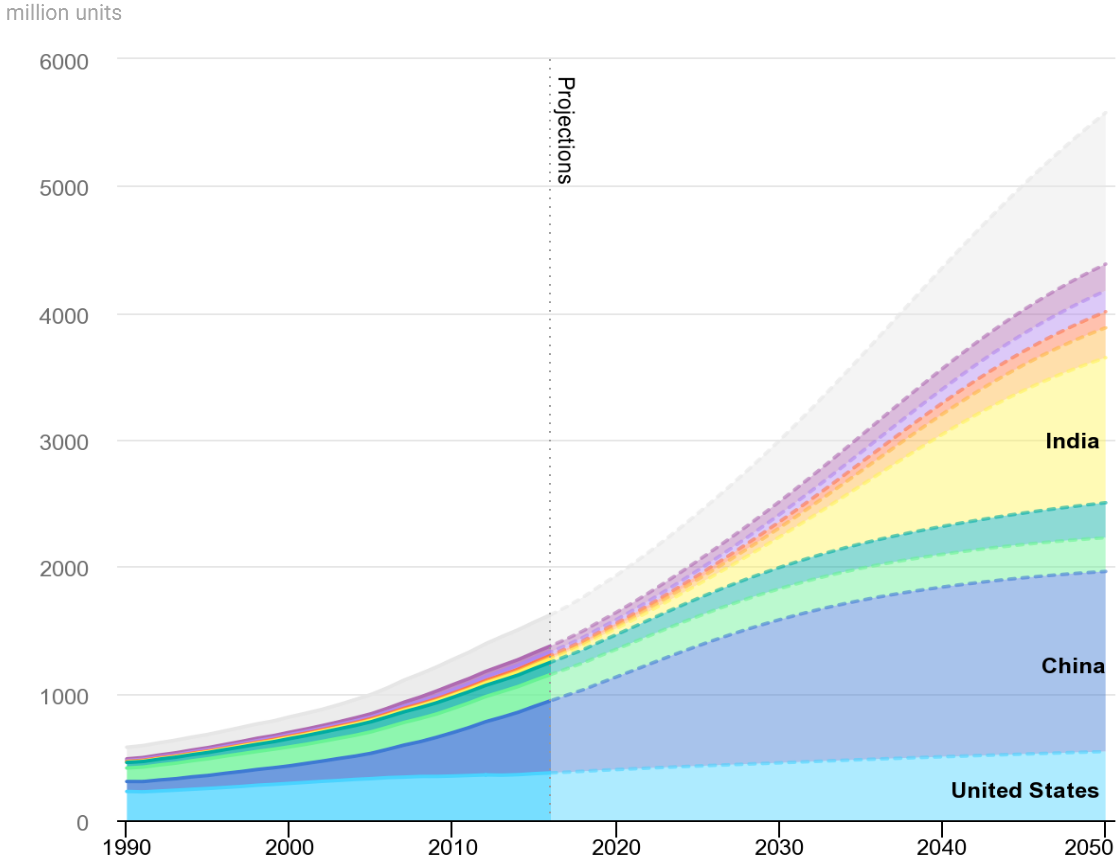
- Environmental Footprint
- Emissions Reduction
- Climate Action
- Energy Efficiency
- Refrigerant Management

Sustainability

- Contribution to Food Security and Food Safety
- Sustainable Urban Planning & Cities
- Renewables
- Innovation and Smart Operations
- Sustainable Consumption of Materials

Population Growth & Energy Bill

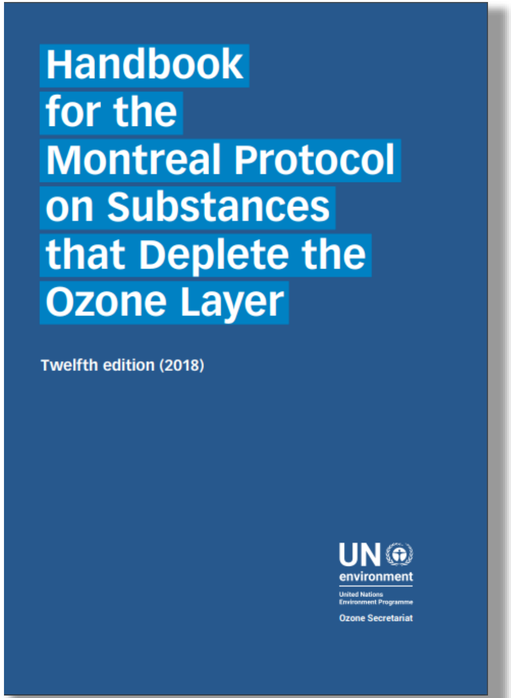
- Cooling is the fastest growing use of energy in buildings
- Cooling will drive peak electricity demand, especially in hot countries
- Most homes in hot countries have not yet purchased their first AC
- Investing in more efficient ACs could cut future energy demand in half



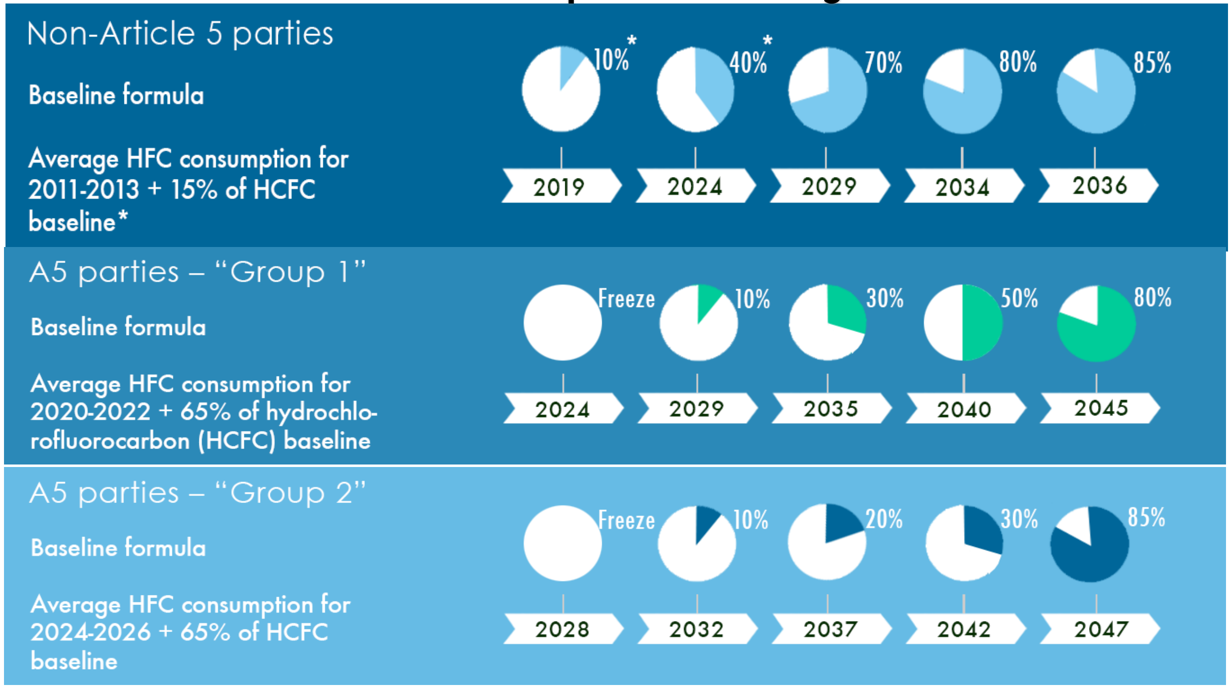
Global air conditioner stock, 1990-2050

IEA Future of Cooling Report (2018) updated 19-Nov-2019

Montreal Protocol –
A tool to protect ozone & climate

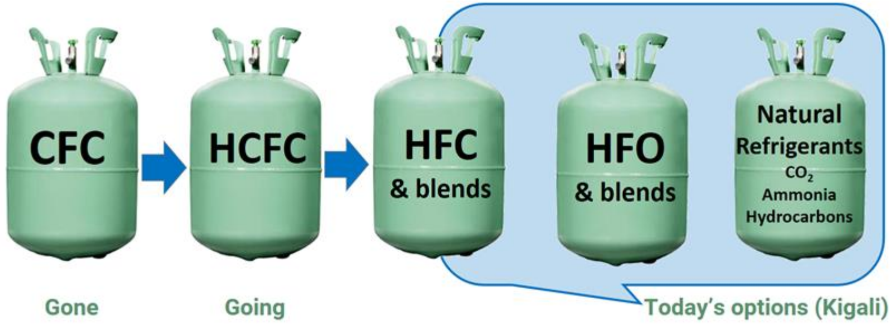


HFC control measures as per the 2016 Kigali Amendment



Refrigerant (re)evolution – transition to low-GWP

- **1830s-1930s** – **whatever worked**: primarily familiar solvents and other volatile fluids including ethers, ammonia (NH3), carbon dioxide (R-744), sulphur dioxide (R-764) and others
- **1931-1990s** – **safety and durability**: primarily chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), ammonia, and water (mostly used in absorption cycles).
- **1990s – 2010s** – **avoidance of Ozone Depleting Substances**, following attention to stratospheric ozone protection arising from the Montreal Protocol.
- **2010s onwards** – intention to adopt refrigerants with **as low a GWP as practicable** due to the focus on climate change.



100 Year GWP	Classification
< 30	Ultra-low or Negligible
< 100	Very low
< 300	Low
300-1000	Medium
> 1000	High
> 3000	Very high
> 10000	Ultra-high

UNEP, 2018 Quadrennial Report of the TEAP/RTOC of the Montreal Protocol

Refrigerant Selection Criteria

Climate impact
Other environmental impacts, including ODP
Energy efficiency
Thermal energy storage
Refrigerant cost
Commercial availability
Technological level
High ambient temperature fitness
Safety risk
Flammability & decomposition after refrigerant releases
Liability, responsibility

UNEP, 2018 Quadrennial Report of the TEAP/RTOC of the Montreal Protocol

Testing Strategies and Setup

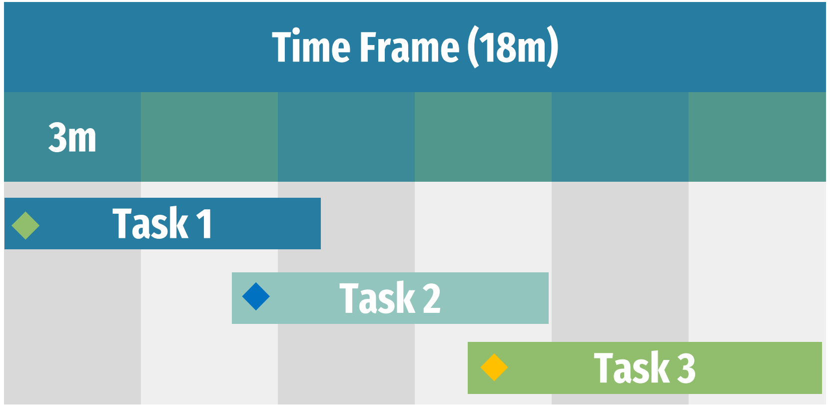
Presented by:

Prof. Sayed Shebl;
The Project Team Manager

Direct Indirect Evaporative Cooling (IEC) in Egypt

Start date	May 25, 2021	End date	Dec. 31, 2022

NIK Technology



Scope

- Phase out of HCFC in the commercial air conditioning manufacturing sector.
- Transformation of Commercial Air Conditioning Companies.

Purpose

- Introduction of a not-in-kind cooling technologies.
- Adoption of low-GWP technologies

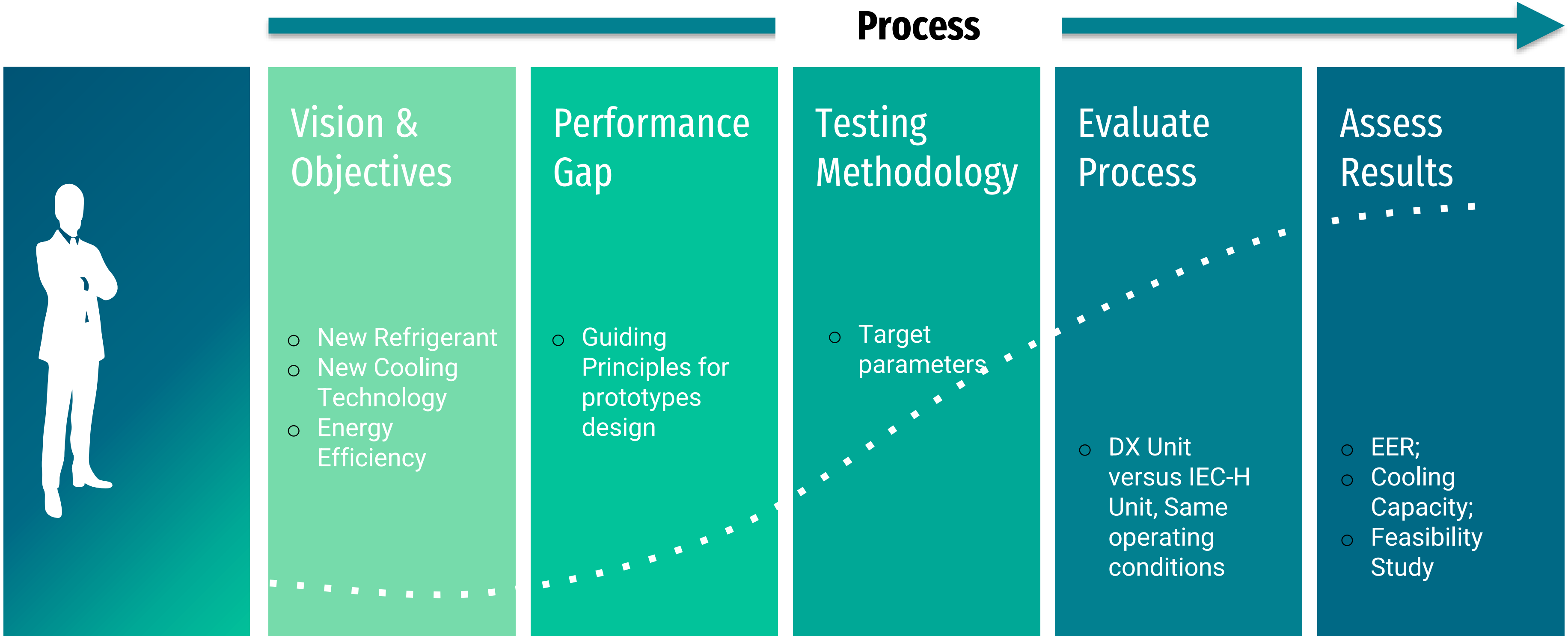
Milestones

1. Technical Assistance for product design
2. Incorporate IEC technology in existing systems
3. Field testing and commercial feasibility

Direct Indirect Evaporative Cooling (IEC) in Egypt

OEMs	
Delta Construction & Manufacturing (DCM)	TIBA Engineering Industries Co.
MISR Engineering Industries	VOLTA EGYPT
Egyptian German Air Treatment Company (EGAT)	Misr Refrigeration & Air Conditioning MFG Co. (MIRACO)

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


Process
Vision & Objectives
New Refrigerant
New Cooling Technology
Energy Efficiency
Performance Gap
Guiding Principles for prototypes design
Testing Methodology
Target parameters
Evaluate Process
DX Unit versus IEC-H Unit, Same operating conditions
Assess Results
EER;
Cooling Capacity;
Feasibility Study

Which Climatic Zone?

Two climatic zones out of Eight representing Egypt

Field Testing Logistics

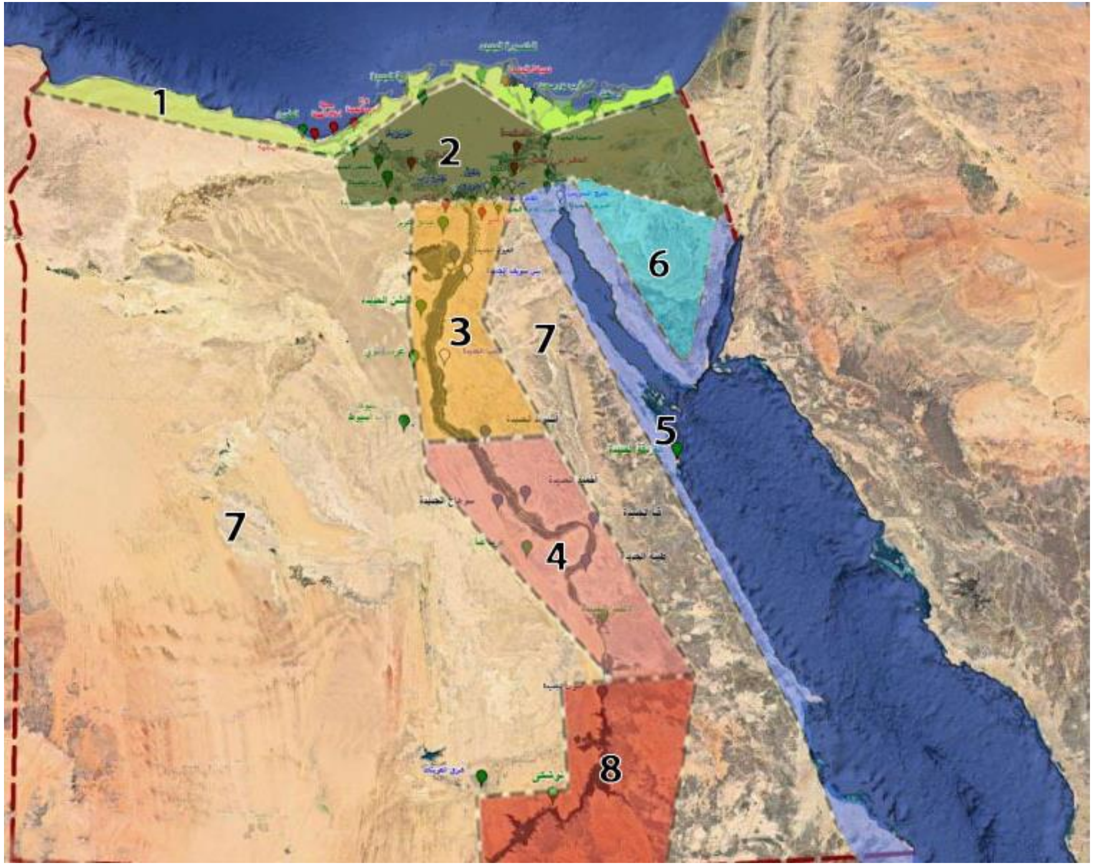
Testing Locations, and Used Apparatuses

Analyzing Data

Provide technical parameters obtained from field testing

Climatic Zones and the New Cities of Egypt

No.	Zone			
1	**North Coast**	• Tourist villages • New Damietta • Alamein	• East of Port Said • New Burj Al Arab • New Rashid	• West of Port Said • New Mansoura • Bir El- Abd
2	**Delta And Cairo**	• 10th of Ramadan • El shrouk • New Cairo • The new capital • New Salhia • Sheikh Zayed	• New of October • Obour City • El- Sadat • Badr • New Zayed • New Ismailia	• New El Obour • Nubaria • New Nubaria • New Alexandria • New Sphinx • Capital Gardens
3	**North Upper Egypt**	• 15th May • New Fayoum • New Beni Suef	• South New Cairo • 6th October • New Minya	• October Gardens • West of Mallawi • The new of El Fashn
4	**Southern Upper Egypt**	• New Assiut • New Sohag • New Akhmim	• West Qena • New Luxor	• New Qena • New Tiba
5	**Eastern Coast**	• New Hurghada	• Suez Gulf	• New Suez
6	**High Heights**			
7	**Desert**	• East Owainat	• West Assiut	
8	**South of Egypt**	• New Aswan	• Toshki	



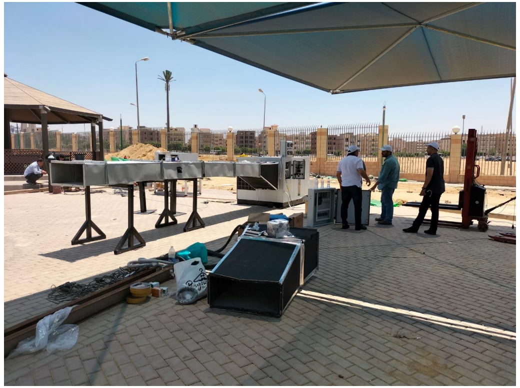
First Location - Climatic Zone 2 (Egyptian Russian University - Badr)

Location

30°08' 36" N 31°43' 06" E

Altitude

208 m
(above sea level)



Second Location - Climatic Zone 5 (Movenpick Soma Bay - Hurghada)

Location

26°49' 39" N 33°56' 13" E

Altitude

2 m
(above sea level)

Testing Progress

Setup prototypes in testing location

Step 1

Step 2

Adjust Airflow

Connect Measuring Apparatuses

Step 3

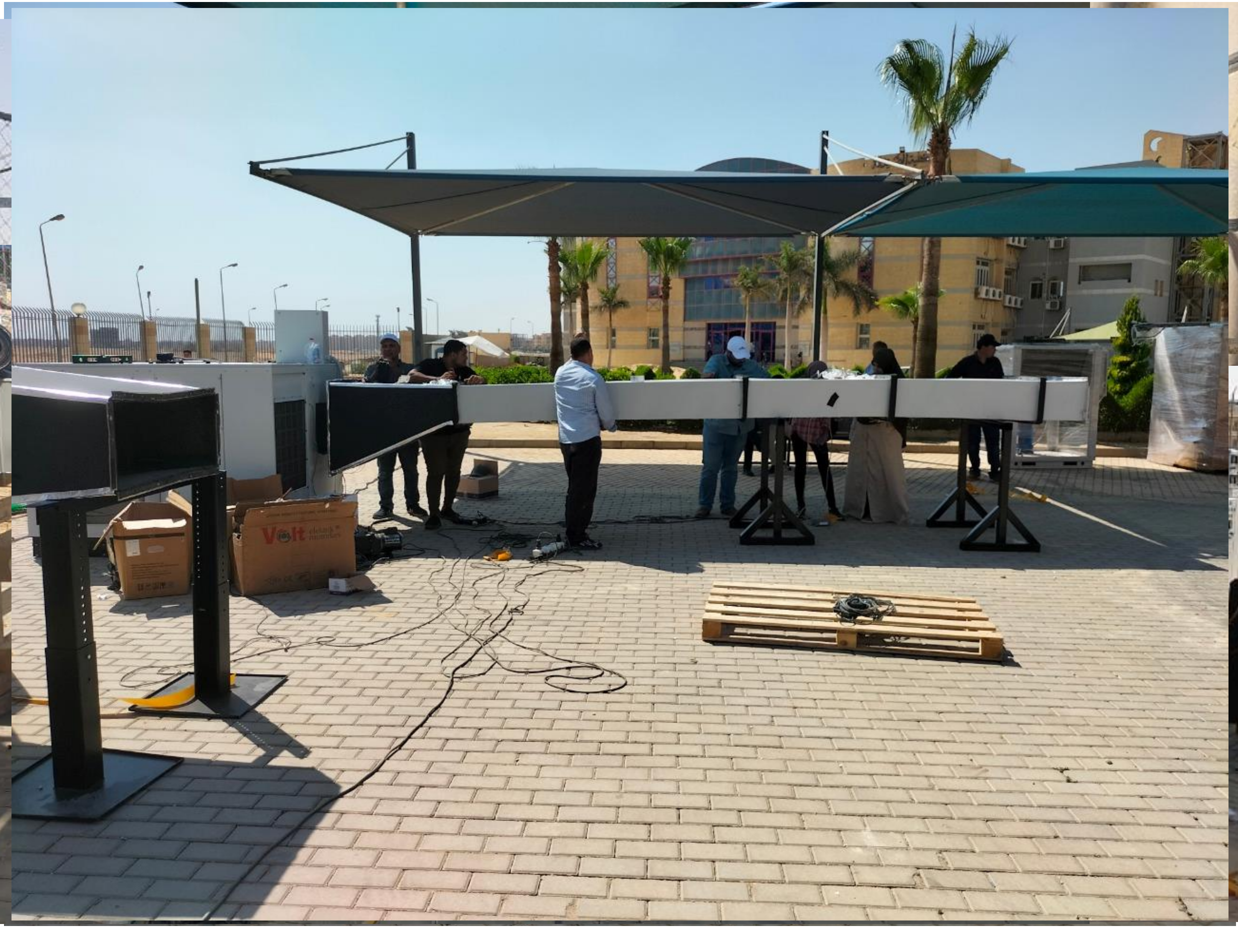
Step 4

Record measurements for 24 hours

Setup prototypes in testing location – CZ2

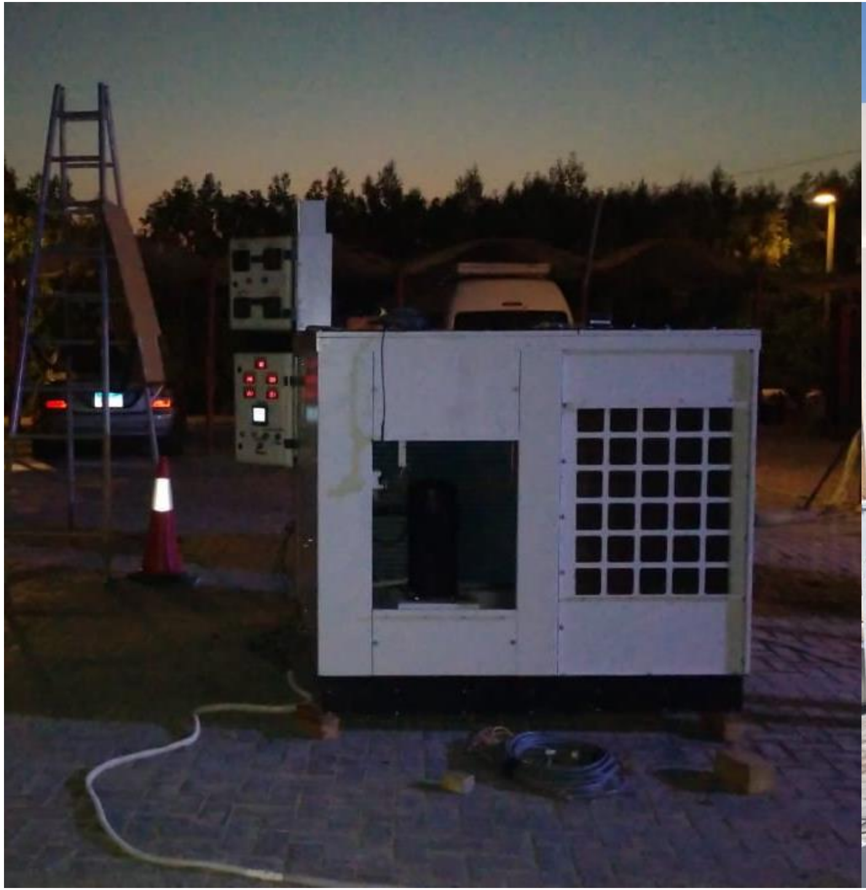
Setup prototypes in testing location – CZ5

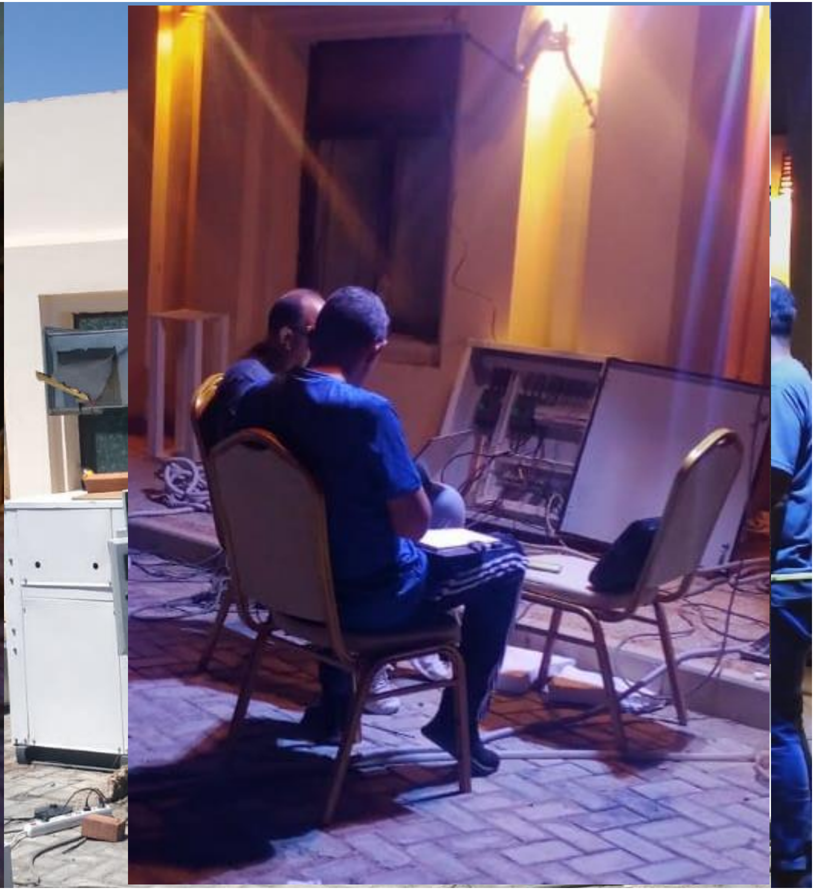
Airflow Setup

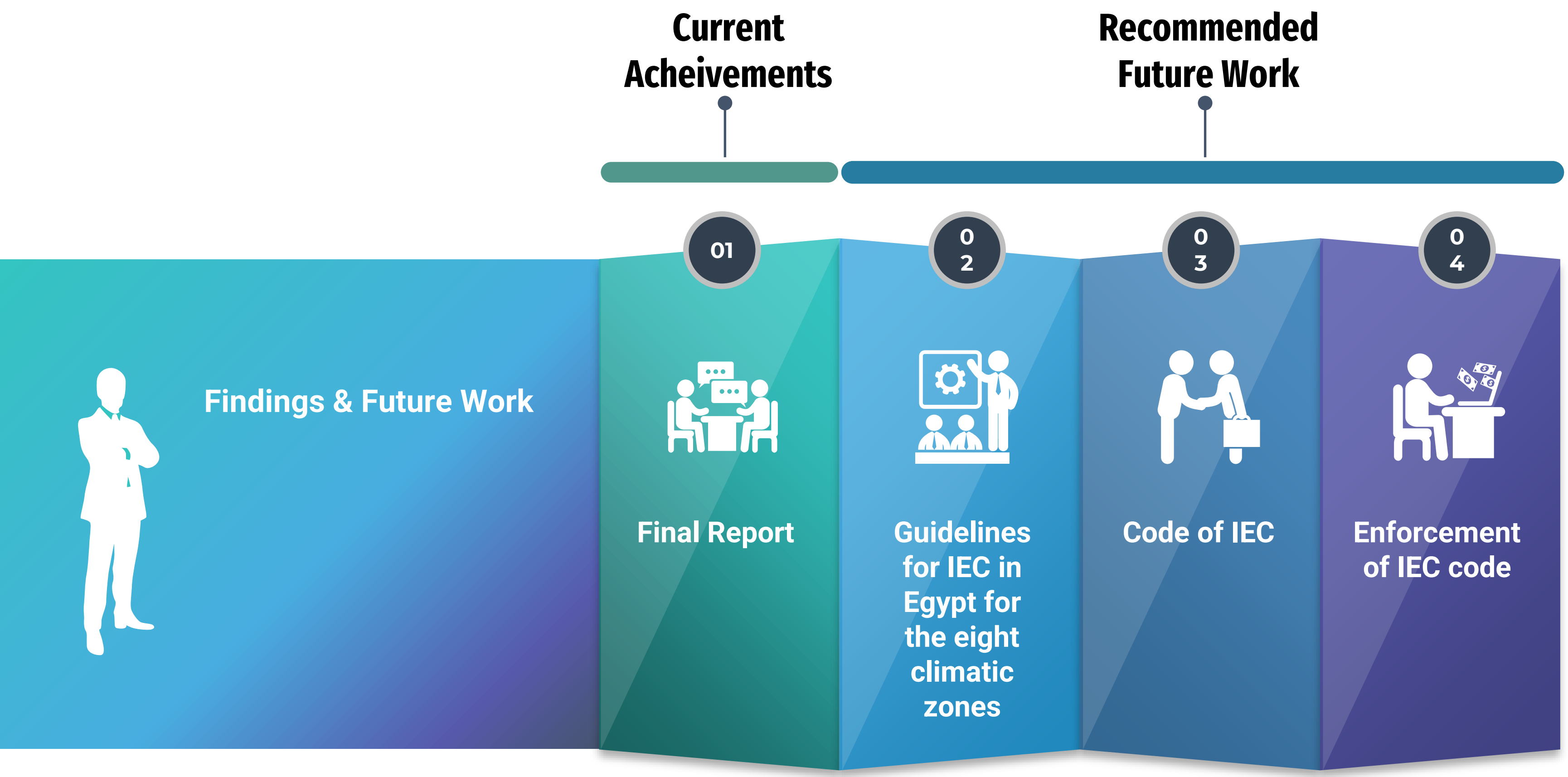


Record Measurement for 24 hours – CZ2

Record Measurement for 24 hours – CZ5





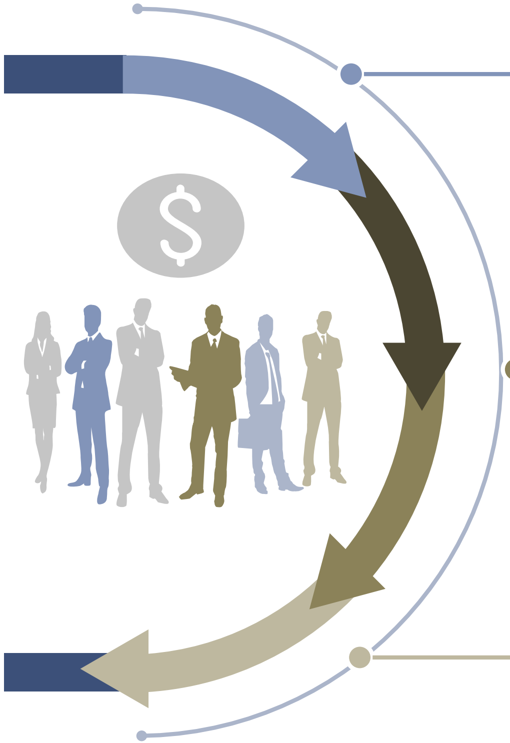

Current
Acheivements
Recommended
Future Work
Findings & Future Work
01
Final Report
0
2
Guidelines
for IEC in
Egypt for
the eight
climatic
zones
0
3
Code of IEC
0
4
Enforcement
of IEC code

Feasibility Study
&
Financial Analysis

Presented by:

Dr. Hossam Heiba
Manager Director of the General Authority for Investment and Free Zones

Feasibility Study



Cost of Operation
Energy & Water Consumption

Net Present Value
NPV amount EGP 24,621 with payback period of 3.11 years.

Total Saving
Favourable difference for IEC-H Unit

Max. Power Consumption IEC Hybrid Unit (W/hr)	8,607
Max. Power Consumption DX Unit (W/hr)	10,802
Annual Electricity Consumption IEC Hybrid Unit	37,698,660
Annual Electricity Consumption DX Unit	47,314,512
Average Cost (kW/hr)	1.60 (EGP)
Electricity cost for IEC Hybrid Unit (EGP)	60,318
Electricity cost for DX Unit (EGP)	75,703
Maximum Water Consumption for IEC Hybrid Unit (Liters/hr)	54
Annual Water consumption for IEC Hybrid Unit (Liters/hr)	236,520
Water Cost per Cubic meter	5.00 (EGP)
Water Cost for IEC Hybrid Unit (EGP)	1,183
Electricity Saving	15,385
Water Expenditure	(1,183)
Net Saving	**14,203**

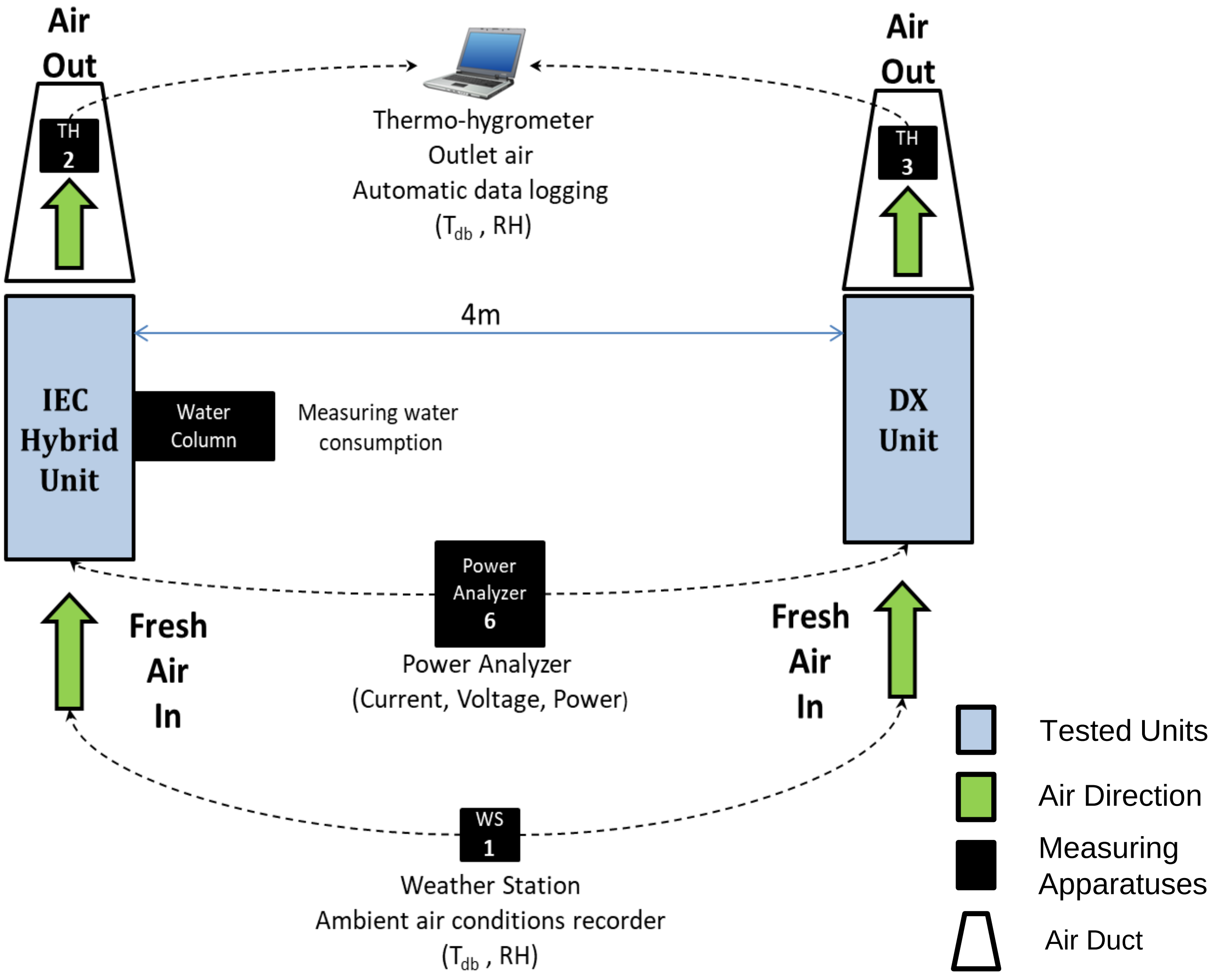
Results
&
Technical Analysis

Presented by:

Prof. Alaa Olama;
The Project general Manager and
Technical Consultant

Schematic Diagram

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 two of the eight climatic zones of Egypt (CZ2 & CZ5).



General 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.

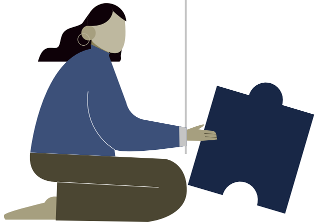
Primary Air Outlet

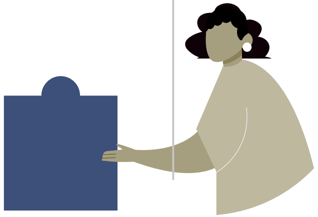
The primary air outlet dry bulb temperature maintained at 15°C

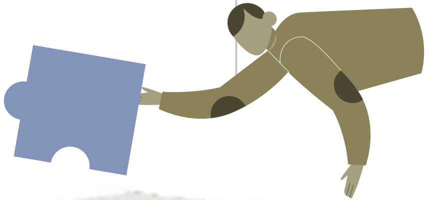
Confidentiality

No intentions to compare the performance of OEMs units. OEMs were labelled by a **confidential number**

Program Components | **Associated Activities** | **Collaborative Progress**





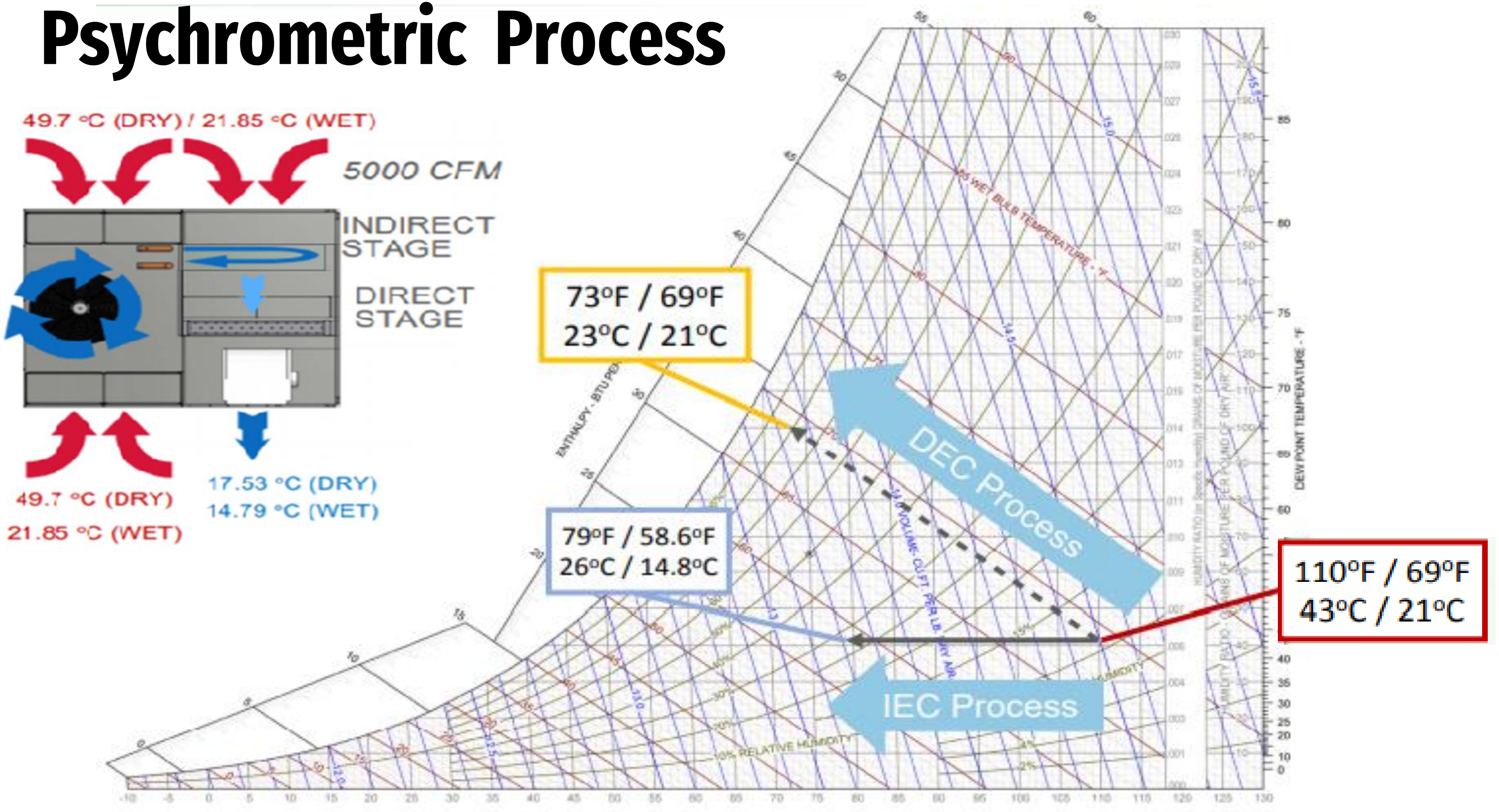


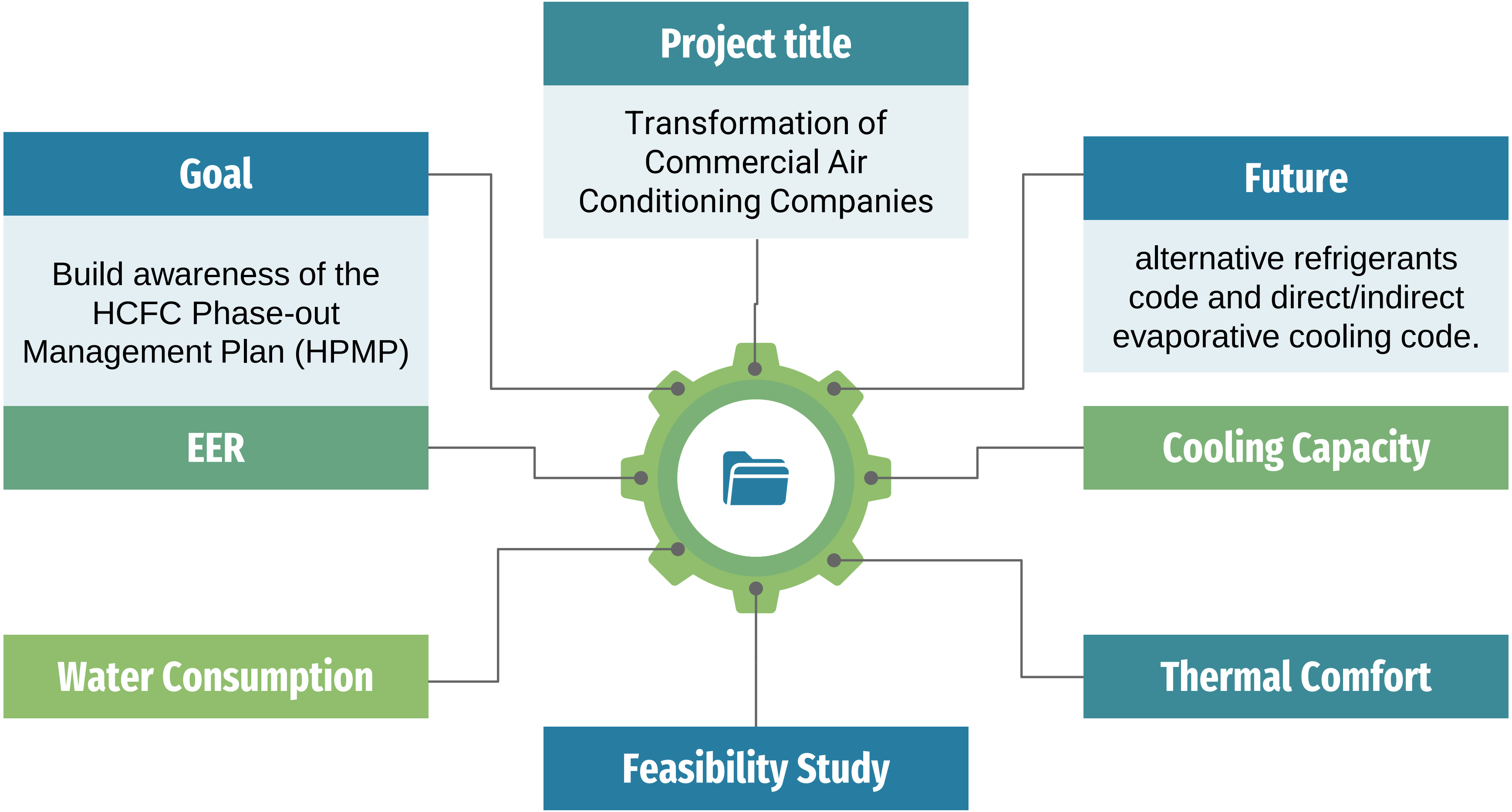
1st Stage — Cooling Tower

2nd Stage — Serpentine and air being cooled through it

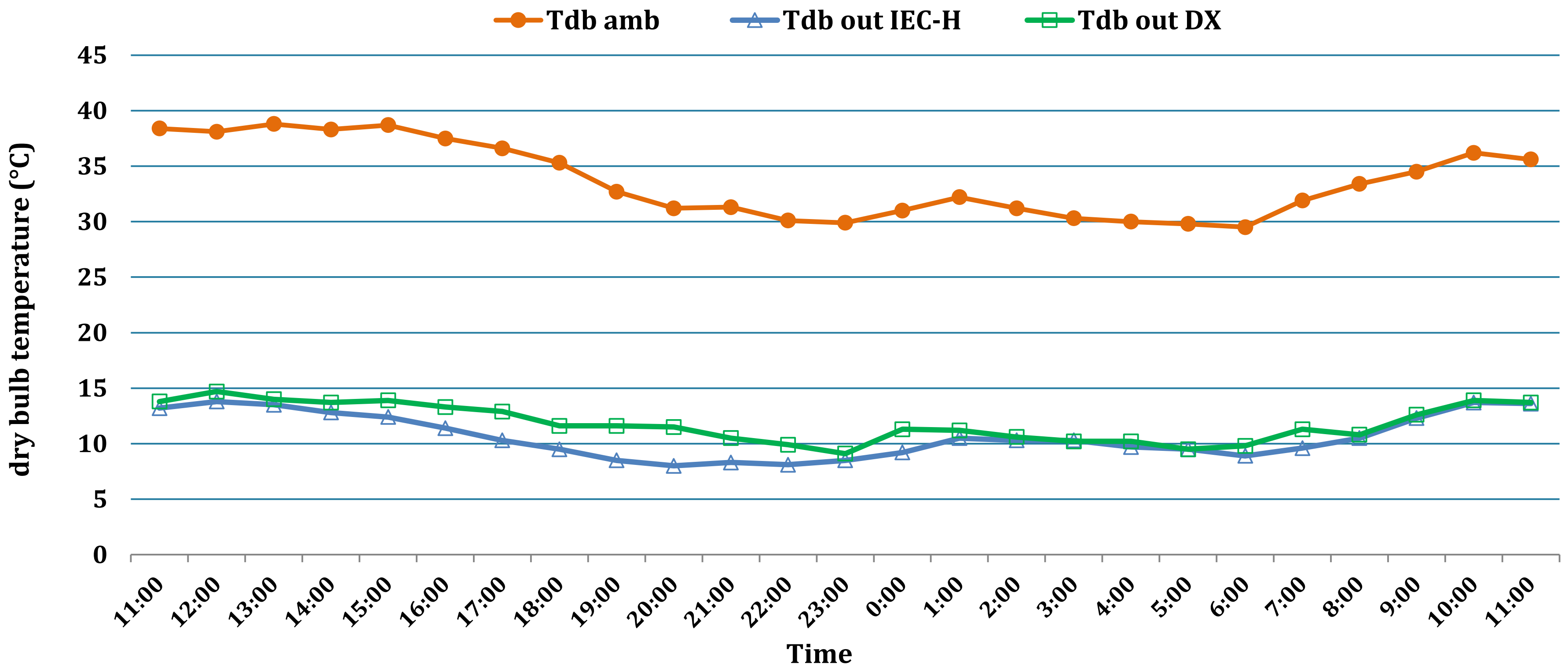
3rd Stage — Evaporation of water in the stream

Psychrometric Process



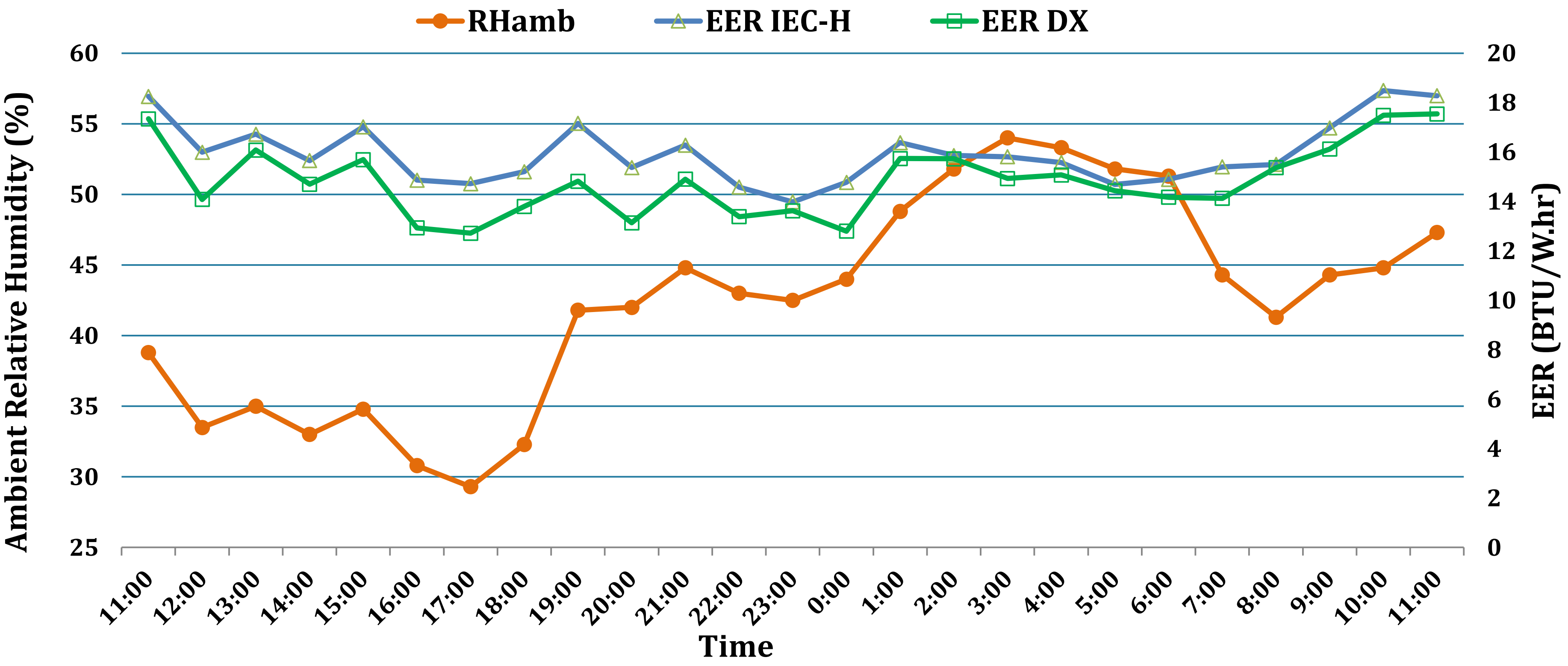

Project title
Transformation of Commercial Air Conditioning Companies
Goal
Build awareness of the HCFC Phase-out Management Plan (HPMP)
Future
alternative refrigerants code and direct/indirect evaporative cooling code.
EER
Cooling Capacity
Water Consumption
Thermal Comfort
Feasibility Study

Results Sample – Inlet Versus Outlet Temperature



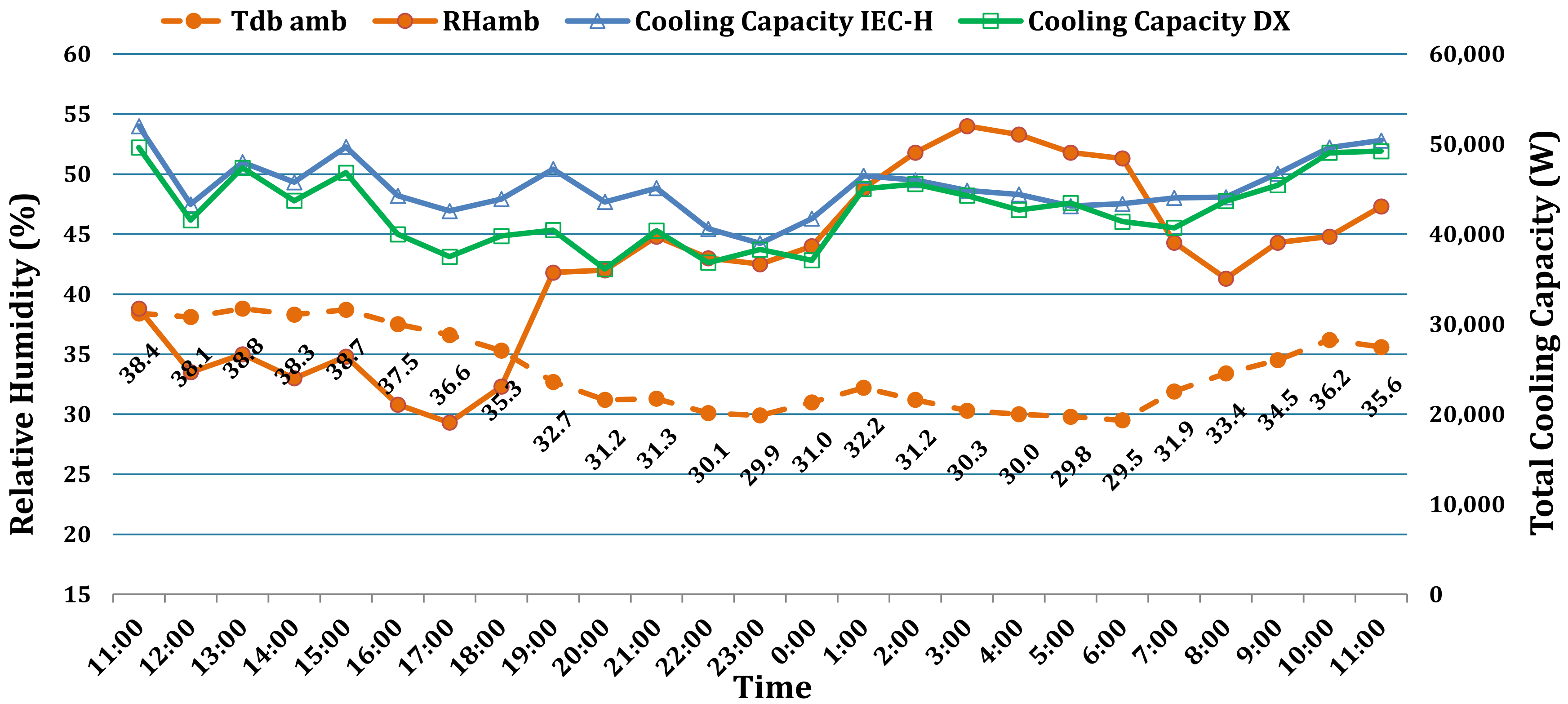
Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units for OEM2 at CZ5

Results Sample – EER



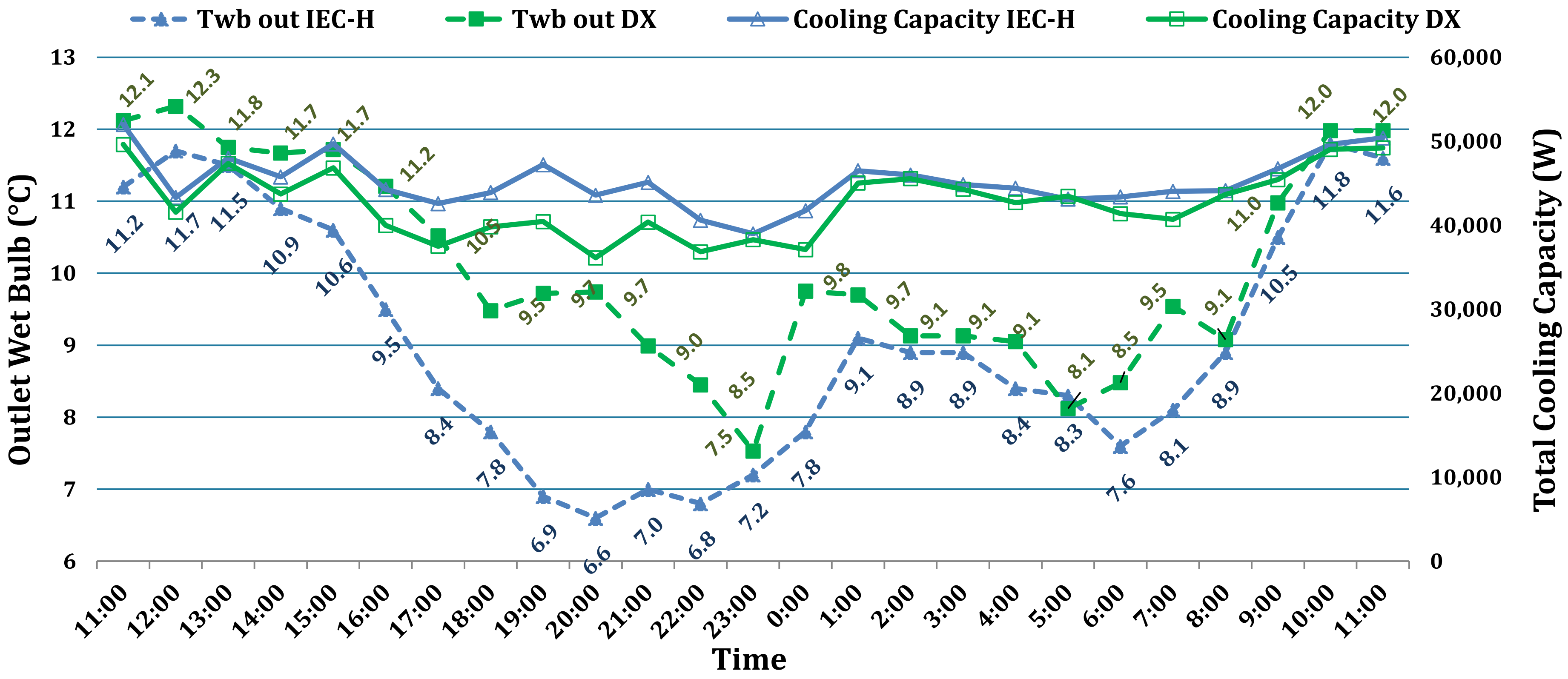
EER for IEC Hybrid Unit Versus DX unit for OEM2 at CZ5

Results Sample – Cooling Capacity



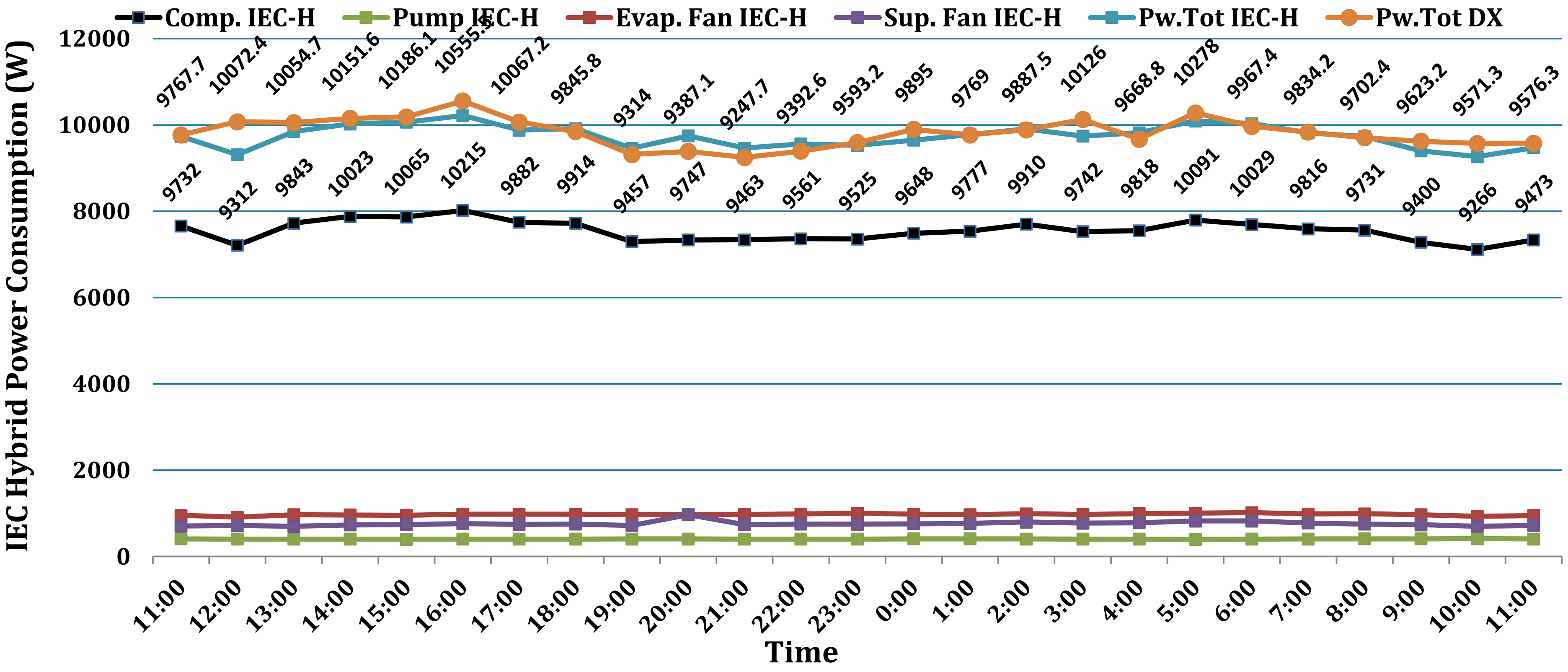
Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions for OEM2 at CZ5

Results Sample – Wetbulb



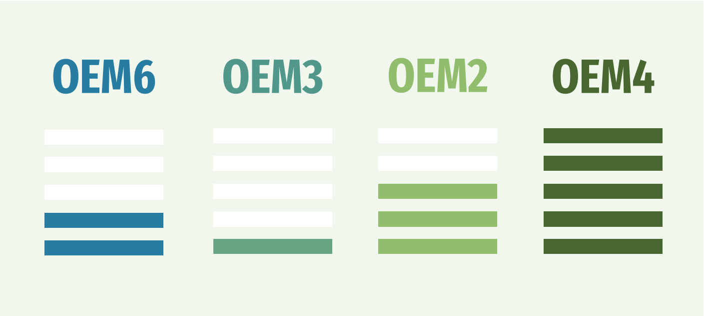
Cooling Capacity versus Outlet Wet Bulb Temperature for IEC Hybrid Unit & DX Unit for OEM2 at CZ5

Results Sample – Power Components



Power Consumption of DX Unit and IEC Hybrid Unit Components for OEM2 at CZ5

IEC-H Unit Compressor capacity compared to DX Unit compressor capacity



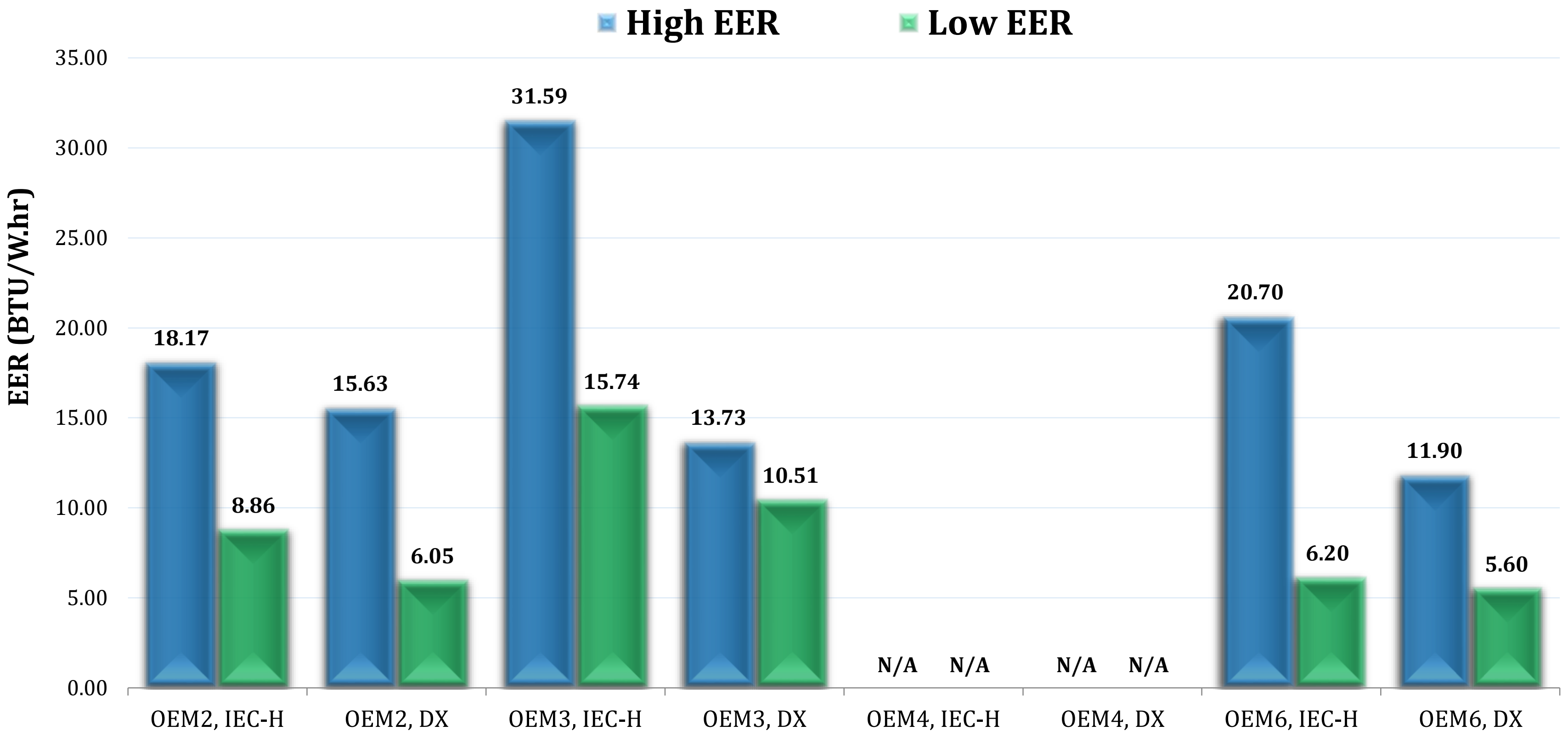
- IEC Compressor smaller by 60% → Lower cooling capacity
- IEC Compressor smaller by 70% → Lower cooling capacity
- IEC Compressor equal to DX Compressor → Equal cooling capacity
- IEC compressor larger by 20% → Equal cooling Capacity

Observations

No direct relationship indicating whether the capacity of the compressor of the IECH units had an impact on the capacity of the units and whether there was a critical capacity size defining this relationship

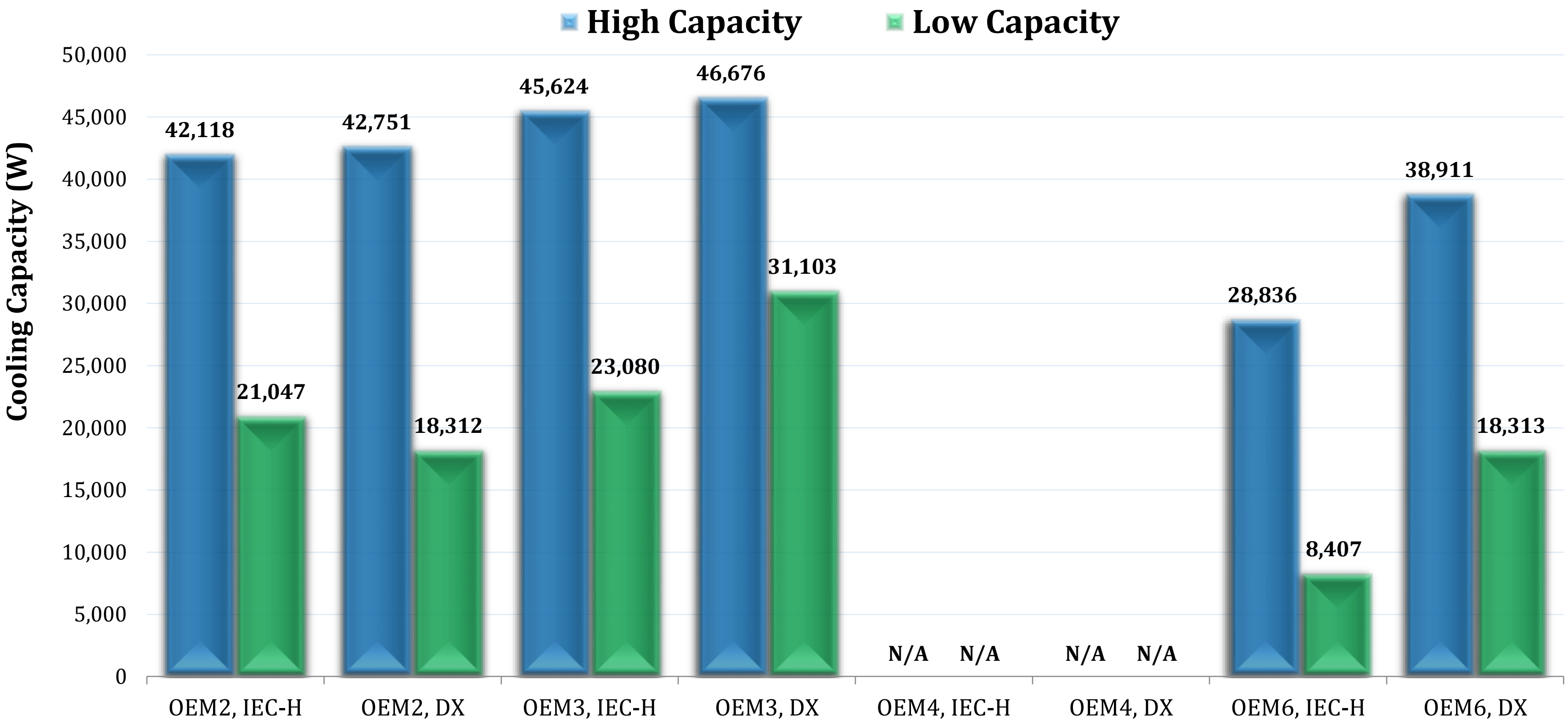
Important point that needs further investigation!

EER in CZ2

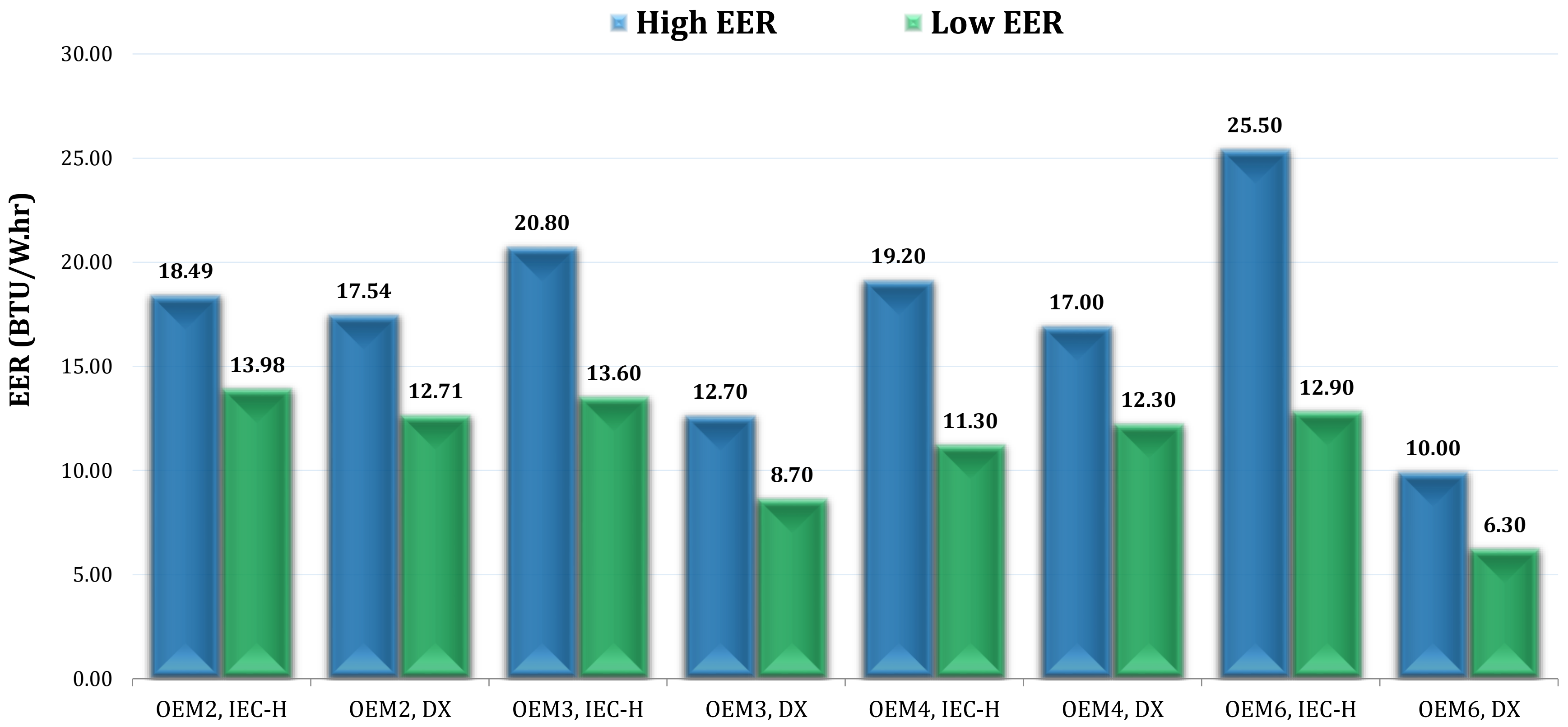


High EER
Low EER
EER (BTU/W.hr)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
18.17
8.86
15.63
6.05
31.59
15.74
13.73
10.51
N/A
N/A
N/A
N/A
20.70
6.20
11.90
5.60
OEM2, IEC-H
OEM2, DX
OEM3, IEC-H
OEM3, DX
OEM4, IEC-H
OEM4, DX
OEM6, IEC-H
OEM6, DX

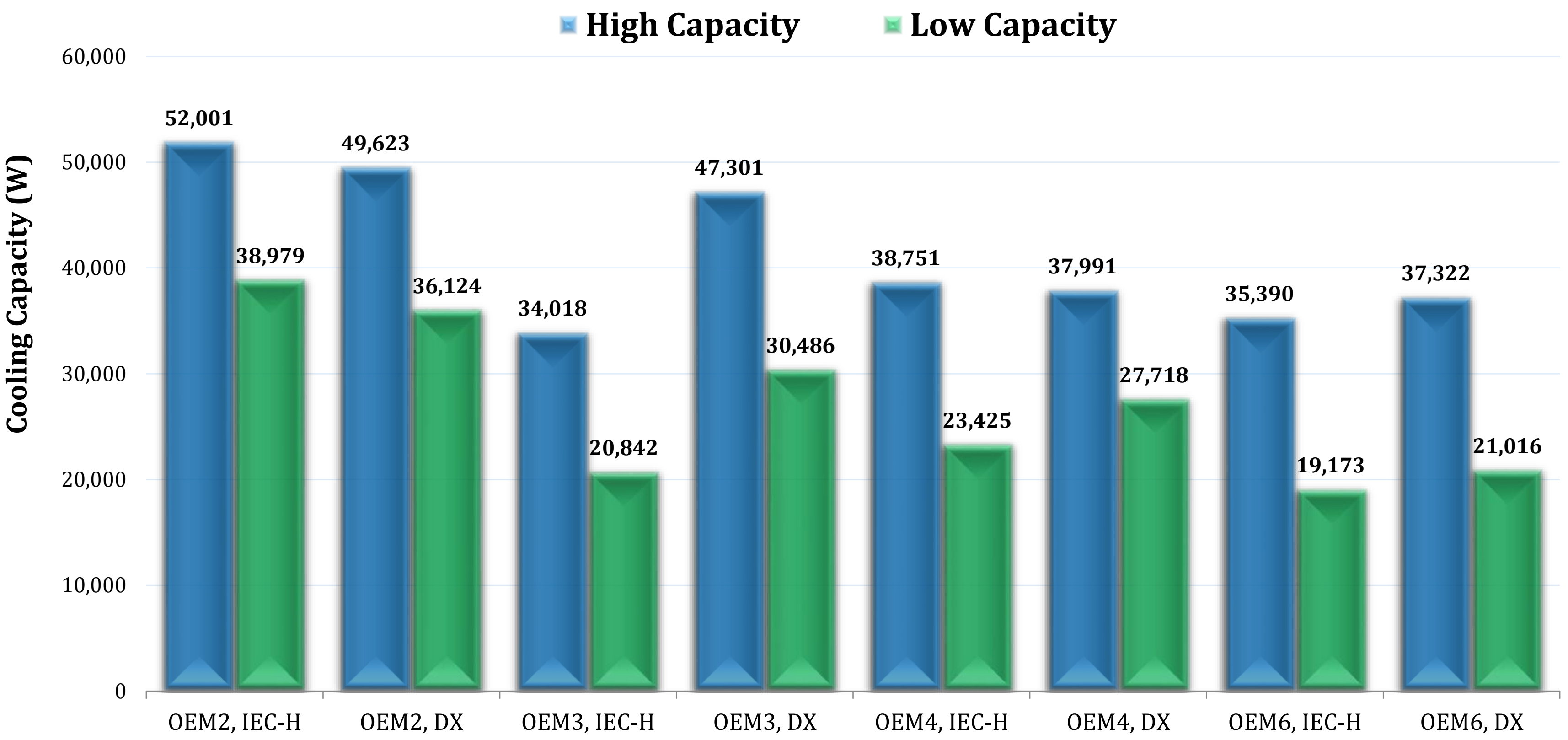
Cooling Capacity in CZ2



EER in CZ5


High EER
Low EER
EER (BTU/W.hr)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
18.49
13.98
17.54
12.71
20.80
13.60
12.70
8.70
19.20
11.30
17.00
12.30
25.50
12.90
10.00
6.30
OEM2, IEC-H
OEM2, DX
OEM3, IEC-H
OEM3, DX
OEM4, IEC-H
OEM4, DX
OEM6, IEC-H
OEM6, DX

Cooling Capacity in CZ5



Conclusion

EER	Financial Analysis	Different Climatic Zones	Technical Analysis
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	Further tests are needed at the highest ambient dry bulb temperatures and the lowest humidity, climatic zone 8.	Superior EERs of the IEC-H units despite the smaller capacity compressors used. The capacities of the IEC-H units were not always larger than these of the DX units.

Future Work

Use **lower GWP refrigerants** approved in Egypt (Promotion of Low-GWP Refrigerants for the Air Conditioning Industry in Egypt, UNEP/UNIDO 2021) refrigerants R-32 and R-454 B.

The **capacity of the compressor** of the IEC-H units had an impact on the capacity of the unit. There was a critical capacity size defining this relationship associated with the climatic zone where it is located.

Further tests are needed at the highest ambient dry bulb temperatures and the lowest humidity, **climatic zone 8**

Thank you