EP

الأمم المتحدة

Distr.
GENERAL

UNEP/OzL.Pro/ExCom/94/33
10 May 2024

ARABIC
ORIGINAL: ENGLISH

برنامج
الأمم المتحدة
للبيئة

اللجنة التنفيذية للصندوق المتعدد الأطراف
لتنفيذ بروتوكول مونتريال
الاجتماع الرابع والتسعون
مونتريال، 27 - 31 مايو/أيار 2024
البند 9(د) من جدول الأعمال المؤقت[1]

مقترح مشروع: مصر

تتألف هذه الوثيقة من تعليقات الأمانة وتوصيتها بشأن مقترح المشروع التالي:

<u>الإزالة التدريجية</u>

• خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية (المرحلة الثانية، الشريحة الرابعة)	منظمة الأمم المتحدة للتنمية الصناعية وبرنامج الأمم المتحدة الإنمائي وبرنامج الأمم المتحدة للبيئة وألمانيا

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

ورقة تقييم المشروع – مشاريع متعددة السنوات

مصر

(1) عنوان المشروع	الوكالة	الاجتماع الذي أقرّ فيه المشروع	تدبير الرقابة
خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية (المرحلة الثانية)	منظمة الأمم المتحدة للتنمية الصناعية (رئيسية) وبرنامج الأمم المتحدة الإنمائي وبرنامج الأمم المتحدة للبيئة وألمانيا	79	إزالة تدريجية بنسبة 70% بحلول عام 2025

(2) أحدث بيانات المادة 7 (المرفق جيم، المجموعة 1)	السنة: 2023	236.65 طن من قدرات استنفاد الأوزون

(3) أحدث البيانات القطاعية للبرنامج القطري (طن من قدرات استنفاد الأوزون)						السنة: 2023			
كيميائي	الأيروسولات	الرغاوى	مكافحة الحريق	التبريد		المذيبات	عامل تصنيع	الاستخدامات المعملية	إجمالي الاستهلاك القطاعي
				التصنيع	الخدمة				
الهيدروكلوروفلوروكربون-22					236.64				236.64
الهيدروكلوروفلوروكربون-124					0.01				0.01

(4) بيانات الاستهلاك (طن من قدرات استنفاد الأوزون)			
خط الأساس لفترة 2009-2010:	386.30	نقطة البداية للتخفيضات المجمعة المستدامة:	484.61
الاستهلاك المؤهل للتمويل (طن من قدرات استنفاد الأوزون)			
موافق عليه بالفعل:	386.41	المتبقي:	98.20

(5) خطة الأعمال المعتمدة		2024	2025	2026	المجموع
منظمة الأمم المتحدة للتنمية الصناعية	إزالة المواد المستنفدة للأوزون (طن من قدرات استنفاد الأوزون)	39.21	1.89	0.00	41.10
	التمويل (دولار أمريكي)	4,322,172	208,650	0	4,530,822
برنامج الأمم المتحدة الإنمائي	إزالة المواد المستنفدة للأوزون (طن من قدرات استنفاد الأوزون)	0.00	0.00	0.00	0.00
	التمويل (دولار أمريكي)	0	0	0	0
برنامج الأمم المتحدة للبيئة	إزالة المواد المستنفدة للأوزون (طن من قدرات استنفاد الأوزون)	1.75	1.02	0.00	2.77
	التمويل (دولار أمريكي)	201,506	118,105	0	319,611
ألمانيا	إزالة المواد المستنفدة للأوزون (طن من قدرات استنفاد الأوزون)	0.00	0.00	0.00	0.00
	التمويل (دولار أمريكي)	0	0	0	0

(6) بيانات المشروع			2017	2018	2019	2020	2021	2022	2023	2024	2025	المجموع
حدود الاستهلاك بموجب بروتوكول مونتريال (طن من قدرات استنفاد الأوزون)			347.64	347.64	347.64	251.08	251.08	251.08	251.08	251.08	125.54	لا ينطبق
الحد الأقصى للاستهلاك المسموح به (طن من قدرات استنفاد الأوزون)			347.64	289.70	289.70	251.08	251.08	251.08	*241.08	*241.08	*115.54	لا ينطبق
التمويل المقرر من حيث المبدأ (دولار أمريكي)	منظمة الأمم المتحدة للتنمية الصناعية	تكاليف المشروع	3,356,641	0	4,668,214	0	4,664,196	0	4,039,413	0	195,000	16,923,464
		تكاليف الدعم	234,965	0	326,775	0	326,494	0	282,759	0	13,650	1,184,643
	برنامج الأمم المتحدة الإنمائي	تكاليف المشروع	1,042,352	0	1,836,750	0	816,620	0	0	0	0	3,695,722
		تكاليف الدعم	72,965	0	128,573	0	57,163	0	0	0	0	258,701
	برنامج الأمم المتحدة للبيئة	تكاليف المشروع	230,000	0	279,500	0	260,000	0	180,000	0	105,500	1,055,000
		تكاليف الدعم	27,480	0	33,394	0	31,064	0	21,506	0	12,605	126,049
	ألمانيا	تكاليف المشروع	0	0	207,300	0	0	0	0	0	0	207,300
		تكاليف الدعم	0	0	26,949	0	0	0	0	0	0	26,949
التمويل الذي أقرته اللجنة التنفيذية (دولار أمريكي)		تكاليف المشروع	4,628,993	0	6,991,764	0	5,740,816					17,361,573
		تكاليف الدعم	335,410	0	515,691	0	414,721					1,265,822
إجمالي التمويل الموصي بإقراره أثناء هذا الاجتماع (دولار أمريكي)		تكاليف المشروع								**2,480,298		**2,480,298
		تكاليف الدعم								**182,527		**182,527

* جرى تخفيض حدّ الاستهلاك الأقصى المسموح به للمواد الملحوظة في المجموعة ألف من المرفق جيم بقدر 10 أطنان من قدرات استنفاد الأوزون عندما أقرّت اللجنة التنفيذية في اجتماعها الرابع والثمانين خطة قطاعية لأجهزة تكييف الهواء المحلية في إطار المرحلة الثانية.
** التمويل الموصى به في الاجتماع الحالي على اعتبار أنّ منظمة الأمم المتحدة للتنمية الصناعية ستقدم، بالنيابة عن مصر، طلب تمويل يشمل رصيد الشريحة الرابعة ويتألف من 1,739,115 دولارا أمريكيا زائد 121,738 دولارا أمريكيا لتكاليف دعم الوكالة في الاجتماع الذي تقدم فيه مقترح المرحلة الأولى من خطة تنفيذ تعديل كيغالي للتخفيض التدريجي للمواد الهيدروفلوروكربونية في مصر أو في الاجتماع السادس والتسعين للجنة التنفيذية إياهما أقرب الأجلين.
ملاحظة: جرى تعديل الاتفاق المبرم بين مصر واللجنة التنفيذية في الاجتماع الرابع والثمانين.

توصية الأمانة:	الاستعراض الفردي

وصف المشروع

1. بالنيابة عن مصر، تقدم منظمة الأمم المتحدة للتنمية الصناعية، بوصفها الوكالة المنفذة الرئيسية، طلب تمويل الشريحة الرابعة من المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية بقيمة إجمالية قدرها 4,523,678 دولارا أمريكيا تتألف من 4,039,413 دولارا أمريكيا زائد 282,759 دولارا أمريكيا لتكاليف دعم منظمة الأمم المتحدة للتنمية الصناعية و180,000 دولار أمريكي زائد 21,506 دولارا أمريكيا لتكاليف دعم برنامج الأمم المتحدة للبيئة.[2] ويشتمل الطلب على تقرير مرحلي عن تنفيذ الشريحة الثالثة وتقرير التحقق من استهلاك المواد الهيدروكلوروفلوروكربونية للفترة من عام 2021 إلى عام 2023 وخطة تنفيذ الشريحة خلال الفترة من عام 2023 إلى عام 2025.

<u>الإفادة باستهلاك المواد الهيدروكلوروفلوروكربونية</u>

2. أفادت مصر باستهلاك 236.65 طن من قدرات استنفاد الأوزون من المواد الهيدروكلوروفلوروكربونية في عام 2023 أي بما يقلّ بنسبة 39 في المائة عن خطّ أساس استهلاك المواد الهيدروكلوروفلوروكربونية المحدد للامتثال. ويرد استهلاك المواد الهيدروكلوروفلوروكربونية خلال الفترة من 2019 إلى 2023 في الجدول 1.

الجدول 1. استهلاك المواد الهيدروكلوروفلوروكربونية في مصر (بيانات الفترة من 2019 إلى 2023 المقدّمة عملا بالمادة 7)

الهيدروكلوروفلوروكربون	2019	2020	2021	2022	2023	خط الأساس
بالأطنان المترية						
الهيدروكلوروفلوروكربون-22	4,083.33	4,481.91	3,759.59	3,244.76	4,302.55	4367.16
الهيدروكلوروفلوروكربون-123	3.75	0.00	7.75	2.50	0.00	5.25
الهيدروكلوروفلوروكربون-124	0.00	0.00	0.34	0.00	0.54	0.00
الهيدروكلوروفلوروكربون-141ب	547.62	0.00	0.00	0.00	0.00	1,178.26
الهيدروكلوروفلوروكربون-142ب	52.37	52.93	34.13	18.37	0.00	251.69
المجموع (بالأطنان المترية)	**4,687.07**	**4,534.84**	**3,801.81**	**3,265.63**	**4,303.09**	**5,802.36**
الهيدروكلوروفلوروكربون-141ب في البوليولات السابقة الخلط المستوردة*	0.00	0.00	0.00	0.00	0.00	**894.00
بالأطنان من قدرات استنفاد الأوزون						
الهيدروكلوروفلوروكربون-22	224.58	246.51	206.78	178.46	236.64	240.19
الهيدروكلوروفلوروكربون-123	0.08	0.00	0.16	0.05	0.00	0.11
الهيدروكلوروفلوروكربون-124	0.00	0.00	0.01	0.00	0.01	0.00
الهيدروكلوروفلوروكربون-141ب	60.24	0.00	0.00	0.00	0.00	129.61
الهيدروكلوروفلوروكربون-142ب	3.40	3.44	2.22	1.19	0.00	16.36
المجموع (بالأطنان المترية)	**288.30**	**249.95**	**209.16**	**179.71**	**236.65**	**386.27**
الهيدروكلوروفلوروكربون-141ب في البوليولات السابقة الخلط المستوردة*	0.00	0.00	0.00	0.00	0.00	**98.34

* البيانات مستمدة من البرنامج القطري
** متوسط الاستهلاك بين عامي 2007 و2009

3. في عام 2023، انحصر استهلاك الهيدروكلوروفلوروكربون-22 في خدمة معدات التبريد وتكييف الهواء القائمة؛ ويرد المزيد من التفاصيل عن زيادة الاستهلاك في قطاع الخدمة في عام 2023 في الفقرة 24 أدناه. وبفضل عمليات التحول التي جرت في إطار المشروع، قد تمكنت مصر من إزالة استهلاك الهيدروكلوروفلوروكربون-22 في صناعة معدات التبريد وتكييف الهواء ورغوة البوليسترين المسحوبة بالضغط. أمّا مادة الهيدروكلوروفلوروكربون-142ب والتي كانت تستخدم كعامل تصنيع مشترك مع الهيدروكلوروفلوروكربون-22 لتصنيع رغوة البوليسترين المسحوبة بالضغط فقد تمّت إزالتها بدورها تماشيا مع حظر استخدام المواد الهيدروكلوروفلوروكربونية في تصنيع رغوة البوليسترين المسحوبة بالضغط بدءا من 1 يناير/كانون الثاني 2023. وقد تمّ حظر استيراد المعدات المحتوية على المواد الهيدروكلوروفلوروكربونية وتصنيعها في 1 يناير/كانون الثاني 2023 وحظر استيراد غاز R-406A في

[2] وفقا لما جاء في خطاب وجهته وزارة البيئة المصرية إلى منظمة الأمم المتحدة للتنمية الصناعية في 2 فبراير/شباط 2024.

1 يناير/كانون الثاني 2023 وحظر استيراد الهيدروكلوروفلوروكربون-141ب في 1 يناير/كانون الثاني 2020 وحظر استيراد الهيدروكلوروفلوروكربون-141ب في البوليولات السابقة الخلط في 1 يناير/كانون الثاني 2018. وتستخدم حاليا وبصورة متقطعة كميات صغيرة من الهيدروكلوروفلوروكربون-123ب ومن الهيدروكلوروفلوروكربون-124 في خدمة معدات التبريد وتكييف الهواء.

التقرير عن تنفيذ البرنامج القطري

4. بلّغت مصر عن بيانات الاستهلاك القطاعي للمواد الهيدروكلوروفلوروكربونية في التقرير عن تنفيذ البرنامج القطري لعام 2023 وهي متماشية مع البيانات المبلغ عنها عملا بالمادة 7 من بروتوكول مونتريال.

تقرير التحقق

5. أكّد تقرير التحقق أنّ مصر تواصل تطبيق نظام الحصص والتراخيص لاستيراد المواد الهيدروكلوروفلوروكربونية وتصديرها وأنّ إجمالي الاستهلاك المبلغ عنه لعامي 2020 و2021 عملا بأحكام المادة 7 من بروتوكول مونتريال وفي التقرير عن تنفيذ البرنامج القطري لعام 2023 صحيح (على النحو المبيّن في الجدول 1 أعلاه). وقد خلص تقرير التحقق إلى أنّ مصر في حالة من الامتثال للحدّ الأقصى للاستهلاك المسموح به للفترة بين عامي 2021 و2023 في ما يتعلق بجميع المواد الملحوظة في المجموعة الأولى من المرفق جيم، على النحو الوارد في الاتفاق المبرم مع اللجنة التنفيذية.

<u>التقرير المرحلي عن تنفيذ الشريحة الثالثة من المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية</u>

الإطار القانوني

6. بدءا من 1 يناير/كانون الثاني، فرضت مصر حظرا على استيراد المعدات المحتوية على الهيدروكلوروفلوروكربون-22 وتصنيعها وعلى استعمال المواد الهيدروكلوروفلوروكربونية أو خلائط من المواد الهيدروكلوروفلوروكربونية في صناعة رغوة البوليسترين المسحوبة بالضغط وعلى استيراد غاز R-406A وعلى استيراد الهيدروكلوروفلوروكربون-142ب. وكان قد فرض حظرٌ على استيراد الهيدروكلوروفلوروكربون-141ب في 1 يناير/كانون الثاني 2020 وعلى الهيدروكلوروفلوروكربون-141ب في البوليولات السابقة الخلط في 1 يناير/كانون الثاني 2018. وقد صدقت مصر على تعديل كيغالي في 22 أغسطس/آب 2023. وفي عام 2022، جرى تعديل التعريفات الجمركية على الواردات بغية إعفاء غازات التبريد ذات إمكانية الاحترار العالمي المنخفضة (بما فيها الهيدروكلوروفلوروكربون-32 وR-290 وR-600a وR-717 وR-744) من رسم نسبته 5 في المائة والمفروض على الهيدروكلوروفلوروكربون-22 والمواد الهيدروفلوروكربونية وخلائط المواد الهيدروفلوروكربونية.

الأنشطة في قطاع التصنيع

<u>صناعة رغوة البوليسترين المسحوبة بالضغط</u>

7. تشمل المرحلة الثانية عملية تحويل أربع شركات تصنع رغوة البوليسترين المسحوبة بالضغط ألا وهي منتجات البناء الكيميائية وانسوتك وكيما فوم وشركة مودرن بلاست حيث يبلغ استهلاكها الإجمالي من الهيدروكلوروفلوروكربون-22 ومن الهيدروكلوروفلوروكربون-142ب 559.0 طنا متري و24.3 طنا متري على التوالي من أجل اعتماد خليط يحتوي على 60 في المائة من الأوليفينات الهيدروفلورية-1234ze و40 في المائة من ثنائي ميثيل الإيثر. وتمّ تسليم المعدات إلى الشركات الأربع وتركيبها وبدأت عمليات تفتيش السلامة. وقد أنجزت عمليات التحويل هذه ووضعت اللمسات الأخيرة على مذكرات التفاهم لإتاحة سداد التكاليف التشغيلية الإضافية والمتوقعة بحلول شهر ديسمبر/كانون الأول 2024.

صناعة رغوة متعددة اليوريثان

8. تشمل المرحلة الثانية الإزالة التدريجية للهيدروكلوروفلوروكربون-141ب من خلال عملية تحويل أسلوب الإنتاج في الشركات المتبقية في قطاع تصنيع رغوة متعددة اليوريثان، بما في الأمر تحوّل ثماني شركات تصنّع أجهزة تبريد محلية وشركتي إنتاج مسخنات مائية كهربائية إلى مادة السيكلوبنتان من أجل إزالة 372.5 طنا متري و50.0 طن متري على التوالي من الهيدروكلوروفلوروكربون-141ب، فضلًا عن مشروع جماعي يشمل 38 شركة صغيرة ومتوسطة الحجم للاستعاضة عن 114.4 طنا متري من الهيدروكلوروفلوروكربون-141ب بفورمات الميثيل. وقد أنجز جلّ هذه العمليات في ما عدا عملية تحويل شركة واحدة وهي شركة بهجت.

9. وكانت منظمة الأمم المتحدة للتنمية الصناعية قد بلّغت[3] اللجنة التنفيذية في اجتماعها الثاني والتسعين أنّ شركة بهجت قد انسحبت من المشروع بعد أن تخلت عن صناعة أجهزة التبريد المحلية بسبب تقلبات السوق في أعقاب جائحة كوفيد 19. وبما أنّ المنظمة كانت قد ابتاعت المعدات وسلمتها الشركة، كان لا بدّ لها وتماشيا مع المقرر 34/79(هـ) أن تجد شركة بديلة من شأنها أن تستعمل المعدات عوضا عن بيعها في المزاد. وفي حين تعذر على المنظمة إيجاد شركة لم تستفد من أيّ تمويل، أعربت تريدكو وهي شركة مؤهلة للتمويل ومشاركة في المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية عن اهتمامها في شراء خط التصنيع من شركة بهجت ونقله عمليا إلى مرافقها. فاقترحت المنظمة أن تمنح تريدكو تلك المعدات واستخدام رصيد مشاريع قطاع صناعة رغوة متعددة اليوريثان وقدره 7,214 دولارا أمريكيا لنقل المعدات من بهجت إلى تريدكو وإنجاز أيّ عمل هندسي ضروري وإتلاف/إخراج عن الخدمة أيّ معدات متبقية تستخدم الهيدروكلوروفلوروكربون-141ب لصنع الرغوة. وقد وافقت اللجنة التنفيذية على الطلب بصورة استثنائية (المقرر 12/92).

10. إنّما سرعان ما بلّغت منظمة الأمم المتحدة للتنمية الصناعية أنّ شركتي بهجت وتريدكو لم تتوصلا إلى اتفاق حول نقل المعدات فسألت الأمانة ما إذا كان في وسعها أن تدعو شركة أخرى وهي سيلتال لشراء خط التصنيع من بهجت حتى تقوم بتحويله إلى السيكلوبنتان بمساعدتها. مرّة أخرى وبصورة استثنائية علما بأنّ الهدف من تغيير الوجهة المستفيدة في الاجتماع الثاني والتسعين وفي الاجتماع الحالي عينه أي تجنّب بيع المعدات التي اشتراها الصندوق المتعدد الأطراف في المزاد بل استعماله لمساعدة شركة مؤهلة للتمويل إلى تحويل مرافقها الإنتاجية الأهلة من المواد الهيدروكلوروفلوروكربونية إلى السيكلوبنتان، سمحت الأمانة للمنظمة أن تشرع في تغيير الجهة المنتفعة مع الإشارة إلى أنّ سيلتال تفي بالشروط التي فرضتها اللجنة التنفيذية على تريدكو في اجتماعها الثاني والتسعين أي (أ) أنّه في حال عدم الحصول على هذه المعدات سيتوجب على سيلتال أن تقوم بشرائها و(ب) إنّ مواصفات المعدات مطابقة لاحتياجات الشركة بما يتيح لها استخدامها بسرعة فور الانتهاء من الإنشاءات المدنية اللازمة و(ج) إنّ الرصيد البالغ 7,214 دولارا أمريكيا لن يغطي الإنشاءات المدنية التي تتحمل سيلتال كلفتها و(د) إنّ الرصيد يستخدم لنقل المعدات والأعمال الهندسية الضرورية وإتلاف/إخراج عن الخدمة أيّ معدات متبقية تستخدم الهيدروكلوروفلوروكربون-141ب لصنع الرغوة.

11. وقد دخلت شركتا سيلتال وبهجت في اتفاق لنقل المعدات. وكانت منظمة الأمم المتحدة للتنمية الصناعية، أثناء صياغة هذه المذكرة، تتخذ الترتيبات اللازمة مع مورد التكنولوجيا والشركتين لاستكمال عملية النقل والتركيب.

صناعة أجهزة تكييف الهواء السكني

12. تشمل المرحلة الثانية عملية تحويل خمس شركات تصنيع أجهزة تكييف الهواء السكني ألا وهي العربي وفريش وميراكو وباور للتكييف ويونيون اير والتي يبلغ استهلاكها الإجمالي من الهيدروكلوروفلوروكربون-22 1,189.78 طنا متري إلى مادة الهيدروفلوروكربون-32 وإن رغبت في الأمر إلى التكنولوجيا القائمة على مادة R-454B عندما تتوفر هذه الأخيرة في الأسواق (المقرر 72/84(ب)). تمّ تسليم المعدات إلى كل من شركة العربي وفريش وباور للتكييف ويونيون اير وتركيبها ودخلت جميعها في الخدمة في ما عدا لدى شركة باور للتكييف. وقد تمّ اشتراء المعدات

---

[3] الفقرات من 31 إلى 36 من المذكرة UNEP/OzL.Pro/ExCom/92/9.

الواجب تركيبها لدى شركة ميراكو إلا أنّه لم يتمّ استلامها بعد ومن المفترض استلامها وتركيبها بحلول ديسمبر/كانون الأول 2024.

13. تماشيا مع المقرر 70/88(أ)(2)، قدمت منظمة الأمم المتحدة للتنمية الصناعية معلومات عن الجدول الزمي الذي وضعته مصر لعملية انتقال شركات صناعة أجهزة تكييف الهواء السكني إلى إنتاج أجهزة ذات إمكانية الاحترار العالمي المنخفضة دون غيرها للسوق المحلية. وبموجب الاقتراح المقدم في الاجتماع الثامن والثمانين، على مصر أن تفرض على الشركات الخمس ألا تصنّع سوى أجهزة تكييف هواء سكنية تحتوي على الهيدروكلوروفلوروكربون-32 لتسويقها محليا بحلول 1 يناير/كانون الثاني 2028. إنّما ومن أجل إسراع الخطى مقارنة مع الجدول الزمي الوارد في الجدول 3 من المذكرة UNEP/OzL.Pro/ExCom/88/47، سيتعيّن على مصر أن تفرض على الشركات ألا تصنّع سوى أجهزة تكييف هواء سكنية تحتوي على الهيدروكلوروفلوروكربون-32 لتسويقها محليا بحلول 31 ديسمبر/كانون الأول 2026 لكي تتأهل للاستفادة من التكاليف التشغيلية الإضافية. وعليه قامت المنظمة بالتوقيع على عقود صرف التكاليف التشغيلية الإضافية يعتمد هذا الموعد الجديد مع شركتي العربي وفريش؛ ووافقت شركة يونيون اير على نوعد أقرب أي 1 يناير/كانون الثاني 2025 في العقد الخاص بالتكاليف التشغيلية الإضافية. ومن المتوقع إمضاء عقد مع شركة باور للتكييف في الفصل الثالث من عام 2024؛ وأسوة بشركة يونيون اير، فقد وافقت شركة باور للتكييف على جدول زمني مسرّع لإنتاج أجهزة تكييف هواء سكنية تحتوي على الهيدروكلوروفلوروكربون-32 يتمّ تسويقها محليا دون سواها بحلول 1 يناير/كانون الثاني 2025. أمّا في ما يخص شركة ميراكو ونظرا للتأخر في عملية التحول لم يجر بعد وضع أي عقد من هذا القبيل.

14. وتماشيا مع المقرر عينه أي 70/88(أ)(2)، قدمت منظمة الأمم المتحدة للتنمية الصناعية نتائج دراستين حول تقييم المخاطر وتقييم الأسواق في قطاع صناعة أجهزة تكييف الهواء السكني؛ وأرفقت الدراستان بهذه المذكرة. وبيّنت التصورات المعتمدة في عملية تقييم المخاطر، في جملة ما خلصت إليه الدراسة، أنّ احتمال مصادفة مصدر اشعال بالتزامن مع كميّة مسربة من غاز الهيدروفلوروكربون-32 والكافية للاشتعال يساوي 10^{-9} (أي صعب للغاية) على نطاق جميع فئات الخطورة وبالتالي اعتبر الخطر المتصل باستخدام الهيدروفلوروكربون-32 في أجهزة تكييف الهواء السكني مقبولا. أما دراسة إقبال السوق فتلخص نتائجها الرئيسية في أنّ الكفاءة في استخدام الطاقة تمثّل الأولوية القصوى للمستهلكين؛ وأنّ توفّر خدمات ما بعد البيع المتينة عامل مؤثر في زيادة الإقبال على وحدات تكييف الهواء السكني المحتوية على غاز الهيدروفلوروكربون-32؛ وأنّ المستهلكين مستعدون لقبول زيادة متواضعة في حدود 5 في المائة في أسعار وحدات تكييف الهواء مقابل مواصفات صديقة للبيئة؛ وأنّ منصات التواصل الرقمية تمثّل الأسلوب المفضل للتواصل حول المنافع البيئية لوحدات تكييف الهواء والحوار مع المستهلكين.

صناعة أجهزة تكييف الهواء التجاري

15. كما تشمل المرحلة الثانية مشروع تقديم مساعدة فنية لشركات ثلاث ألا وهي إيجات وفولتا ودلتا للإنشاء والتصنيع لكي تنتقل في صناعة معدات تكييف الهواء المركزي للاستخدامات السكنية والتجارية الخفيفة (أي دون مستوى 144,000 وحدة حرارية بريطانية/ساعة (12 طن من التبريد)) إلى بدائل ذات إمكانية الاحترار العالمي المنخفضة وفي تصنيع الأجهزة الكبرى إلى مزيج من البدائل ذات إمكانية الاحترار العالمي المنخفضة والتبريد البخاري غير المباشر أي إلى تصنيع وحدات هجينة من التبريد البخاري غير المباشر والتمدد المباشر. وقد بلّغت منظمة الأمم المتحدة للتنمية الصناعية اللجنة التنفيذية في اجتماعها الثامن والثمانين أنّه أثناء المحادثات المعقودة مع أصحاب الشأن أعربت ثلاث شركات أخرى تصنّع وحدات تكييف هواء تجاري وهي الشركة الهندسية طيبة وشركة مصر للصناعات الهندسية وميراكو كاريير[4] عن اهتمامها في المشاركة في المشروع. وبعد بحث الأمر مع الأمانة، تمّ تلقي رسائل تؤكد مشاركتها والتزامها بالسهر على تحويل المعدات الخاصة بمكوّن التمدد المباشر إلى بدائل ذات إمكانية الاحترار العالمي المنخفضة ليس إلا.

[4] لن تضيف مشاركة هذه المؤسسات الثلاث كلفة على الصندوق المتعدد الأطراف ولن يقدّم أيّ تمويل مباشر لها في إطار نشاط المساعدة الفنية المقترح إلا أنّ مشاركتها ستيسر اعتماد التكنولوجيا القائمة على إمكانية الاحترار العالمي المنخفضة في الأسواق وتساهم تاليا في ضمان استدامة النشاط.

16. ورفعت منظمة الأمم المتحدة للتنمية الصناعية تقريرا عن نتائج أنشطة المساعدة الفنية المقدمة لشركات تصنيع أجهزة تكييف الهواء التجاري حيث تبيّن أنّ أداء الوحدات الهجينة من التبريد البخاري غير المباشر والتمدد المباشر يتفوق على أداء وحدات التمدد المباشر. وقد جرى اختبار النماذج الأولية في منطقتين مناخيتين نموذجيتين عن مناخ القاهرة في الصيف وهما دلتا النيل ومنطقة الساحل الشرقي. وقد بيّن التحليل الاقتصادي وفورات صافية متأتية من الوحدات الهجينة من التبريد البخاري غير المباشر والتمدد المباشر مقارنة مع وحدات التمدد المباشر بسبب استهلاكها المنخفض للطاقة الكهربائية وذلك مع الأخذ في الحسبان الكلفة الأصلية المرتفعة للوحدة الهجينة وتكاليف الماء العالية. وقد تبلغ الوحدة عتبة الربحية بعد 3.11 عاما. والتقرير مرفق بهذه المذكرة.

17. وفي إطار حملة التوعية على أجهزة تكييف الهواء التجاري ذات إمكانية الاحترار العالمي المنخفضة، عرضت وحدات تكييف ذات الكفاءة في استخدام الطاقة والوحدات الهجينة من التبريد البخاري غير المباشر والتمدد المباشر في المؤتمر الدولي الخامس عشر في الإنشاء المستدام وتكنولوجيا النانو والبناء البيئي المتقدم المنعقد في القاهرة في 2 و3 مارس/آذار 2024. وشاركت في المعرض شركة سابعة وهي Smart Sustainable Air Technology التي قدّمت بدورها وحدة هجينة من التبريد البخاري غير المباشر والتمدد المباشر بعدما اطلعت على هذه التكنولوجيا بفضل المشروع. وأصبحت اليوم أربع شركات أي دلتا للإنشاء والتصنيع وفولتا والشركة الهندسية طيبة وشركة مصر للصناعات الهندسية تقدم وحدات هجينة من التبريد البخاري غير المباشر والتمدد المباشر في عرضها العادي للمنتجات المصنّعة.

قطاع خدمة أجهزة التبريد

18. في إطار تنفيذ الشريحة الثالثة، نفذت الأنشطة التالية:

(أ) تدريب 115 ضابط جمارك ومستورد (بمن فيهم 19 امرأة) على كشف غازات التبريد غير القانونية والمغشوشة وعلى برنامج مراقبة سوق غازات التبريد وعلى تنفيذ الحظر الساري بدءا من 1 يناير/كانون الثاني 2023؛ وتدريب 375 فنيا (بمن فيهم 150 فنية) على الممارسات الحميدة في خدمة أجهزة التبريد وتكييف الهواء؛

(ب) تدريب 471 موظفا ومستشارا (بمن فيهم 87 امرأة) على التوريد المراعي للبيئة في إطار التدريب على تفعيل مدونة غازات التبريد؛ ومن المفترض عقد دورة تدريبية أخرى في شهر مايو/أيار 2024؛

(ج) ابتياع معدات لصالح ثمانية مراكز تدريب (وحدات استرداد ومضخات تفريغ ومجموعات حلقات تثبيت من نوع Lokring وأجهزة كشف التسرب ومقاييس ضغط المشعب بأربع صمامات وأدوات الخدمة)؛

(د) تسليم علب عدة ومعدات للخدمة إلى سبعة مراكز تدريب.[5]

19. وقد طرأ تأخير على تنفيذ الأنشطة التالية فما زالت في مراحل تنفيذ متباينة:

(أ) ما زالت الأدوات التنظيمية والمؤسسية والرامية إلى تفعيل برنامج الترخيص في مرحلة التصميم ولم تجرَ بعد أنشطة التدريب والتوعية على المدونات والمعايير المحلية؛

(ب) أطلق البرنامج الريادي لترخيص فنيي خدمة ما بعد البيع بفضل التعاقد إنّما الدفعة الأولى من الفنيين ما زالت في انتظار الترخيص. وقد تمّ ابتياع 167 عدّة أدوات لاسترداد غازات التبريد (مثل وحدة الاسترداد والاسطوانة ومضخة التفريغ ومجموعة أدوات الخدمة) إلا أنّ توزيعها على ورش الخدمة مرهون بترخيص الفنيين؛

[5] وتحتوي على وحدات استرداد ومجموعات حلقات تثبيت من نوع Lokring وأجهزة للتدرب على غازات تبريد متنوعة وأدوات الخدمة والمستهلكات.

(ج) جرت مراجعة أربع مدونات وطنية. وتمّ تحديث المدونة الخاصة بالتبريد الحضري المركزي. أمّا المدونة الخاصة بالتبريد المستدام في الجماعات الحضرية الجديدة فبلغت مراحلها الأخيرة[6] في حين أنّ المدونة الخاصة بالتدفئة والتهوية وتكييف الهواء في مراحلها الأولى وأنّ تحيين المدونة الخاصة بسلسلة التبريد لم يبدأ بعد؛

(د) تمّ شراء مئتي مجموعة معدات (أليات استرداد ومضخة تفريغ ومقياس تفريغ ومقاييس الضغط العالية الدقة واسطوانات وميزان حرارة) للمركز الريادي لاسترداد غازات التبريد واستصلاحها؛ ستوزع هذه المعدات على ورش الخدمة لتقوم بتجميع المواد الخاضعة للرقابة وتسليمها إلى مركز الاستصلاح الذي تمّ إنشاؤه. إنّ تشغيل مركز الاستصلاح سيبدأ فور الحصول على رخصة التشغيل المفترض صدروها بحلول 31 مايو/أيار 2024؛ حينها سيتمكن من استلام غازات التبريد المستردة والشروع في استصلاحها. ومن المتوقع بلوغ الهدف القاضي باسترداد 80 طنا متري من غازات التبريد واستصلاح ما لا يقل عن 56 طنا متري منها بحلول شهر يونيو/حزيران 2026؛

(ه) جرى تقييم الاحتياجات من المعدات لشبكة خدمة أجهزة تكييف الهواء بعد البيع وتوقيع عقد مع خبير في السلامة مكلف اسداء المشورة حول تدابير السلامة في مراكز شبكة خدمة أجهزة تكييف الهواء بعد البيع؛ إنّما لم يتمّ بعد شراء عدد أدوات الخدمة المحمولة للطواقم الميدانية ولا أدوات الدعم لمراكز خدمة ما بعد البيع؛

(و) نفّذ برنامج احتواء غازات التبريد ومنع تسربها وجرى أثناءه التركيز على معدات التبريد وتكييف الهواء الضخمة؛ ومن المفترض أن تجري في شهر ديسمبر/كانون الأول 2024 عملية التفتيش والترخيص الريادية لمبنى أو مبنيين؛

(ز) تأخر تسليم المعدات إلى مركز التدريب المختار لاستضافة مركز الامتياز الخاص بغازات التبريد القابلة للاشتعال والذي كان من المفترض أن يتمّ في شهر مارس/آذار 2022؛ إلا أن المناهج التدريبية جاهزة ومن المتوقع أن يبدأ المركز نشاطه التشغيلي فور استلامه المعدات؛

(ح) وضعت مسودة دليل ممارسات الخدمة الجيدة لكي تدرج في مناهج التدريب والتي كان من المفترض أن تكون جاهزة في ديسمبر/كانون الأول 2022 إلا أنّها ما زالت في طور المراجعة والتعليق؛

(ط) بدأ العمل على وضع نظام لتقفي آثار غازات التبريد عن طريق وسم الأسطوانات برموز الاستجابة السريعة إلا أن العمل لم ينته بعد مع العلم أنّ وسم أسطوانات غازات التبريد برموز الاستجابة السريعة سيكون إلزاميا بحلول عام 2026.

20. أمّا الأنشطة التالية، فلم يبدأ تنفيذها بعد:

(أ) الأنشطة المتعلقة ببرنامج التدريب في الموقع على ممارسات الخدمة الجيدة في ورش الخدمة الصغيرة الحجم حيث يعمل فني واحد أو فنيان اثنان والتي لا تستهلك أكثر من اسطوانتين أو ثلاث أسطوانات من غازات التبريد في الشهر الواحد. وكان من المفترض تدريب ما بين 150 و200 فني وتسليمهم شهادات مشاركة في التدريب. ومن المزمع استكمال هذه الأنشطة التدريبية بأنشطة تدريب إضافية تستهدف ورش الخدمة الصغيرة الحجم في إطار الشريحة الرابعة.

[6] وقد شرح وزير التعاون الدولي أنّ المدن الجديدة تندرج في إطار برنامج المدن الذكية التي تستمد طاقتها من الطاقة المتجددة والتكنولوجيا الذكية والبنية الأساسية المستدامة والخضراء والمترابطة بواسطة شبكات النقل المتعدد الوسائط (https://sponsosred.bloomberg.com/article/ministry-of-international-cooperation/egypt-new-cities: تاريخ الاطلاع 10 أبريل/نيسان 2024).

(ب) إطلاق مصر برنامج رخصة قيادة للتبريد وهو النظير الوطني لبرنامج الترخيص. وكان من المفترض أطلاق المشروع الريادي في عام 2022؛ ستواصل مصر العمل على أساس برنامج الترخيص لخدمة ما بعد البيع على أن تعيد إدخال برنامج رخصة قيادة للتبريد في عام 2029.

تنفيذ المشروع ورصده

21. تقوم وحدة إدارة ورصد المشروع بتنسيق خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية ورصد تنفيذها وفي هذا الصدد تقوم بزيارة الجهات المستفيدة وأصحاب الشأن وتنظيم ورش العمل والاجتماعات وإعداد التقارير ذات الصلة. وقد بلغت مصاريف وحدة إدارة ورصد المشروع في إطار الشريحة الثالثة 125,702 دولارا أمريكيا (من أصل تمويل قدره 245,000 دولار أمريكي) بما في ذلك رواتب الموظفين وتكاليف التشغيل (86,880 دولار أمريكي) وأجور الاستشاريين (13,822 دولارا أمريكيا) ودعم عملية تحول صناعة أجهزة تكييف الهواء المحلية (10,000 دولار أمريكي) والمصاريف الطارئة (15,000 دولار أمريكي).

<u>مستوى صرف الأموال</u>

22. بتاريخ مارس/آذار 2024 ومن أصل 17,361,573 دولارا أمريكيا أقر لتاريخه، صرف 10,815,162 دولارا أمريكيا (7,236,700 دولار أمريكي لمنظمة الأمم المتحدة للتنمية الصناعية و2,639,762 دولارا أمريكيا لبرنامج الأمم المتحدة الإنمائي و731,400 دولار أمريكي لبرنامج الأمم المتحدة للبيئة و207,300 دولار أمريكي لألمانيا) على النحو المبين في الجدول 2. سيصرف الرصيد البالغ 6,546,411 دولارا أمريكيا بين عامي 2024 و2026.

الجدول 2. التقرير المالي عن المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية في مصر (دولار أمريكي)

الشريحة		منظمة الأمم المتحدة للتنمية الصناعية	برنامج الأمم المتحدة الإنمائي	برنامج الأمم المتحدة للبيئة	ألمانيا	المجموع	نسبة الصرف (%)
الأولى	المبلغ المقرر	3,356,641	1,042,352	230,000	0	4,628,993	95
	المبلغ المصروف	3,117,186	1,035,119	230,000	0	4,382,305	
الثانية	المبلغ المقرر	4,668,214	1,836,750	279,500	207,300	6,991,764	70
	المبلغ المصروف	2,960,540	1,448,333	279,500	207,300	4,895,673	
الثالثة	المبلغ المقرر	4,664,196	816,620	260,000	0	5,740,816	27
	المبلغ المصروف	1,158,974	156,310	221,900	0	1,537,184	
المجموع	**المبلغ المقرر**	**12,689,051**	**3,695,722**	**769,500**	**207,300**	**17,361,573**	**62**
	المبلغ المصروف	**7,236,700**	**2,639,762**	**731,400**	**207,300**	**10,815,162**	
	الرصيد	**5,452,351**	**1,055,960**	**38,100**	**0**	**6,546,411**	

<u>خطة تنفيذ الشريحة الرابعة من المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية</u>

23. يجري تنفيذ أنشطة الشريحة الرابعة بين يونيو/حزيران 2024 وديسمبر/كانون الأول 2026 ويرد موجزها في الجدول 3.

الجدول 3. موجز للأنشطة المزمع تنفيذها في إطار الشريحة الرابعة وكلفتها

النشاط		**الوكالة**	**الكلفة (دولار أمريكي)**
التصنيع	استكمال عملية تحويل شركات تصنيع أجهزة تكييف الهواء السكني الخمس	منظمة الأمم المتحدة للتنمية الصناعية	3,249,213
السياسة وتفعيلها	شراء 15 جهاز تعرف على غازات التبريد وتسليمها إلى الجمارك ووكلاء الاستيراد	منظمة الأمم المتحدة للتنمية الصناعية	60,000
	مواصلة تفعيل الشبكة التنظيمية وتحيين المدونات الوطنية	برنامج الأمم المتحدة للبيئة	10,000
	تنظيم خمس ورش عمل لتدريب 75 من ضباط الجمارك وأصحاب الشأن ذات الصلة على ضبط المواد الخاضعة للرقابة المستوردة والمصدرة	برنامج الأمم المتحدة للبيئة	15,000
	تنظيم خمس ورش توعية لستين ضابط جمارك من أصحاب الشأن على نظام تقفي أثر غازات التبريد بواسطة رموز الاستجابة السريعة	برنامج الأمم المتحدة للبيئة	15,000
	تحيين المدونات والمعايير الوطنية لدعم برنامج احتواء غازات التبريد ومنع تسربها وتنظيم أربع ورش توعية تستهدف 200 مشارك بغية تفعيل المدونات المحينة	برنامج الأمم المتحدة للبيئة	40,000
خدمة أجهزة التبريد	توفير معدات خدمة أجهزة التبريد وتكييف الهواء لترقية ثمانية مراكز تدريب إضافية (مثل وحدات الاسترداد ومضخات التفريغ ومجموعات حلقات التثبيت من نوع Lokring وأجهزة كشف التسرب ومقاييس ضغط المشعب بأربع صمامات وأدوات الخدمة)	منظمة الأمم المتحدة للتنمية الصناعية	80,000
	استكمال توريد عدد أدوات الخدمة المحمولة للطواقم الميدانية وأدوات دعم مراكز خدمة ما بعد البيع لدى خمس شركات تصنيع أجهزة تكيف الهواء السكني (يشمل ثلاث من الشريحة الحالية) وتدريب 100 فني خدمة ما بعد البيع وترخيصهم	منظمة الأمم المتحدة للتنمية الصناعية	50,000
	تنظيم عشر ورش عمل إضافية في الموقع لتدريب ما بين 150 و200 فني على ممارسات الخدمة الجيدة في ورش الخدمة الصغيرة الحجم حيث يعمل فني واحد أو فنيان اثنان والتي لا تستهلك سوى اسطوانتين أو ثلاث أسطوانات	منظمة الأمم المتحدة للتنمية الصناعية	20,000
	تنظيم ورشة تدريب لثلاثمئة وخمس وسبعين فني إضافي على ممارسات الخدمة الجيدة لأجهزة التبريد وتكييف الهواء	برنامج الأمم المتحدة للبيئة	50,000
الاسترداد والاستصلاح	توفير 200 عدة أدوات استرداد إضافية تشتمل على وحدات استرداد واسطوانات وتوزيعها على ورش الخدمة التي يعمل فيها فنيون مرخصون	منظمة الأمم المتحدة للتنمية الصناعية	250,000
	دعم مركز الاستصلاح القائم وإنشاء المركز الآخر الذي جرى تحديده	منظمة الأمم المتحدة للتنمية الصناعية	150,200
التوعية	تنظيم حملة توعية للاستشاريين والمتعاقدين وغيرهم من أصحاب الشأن على البدائل التكنولوجية لغازات التبريد المتوفرة وأساليب استعمالها	برنامج الأمم المتحدة للبيئة	15,000
إدارة المشروع	رواتب الموظفين ومصاريف الاجتماعات والسفر والتوثيق وإعداد التقارير وكلفة التشغيل (90,000 دولار أمريكي)؛ وأجور الاستشاريين وعملية رصد التنفيذ وتقييمه وإعداد تقارير التحقق (40,000 دولار أمريكي)؛ ودعم عمليات التحول في قطاع تكييف الهواء المحلي (35,000 دولار أمريكي) ومصاريف طارئة (15,000 دولار أمريكي)	منظمة الأمم المتحدة للتنمية الصناعية	180,000
	كلفة الاجتماعات (9,000) وأجور الاستشاريين (10,000 دولار أمريكي) ومصاريف السفر (16,000 دولار أمريكي)	برنامج الأمم المتحدة للبيئة	35,000
المجموع الفرعي (منظمة الأمم المتحدة للتنمية الصناعية)			4,039,413
المجموع الفرعي (برنامج الأمم المتحدة للبيئة)			180,000
المجموع			**4,219,413**

تعليقات الأمانة وتوصيتها

التعليقات

الإفادة باستهلاك المواد الهيدروكلوروفلوروكربونية

24. عمدت الأمانة إلى فهم الأسباب التي جعلت مصر تبلّغ عن استهلاك قطاع الخدمة في عام 2023 كمية من الهيدروكلوروفلوروكربون-22 تساوي ثلاث مرات الكمية المستهلكة في عام 2022. وبعد بحث الأمر مع منظمة الأمم للتنمية الصناعية، وضحت الأخيرة أنّ الزيادة تعزى لكون موردي غازات التبريد قاموا بتخزين كميات من الهيدروكلوروفلوروكربون-22 استباقا لارتفاع الأسعار. وهذه الزيادة متوقعة كنتيجة للتخفيض الجذري في حصص الاستيراد بدءا من عام 2025 تماشيا مع الأهداف الواردة في الاتفاق المبرم بين مصر واللجنة التنفيذية.

التقرير المرحلي عن تنفيذ الشريحة الثالثة من المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية

الإطار القانوني

25. سبقت وأصدرت مصر حصص استيراد المواد الهيدروكلوروفلوروكربونية لعام 2024 وتبلغ 241.08 طن من قدرات استنفاد الأوزون وهي قيمة أقل من أهداف الرقابة الملحوظة في بروتوكول مونتريال وتتماشى مع الهدف المخصص لهذا العام والمنصوص عليه في الاتفاق الخاص بخطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية.

الأنشطة في قطاع التصنيع

صناعة أجهزة تكييف الهواء السكني

26. في سياق استعراض الأمانة التدابير التنظيمية المخطط لها والتي رفعت إلى الاجتماع الثامن والثمانين عملا بالمقرر 72/84(هـ)(1)د، اعتبرت أنّها لن تكفي لضمان الإقبال على التكنولوجيا بحلول انتهاء المرحلة الثانية. وعليه، كانت اللجنة التنفيذية قد طلبت من منظمة الأمم المتحدة للتنمية الصناعية، في جملة ما طلبت، أن تقدّم كجزء من طلب تمويل الشريحة الرابعة إطارا تنظيميا شاملا يضمن الإقبال على التكنولوجيا ذات إمكانية الاحترار العالمي المنخفضة المتفق عليها (المقرر 70/88(أ)(2)(أ). فقدمت المنظمة ملخصا وافيا عن الأنظمة المعتمدة في مصر. وعند استعراض المعلومات، أخذت الأمانة علما بأنّ مصر اعتمدت لوائح ناظمة متينة تتيح الامتثال لأهداف إزالة المواد الهيدروفلوروكربونية الملحوظة في بروتوكول مونتريال. إلا أنّه، وفي ما عدا اعفاء الهيدروفلوروكربون-32 وغازات التبريد ذات إمكانية الاحترار العالمي المنخفضة من رسوم الاستيراد، يبدو للأمانة أنّ مصر لم تنفذ بعد الأنظمة المصممة لتحقيق إقبال السوق المحلية على وحدات تكييف الهواء السكني المحتوية على الهيدروفلوروكربون-32 وتخليها عن تلك التي تحتوي على غاز R-410A.

27. فضلا عن ذلك ومع الأخذ علما بالتقدم في تحويل خطوط الإنتاج من أجل تصنيع وحدات تكييف الهواء السكني المحتوية على الهيدروفلوروكربون-32، استفسرت الأمانة عن كمية الوحدات المحتوية على الهيدروكلوروفلوروكربون-32 التي تصنعها الشركات الخمس مقارنة مع تلك التي تحتوي على غاز R-410A. فوضحت منظمة الأمم المتحدة للتنمية الصناعية أنّه بين 1 يناير/كانون الأول 2023 و13 مارس/آذار 2024، انتجت الشركات الخمس مجتمعة 1,294,642 وحدة تكييف هواء سكني منها 507 (أي 0.04 في المائة) من النوع الذي يحتوي على الهيدروفلوروكربون-32.

28. في ضوء الغياب الظاهر للتدابير التنظيمية والإنتاج الصناعي المحدود المشار إليهما أعلاه وعلما بأنّ مصر صدقت على تعديل كيغالي في 22 أغسطس/آب 2023 وأنّ منظمة الأمم المتحدة للتنمية الصناعية تنوي رفع مقترح

المرحلة الأولى من خطة تنفيذ تعديل كيغالي إلى الاجتماع الخامس والتسعين أو السادس والتسعين، سعت الأمانة إلى زيادة فهمها للعلاقة القائمة بين الجدول الزمني لتصنيع وحدات تكييف الهواء السكني التي تحتوي على غازات ذات إمكانية الاحترار العالمي المنخفضة للأسواق المحلية في إطار خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية والأنشطة المخطط لها في إطار خطة تنفيذ تعديل كيغالي. فشرحت منظمة الأمم المتحدة للتنمية الصناعية أنّه فضلا عن الشركات الخمس التي تصنع وحدات تكييف الهواء السكني والتي يجري تحويلها في إطار خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية، ثمة سبع شركات أخرى تقوم بتصنيع وحدات تكييف الهواء السكني المحتوية على غاز R-410A؛ و تعتبر منظمة الأمم المتحدة للتنمية الصناعية أنّ ستا من هذه الشركات السبع قد يكون أهلا للتمويل في إطار خطة تنفيذ تعديل كيغالي في مصر، مع العلم أن الأمر ما زال غير مؤكد؛ وأنّ مصر تنوي أدراج عملية تحويل صناعة أجهزة تكييف الهواء السكني إلى الهيدروفلوروكربون-32 بأسره في المرحلة الأولى من خطة تنفيذ تعديل كيغالي؛ وأنّ الجدول الزمني لتنفيذ خطة تنفيذ تعديل كيغالي يمتد من عام 2025 إلى عام 2029. كما أخطرت منظمة الأمم المتحدة للتنمية الصناعية الأمانة أنّه في إطار إعداد خطة تنفيذ تعديل كيغالي، تجري عملية مسح وجمع بيانات شاملة لشركات تصنيع أجهزة تكييف الهواء السكني الإضافية؛ لذلك لم تتوفر بعد البيانات لمقابلة انتاج وحدات تكييف الهواء السكني المحتوية على غاز R-410A للسوق المحلية في الشركات الخمس المشاركة في خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية مع انتاج الشركات السبع الأخرى.

29. ولدى استعراض الاقتراح المقدم إلى اللجنة التنفيذية في اجتماعها الرابع والثمانين، يبدو وكأنّ الأمانة وعن غير قصد منها أساءت فهم الاقتراح أصلا فاعتبرت أنّ الشركات الخمس الجاري تحويلها في إطار خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية تجسد قطاع صناعة أجهزة تكييف الهواء السكني بأسره وعلى هذا الأساس اقترحت على مصر النظر في اعتماد طائفة من السياسات والتدابير التنظيمية التي قد تساهم في إنجاح المشروع. وعليه أخذت اللجنة التنفيذية علما بالتزام مصر القيام، في جملة أمور أخرى، بضبط كامل لأجهزة تكييف الهواء السكني المحتوية على غازي R-410A وR-407C المستوردة أو المسوقة محليا؛ والسعي إلى تأمين إقبال السوق المحلية على الأجهزة المحتوية على غاز الهيدروفلوروكربون-32 وتباعا على غاز R-454B إذا ما ارتأت الشركات الأمر عندما تتوفر هذه التكنولوجيا؛ وتقديم تحيين للتدابير التنظيمية المخطط اعتمادها أو المعتمدة فعلا وخطة زمنية لتحول الشركات إلى تصنيع أجهزة تحتوي على الهيدروفلوروكربون-32 أو أي بديل آخر ذات إمكانية احترار عالمي أكثر انخفاضا لبيعها دون سواها في الأسواق المحلية وذلك كجزء من طلب تمويل الشريحة الثالثة في عام 2021 (المقرر72/84(هـ)(1)ب-د). لذلك يصعب على الأمانة أن تفهم كيف تتمكن مصر من وضع إطار تنظيمي شامل لكفالة الإقبال على الأجهزة القائمة على الهيدروفلوروكربون-32 بعد أن قام بعض الشركات بالانتقال إلى تصنيع أجهزة تحتوي على الهيدروفلوروكربون-32 ستباع في للسوق المحلية في حين ما زال البعض الآخر ينتج أجهزة تحتوي على غاز R-410A لبيعها في السوق ذاتها. وعلى المنوال نفسه، يصعب على الأمانة أن تفهم كيف تستطيع مصر، كما اقترحت، فرض رسم على المعدات المحتوية على غاز R-410A في حين أنّ شركات وطنية ما زالت تصنّع أجهزة تحتوي على هذا الغاز في ضوء مبدأ عدم التمييز الذي تفرضه منظمة التجارة العالمية.

30. وفضلا عما سبق، أخذت الأمانة علما بأنّ مصر قد بلّغت أمانة الأوزون عن اعتزامها الاستفادة من الإعفاء الخاص بدرجة الحرارة المحيطة العالية المذكور في الفقرات من 26 إلى 37 من مقرر اجتماع الأطراف 2/28 والذي يدرج أجهزة تكييف الهواء السكني، في جملة أجهزة أخرى، على قائمة الأجهزة المعفاة.

31. بغض النظر عن هذا الوضع، تلاحظ الأمانة بشكل عام، أنّه كلما قررت البلدان الملحوظة في المادة 5 أن تحول أجهزة تكييف الهواء السكني إلى التكنولوجيا القائمة على غاز الهيدروفلوروكربون-32، جرى بالفعل تنفيذ عمليات التحول. وتثمن الأمانة التزام مصر والشركات التي وقعت على عقود الكلفة التشغيلية الإضافية بالوفاء بالجدول الزمني لإنتاج أجهزة تكييف الهواء التي تحتوي على الهيدروفلوروكربون-32 للبيع في السوق المحلية دون سواها وذلك بين 1 يناير/كانون الثاني 2025 و31 ديسمبر/كانون الأول 2026 كما تأخذ علما مع التقدير بتأكيدات منظمة الأمم المتحدة للتنمية الصناعية بأنّها لن تسدد التكاليف التشغيلية الإضافية قبل التحقق من أنّ الشركات تقوم بتصنيع أجهزة تحتوي على الهيدروفلوروكربون-32 تماشيا مع المقرر 35/77(أ)(4). وعليه وقع الاتفاق على أنّ توصي الأمانة بإقرار التمويل المخصص لصناعة أجهزة تكييف الهواء السكني في الشريحة الرابعة في ما عدا قيمة التكاليف التشغيلية

الإضافية المتفق عليها والخاصة بالشركتين اللتين لم توقعا بعد على عقود الكلفة التشغيلية الإضافية أي ميراكو وشركة باور للتكييف حيث تبلغ قيمة المبالغ المتفق عليها 1,454,835 دولارا أمريكيا و284,280 دولارا أمريكيا على التوالي على اعتبار أنّ منظمة الأمم المتحدة للتنمية الصناعية قد تقدم، بالنيابة عن مصر، طلب تمويل يشمل رصيد الشريحة الرابعة والبالغ قيمة 1,739,115 دولارا أمريكيا في الاجتماع الذي تقدم فيه مقترح المرحلة الأولى من خطة تنفيذ تعديل كيغالي أو في الاجتماع السادس والتسعين إياهما أقرب الأجلين.

صناعة أجهزة تكييف الهواء التجاري

32. يرد في التقرير المقدم إلى هذا الاجتماع أنّ الوحدات الهجينة من التبريد البخاري غير المباشر والتمدد المباشر تأتي بجديد في مجال تكنولوجيات تكييف الهواء المنقطعة النظير إذ تمثل بديلا لتطبيقات تكييف الهواء يتجاوز في فعاليته فعالية أجهزة التمدد المباشر المعمول بها حاليا. وتتفق الأمانة مع هذا التقييم المشجع وتعتبر أنّه من المستحسن أن تطلع البلدان الأخرى الملحوظة في المادة الخامسة والمصنعة لأجهزة تكييف الهواء التجاري على استنتاجات التقرير إلا أنّها لا تملك إلا أن تلاحظ أنّ غاز التبريد المستخدم في الوحدات الهجينة هو غاز R-410A وليس الهيدروفلوروكربون-32 أو أي بديل آخر ذات إمكانية الاحترار العالمي المنخفضة على النحو المتفق عليه عند إقرار المشروع. فشرحت منظمة الأمم المتحدة للتنمية الصناعية أنّ السبب في ذلك يعود إلى غياب المكونات الأساسية من أجهزة ضغط وصمامات تمدد في ذلك الحين وبما أنّها أصبحت متوفرة، من المفترض أن يجري اختبار وحدات تحتوي على الهيدروفلوروكربون-32 (وأخرى تحتوي على غاز R-454B، إن توفرت) في منطقة مناخية تتميز بدرجة حرارة محيطة عالية بمقياس حرارة جاف البصلة ونسبة متدنية من الرطوبة خلال صيف 2024.

33. اعتبرت اللجنة التنفيذية في اجتماعها التاسع والسبعين أنّ استدامة عملية التحول في صناعة أجهزة تكييف الهواء التجاري يمثل شغلا شاغلا لأنّ السوق تلجأ أصلا إلى المواد الهيدروفلوروكربونية ذات إمكانية الاحترار العالمي العالية بما فيها الهيدروفلوروكربون-134أ وغاز R-410A في الوحدات المعبأة والوحدات المركزية ومبردات المباني. فوقع الاتفاق على أن تقوم مصر، بواسطة منظمة الأمم المتحدة للتنمية الصناعية، بالإفادة بتنفيذ السياسات والتدابير الكفيلة باستدامة عملية التحول في إطار تقارير التنفيذ المرحلي لشرائح المرحلة الثانية من خطة إدارة إزالة المواد الهيدروفلوروكربونية إلى أن يتحقق إقبال الأسواق على البدائل.[7] وفي الاجتماع الثامن والثمانين، اعتبرت منظمة الأمم المتحدة للتنمية الصناعية أنّ اختيار السياسات والتدابير يتوقف على الاستكمال الناجح لأنشطة المساعدة الفنية بما فيها تجميع النماذج الأولية واختبارها وتطوير التكنولوجيا الهجينة من التبريد البخاري غير المباشر والتمدد المباشر والتي كان من المفترض الفروغ منه بحلول سبتمبر/أيلول 2022. فطلبت اللجنة التنفيذية إلى المنظمة أن تقدم، في معرض طلب تمويل الشريحة الرابعة، التدابير السياسية المقترحة لكفالة استدامة عملية التحول إلى البدائل ذات إمكانية الاحترار العالمي المنخفضة في صناعة أجهزة تكييف الهواء التجاري (المقرر 70/88(أ)(2)ب). وأشارت المنظمة إلى أنّ التدابير السياسية ستوضع على أثر عملية الاختبار الإضافية التي ستجري في صيف 2024. وقد ترغب اللجنة التنفيذية في النظر في أي معلومات متصلة بصناعة أجهزة تكييف الهواء التجاري، بما فيها التدابير السياسية المحتملة، عند استعراضها مقترح المرحلة الأولى من خطة تنفيذ تعديل كيغالي في مصر والمفترض تقديمه في الاجتماع السادس والتسعين.

قطاع خدمة أجهزة التبريد

34. أخذت الأمانة علما بأنّ عددا من الأنشطة المخطط لها في قطاع الخدمة سجل تأخيرا في التنفيذ بما في ذلك وضع الأدوات التنظيمية والمؤسسية لتفعيل برنامج الترخيص والتدريب والتوعية على المدونات والمعايير المحلية ووضع اللمسات الأخيرة على الدليل الخاص بمناهج التدريب وترخيص 500 فني في إطار برنامج الترخيص الريادي ووضع اللمسات الأخيرة على أربع مدونات وطنية والمشروع الريادي لتفتيش بعض المباني وترخيصها وتنفيذ مشروع رموز الاستجابة السريعة الإلزامية لأسطوانات غازات التبريد. وفي حين اعتبرت الأمانة أنّه كان لجائحة كوفيد 19 تأثير محتمل على التأخير وأنّ بعض المشاريع مبتكر إلى حدّ ما، مثلا برنامج ترخيص المباني أو مشروع رموز

[7] الفقرة 50(ب) من المذكرة UNEP/OzL.Pro/ExCom/79/32.

الاستجابة السريعة على أسطوانات غازات التبريد، إلا أنّها حثت منظمة الأمم المتحدة للتنمية الصناعية وبرنامج الأمم المتحدة للبيئة على تكثيف جهود المساعدة مشيرة إلى نسبة التخفيض العالية الواجب بلوغها في عام 2025 على النحو الوارد في الاتفاق المبرم بين مصر واللجنة التنفيذية.

35. عندما استعرضت الأمانة المقترح المرفوع إلى الاجتماع التاسع والسبعين، اعتبرت أنّ الأنشطة التدريبية التي تستهدف ورش الخدمة الصغيرة حيث يعمل فني واحد أو فنيان اثنان والتي تستهلك أسطوانتين أو ثلاث أسطوانات من غاز التبريد في الشهر الواحد أمرٌ جدّ مفيد نظرا للقدرات تلك الورش المحدودة. كما شجعت الأمانة منظمة الأمم المتحدة للتنمية الصناعية على تكثيف جهودها لتنظيم دورات التدريب الواردة في الشريحة الثالثة وتلك الواردة في الشريحة الرابعة. وأخذت الأمانة علما أيضا بأنّ مصر قد تطبق البرنامج الوطني لرخصة القيادة في التبريد في عام 2029 رهنا بنتائج برنامج الترخيص لخدمة ما بعد البيع.

36. أمّا في ما يخص مركز الاستصلاح الذي تمّ تحديده منذ عام 2021، فسعت الأمانة إلى فهم أسباب التأخير في الاستحصال على الرخصة اللازمة للبدء بالتشغيل. وشرحت منظمة الأمم المتحدة للتنمية الصناعية أنّه للمركز رخصة لإعادة تعبئة غازات التبريد والتأخر في الحصول على رخصة لأنشطة الاستصلاح يعزى إلى أنّ هذه الأنشطة تمثل فئة من العمليات التجارية المستجدة استحدثتها وزارة الصناعة. أمّا مركز الاستصلاح الآخر المزمع إنشاؤه بموجب الشريحة الرابعة، فلن يواجه، بتقدير المنظمة، التأخير نفسه لأنّه سبق وتأسست فئة الأنشطة التجارية الجديدة.

37. كما عانى المشروع على صعيد توريد المعدات، بما في ذلك مركز الامتياز لغازات التبريد القابلة للاشتعال، من تأخير في التخليص الجمركي. ومن الجدير بالذكر أنّه في حين جرى تخليص الجزء الأكبر من المعدات بقي البعض منها محجوزا لدى الجمارك فلن تنظم ورش التدريب في مركز الامتياز قبل استلام المعدات. وكانت اللجنة التنفيذية في اجتماعها الثالث والتسعين قد أرجأت إلى 30 يونيو/حزيران 2024 موعد إنجاز مكوّن التدريب الذي تنفذه ألمانيا (EGY/PHA/84/INV/142). لذلك توصي الأمانة إطالة مدة المشروع إلى 31 أكتوبر/تشرين الثاني 2024 ريثما ينتهي تخليص المعدات اللازمة من الجمارك وتنظيم الدورات التدريبية.

<u>تنفيذ السياسة الجنسانية</u>

38. أقرّت المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية قبل اعتماد سياسة مراعاة المنظور الجنساني في العمليات (المقرر 92/84(د)). ومع ذلك شاركت مهندسات في مشاريع التحويل في شركتي العربي وفريش كما تعقبت وحدة الأوزون الوطنية مشاركة النساء في شتى الأنشطة التدريبية (مبلغ عنها في ما سبق.). وقد شاركت نساء ثلاث في دورة تدريب المدربين ونالت مهندسات ثلاث شهادات تقدير من وزارة البيئة ووزارة العمل ووزارة التضامن الاجتماعي مشيدة بمساهمتهن في تنظيم دورة تدريب المدربين وترقية مركز التدريب بما يتيح له التدريب على الغازات القابلة للاشتعال. ويرجى من أنشطة التدريب وشهادات التقدير هذه أن تساهم في زيادة مشاركة المدربات والفنيات في الأنشطة التدريبية المقبلة. أمّا مسودة السياسة التي وضعتها وحدة الأوزون الوطنية للنهوض بمراعاة البعد الجنساني فهي في انتظار اللمسات الأخيرة.

<u>استدامة إزالة المواد الهيدروكلوروفلوروكربونية وتقييم المخاطر</u>

39. حرصا على استدامة عمليات التحول في قطاعي رغوة البوليسترين المسحوبة بالضغط والبوليوريثان، فرضت مصر حظرا على استخدام المواد الهيدروكلوروفلوروكربونية في صناعة رغوة البوليسترين المسحوبة بالضغط (بدءا من 1 يناير/كانون الأول 2023) وعلى استيراد الهيدروكلوروفلوروكربون-141ب (بدءا من 1 يناير/كانون الثاني 2020) والهيدروكلوروفلوروكربون-141ب في البوليولات السابقة الخلط (بدءا من 1 يناير/كانون الثاني 2018). كما حظرت مصر استيراد الهيديروكلوروفلوروكربون-142ب وغاز R-406A واستيراد المعدات المحتوية على المواد الهيدروكلوروفلوروكربونية وتصنيعها بداء من 1 يناير/كانون الثاني 2023. وكلها تدابير تساهم، فضلا عن تفعيل النظام الوطني للحصص والتراخيص، في استدامة إزالة المواد الهيدروكلوروفلوروكربونية.

40. ويرجح أن تعود الزيادة الملموسة في استهلاك الهيدروكلوروفلوروكربون-22 في عام 2023 إلى تخزين كميات من هذه المادة كما أنّه من غير المرجح استمرار هذا المخزون ومن شأنه أن يؤدي إلى تخفيض في كمية الهيدروكلوروفلوروكربون المستورد في عامي 2024 و2025. وقد لاحظت الأمانة التراجع الملموس في الاستهلاك لبلوغ أهداف عام 2025 وشجعت منظمة الأمم المتحدة للتنمية الصناعية وبرنامج الأمم المتحدة للبيئة على مواصلة مساعدة مصر على تنفيذ الأنشطة الواردة في خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية بما يجعلها تستمر في حالة من الامتثال للاتفاق المبرم مع اللجنة التنفيذية.

41. تعتبر الأمانة أن خطر عدم استدامة إزالة المواد الهيدروكلوروفلوروكربونية في قطاعي تصنيع أجهزة تكييف الهواء السكني والتجاري منخفضٌ إلا أنّها تعي صعوبة تقييم خطر عدم استدامة عملية التحول إلى التكنولوجيات ذات إمكانية الاحترار العالمي المنخفضة في هذين القطاعين بسبب استخدامهما الواسع النطاق لغاز R-410A وفي غياب المعلومات التي لن تتوفر قبل أن تقدم مصر مقترح المرحلة الأولى من خطة تنفيذ تعديل كيغالي حيث تبيّن كيف تعتزم مصر، وإن عزمت، تطبيق إعفاء درجة الحرارة المحيطة العالية على هذين القطاعين وتكشف المشهد الكامل لصناعة أجهزة تكييف الهواء السكني والتجاري المحتوية على غاز R-410A وتتضمن عمليات التحويل الإضافية المحتملة وتحمل في طياتها السياسات والتدابير التنظيمية التي من شأنها أن تزيد من إقبال السوق على التكنولوجيات التي أقرّت في خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية. وتتوضح الصورة بشكل أفضل أمام اللجنة التنفيذية عندما يرفع إلى عنايتها الطلب المشترك لتمويل المرحلة الأولى من خطة تنفيذ تعديل كيغالي في مصر مصحوبا بطلب تمويل قدره 1,739,115 دولارا أمريكيا زائد تكاليف دعم منظمة الأمم المتحدة للتنمية الصناعية. ونظرا لحجم الأرصدة في حوزة منظمة الأمم المتحدة للتنمية الصناعية، لا ترى الأمانة أنّ إرجاء النظر في فتح الاعتمادات المتبقية إلى الاجتماع الخامس والتسعين أو السادس والتسعين من شأنه أن يؤخر استكمال عمليات التحويل في صناعة أجهزة تكييف الهواء السكني. بل وإنها تعتبر أنّ إقرار التمويل المطلوب من شأنه أن يمكّن شركات القطاع التي وقعت على عقود التكاليف التشغيلية الإضافية من الاقتصار على توريد السوق المحلية بأجهزة تكييف هواء سكني تحتوي على الهيدروكلورفلوركربون-32 دون سواها بحلول 1 يناير/كانون الثاني 2025 أو 1 ديسمبر/كانون الأول 2026. وهذه المدة من الزمن التي تقلّ عما ورد في الجدول 3 من المذكرة UNEP/OzL.Pro/ExCom/88/47 ستمثل فسحة لبناء الثقة في التكنولوجيا وعاملا لتسهيل عمليات التحول اللاحقة.

الخلاصة

42. لمصر نظام حصص وتراخيص استيراد ساري المفعول كما أنّ الاستهلاك المحقق منه في عام 2021 و2022 و2023 أدنى من مستوى الأهداف المحددة في الاتفاق مع اللجنة التنفيذية. واستكملت عمليات التحول في قطاعي تصنيع رغوة البوليسترين المسحوبة بالضغط والبوليوريثان. وفرضت مصر عددا من حالات الحظر كفالة لاستدامة إزالة المواد الهيدروكلوروفلوروكربونية. وقد بلغ معدل صرف أموال الشريحة الثالثة المقررة لتاريخه نسبة 27 في المائة و62 في المائة على التوالي. ومع أنّه قدمت المساعدة الفنية لمساعدة صناعة أجهزة تكييف الهواء التجاري على إنتاج أجهزة تعتمد تكنولوجيا مبتكرة وهي تكنولوجيا الوحدات الهجينة من التبريد البخاري غير المباشر والتمدد المباشر إلا أنّها لم تشرع بعد بتصنيع تلك الأجهزة مستخدمة الهيدروكلوروفلوروكربون-32 أو البدائل ذات إمكانية الاحترار العالمي المنخفضة. إنّ الاختبارات الإضافية التي ستجرى في صيف 2024 من شأنها أن تساهم في نيل هذه الغاية. فضلا عن ذلك وفي حين تمّ تركيب معدات لتصنيع أجهزة تكييف الهواء السكني في أربع من أصل خمس شراكات مشاركة في خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية إلا أنّ تصنيع الأجهزة للسوق المحلية في تلك الشركات ما زال يعتمد بشكل شبه خالص غاز R-410A كما جرى التعرف على مزيد من الشركات التي تصنّع أجهزة تكييف الهواء السكني المحتوية على غاز R-410A لسد احتياجات السوق المحلية. وتعتبر الأمانة أنّ تصديق مصر على تعديل كيغالي وقرارها سداد التكاليف التشغيلية الإضافية إلى الشركات التي تلتزم تسويق وحدات تكييف الهواء السكني المحتوية على الهيدروفلوروكربون-32 دون سواها على الأسواق المحلية بحلول 31 ديسمبر/كانون الأول 2026 أو قبل هذا الموعد إشارة ذات دلالة للقطاع الصناعي والأسواق من شأنها أن تيسر التحول إلى مادة الهيدروفلوروكربون-32. ونظرا للتخفيض الهام في الاستهلاك الذي يمثله الهدف المحدد لعام 2025، لا بدّ من أن تواصل مصر بذل جهود

مطردة بدعم من منظمة الأمم المتحدة للتنمية الصناعية وبرنامج الأمم المتحدة للبيئة لضمان امتثالها للاتفاق المبرم مع اللجنة التنفيذية.

التوصية

43. قد ترغب اللجنة التنفيذية في:

(أ) أن تأخذ علما بالتقرير المرحلي عن تنفيذ الشريحة الثالثة من المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية في مصر؛

(ب) أن تقرّ إرجاء موعد استكمال المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية (الشريحة الثانية) (EGY/PHA/84/INV/142) إلى 31 أكتوبر/تشرين الأول 2024 مما يتيح فرصة لإنجاز الأنشطة الجارية؛

(ج) أن تقرّ تمويل الشريحة الرابعة من المرحلة الثانية من خطة إدارة إزالة المواد الهيدروكلوروفلوروكربونية في مصر بقيمة 2,662,825 دولارا أمريكيا والمتألف من 2,300,298 دولارا أمريكيا زائد 161,021 دولارا أمريكيا لتكاليف دعم منظمة الأمم المتحدة للتنمية الصناعية و180,000 دولار أمريكي زائد 21,506 دولارا أمريكيا لتكاليف دعم برنامج الأمم المتحدة للبيئة؛ وخطة التنفيذ المتصلة بها للفترة من 2024 إلى 2026 على اعتبار أنّ منظمة الأمم المتحدة للتنمية الصناعية ستقدم، بالنيابة عن مصر، طلب تمويل يشمل رصيد الشريحة الرابعة ويتألف من 1,739,115 دولارا أمريكيا زائد 121,738 دولارا أمريكيا لتكاليف دعم الوكالة في الاجتماع الذي تقدم فيه مقترح المرحلة الأولى من خطة تنفيذ تعديل كيغالي للتخفيض التدريجي للمواد الهيدروفلوروكربونية في مصر أو في الاجتماع السادس والتسعين للجنة التنفيذية إياهما أقرب الأجلين.

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.

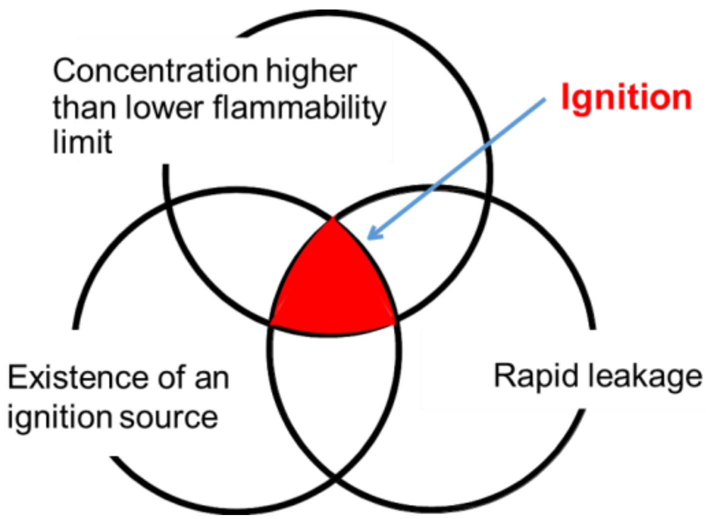


Figure 1: FACTORS AND PROBABILITY OF IGNITION

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.

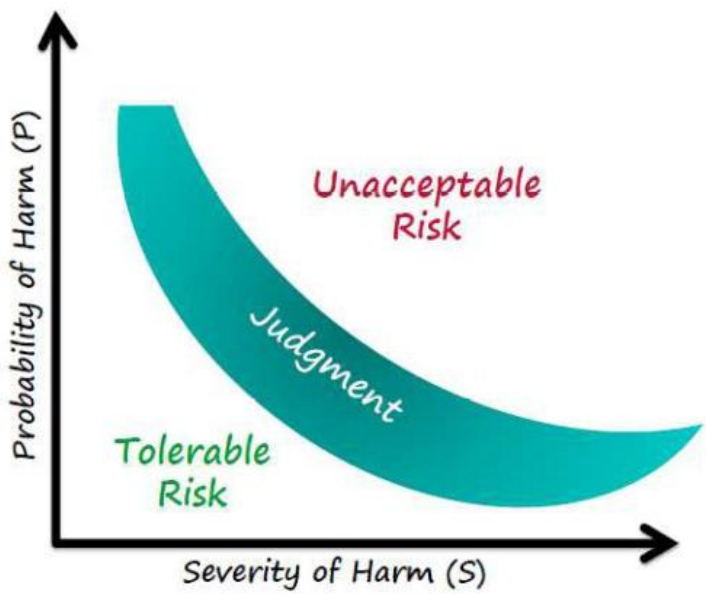


FIGURE 2: TOLERABLE VS. ACCEPTABLE RISK (SOURCE: UL)

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)

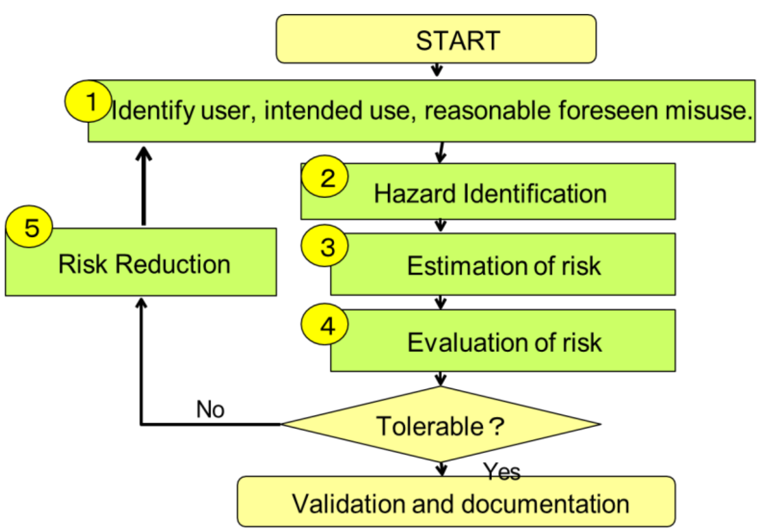


FIGURE 4: PROCEDURE OF RISK EVALUATION

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.

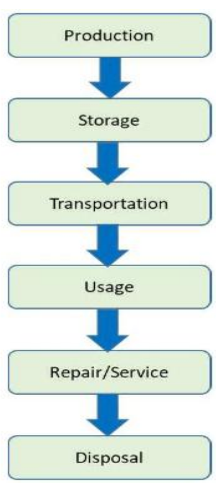


FIGURE 5: LIFE CYCLE RANGE FOR ASSESSMENT

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	Tolerable risk 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:

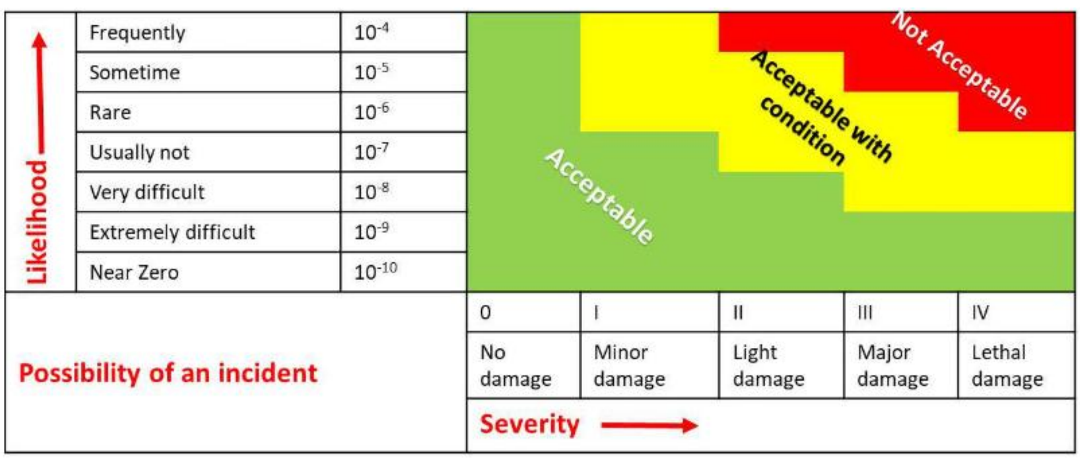


FIGURE 6: RISK MAP

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).

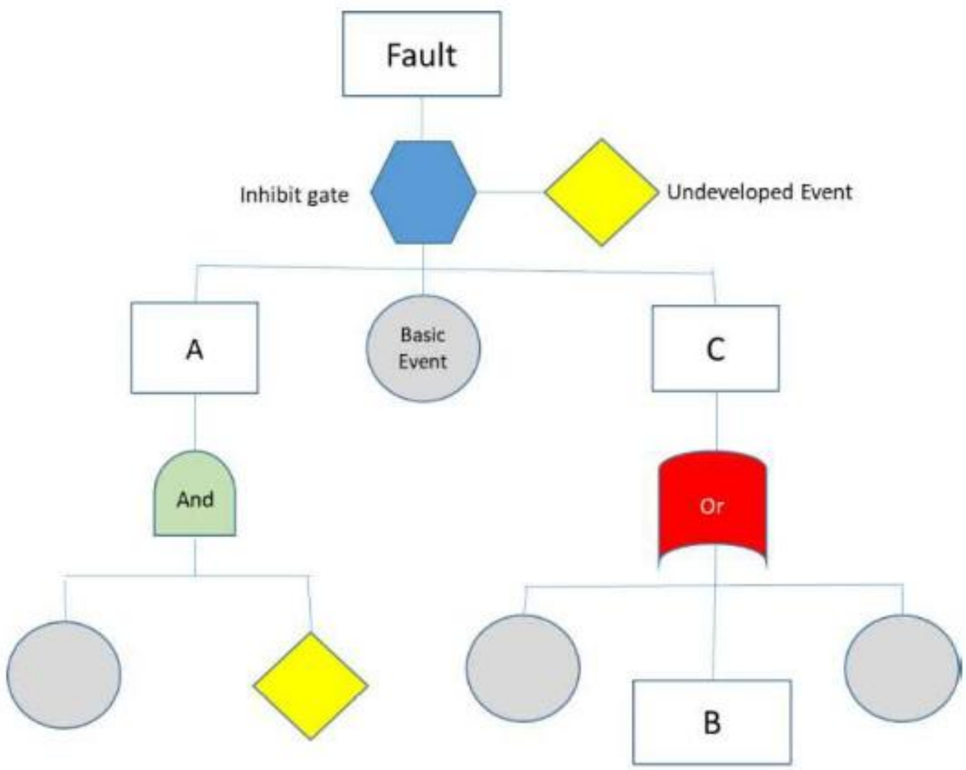


FIGURE 7: FAULT TREE ANALYSIS (FTA) MODEL

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).

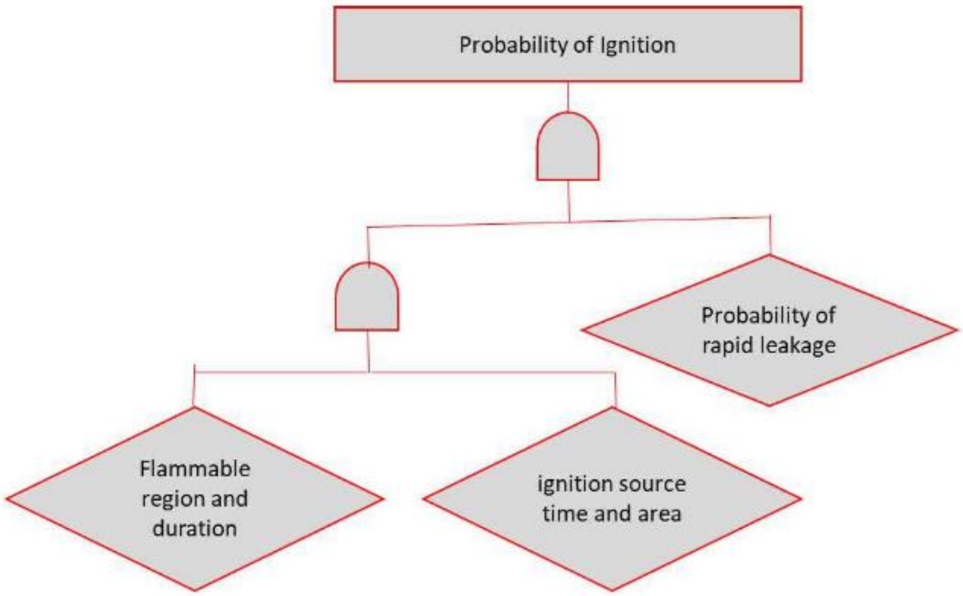


FIGURE 8: PROBABILITY OF IGNITION FTA

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:

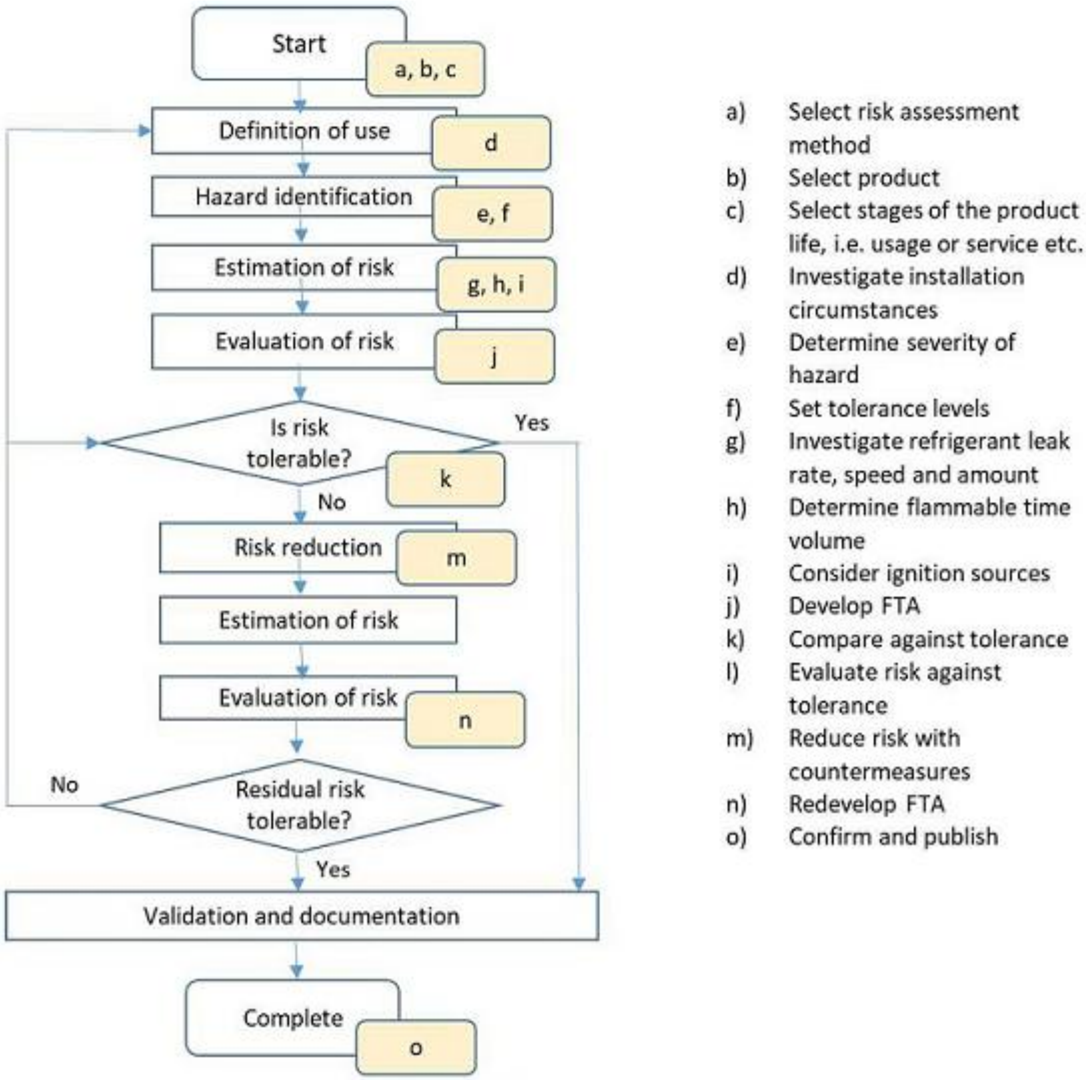


FIGURE 9: FTA REITERATIVE PROCESS

- 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.

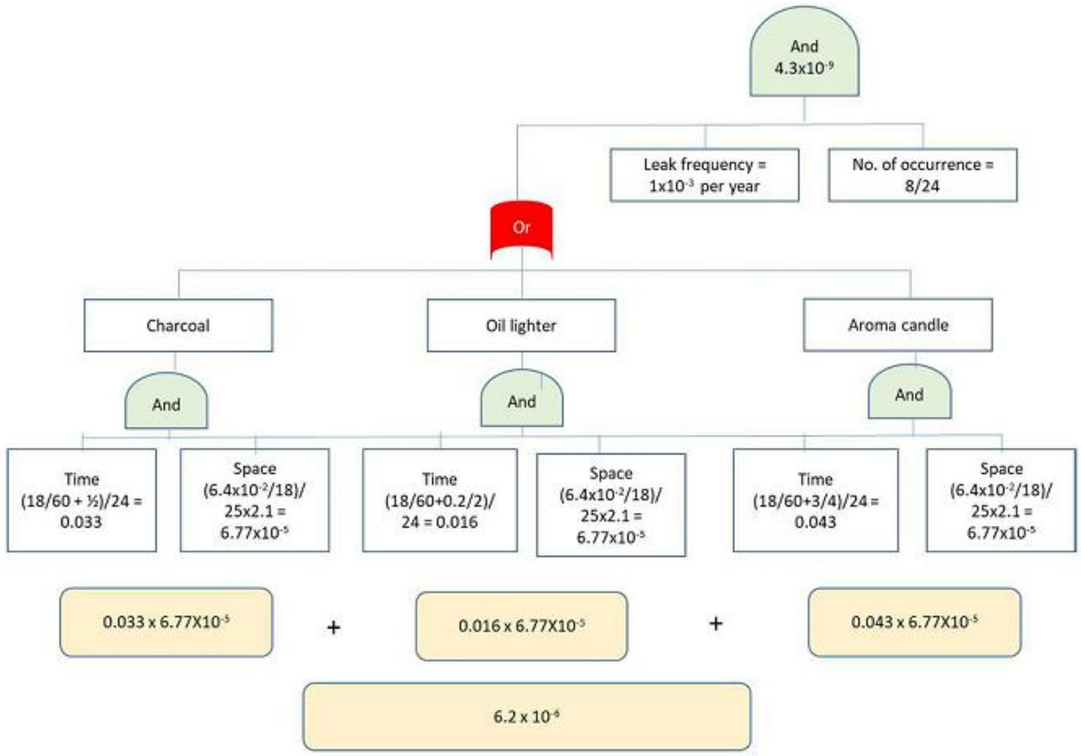


FIGURE 10: FTA FOR USAGE STAGE

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.

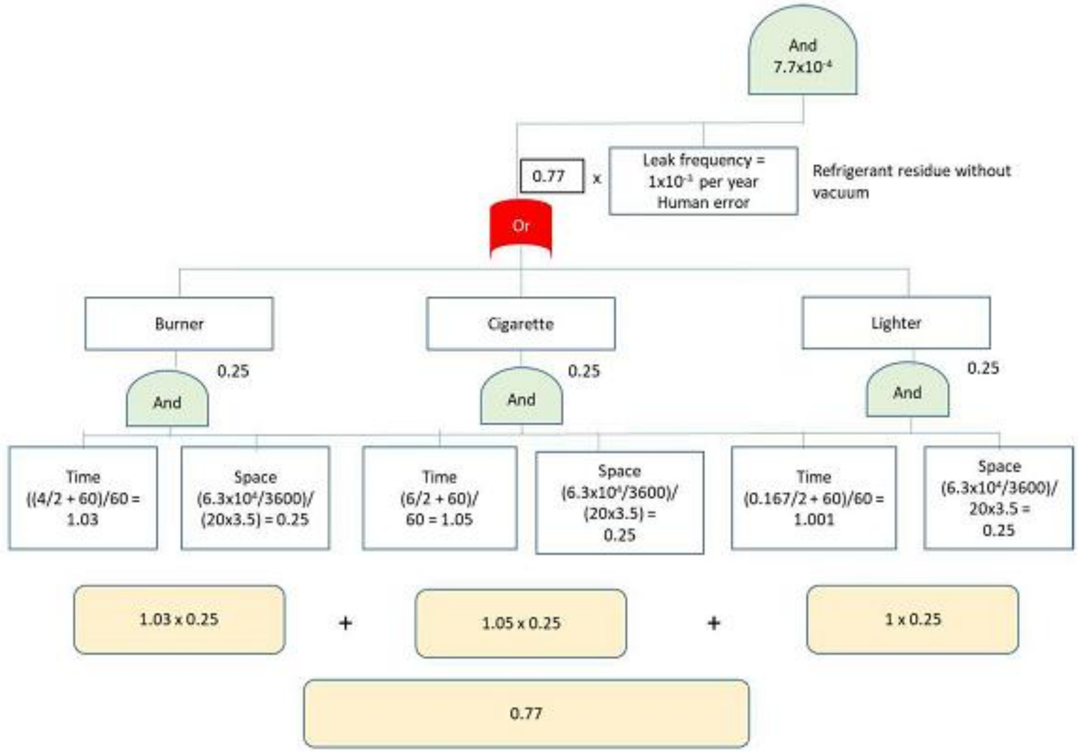


FIGURE 11: FTA FOR SERVICING STAGE

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

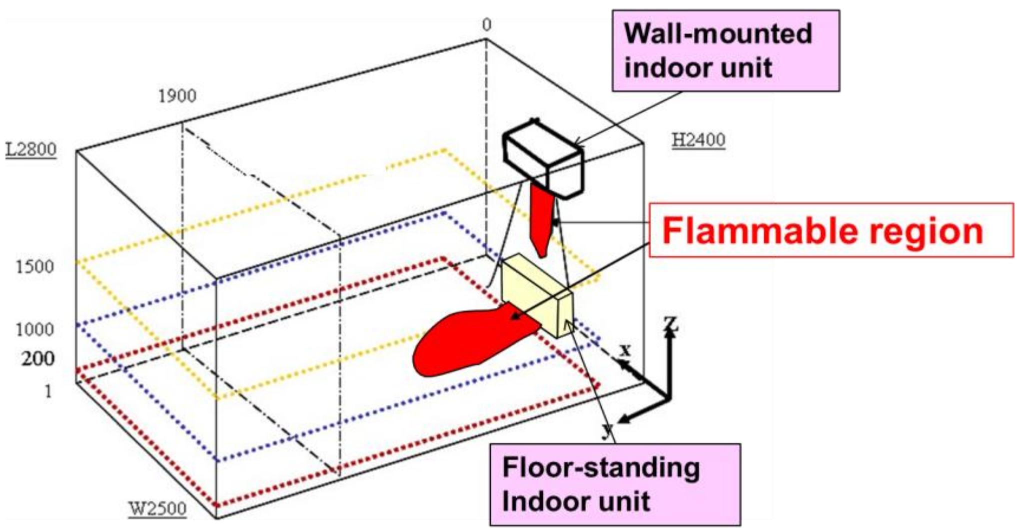


FIGURE 12: Flammable gas region

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.

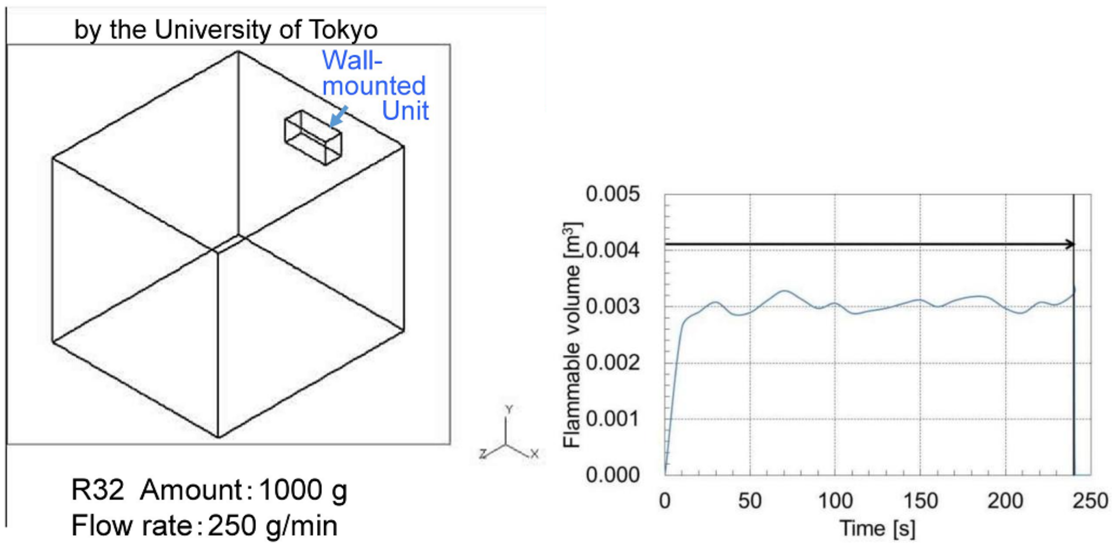


FIGURE 13: Flammable gas of the wall mounted AC

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.

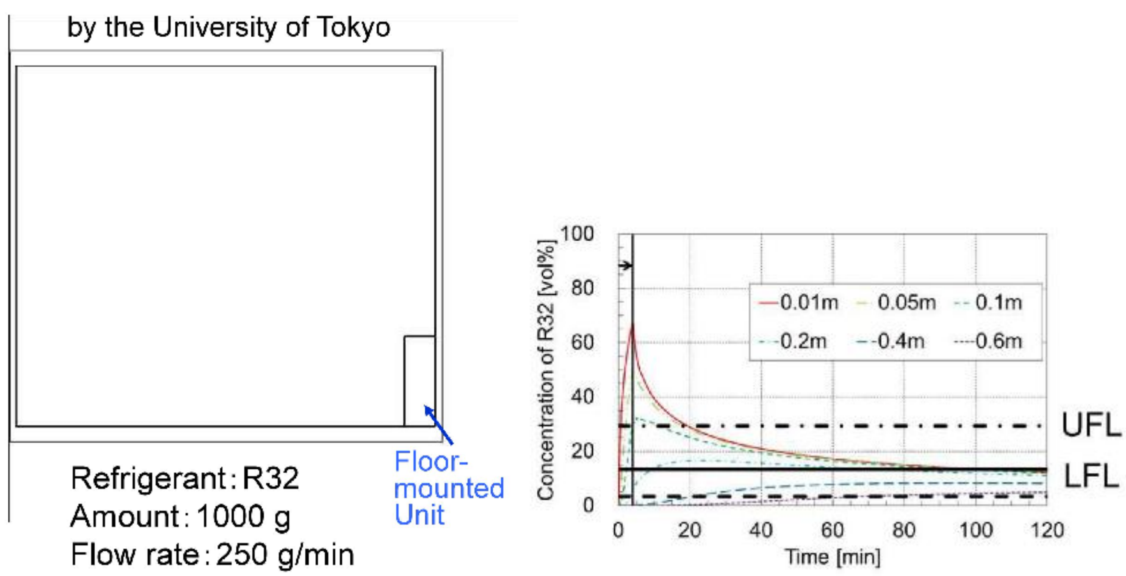


FIGURE 14: Flammable gas of the floor mounted AC

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.

For more information on the study please contact Mohamed **NEGM** - Communication Expert M.NEGM2@UNIDO.ORG or Viktoriia **KOTLUBEI** - International Consultant V.KOTLUBEI@UNIDO.ORG

Table of contents:

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**	

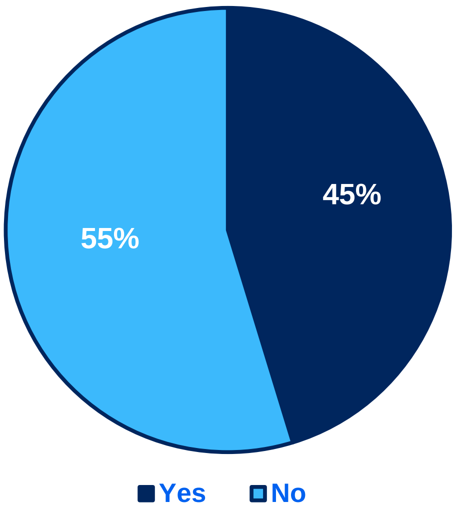
8) What is the feature that you wish/would like to have, that is not available in your current AC?	**Gather info on respondents' potential wishes in ACs.**

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)

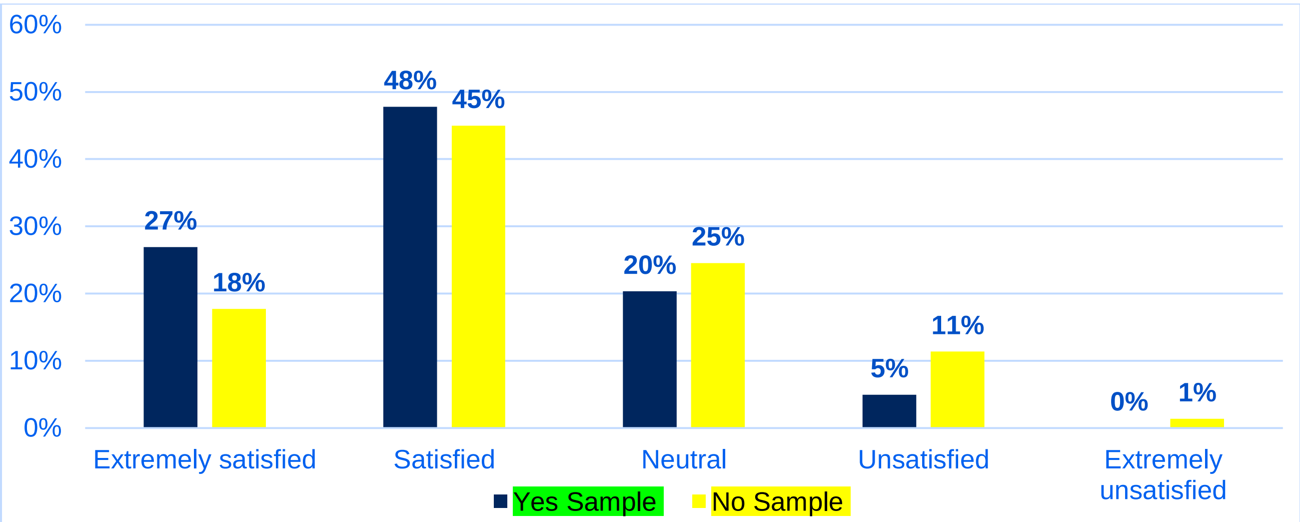
The survey was conducted with the participation of 402 individuals. 182 respondents confirmed that they had purchased eco-friendly air-conditioners (ACs) and were referred to as the **"Yes Sample"**. The remaining 220 individuals who did not buy eco-friendly ACs were referred to as the **"No Sample"**.

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?

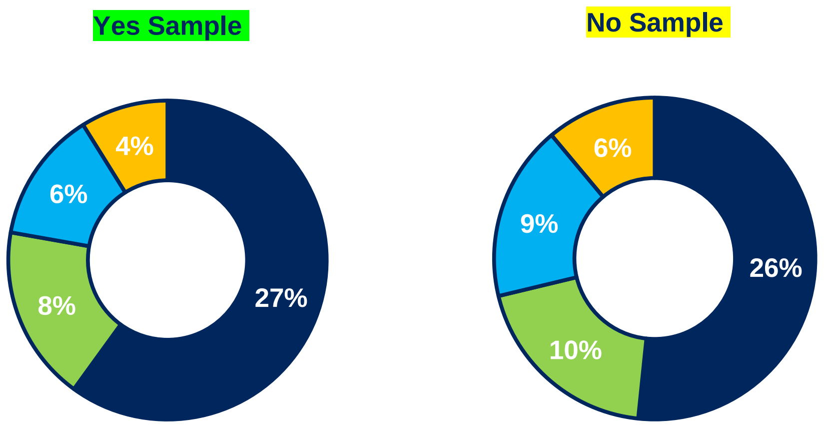
As for the assessment of the satisfaction level with the current ACs products in the Egyptian Market. The statistical analysis of the sample shows that **48%** of the **Yes Sample** and **45%** of the **No Sample** was satisfied with the ACs in the Egyptian Market.



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

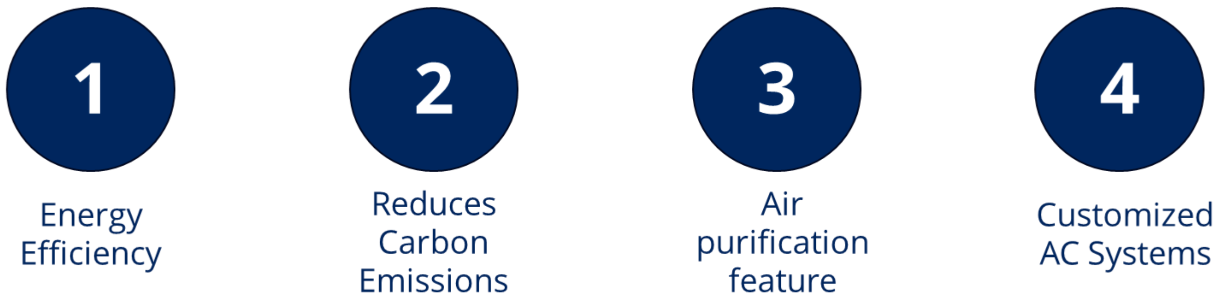
Concerning the definition of the **Eco-friendly,** the statistical analysis of the sample shows that **27%** from **Yes Sample** define Eco-Friendly as it saves electricity, **8%** define it as a protects the environment, **6%** doesn't define it as emit harmful gases or emissions into the air, and **4%**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



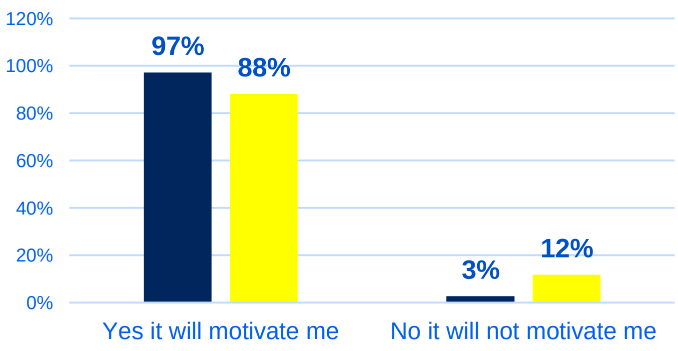
What is your definition when you hear that this product is "Eco-friendly"?

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.



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

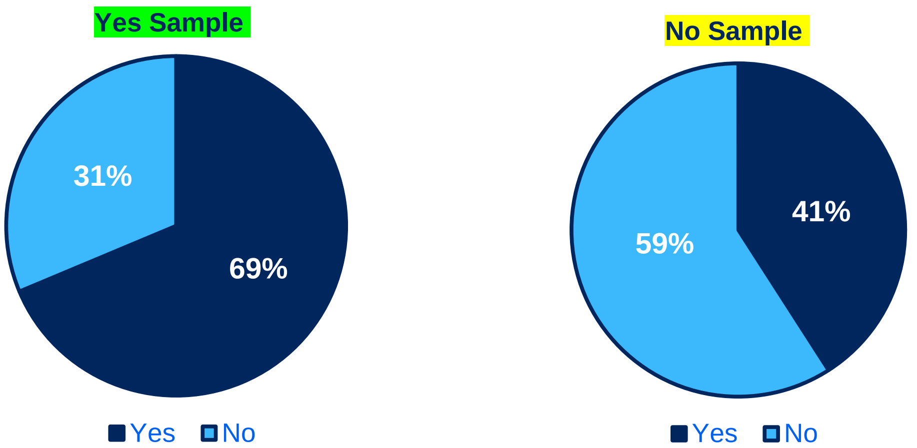
The survey also revealed that **97%** of the **Yes Sample** are motivated by the idea of the eco-friendly AC while **3%** are not motivated by the idea. While **88%** from the **No Sample** are motivated and **12%** are not motivated by the idea of Eco-friendly ACs.



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

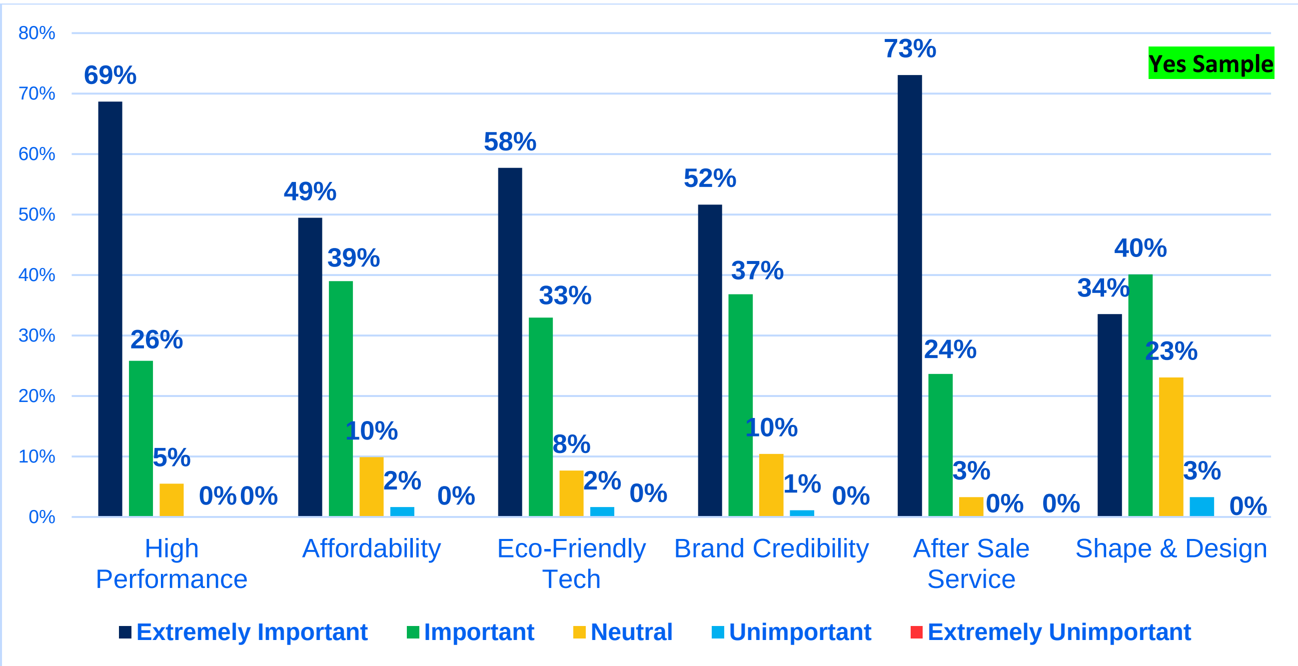
According to the statistical analysis of the sample, **69%** of the respondents who answered **"Yes"** were aware that using AC with R32 can help combat climate change and reduce global warming while being more efficient in consuming electricity, while **31%** were not aware of this.

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.



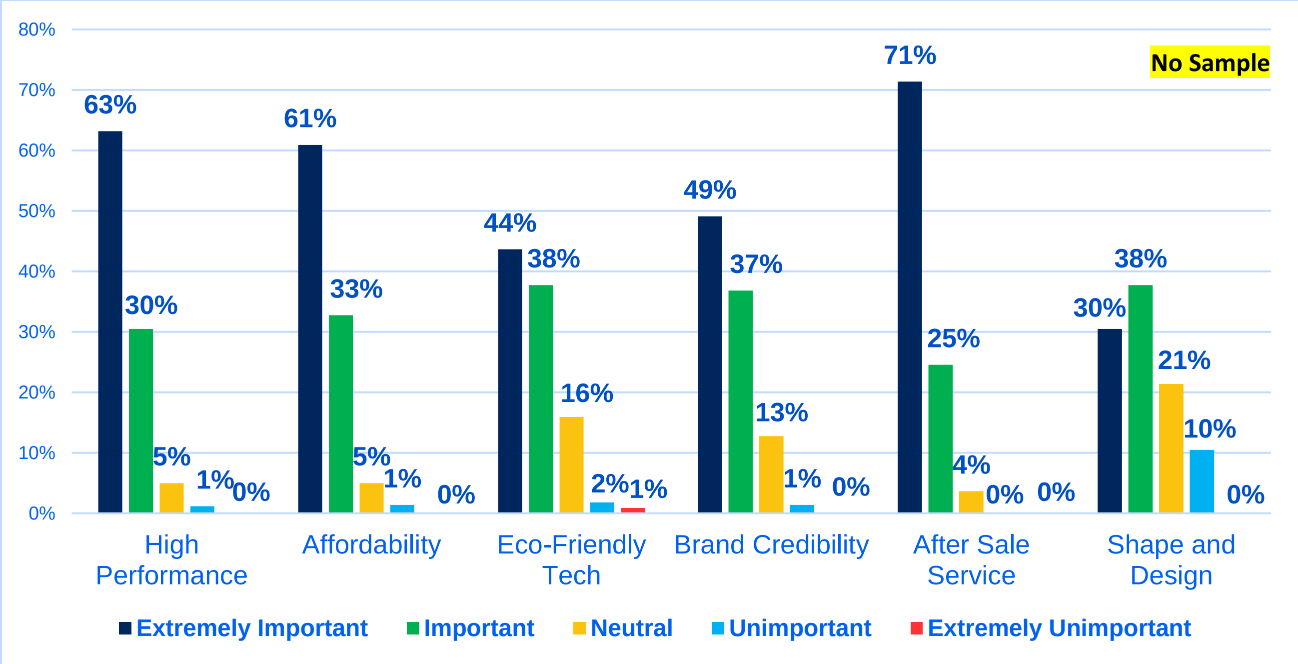
Knowledge of R32 benefits to ozone layer

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.

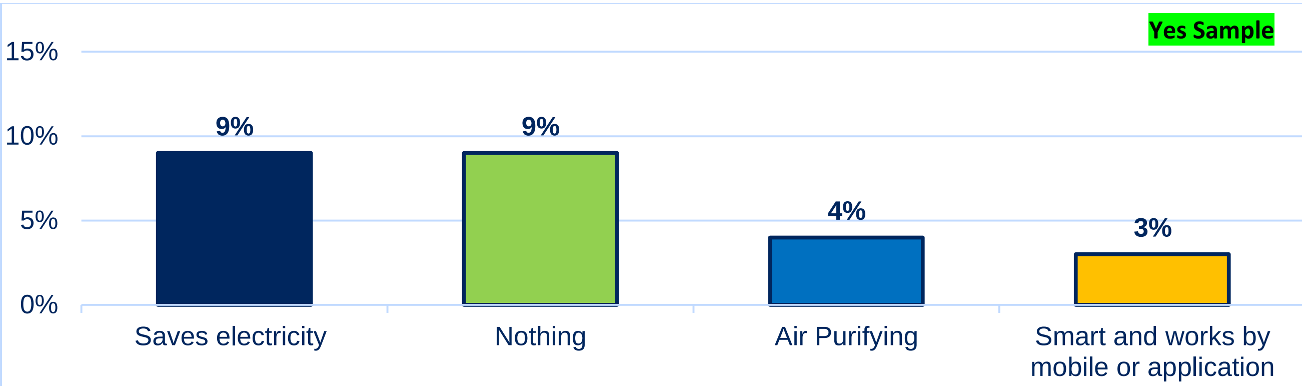


Factors that affecting AC consumers decisions

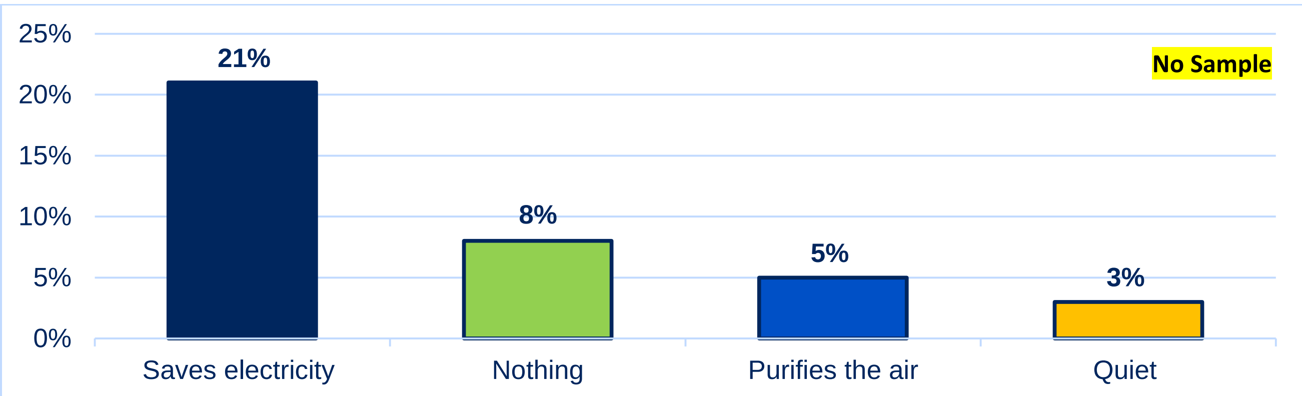
While, the respondents of **No Sample** rated 'After Sale Service' as the most important factor with an extremely high percentage of 71%, followed by 'High Performance' at 63%, 'Affordability' at 61%, and 'Brand Credibility' at 49%.



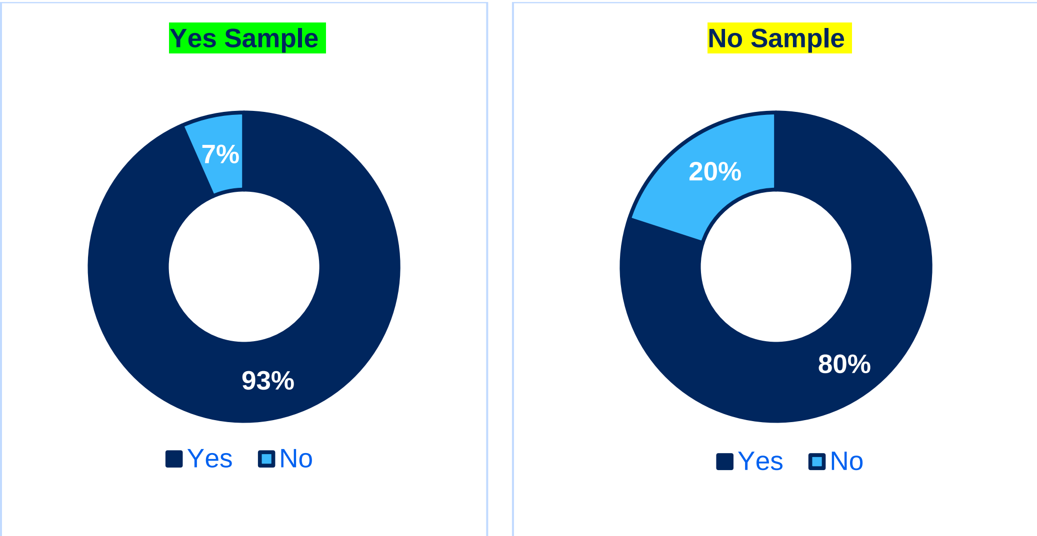
Regarding the identification of respondent preferences that are not currently available in the AC. The statistical analysis of the sample shows that **9%** of the **Yes Sample** wish to have ACs that save electricity and power, followed by **4%** that wish to have Air Purifying ACs, and **3%** wish to 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

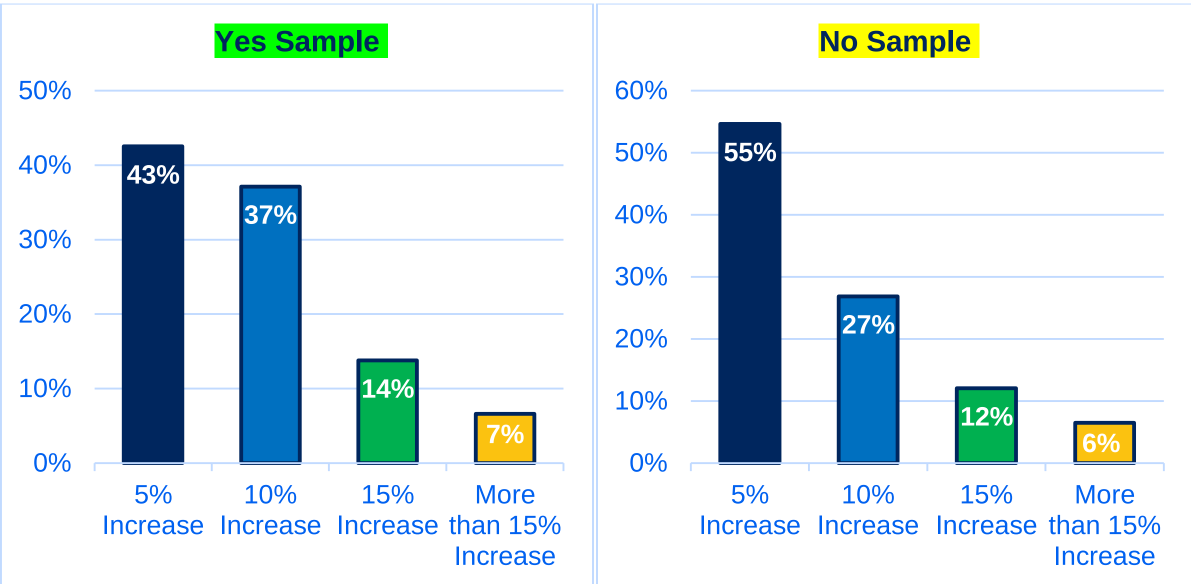


The last part of the survey is designed to investigate the respondents' willingness to pay for an Eco-Friendly AC that offers Energy efficiency, lower energy consumption, saving the environment, and reducing global warming. The statistical analysis of the sample shows that 93% of the **Yes Sample** and 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

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

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

Table of Contents

List of Figures

List of Tables

Acronyms

HPMP	HCFC Phase-out Management Plan
IEC-H	Indirect Evaporative Cooling - Hybrid
DX	Direct Expansion
CZ	Climatic Zone
GWP	Global Warming Potential
NPV	Net Present Value
EFLH	Equivalent Full Load Hours Per Year
EER	Energy Efficiency Ratio
COP	Coefficient of Performance
IRR	The internal rate of return
EGP	Egyptian Pound
$T_{db\ amb}$	Ambient dry bulb temperature for both Units
$T_{wb\ amb}$	Ambient wet bulb temperature for both Units
RH_{amb}	Ambient Relative Humidity for both Units
$T_{db\ out}$ IEC-H	Outlet dry bulb temperature for IEC Hybrid Unit
$T_{wb\ out}$ IEC-H	Outlet wet bulb temperature for IEC Hybrid Unit
RH_{out} IEC-H	Outlet Relative Humidity for IEC Hybrid Unit
W_{Lvl} IEC-H	Water level change for IEC Hybrid Unit per hour
W_{Vol} IEC-H	Evaporated Water Consumed for IEC Hybrid Unit per hour (Volumetric Flow Rate)
Comp. IEC-H	Compressor power consumption for IEC Hybrid Unit
Pump IEC-H	Pump consumption for IEC Hybrid Unit
Evap. Fan IEC-H	Evaporative Fan consumption for IEC Hybrid Unit
Sup. Fan IEC-H	Supply Fan consumption for IEC Hybrid Unit
Pw_{Tot} IEC-H	Total Power consumption for IEC Hybrid Unit
$T_{db\ out}$ DX	Outlet dry bulb temperature for DX Unit
$T_{wb\ out}$ DX	Outlet wet bulb temperature for DX Unit
RH_{out} DX	Outlet relative humidity for DX Unit
Pw_{Tot} DX	Total Power consumption for DX Unit
h_{amb}	Enthalpy of Ambient inlet Air
h_{out} DX	Enthalpy of outlet Air for DX Unit
h_{out} IEC-H	Enthalpy of outlet Air for IEC Hybrid Unit
ρ_{amb}	Density of Ambient Air

Executive Summary:

This Project is contracted to provide assistance to the Egyptian Government in carrying out the project entitled “HCFC PHASE-OUT MANAGEMENT PLAN (HPMP) EGYPT (STAGE II)”

The project required each OEMs to individually manufacture a custom-built Indirect Evaporative Cooling Hybrid Air Conditioner (IEC-H) prototypes and a central DX unit to test and compare their performances under actual operating conditions in 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

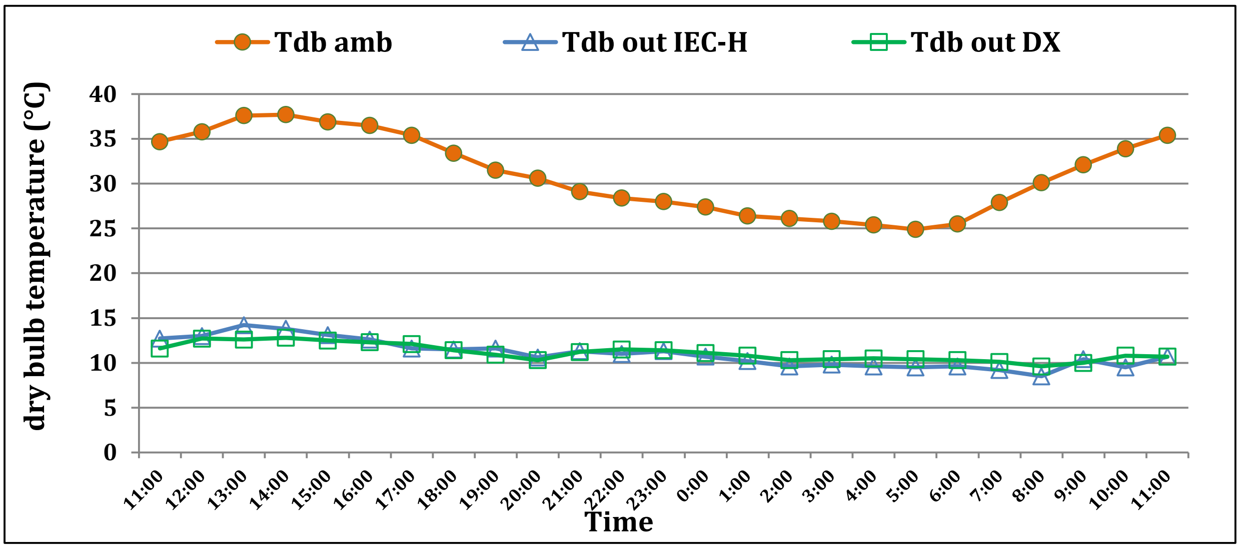


Fig 4: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM2 at CZ2

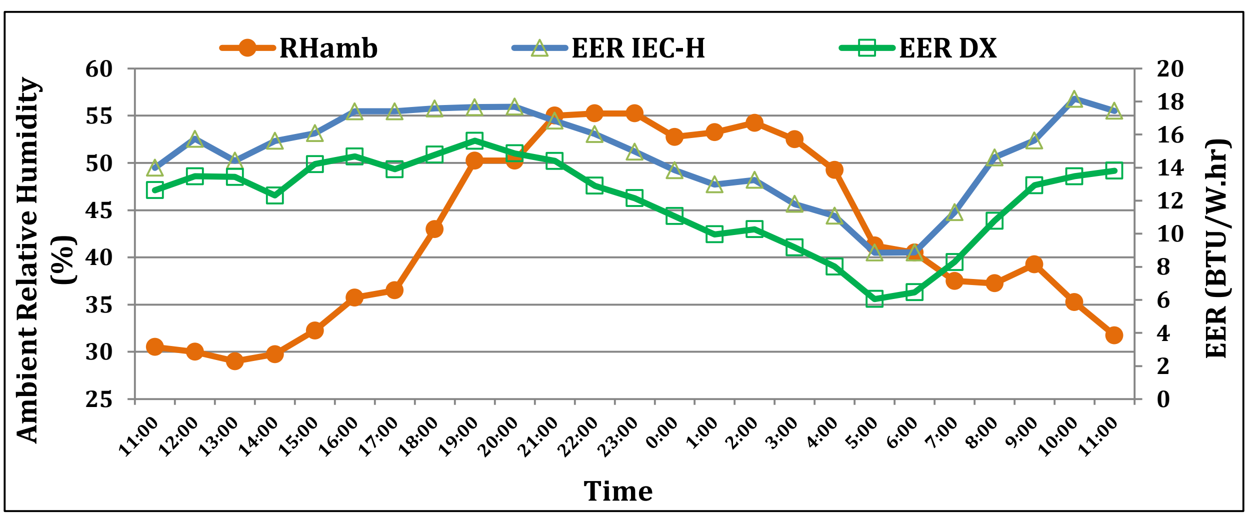


Fig 5: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM2 at CZ2

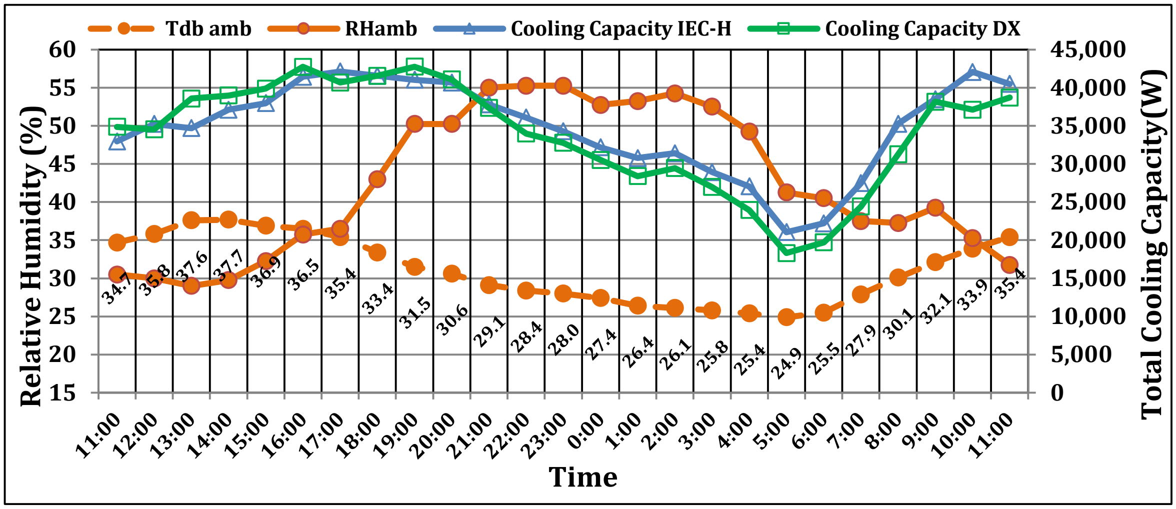


Fig 6: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM2 at CZ2

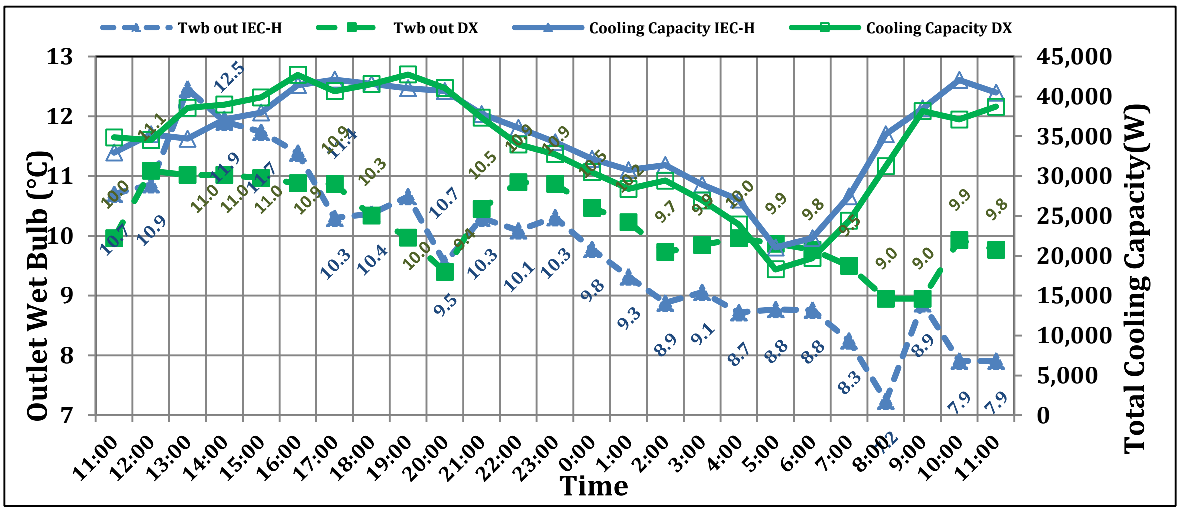
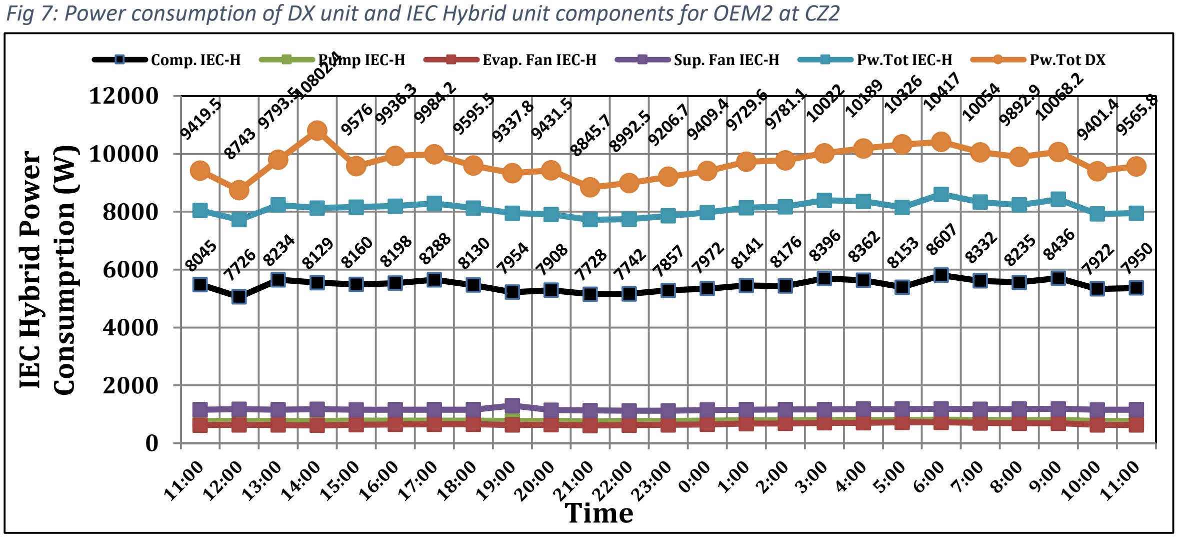


Fig 7: Power consumption of DX unit and IEC Hybrid unit components for OEM2 at CZ2



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

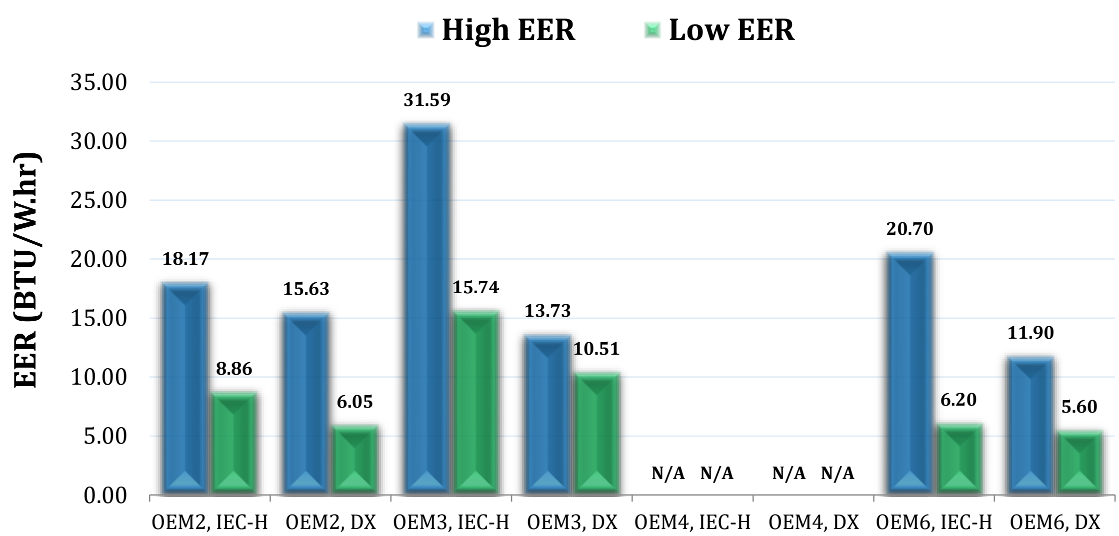
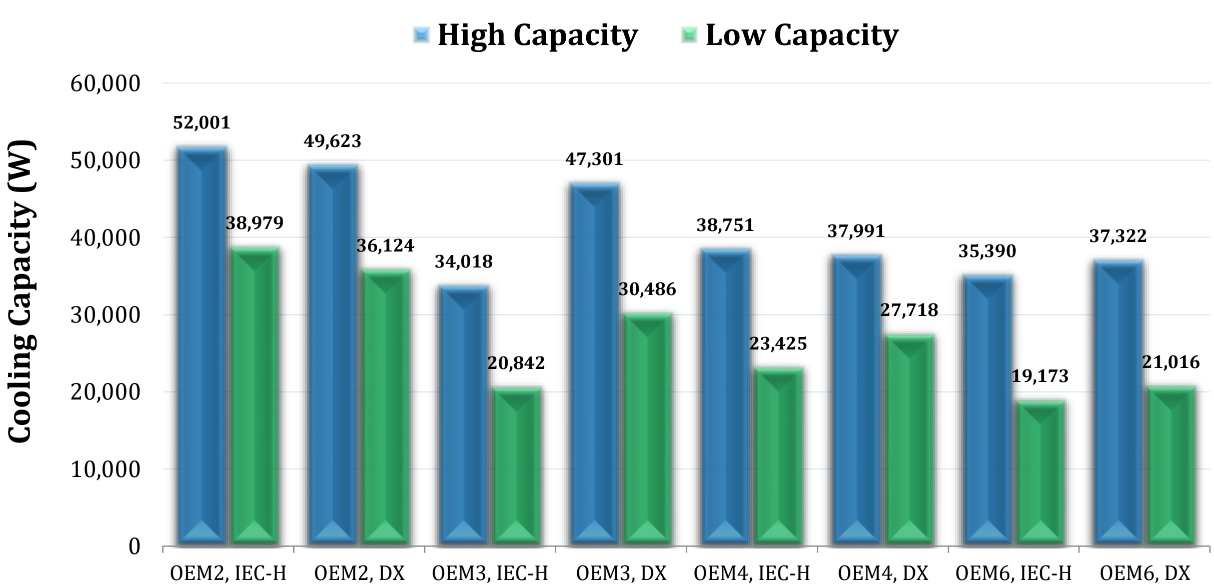


Fig 15: High and Low Capacity (in W) for Climatic Zone 5



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.

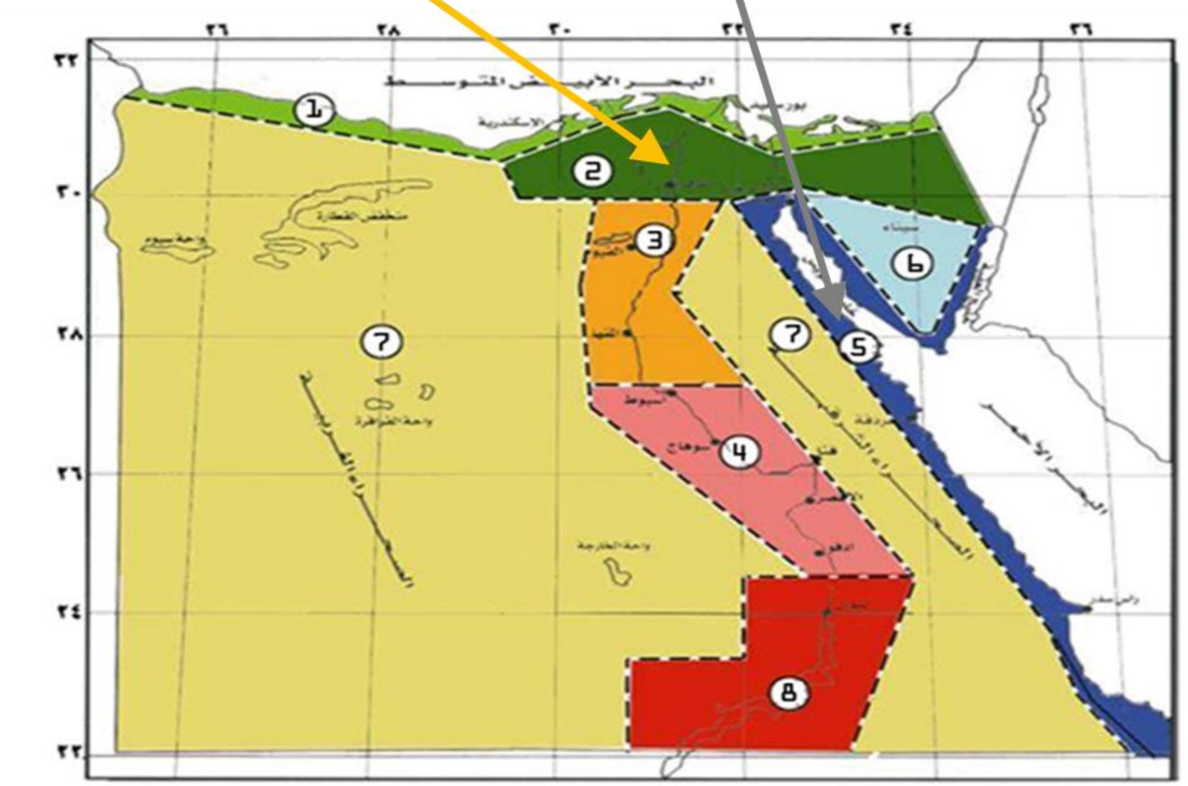
Chapter 1

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?

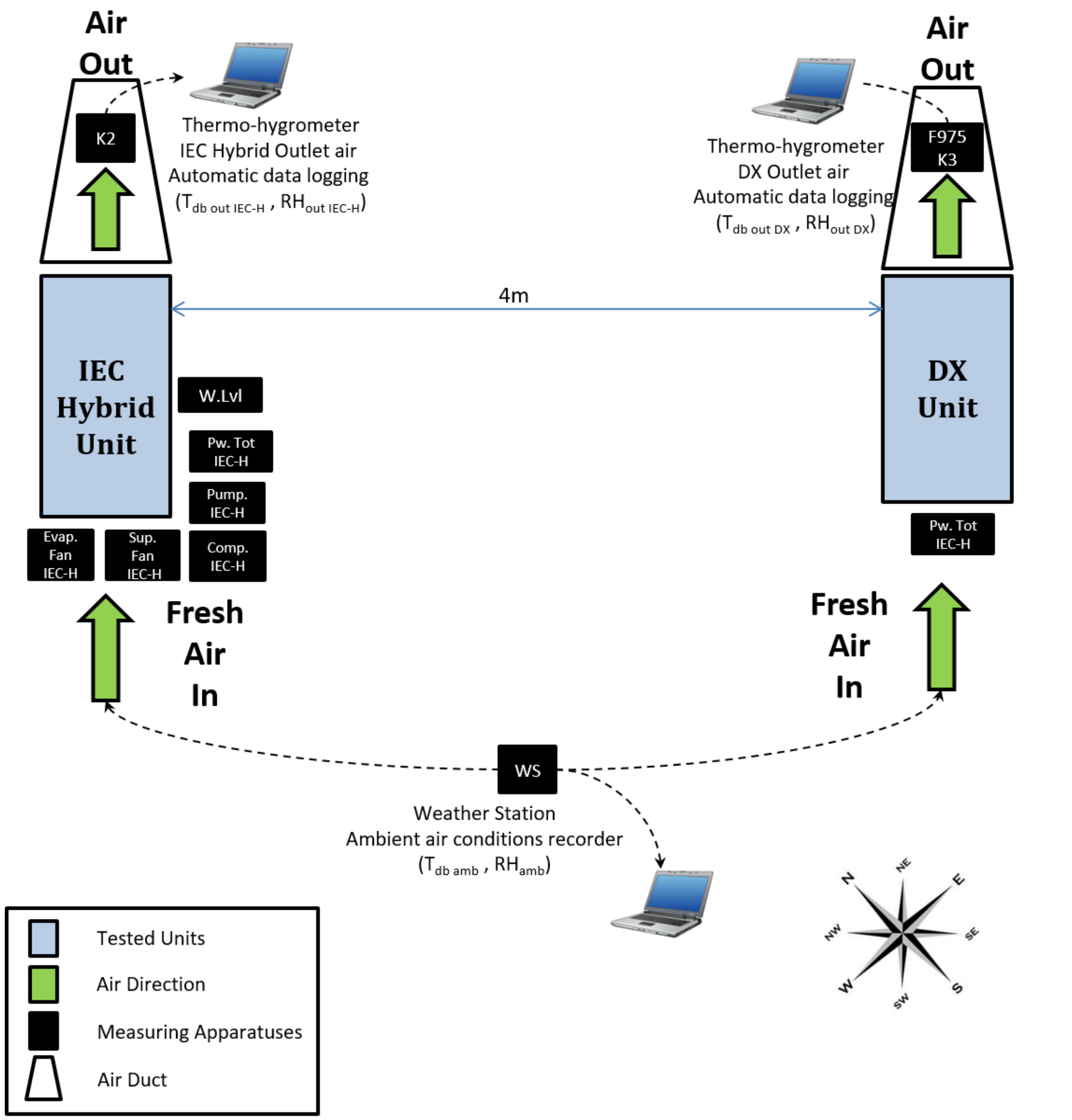
Each OEM tested two of his units in the same 24 hours, one IEC-H next to one DX unit.
Each OEM tested in the two designated climatic zones, 2 and 5.
Both units tested were full fresh air and had the same air flow rate.
Initially it was hoped the OEMs will use lower-GWP refrigerants approved to use in 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

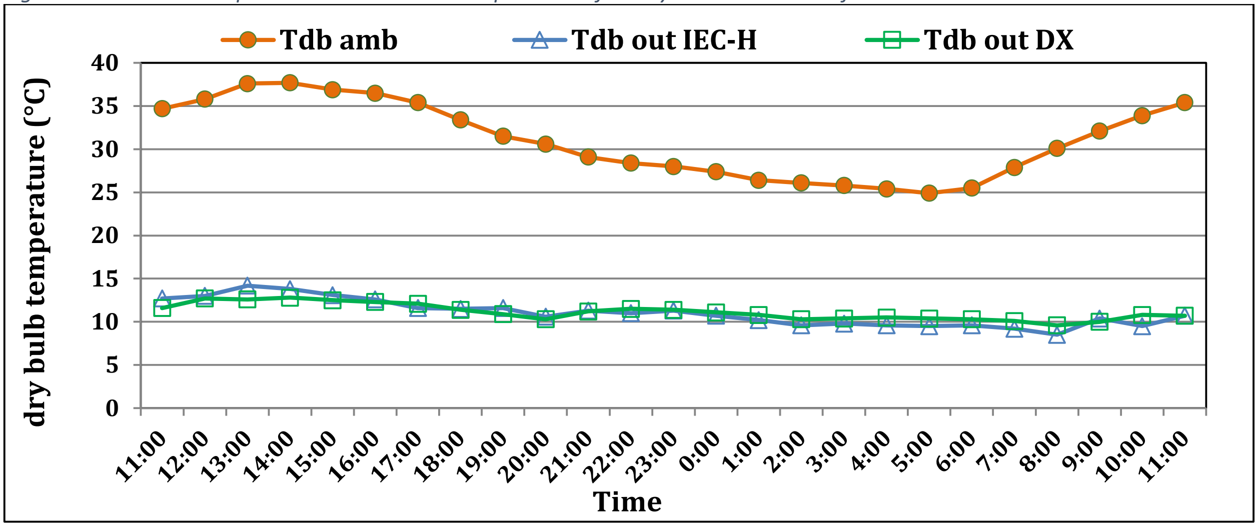


Fig 4: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM2 at CZ2

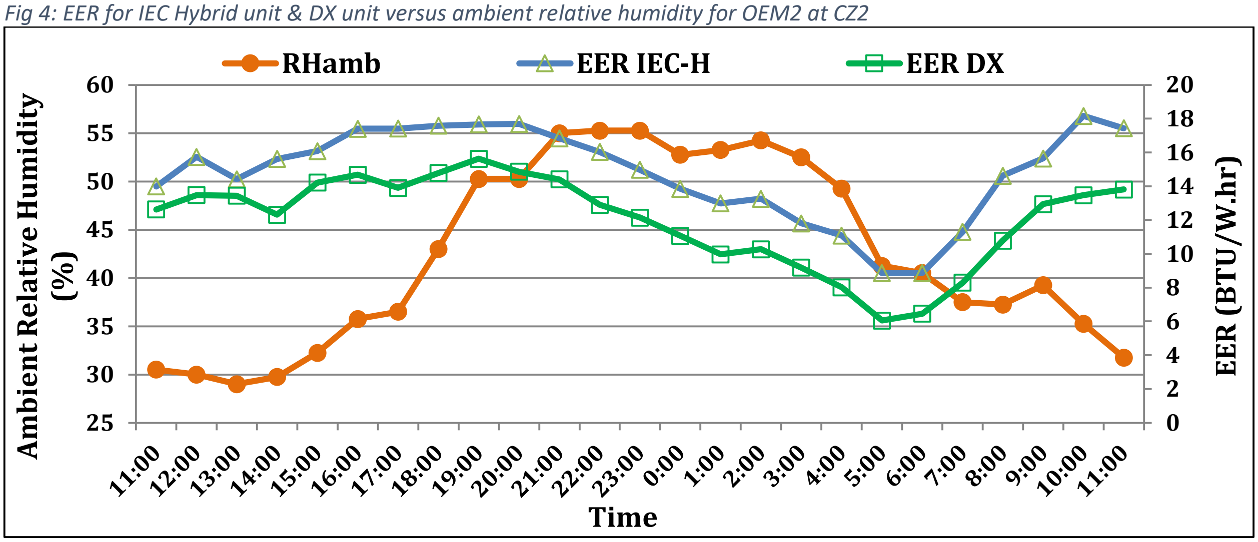


Fig 5: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM2 at CZ2

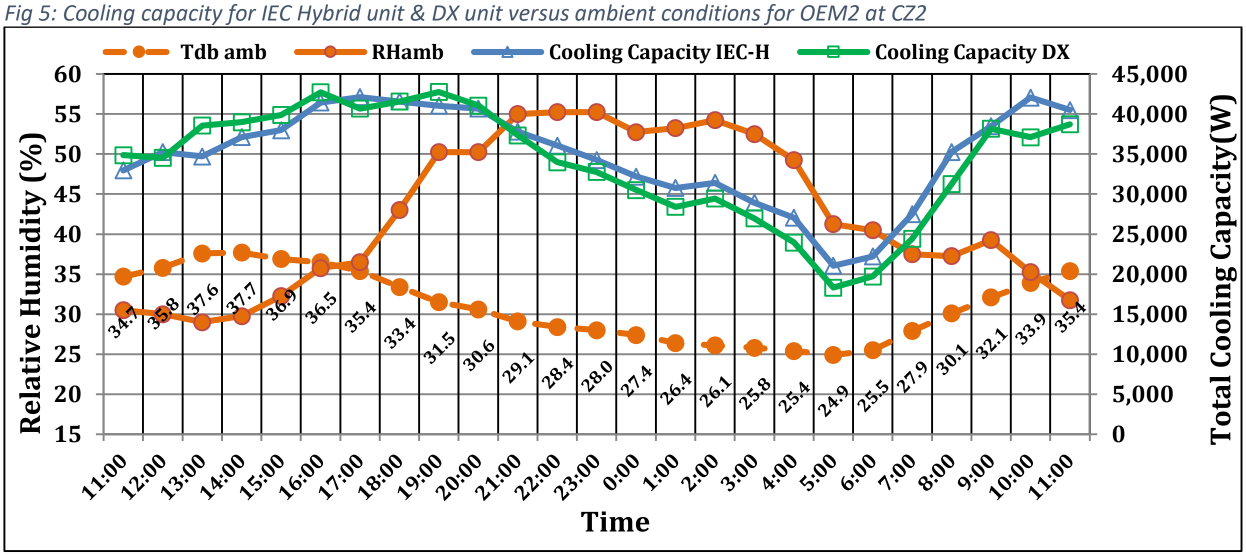


Fig 6: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM2 at CZ2

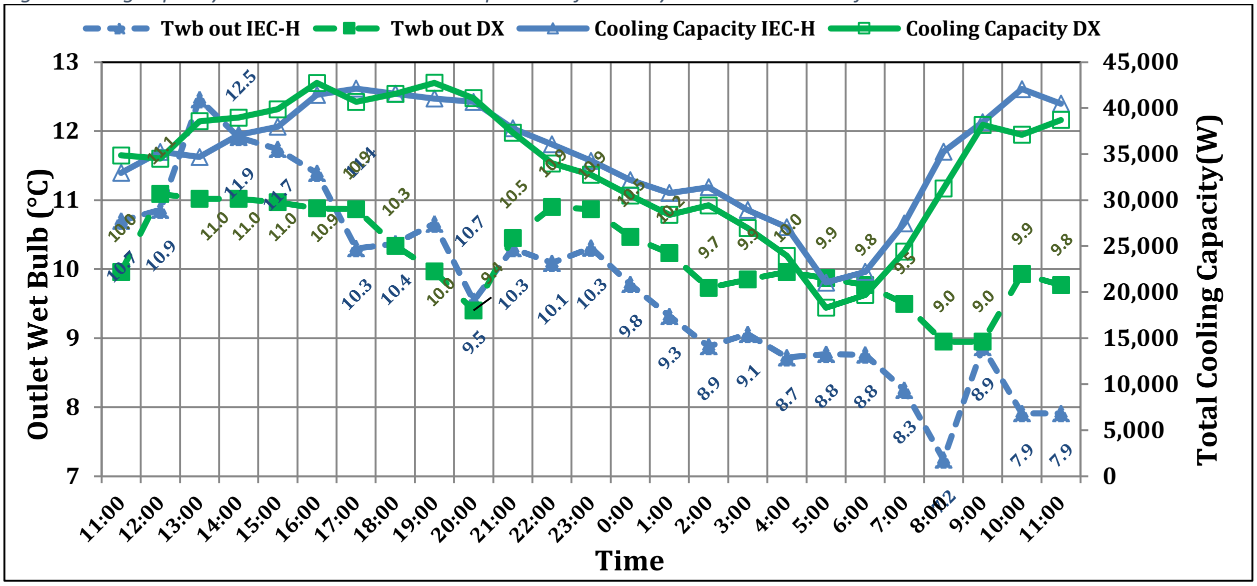
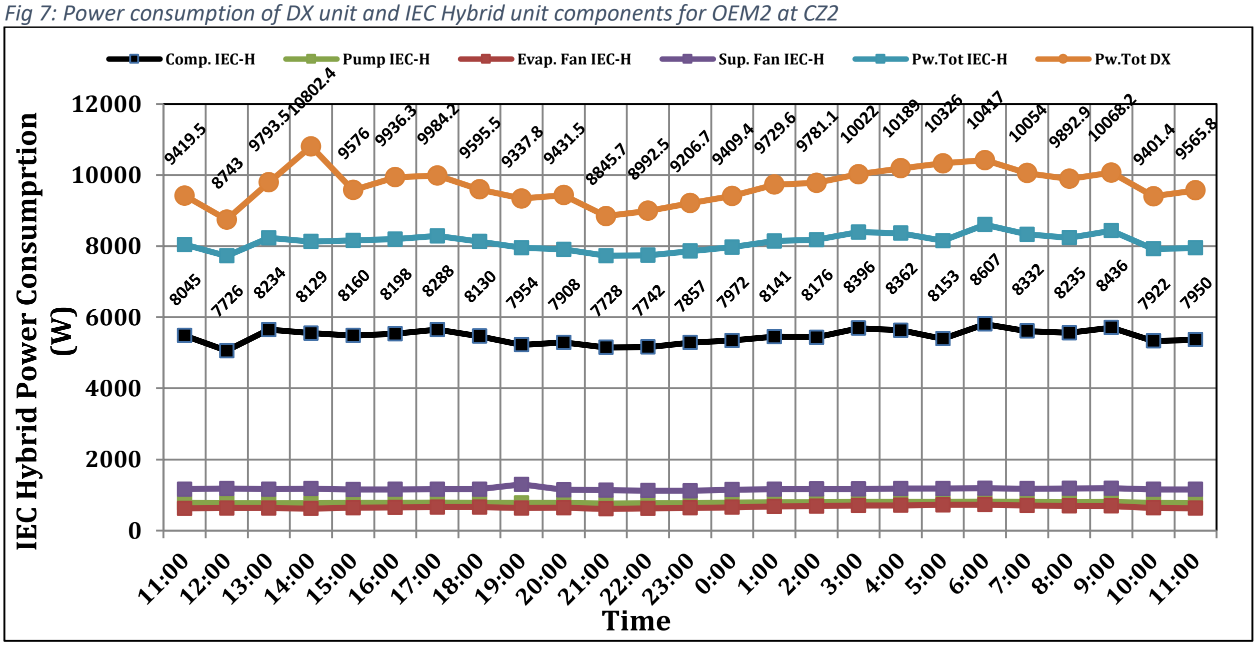


Fig 7: Power consumption of DX unit and IEC Hybrid unit components for OEM2 at CZ2



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

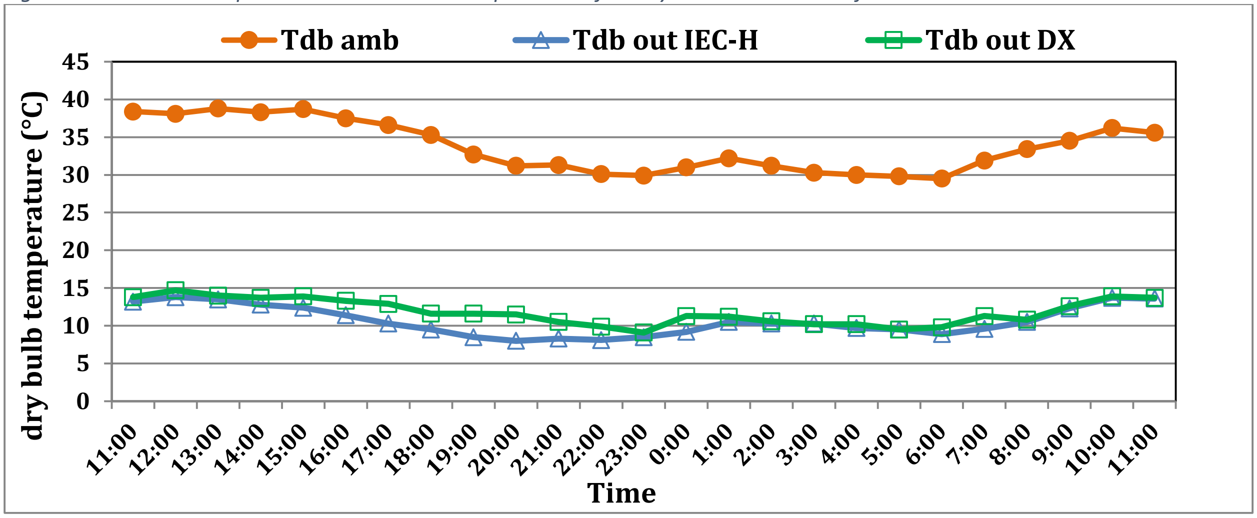


Fig 9: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM2 at CZ5

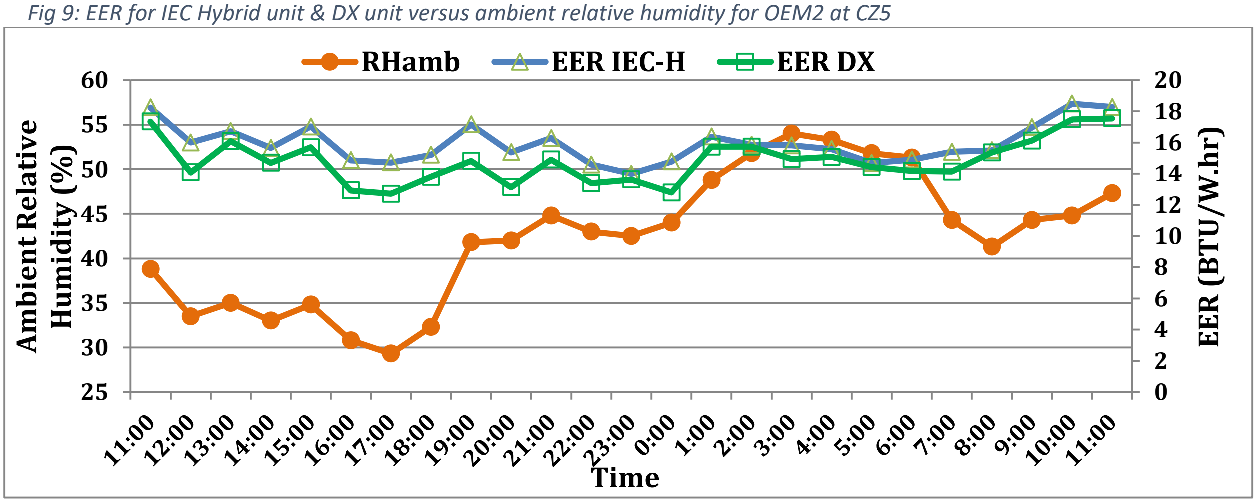


Fig 10: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM2 at CZ5

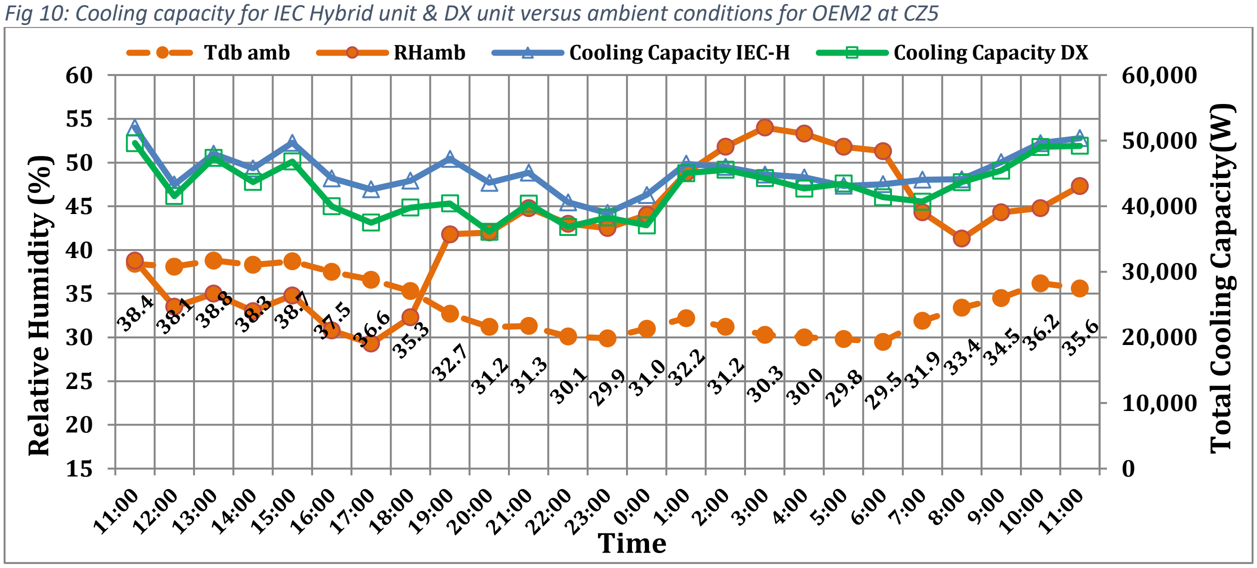


Fig 11: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM2 at CZ5

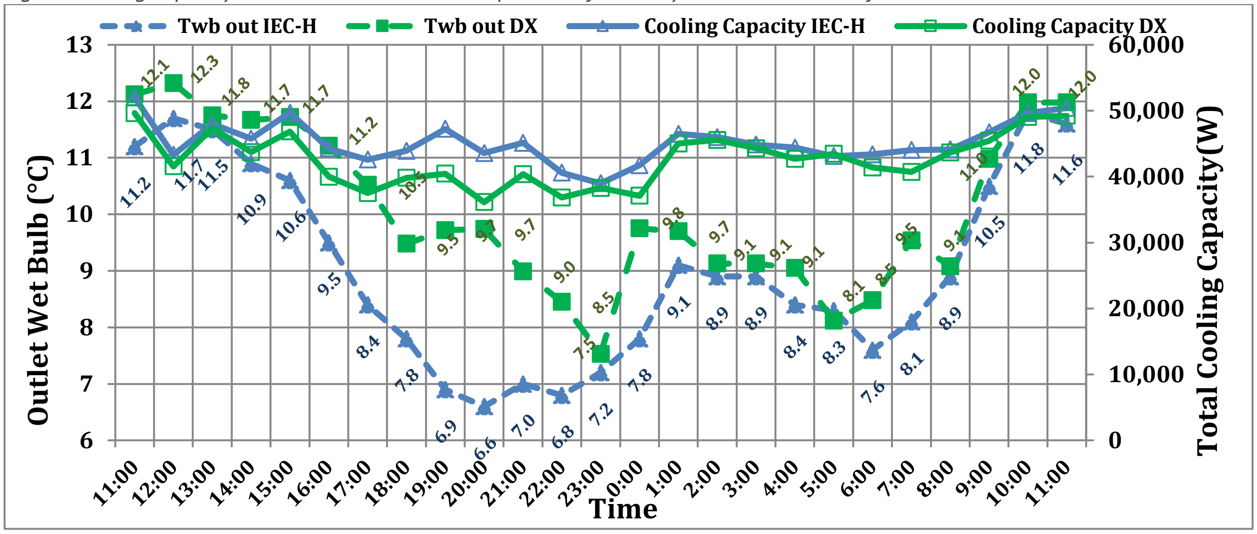
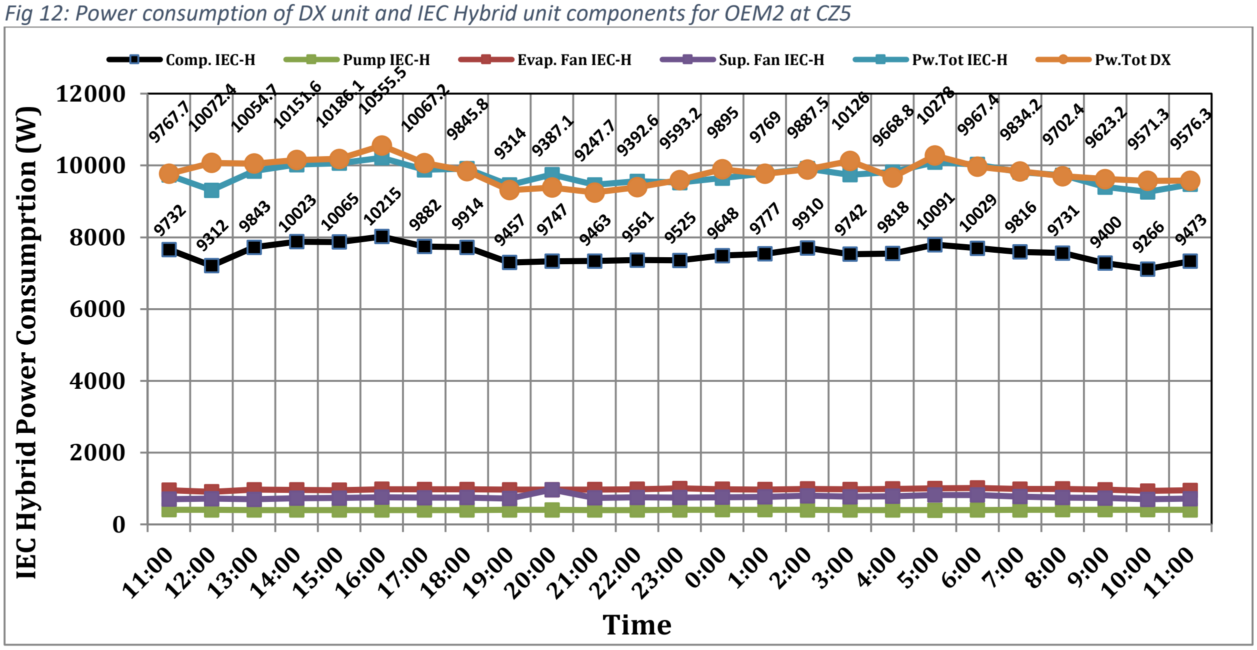


Fig 12: Power consumption of DX unit and IEC Hybrid unit components for OEM2 at CZ5



Analysis of the results of OEM2 at CZ5:

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

CZ5					
High and low, ℃					
$T_{db\ amb}$	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 ^{o}C to 29.5^{o}C compared at CZ2, to 37.7 ^{o}C to 24.9 ^{o}C) 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.

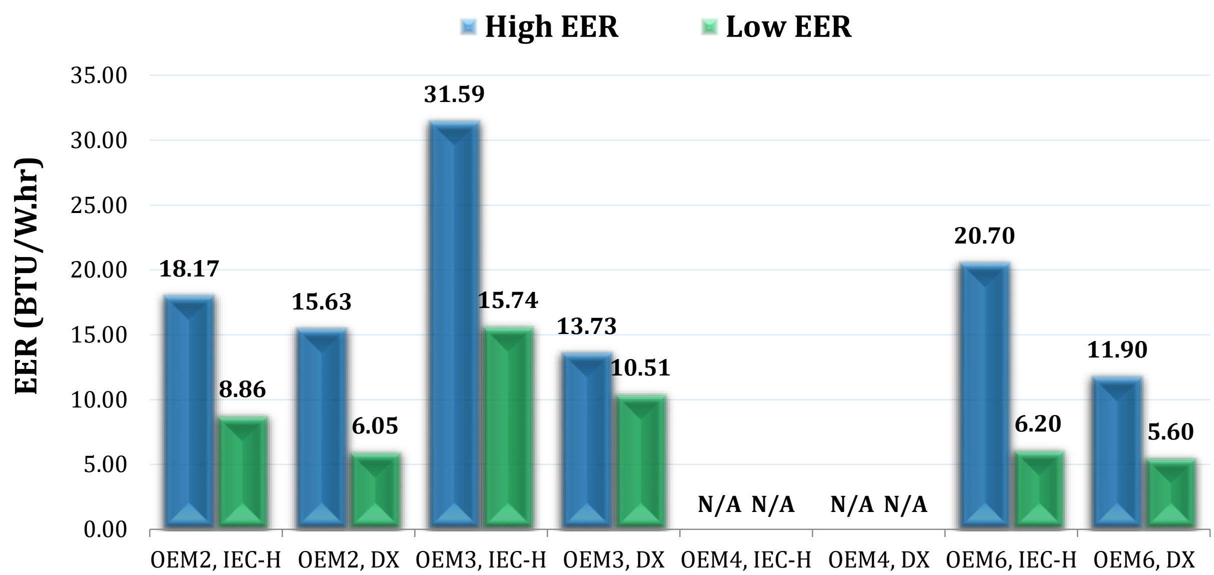
Chapter 5

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

5.1. The Final Results Analysis

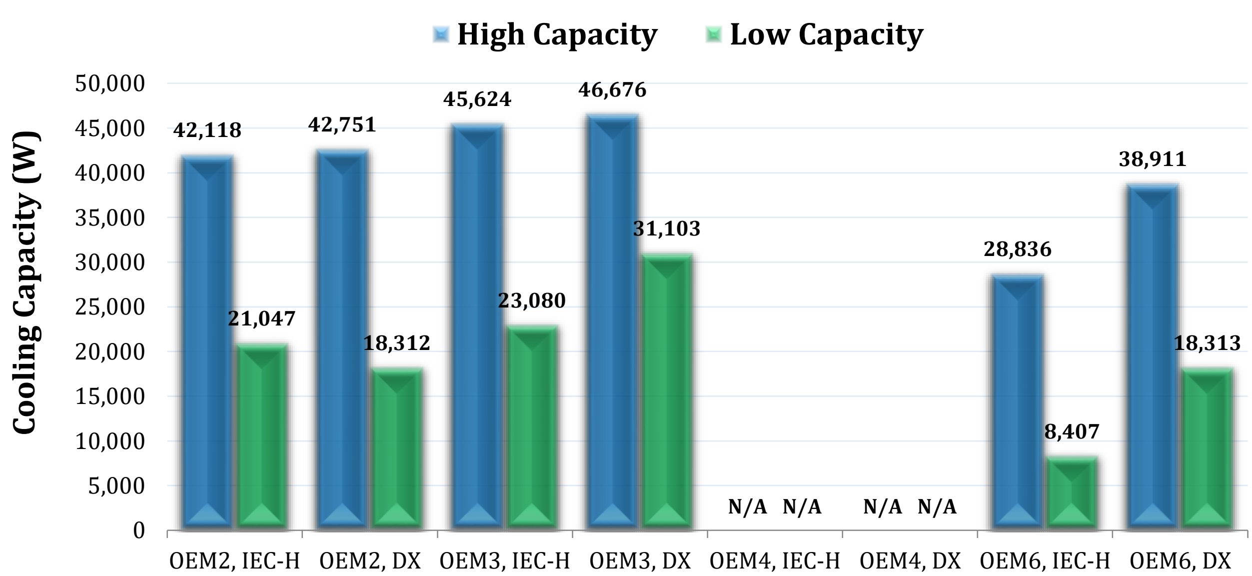
5.1.1. EER HIGH and LOW - CZ2

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



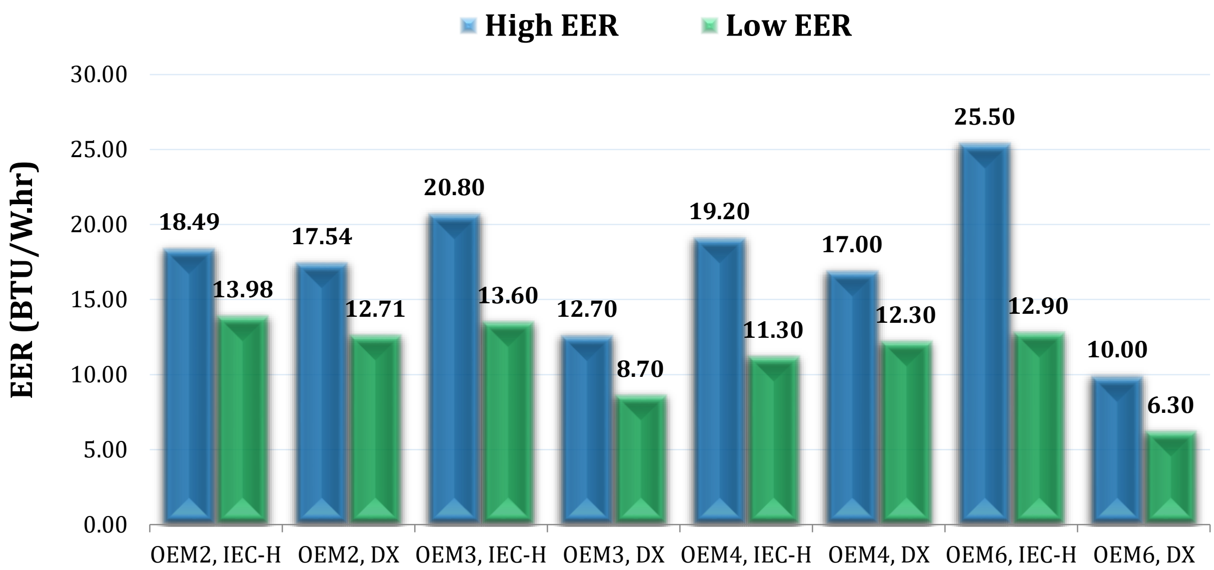
5.1.2. CAPACITY HIGH and LOW - CZ2

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



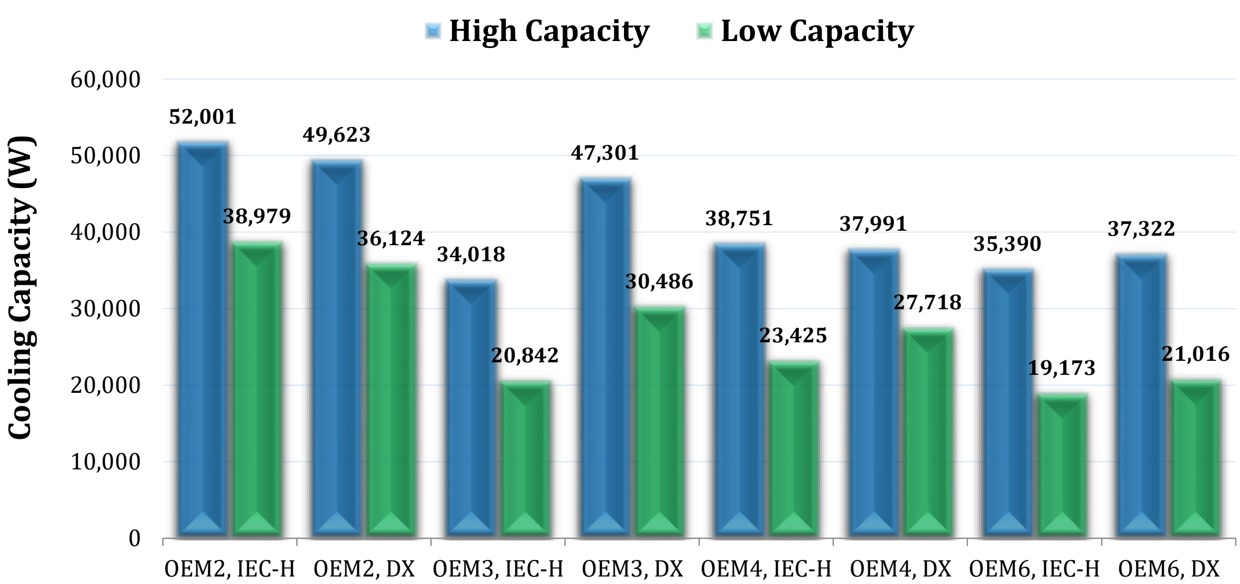
5.1.3. EER HIGH and LOW - CZ5

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

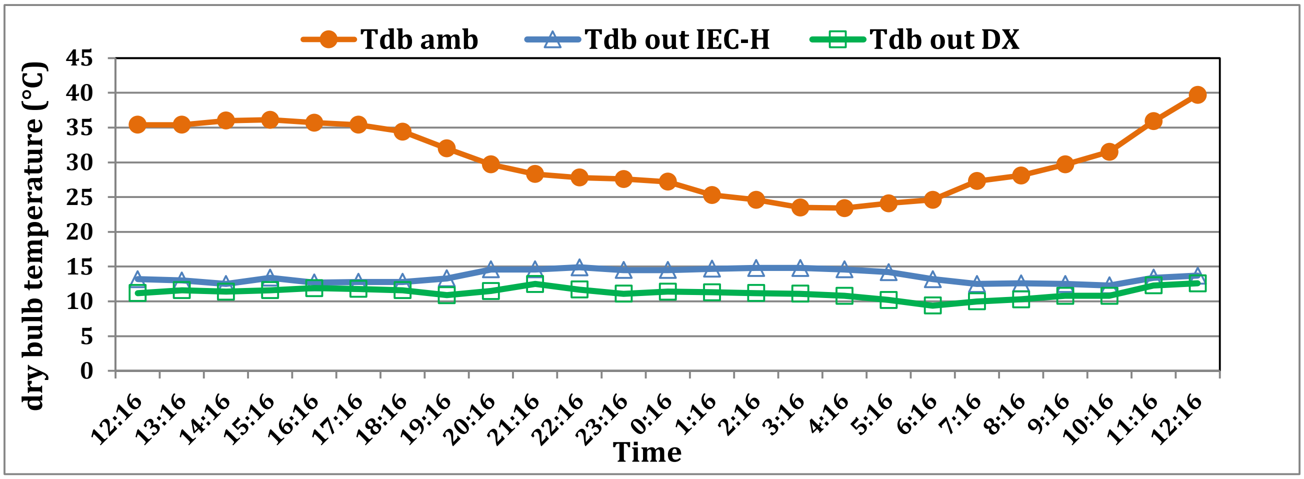


Fig 18: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM3 at CZ2

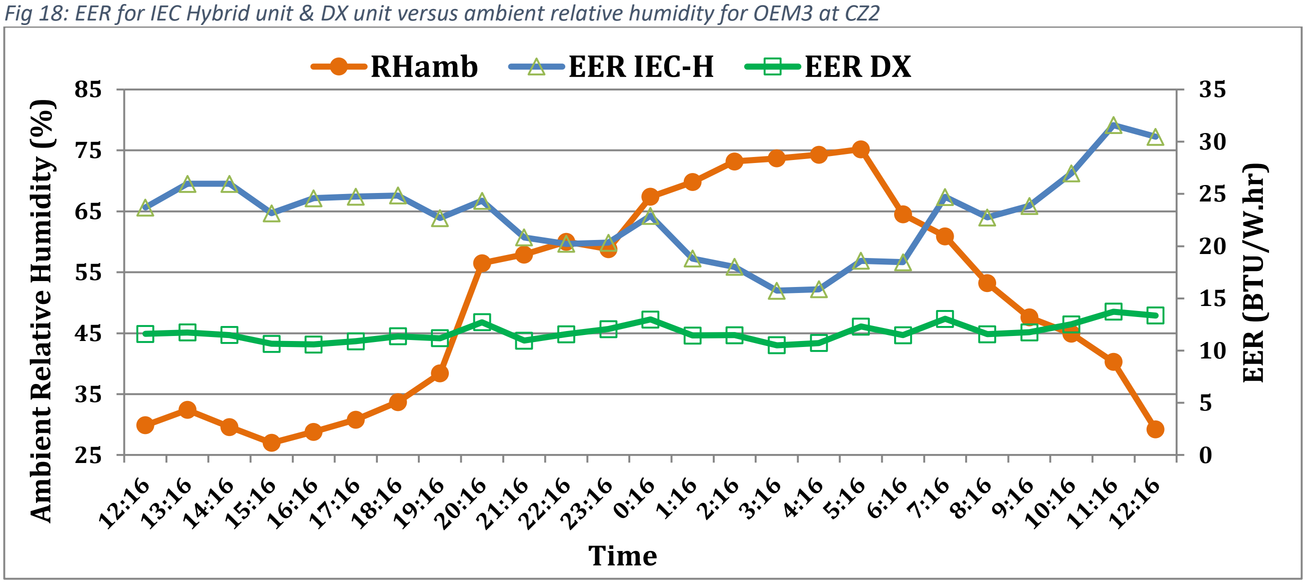


Fig 19: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM3 at CZ2

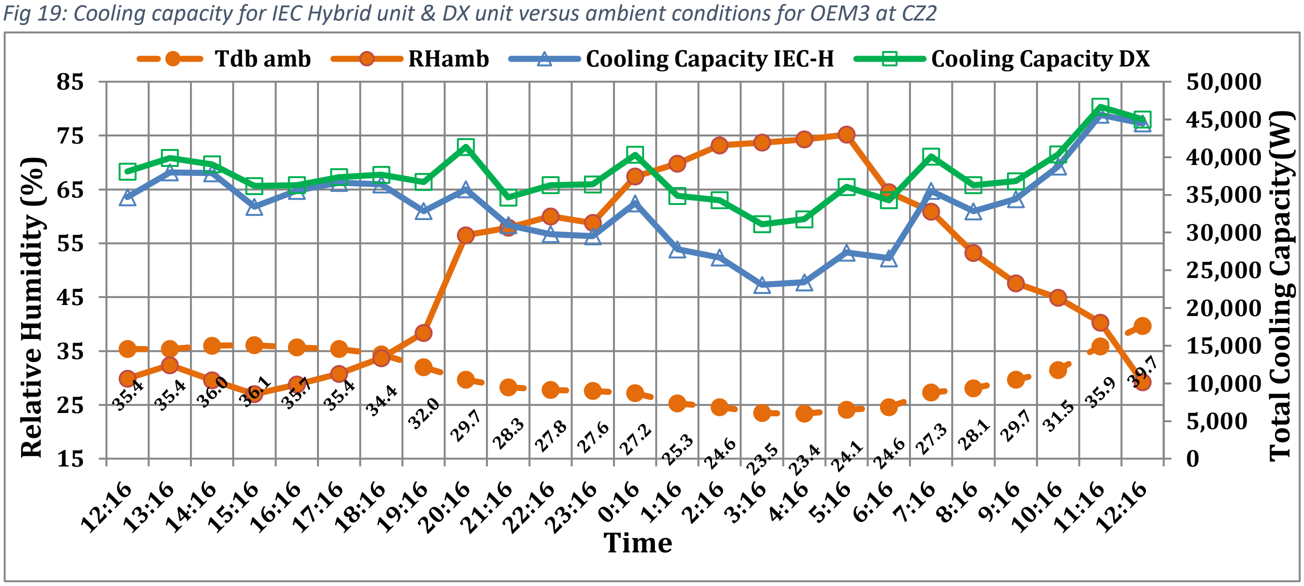


Fig 20: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM3 at CZ2

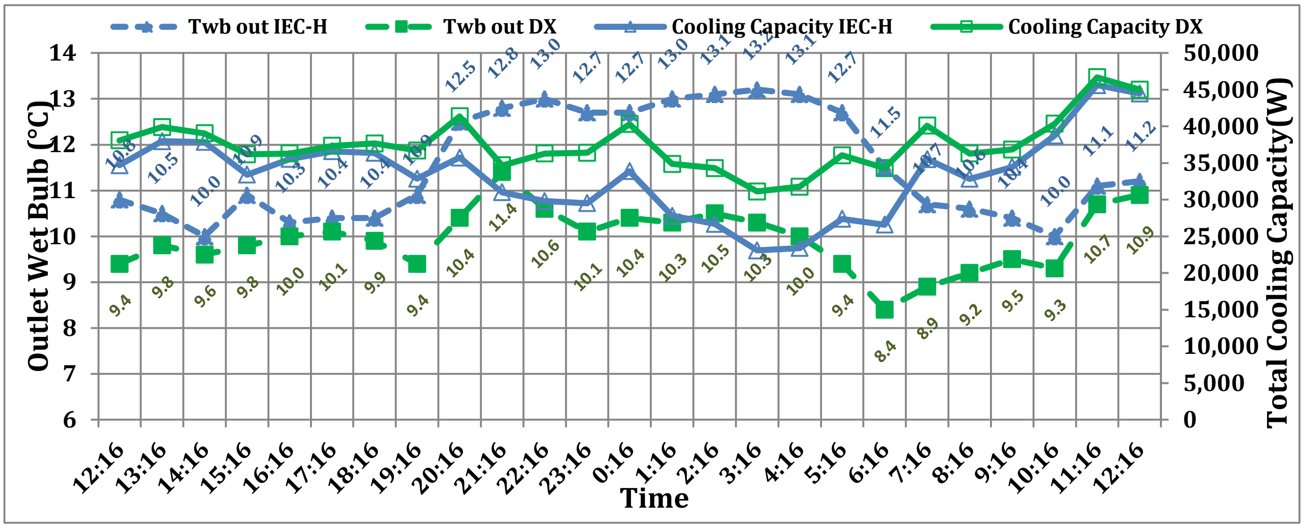
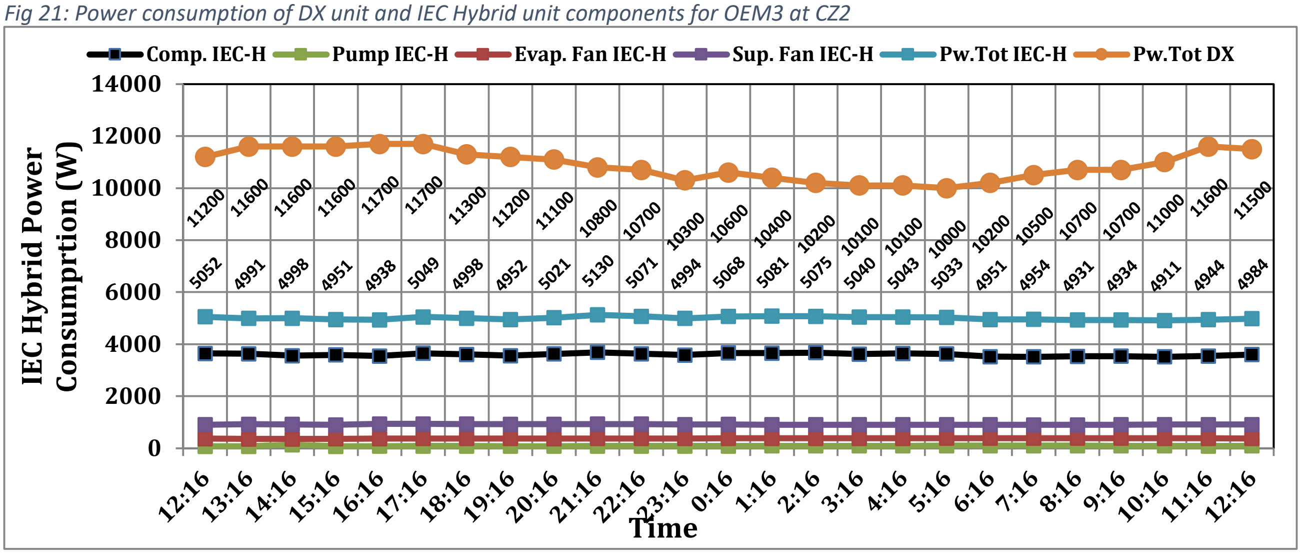


Fig 21: Power consumption of DX unit and IEC Hybrid unit components for OEM3 at CZ2



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 ^{o}C to 9.4 ^{o}C, 3.2 ^{o}C swing
- The swing in $T_{db\ out}$ of IEC-H unit is from to 14.9 ^{o}C to 12.3 ^{o}C, 2.6 ^{o}C swing
- The daily $T_{db\ amb}$ changes from 39.7 ^{o}C down to 23.4^{o}C, a swing of 16.3 ^{o}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

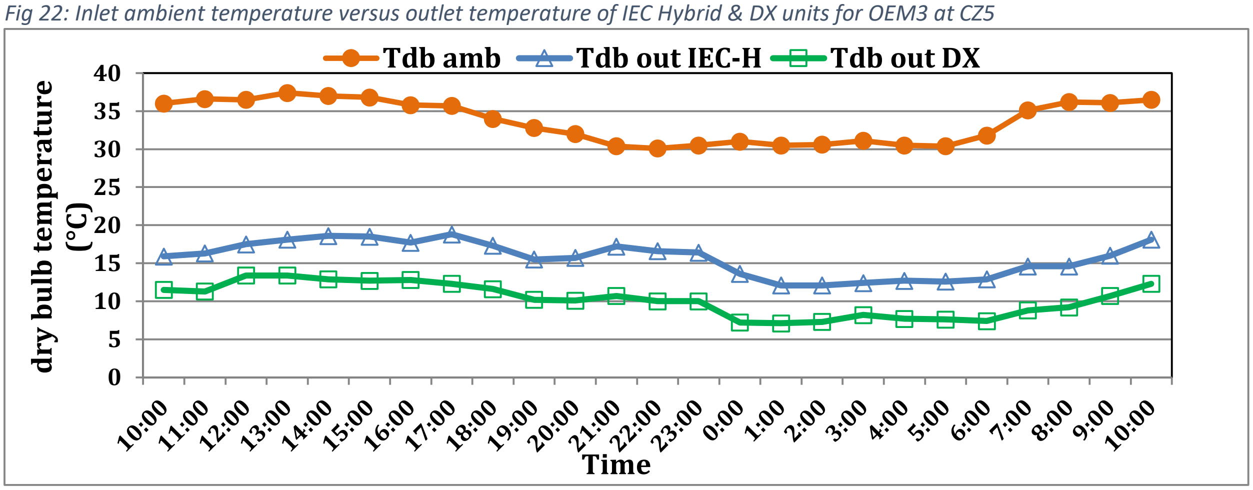


Fig 23: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM3 at CZ5

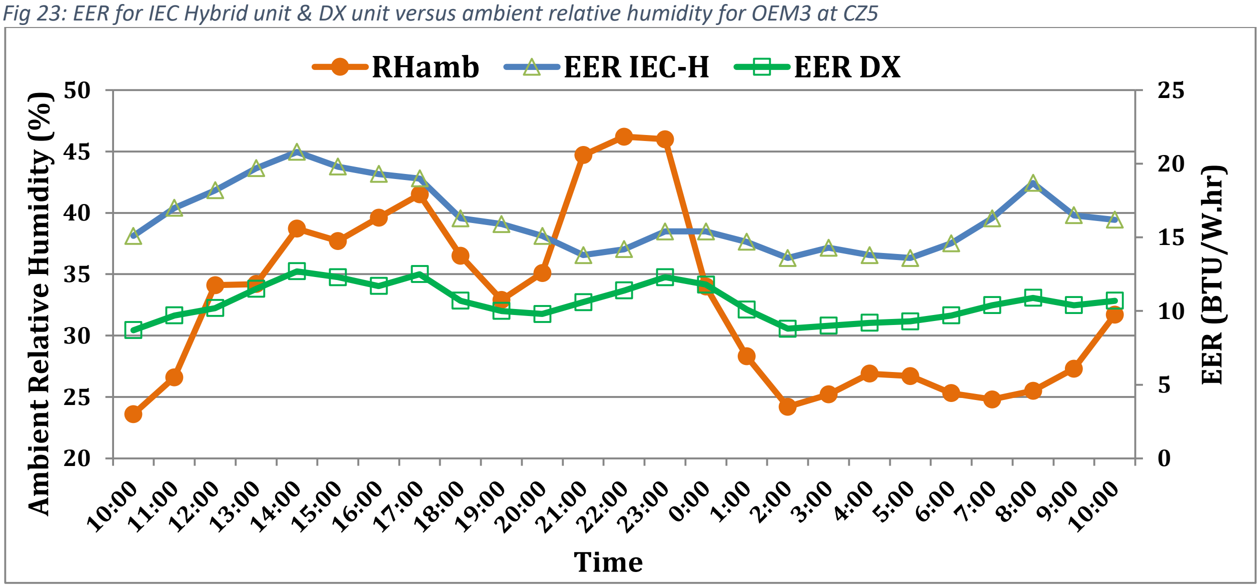


Fig 24: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM3 at CZ5

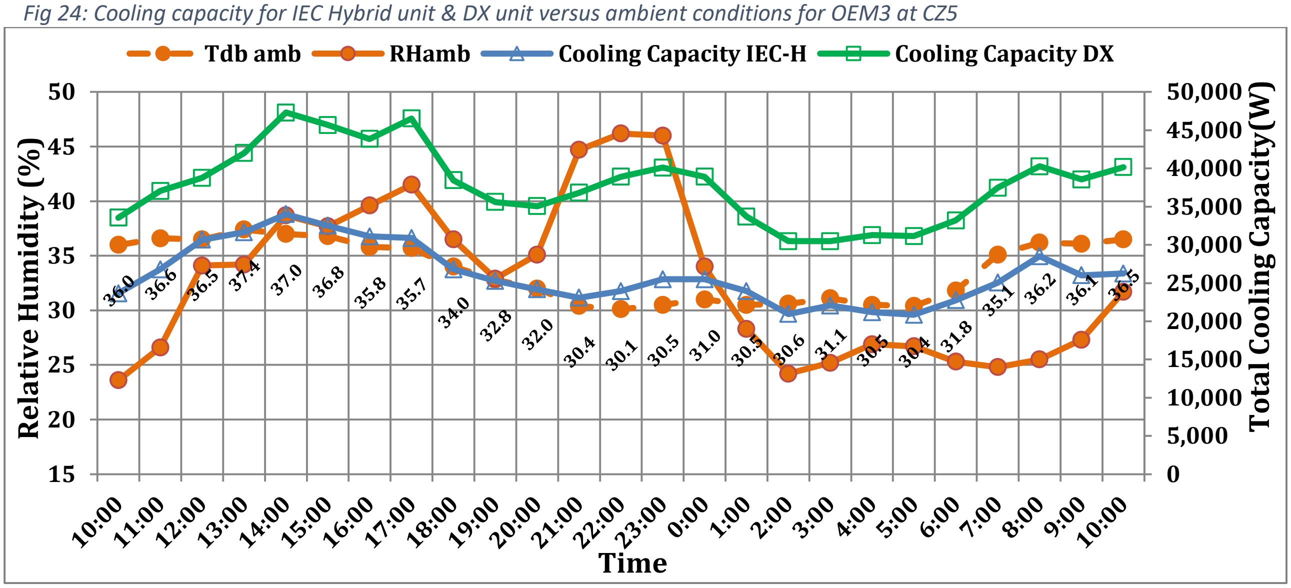


Fig 25: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid & DX units for OEM3 at CZ5

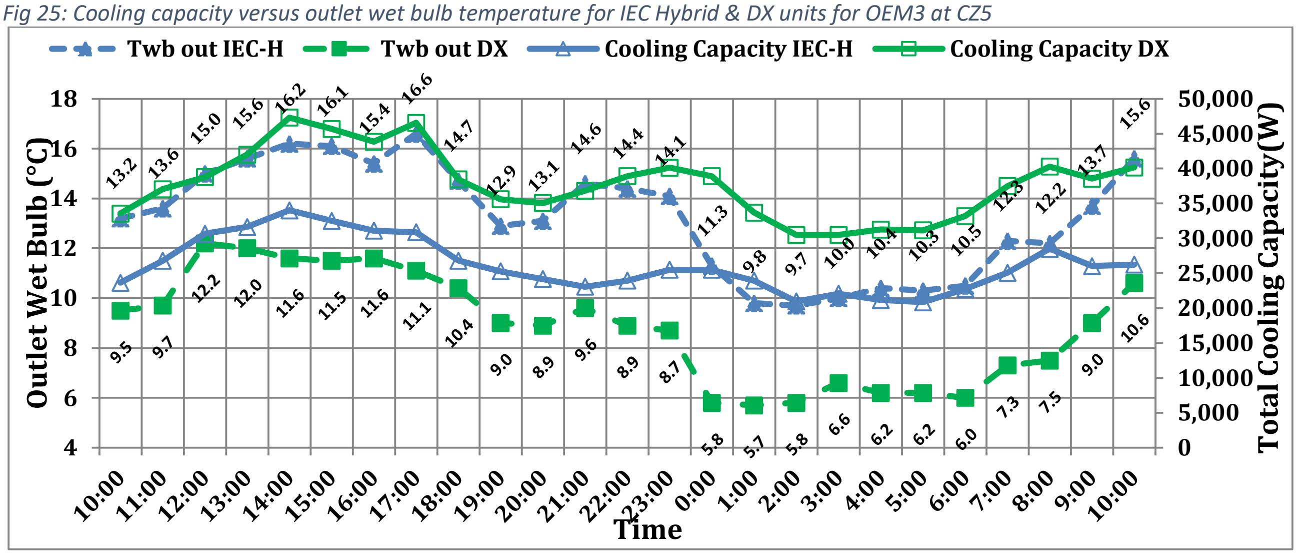
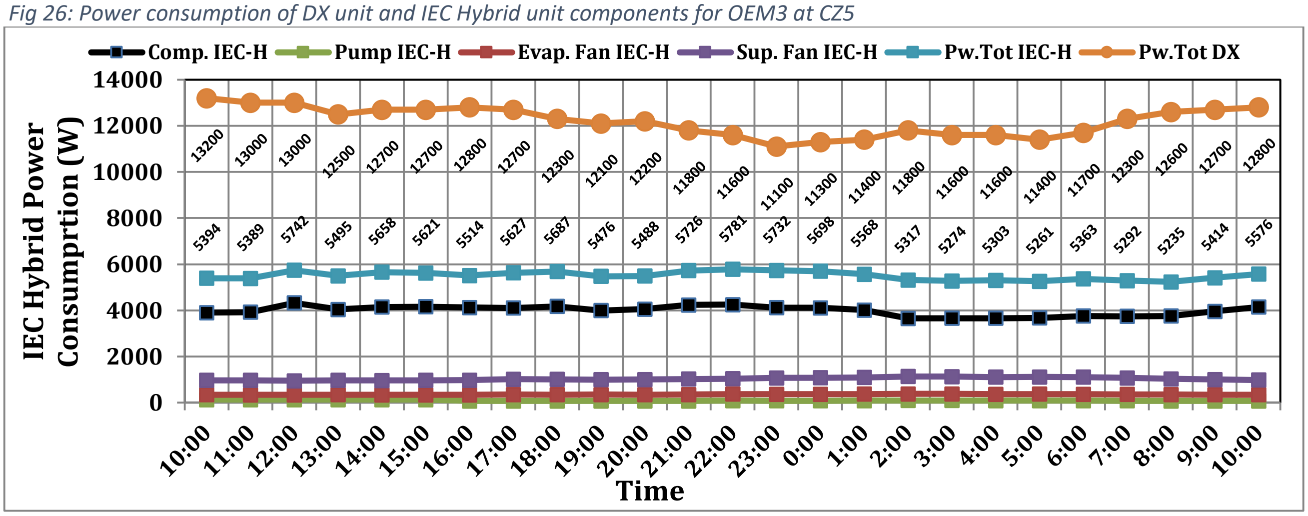


Fig 26: Power consumption of DX unit and IEC Hybrid unit components for OEM3 at CZ5



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 ^oC to 7.1 ^oC, 6.3^oC swing
  - The swing in of $T_{db\ out}$ IEC-H unit is from to 18.8 ^oC to 12.1 ^oC, 6.7 ^oC swing
  - The daily $T_{db\ amb}$ changes are from 37.4 ^oC down to 30.1^oC, a swing of 7.3 ^oC.

- **$T_{wb\ out}$ 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

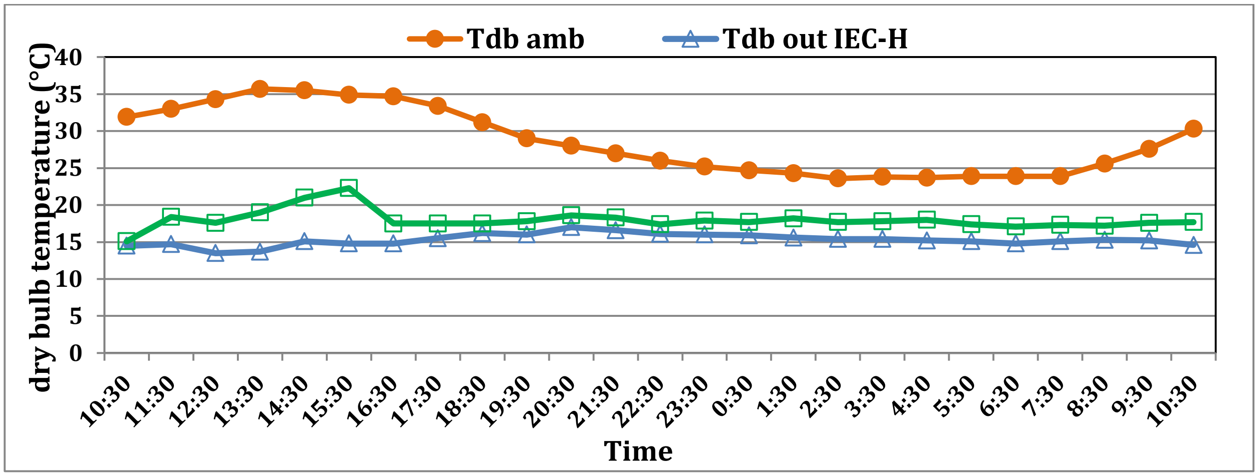


Fig 28: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM4 at CZ2

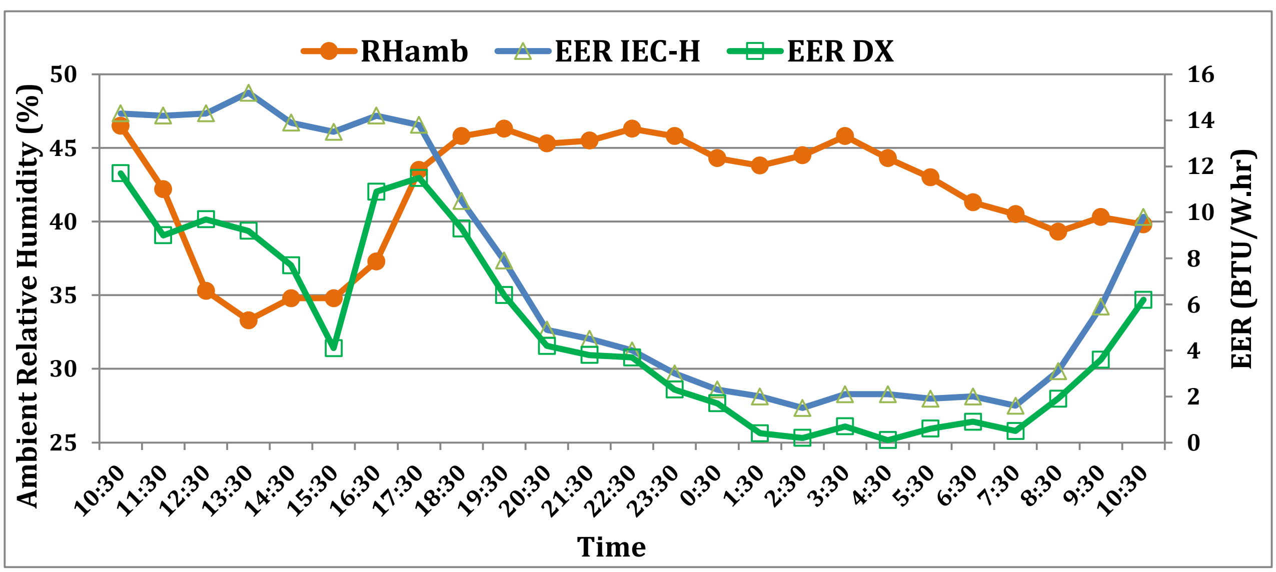


Fig 29: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM4 at CZ2

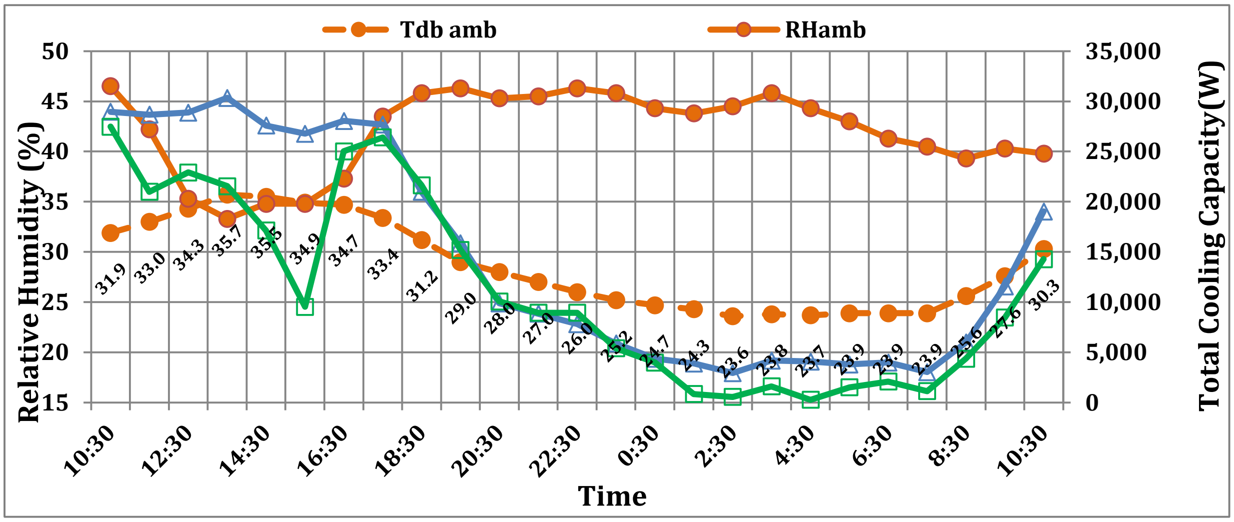


Fig 30: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM4 at CZ2

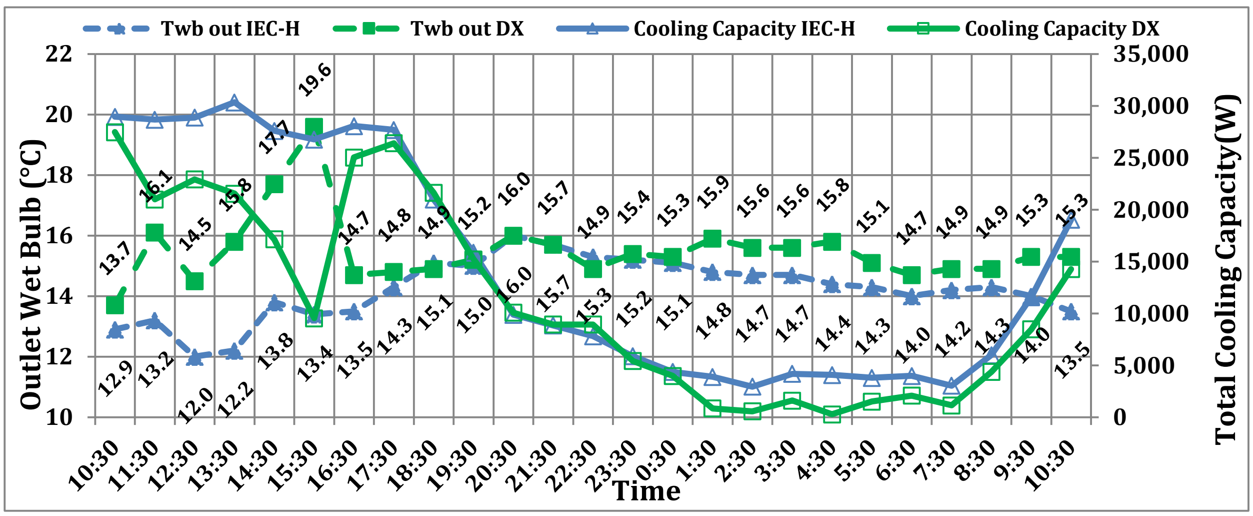
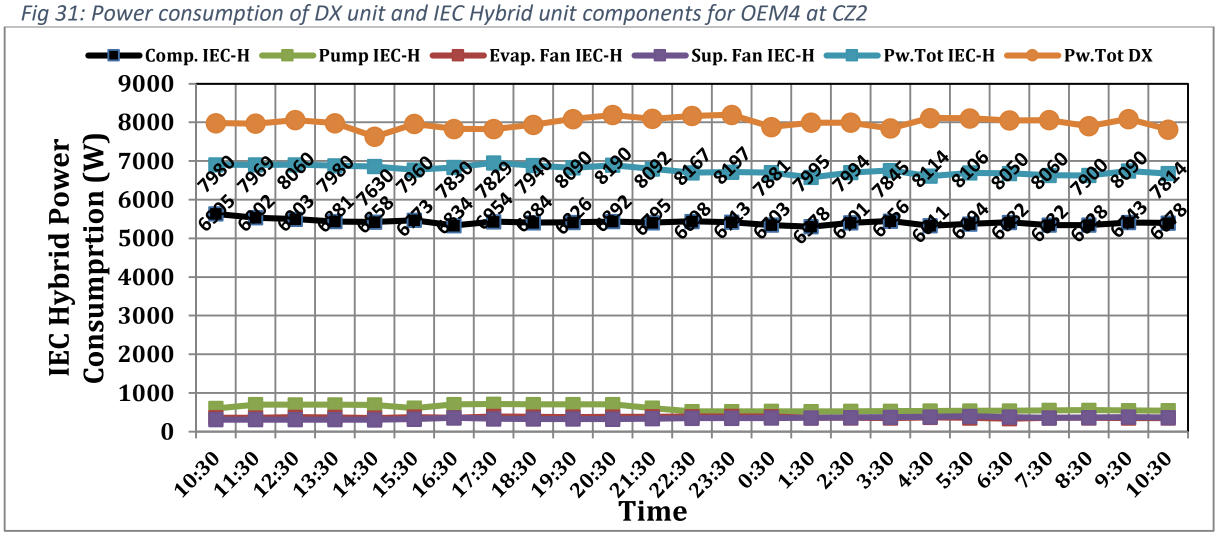


Fig 31: Power consumption of DX unit and IEC Hybrid unit components for OEM4 at CZ2



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

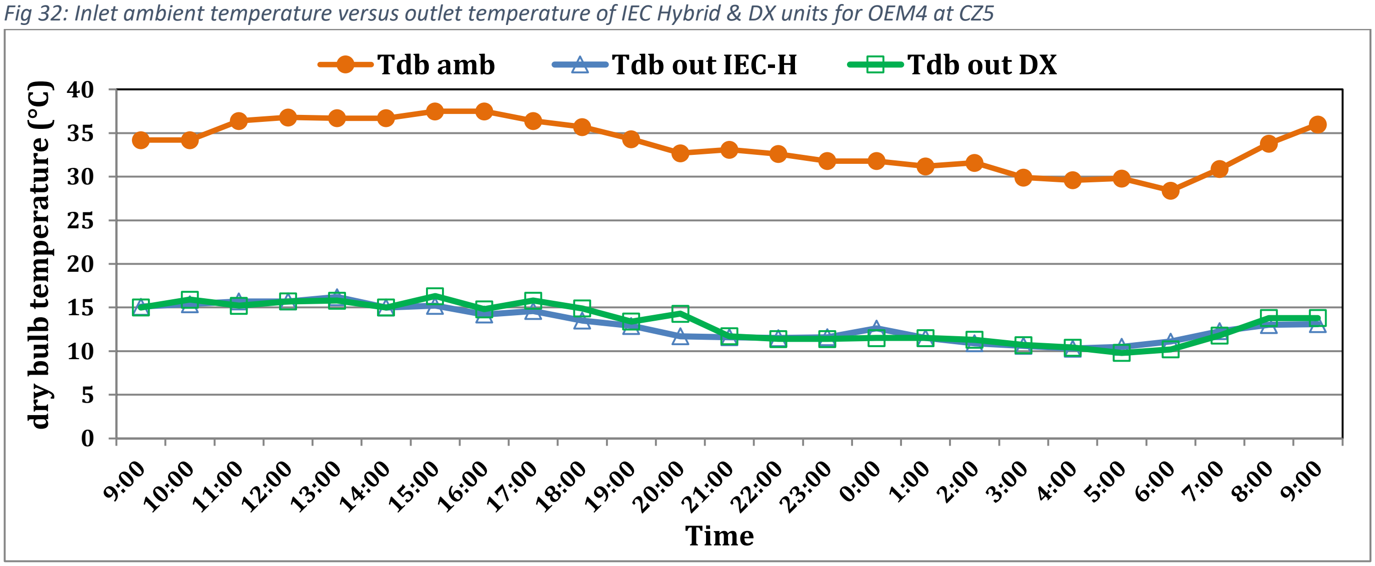


Figure 33: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM4 at CZ5

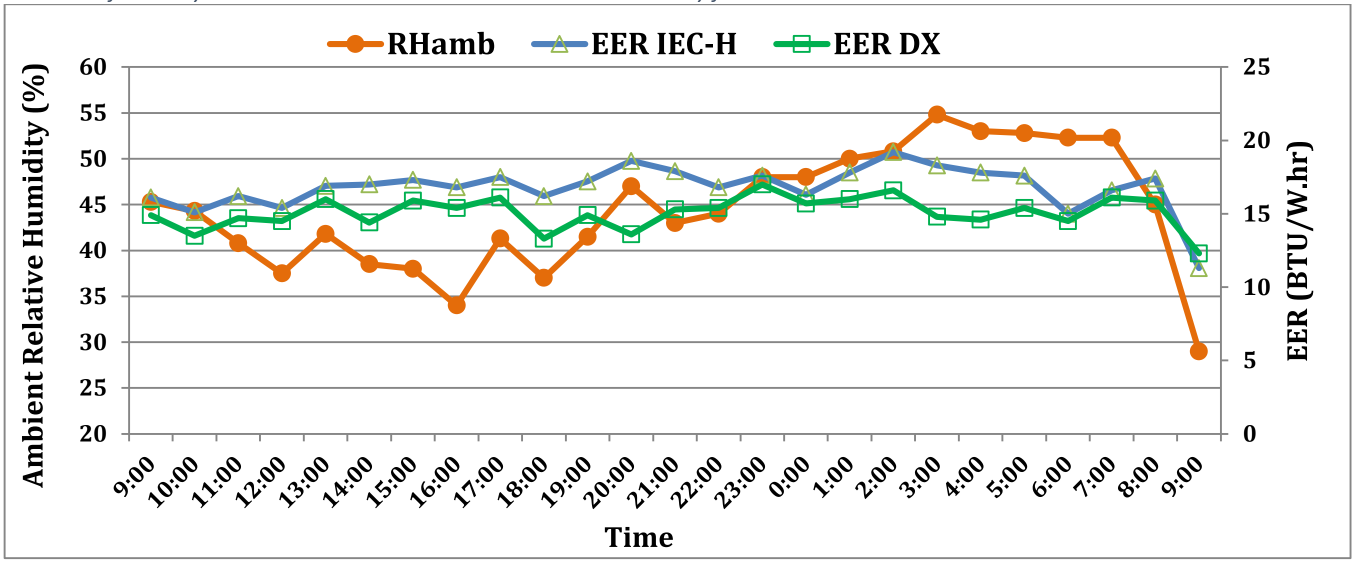


Fig 34: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM4 at CZ5

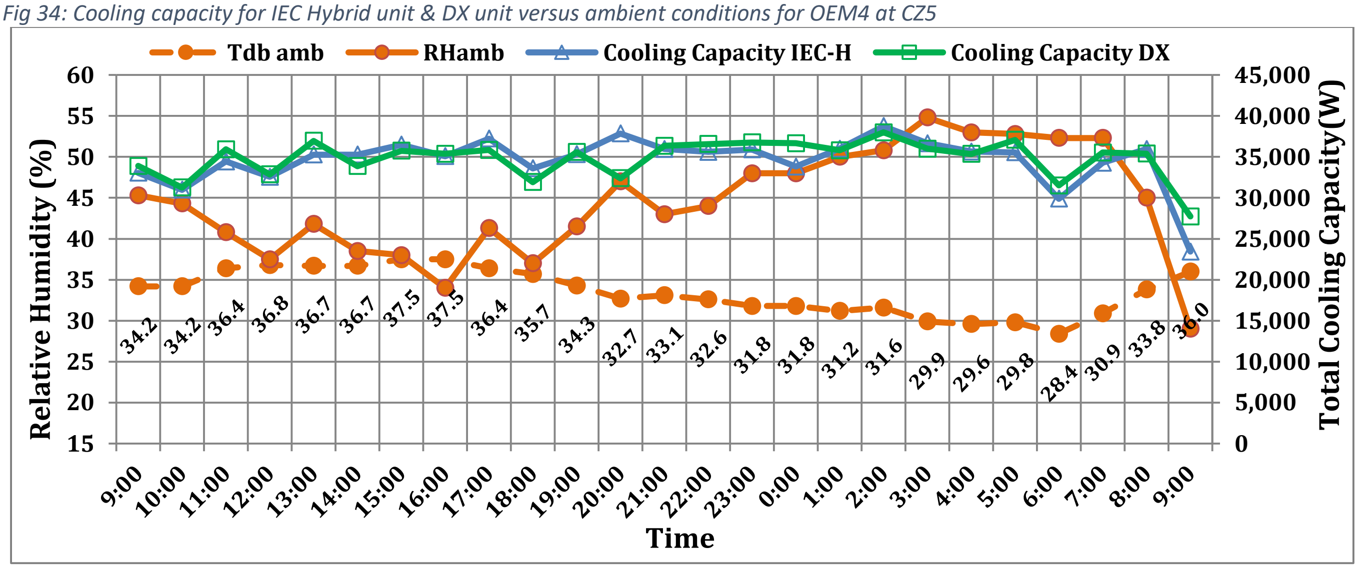


Fig 35: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid & DX units for OEM4 at CZ5

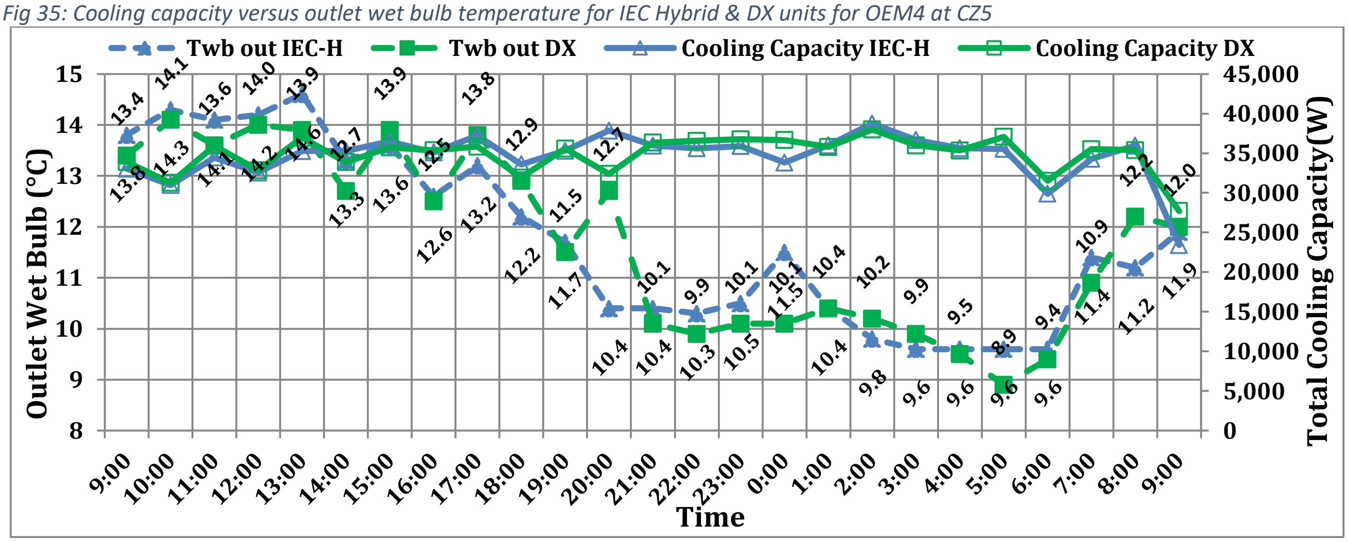
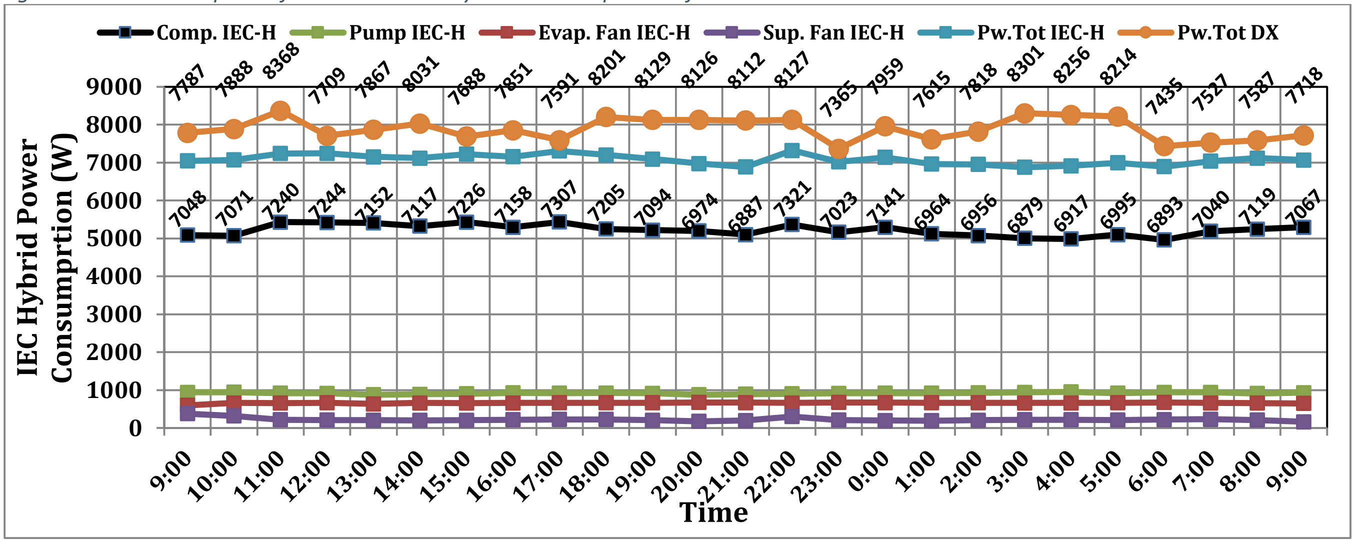


Fig 36: Power consumption of DX unit and IEC Hybrid unit components for OEM4 at CZ5



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

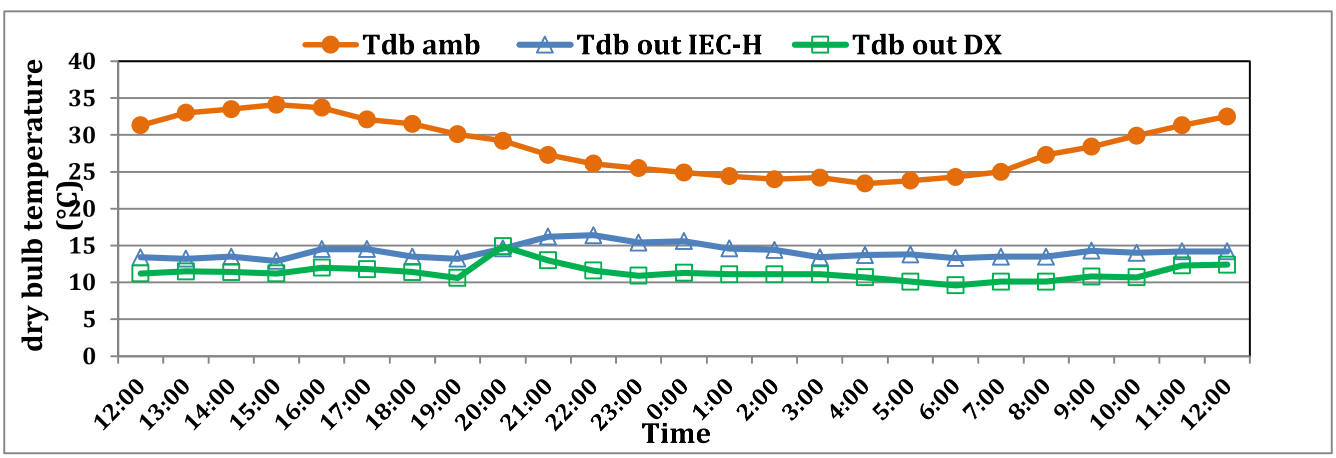


Fig 38: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM6 at CZ2

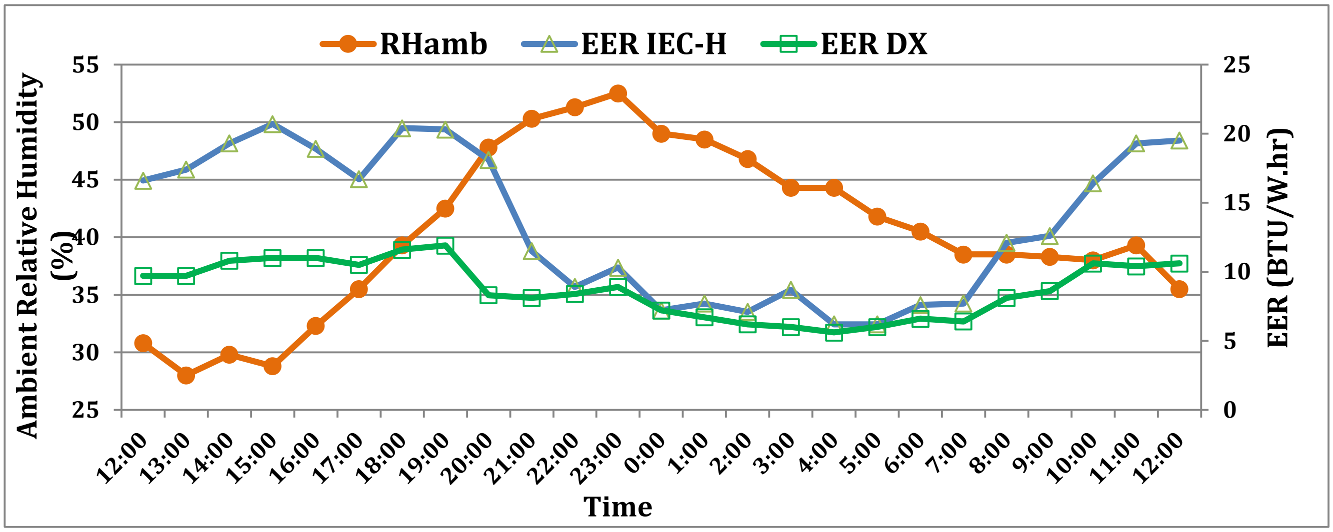


Fig 39: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM6 at CZ2

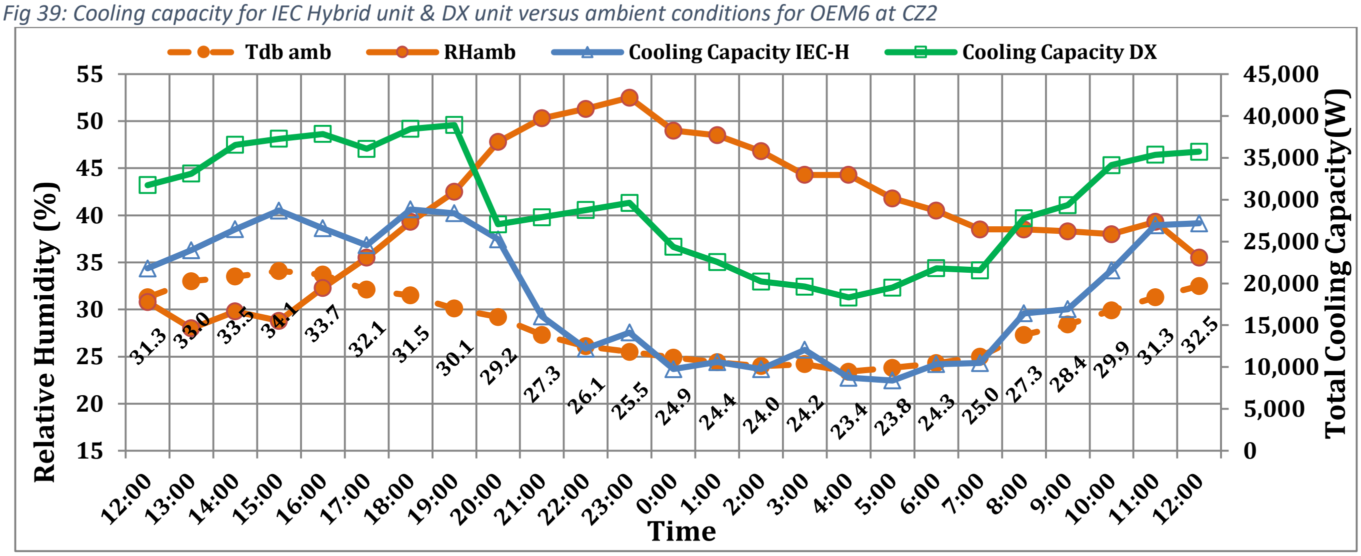


Fig 40: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid & DX units for OEM6 at CZ2

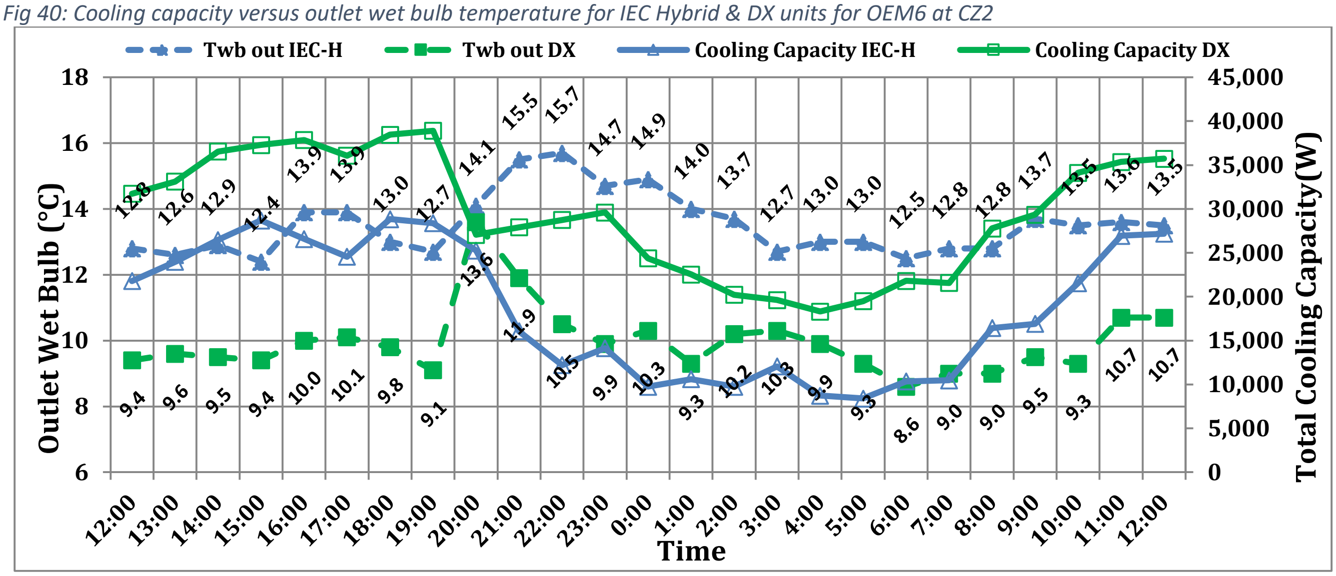
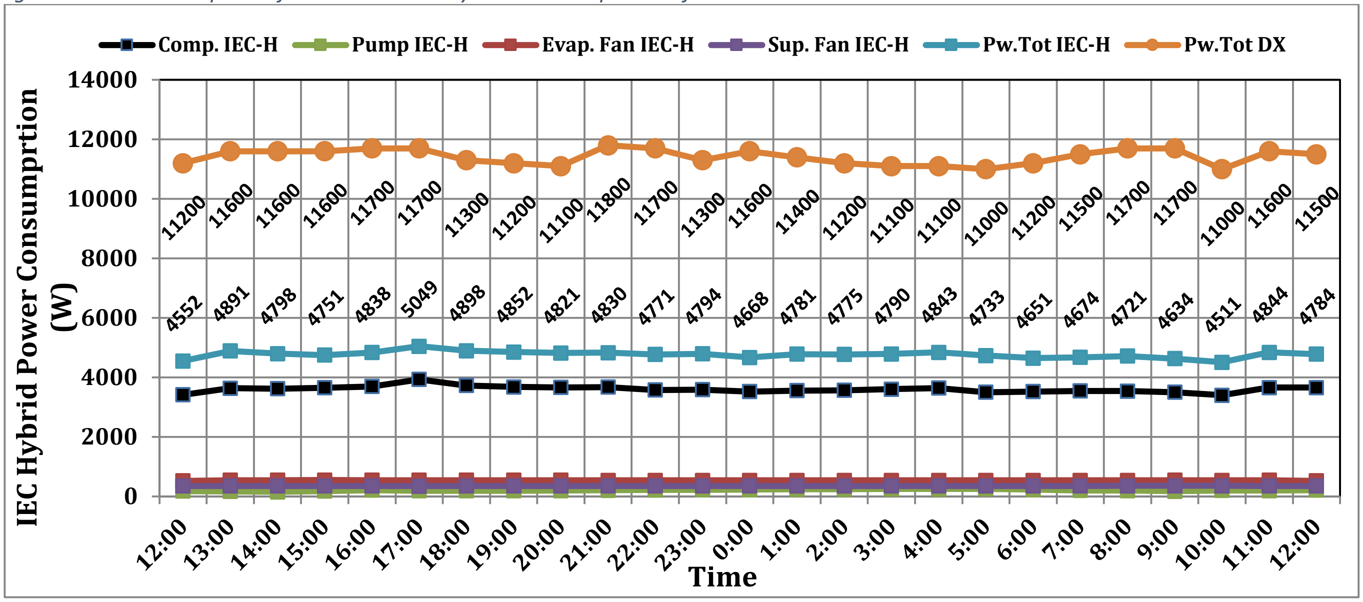


Fig 41: Power consumption of DX unit and IEC Hybrid unit components for OEM6 at CZ2



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

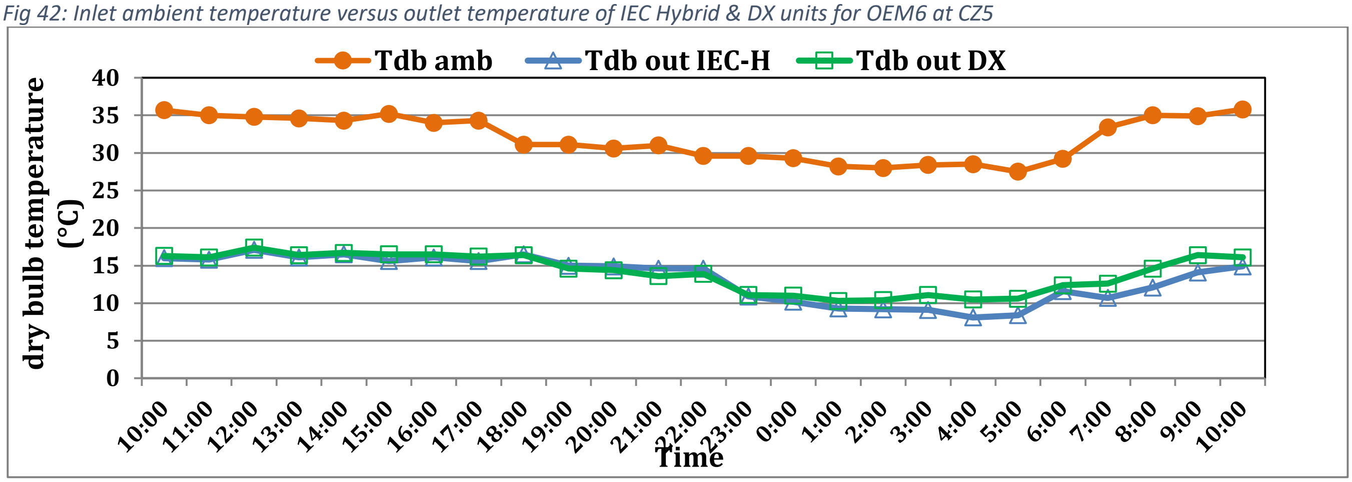


Fig 43: EER for IEC Hybrid unit & DX unit versus ambient relative humidity for OEM6 at CZ5

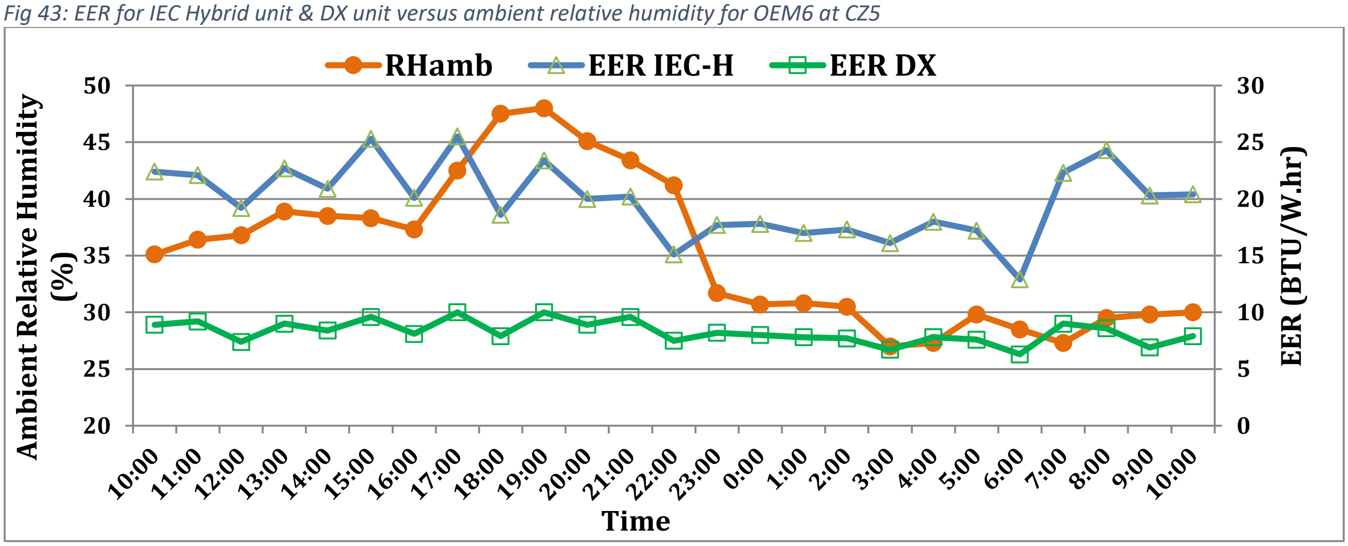


Fig 44: Cooling capacity for IEC Hybrid unit & DX unit versus ambient conditions for OEM6 at CZ5

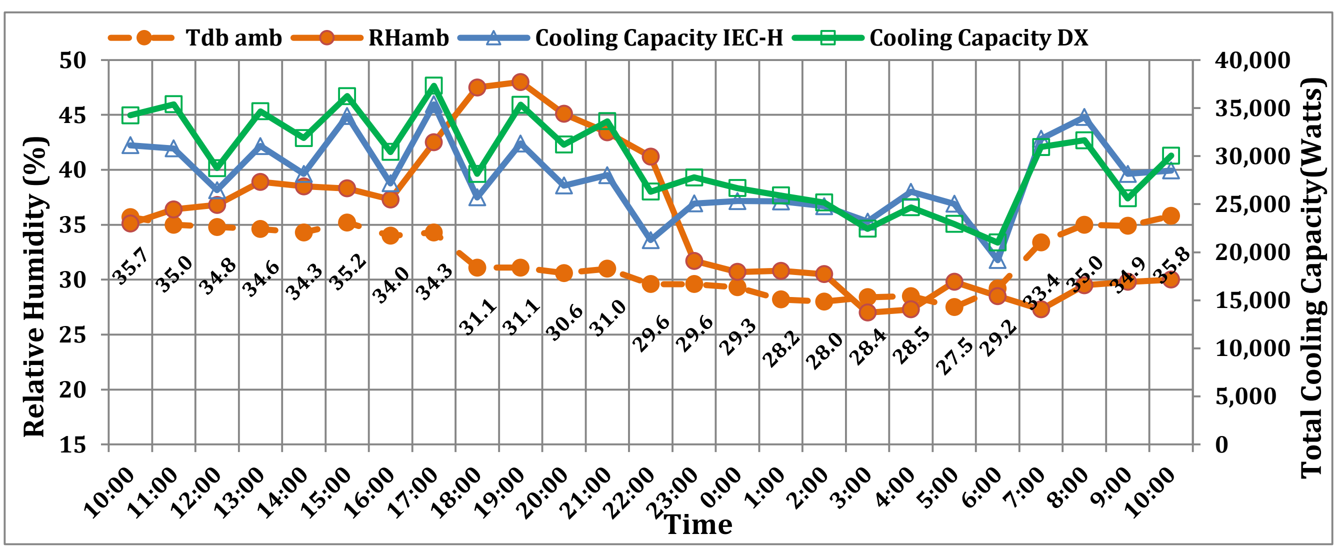


Fig 45: Cooling capacity versus outlet wet bulb temperature for IEC Hybrid unit & DX unit for OEM6 at CZ5

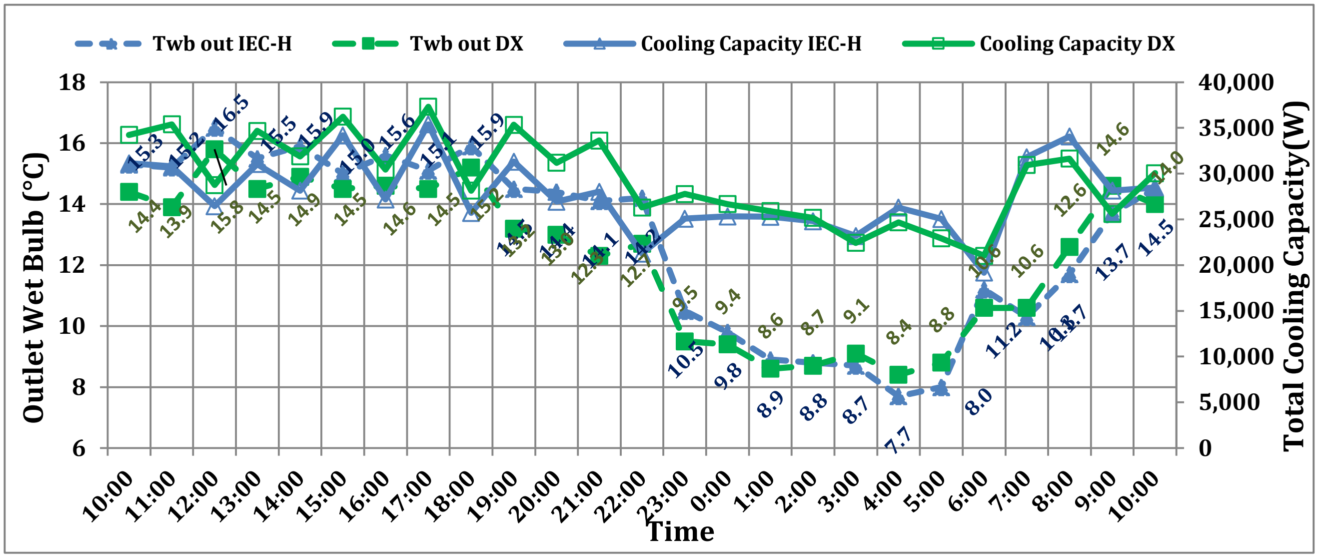
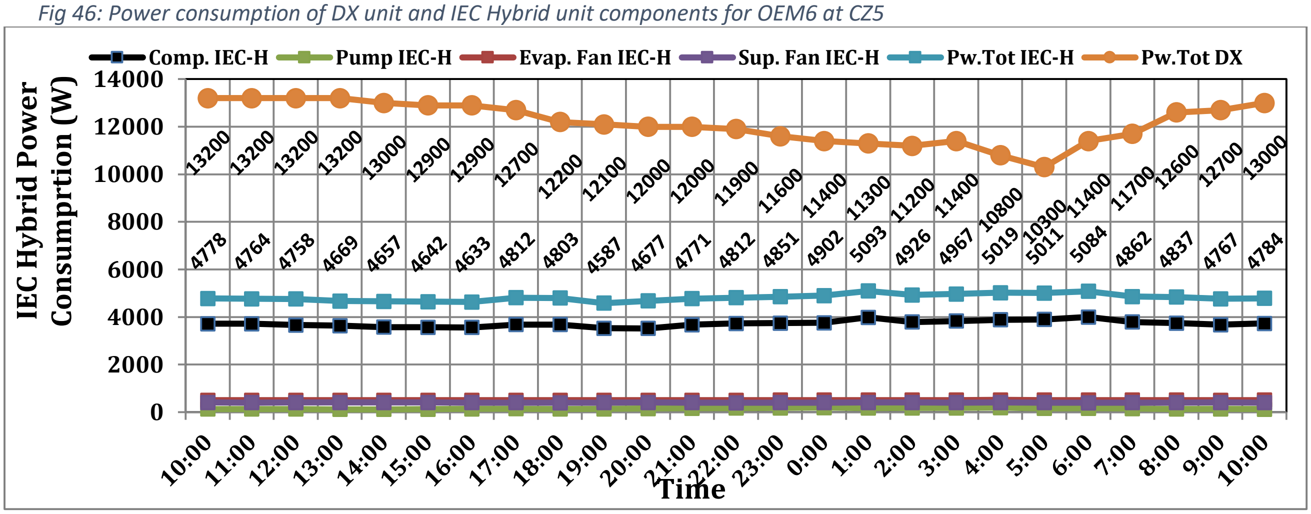


Fig 46: Power consumption of DX unit and IEC Hybrid unit components for OEM6 at CZ5



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.

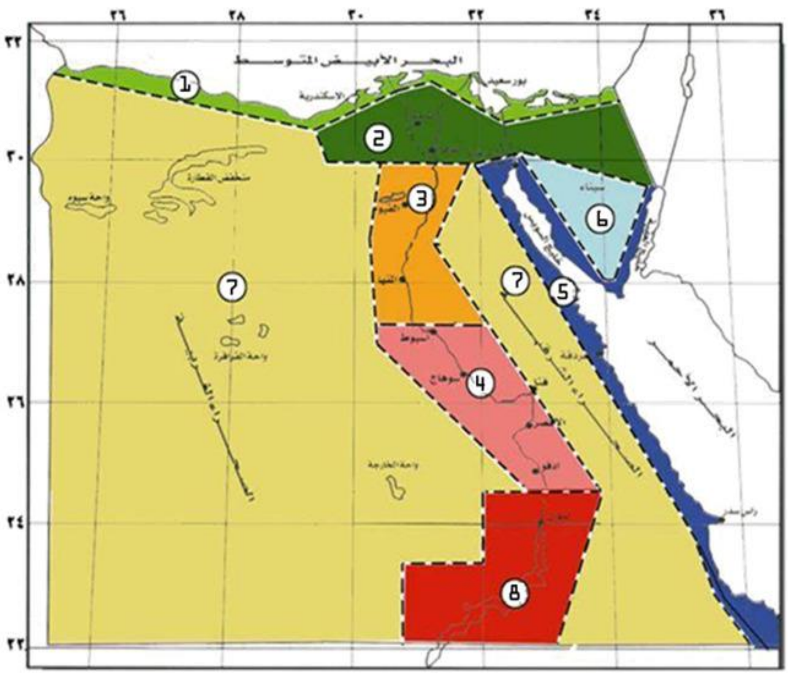
2. General Scope of Pre-tests

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.

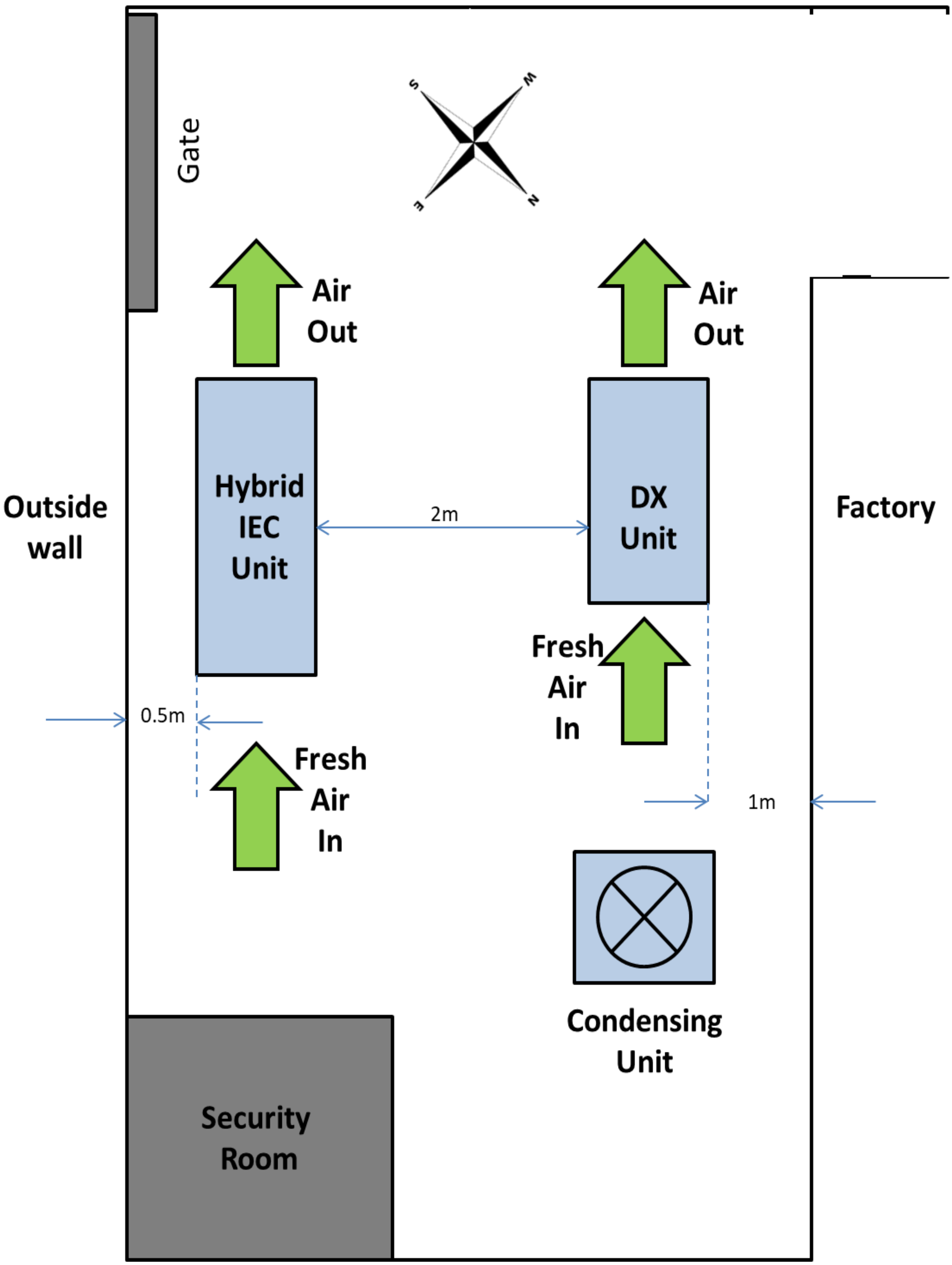


Figure (1) schematic diagram for both units

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 6^{th} 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.

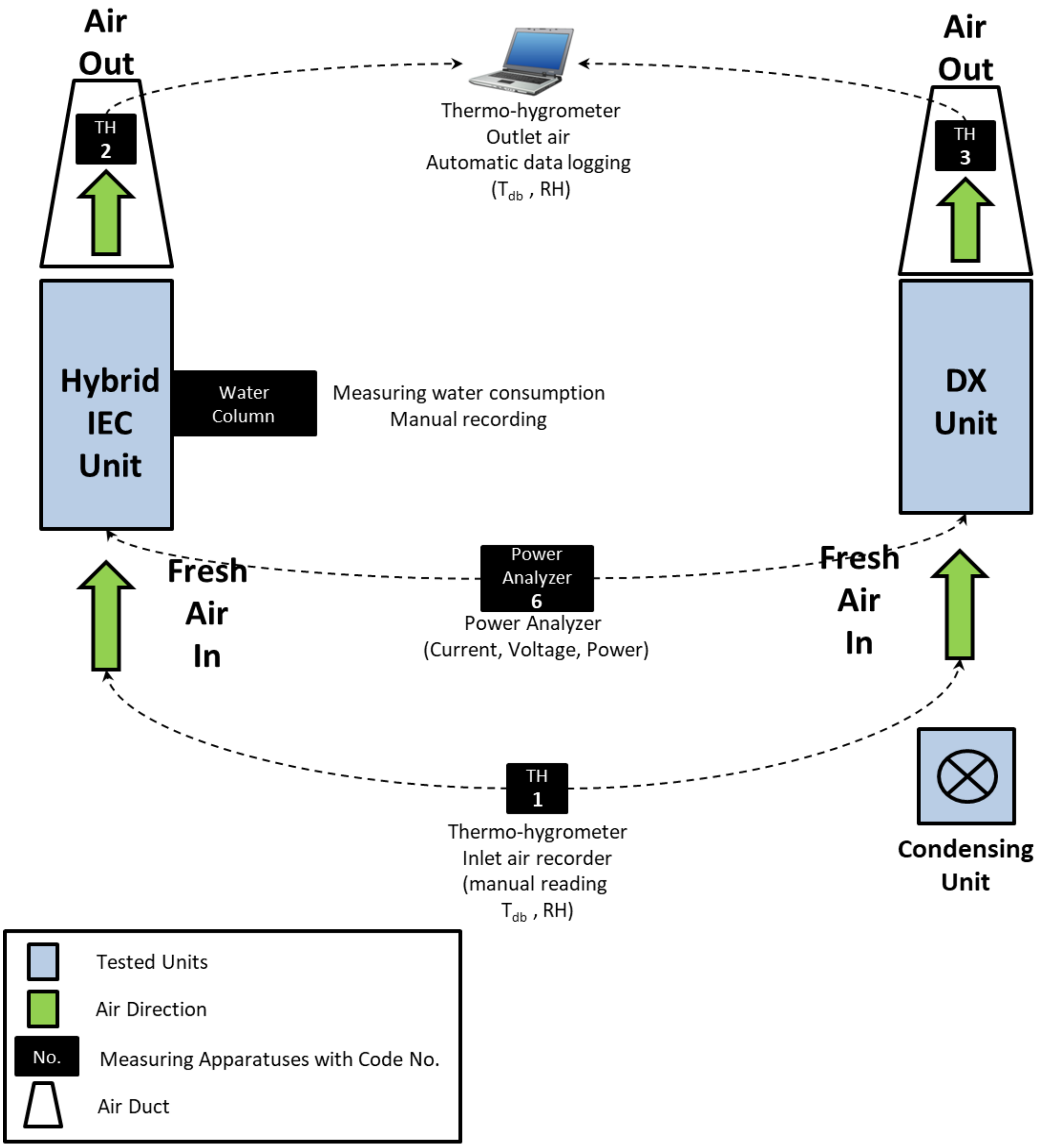


Figure 2 schematic diagram for the connection of the measuring devices on the site

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

Eng. Sally Aladdin

Checked by

Prof. Sayed Shebl

Approved by

Prof. Alaa Olama

Eng. Nourhan Abdel Rahman

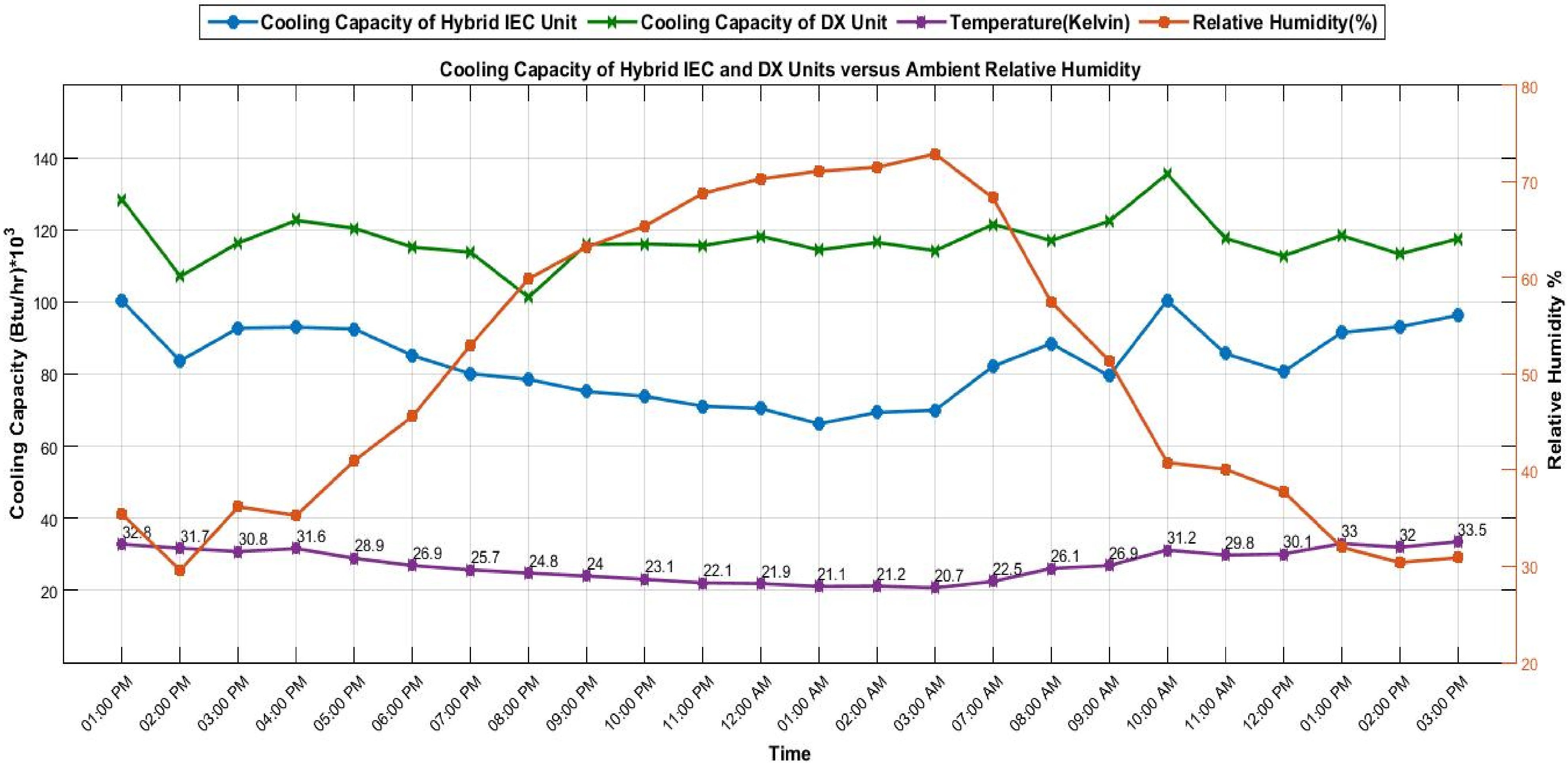


Figure (3): Cooling Capacity of (Hybrid IEC & DX) Units

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

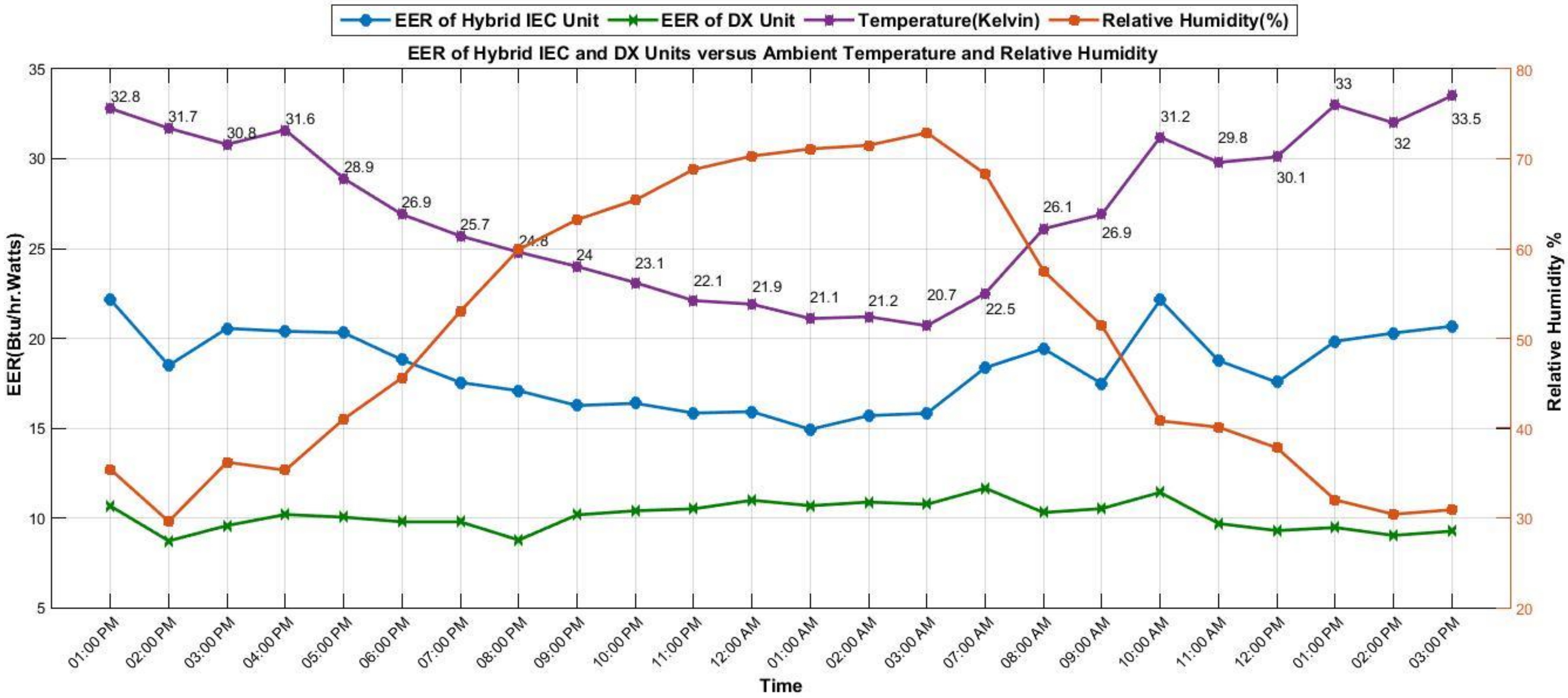


Figure (4): EER of (Hybrid IEC & DX) Units

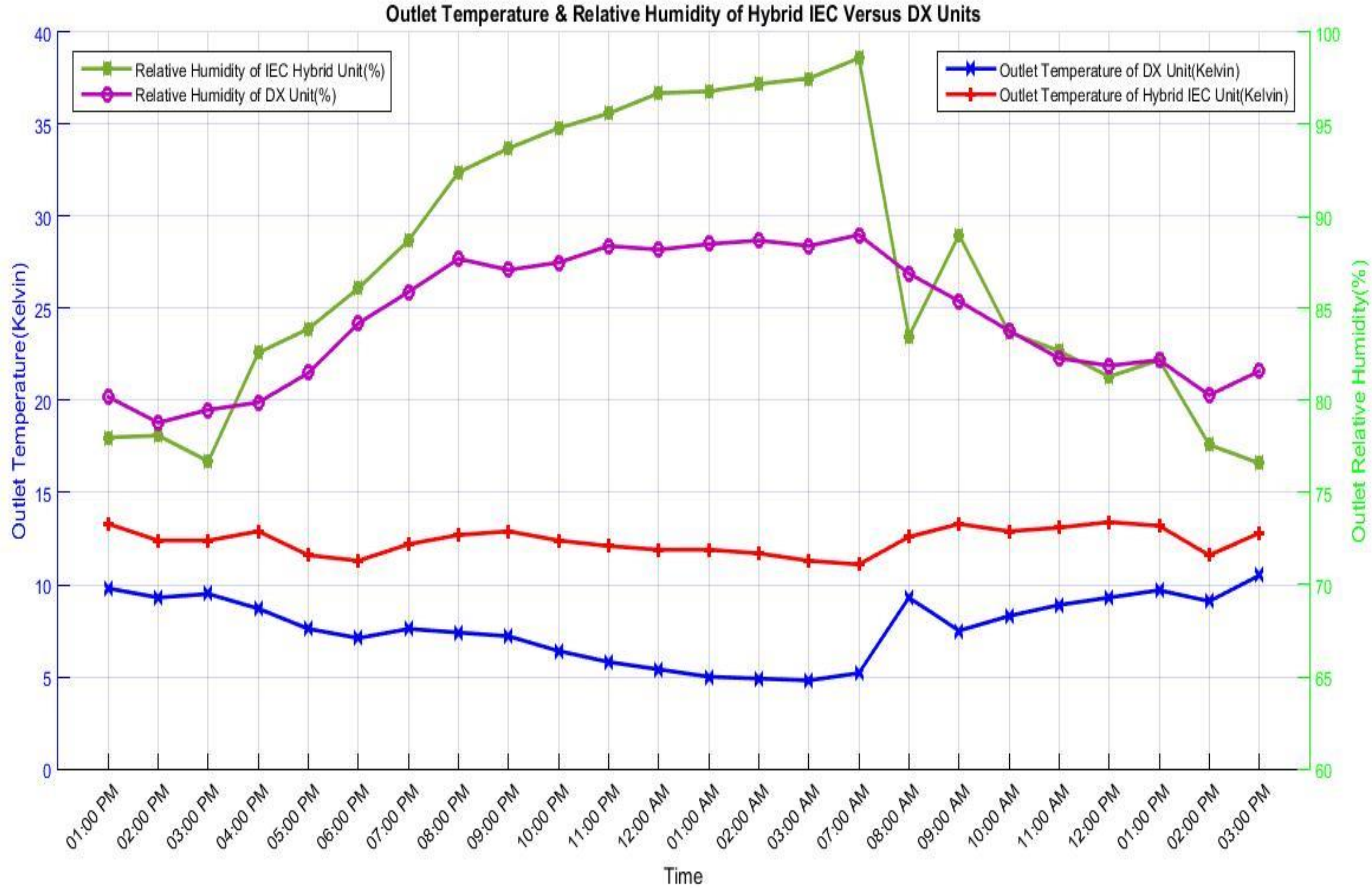


Figure (5): ambient (Relative humidity and Temperature) of (Hybrid IEC & DX) Units

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

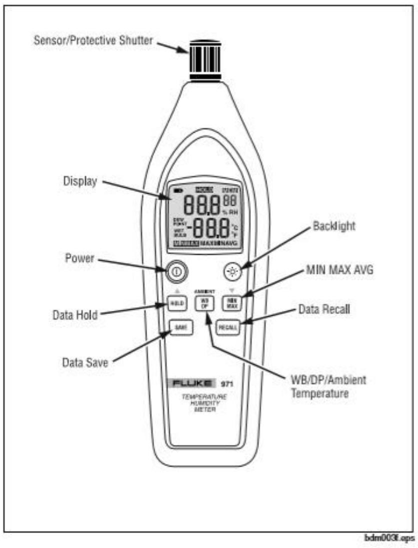
FLUKE®

971

Temperature Humidity Meter

Users Manual

PN 2441047
September 2005 Rev.1, 5/06



Introduction

⚠ Caution

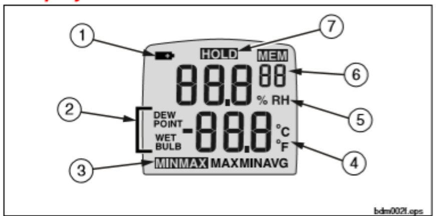
To extend sensor life, keep the sensor's protective shutter closed whenever the meter is not in use.

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	(battery symbol)	Low battery when shown in the display.
CE	Conforms to European Union requirements	(C-tick symbol)	Conforms to Australian standards.
(CSA symbol)	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 [battery symbol] 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.

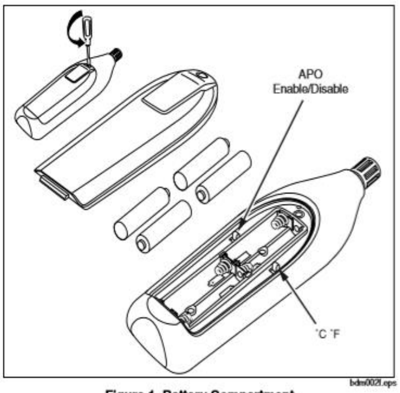


Figure 1. Battery Compartment

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.

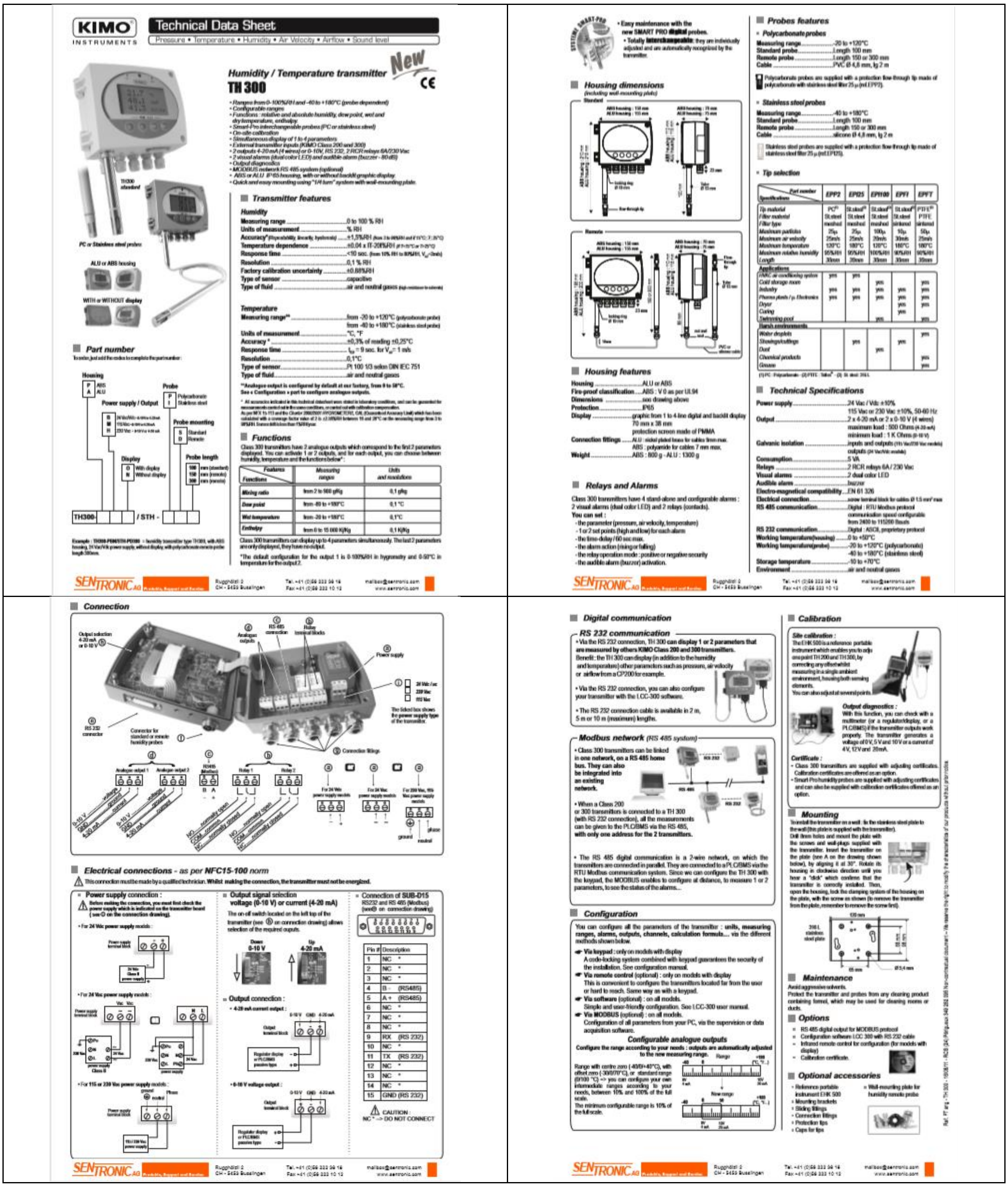
THIS WARRANTY IS YOUR ONLY REMEDY. NO OTHER WARRANTIES, SUCH AS FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSED OR IMPLIED. FLUKE IS NOT LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OR LOSSES, ARISING FROM ANY CAUSE OR THEORY. Since some states or countries do not allow the exclusion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

Fluke Corporation
P.O. Box 9090
Everett, WA 98206-9090
U.S.A.

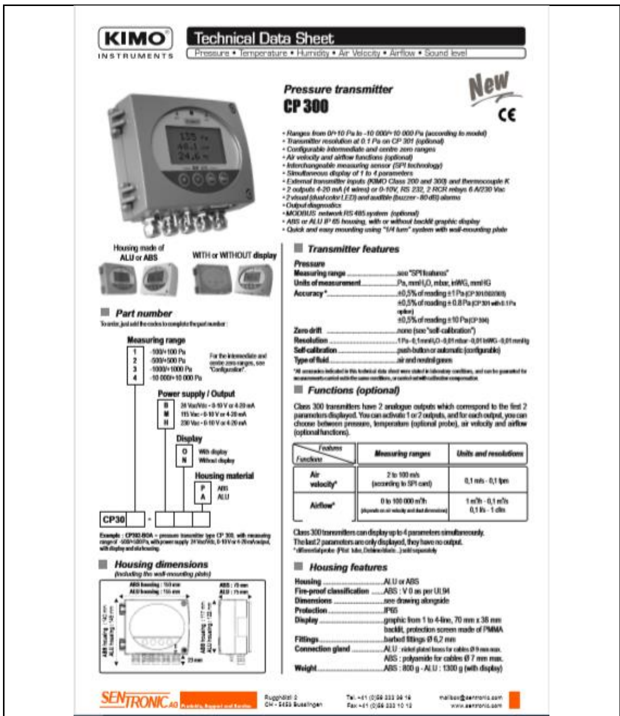
Fluke Europe B.V.
P.O. Box 1186
5602 BD Eindhoven
The Netherlands

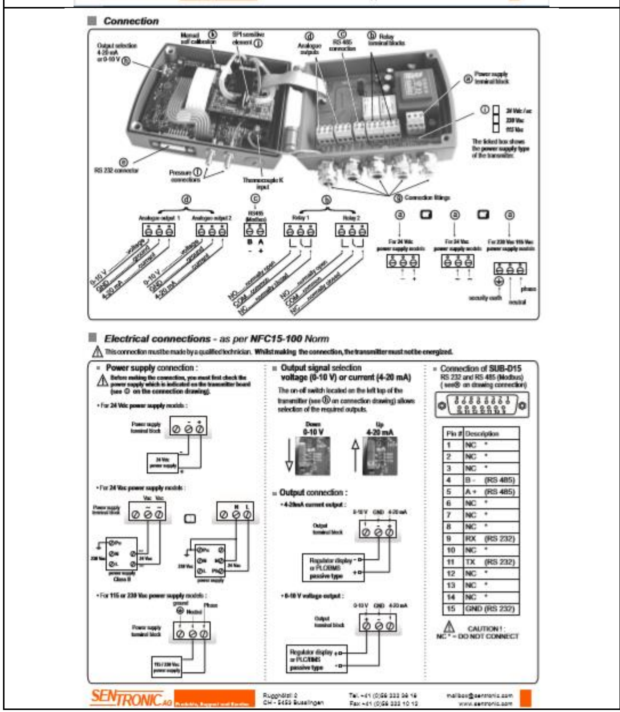
11/99

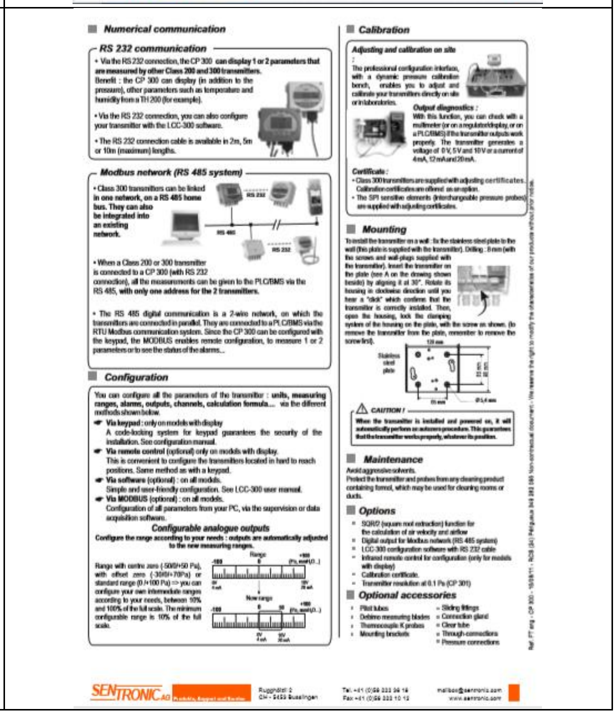
Measuring Instruments - Code 2 & 3



Measuring Instruments - Code 4 & 5







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

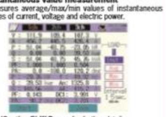
Data in the internal memory or CF card can be saved in a PC via a USB lead or a CF Card reader. As well supplied software facilitates setting, optional analysis software facilitates data analysis.

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

Instantaneous value measurement
Measures average/max/min values of instantaneous values of current, voltage and electric power.



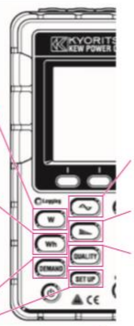
See **(Section 5) W Range** for further details.

Integration value measurement
Measures active/ apparent/ reactive powers on each CH.

See **(Section 6) Wh Range** for further details.

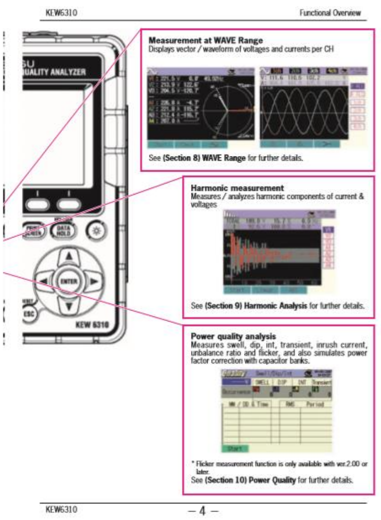
Demand measurement
Measures demand values based on the preset target values. Digital output signals alert the user that the predicted value may exceed the target value.

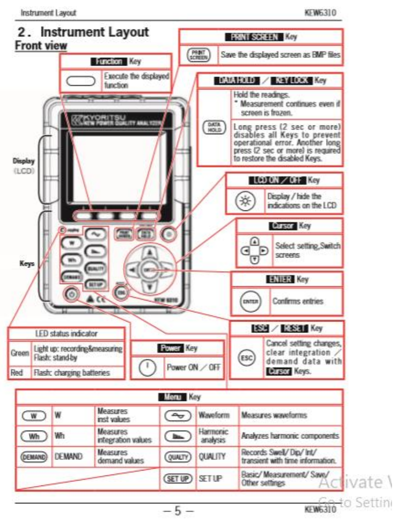
See **(Section 7) DEMAND Range** for further details.

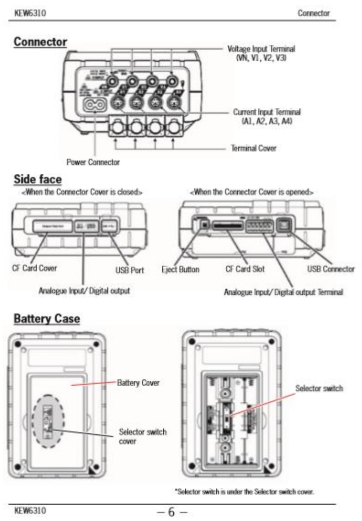


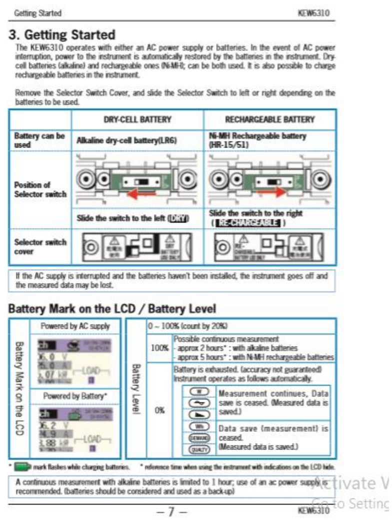
SET UP
Setting of KEW6310 or of measurements.

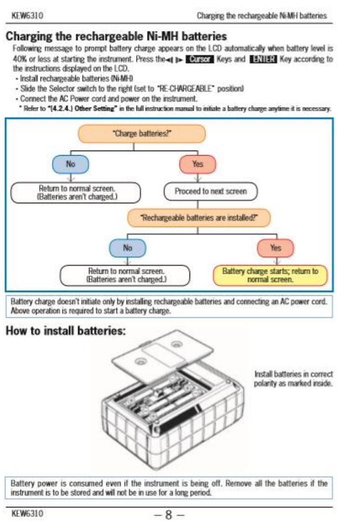
See **(Section 4) Setting** for further details.

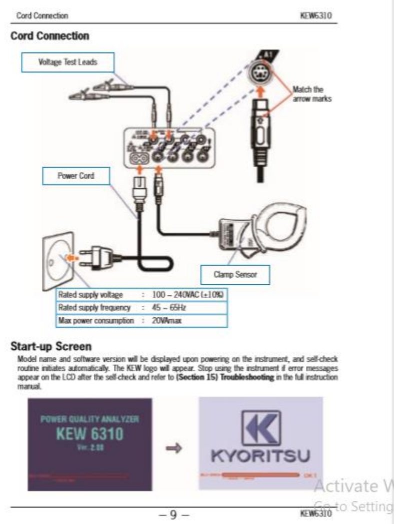

KEW6310
Functional Overview
Measurement at WAVE Range
Displays vector / waveform of voltages and currents per CH
See (Section 8) WAVE Range for further details.
Harmonic measurement
Measures / analyzes harmonic components of current & voltages
See (Section 9) Harmonic Analysis for further details.
Power quality analysis
Measures swell, dip, int, transient, inrush current, unbalance ratio and flicker, and also simulates power factor correction with capacitor banks.
See (Section 10) Power Quality for further details.
KEW6310
– 4 –

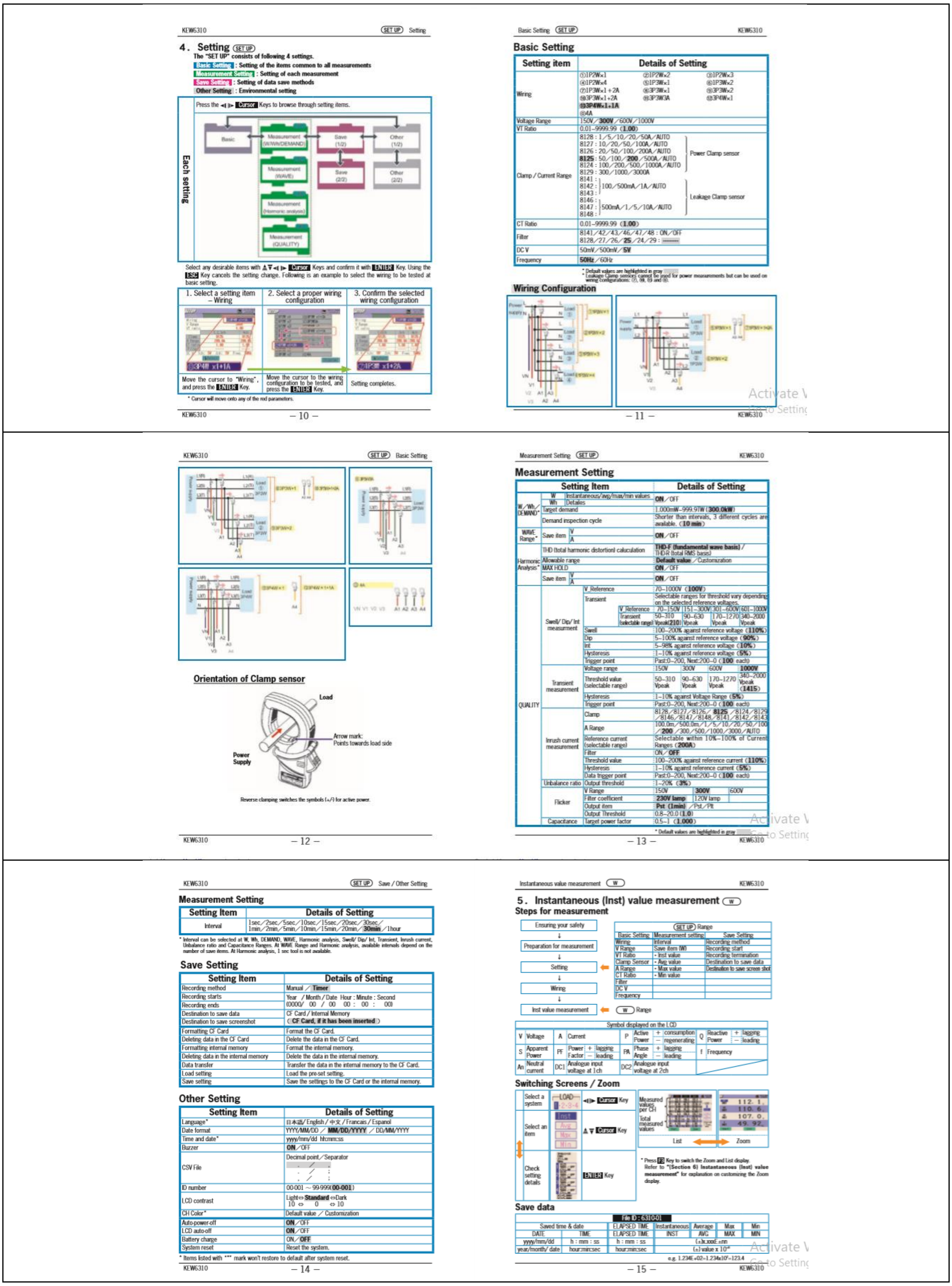

Instrument Layout
KEW6310
2. Instrument Layout
Front view
PRINT SCREEN Key
Save the displayed screen as BMP files
Function Key
Execute the displayed function
DATA HOLD / KEY LOCK Key
Hold the readings.
Long press (2 sec or more) disables all Keys to prevent operational error. Another long press (2 sec or more) is required to restore the disabled Keys.
Display (LCD)
LCD ON / OFF Key
Display / hide the indications on the LCD
Cursor Key
Select setting, Switch screens
Keys
ENTER Key
Confirms entries
LED status indicator
Green Light up: recording&measuring Flash: stand-by
Red Flash: charging batteries
Power Key
Power ON / OFF
ESC / RESET Key
Menu Key
W Measures inst values
Wh Measures integration values
DEMAND Measures demand values
Waveform Measures waveforms
Harmonic analysis Analyzes harmonic components
QUALITY Records Swell/ Dip/ Int/ transient with time information.
SET UP Basic/ Measurement/ Save/ Other settings
– 5 –
KEW6310


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
Eject Button
CF Card Slot
USB Connector
Analogue Input/ Digital output
Analogue Input/ Digital output Terminal
Battery Case
Battery Cover
Selector switch cover
Selector switch
*Selector switch is under the Selector switch cover.
KEW6310
– 6 –

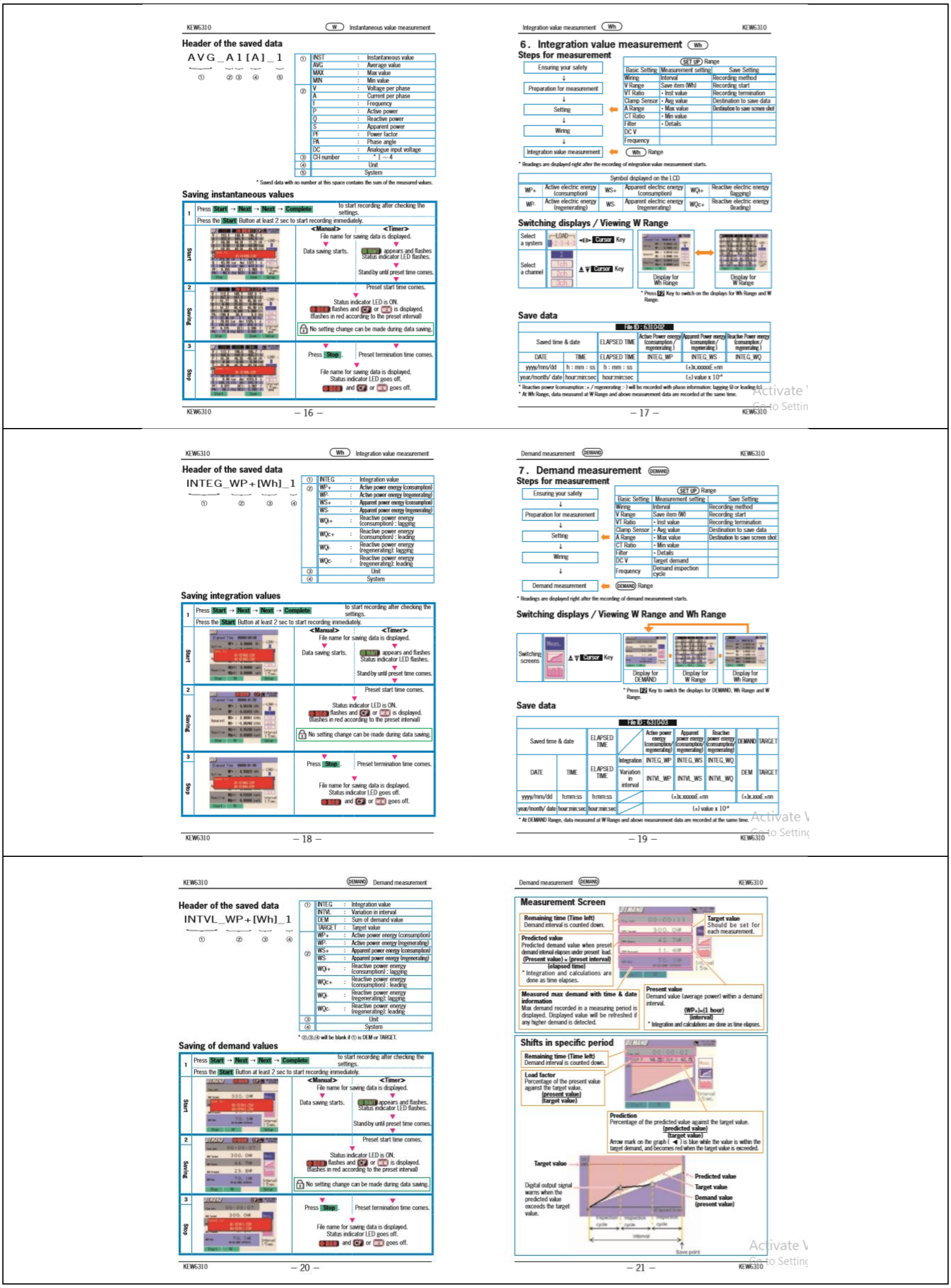

Getting Started
KEW6310
3. Getting Started
DRY-CELL BATTERY
RECHARGEABLE BATTERY
Battery can be used
Alkaline dry-cell battery(LR6)
Ni-MH Rechargeable battery (HR-15/51)
Position of Selector switch
Slide the switch to the left (DRY)
Slide the switch to the right (RE-CHARGEABLE)
Selector switch cover
Battery Mark on the LCD / Battery Level
Powered by AC supply
Powered by Battery*
Battery Mark on the LCD
Battery Level
– 7 –
KEW6310


KEW6310
Charging the rechargeable Ni-MH batteries
Charging the rechargeable Ni-MH batteries
"Charge batteries?"
No
Yes
Return to normal screen. (Batteries aren't charged.)
Proceed to next screen
"Rechargeable batteries are installed?"
No
Yes
Return to normal screen. (Batteries aren't charged.)
Battery charge starts; return to normal screen.
How to install batteries:
Install batteries in correct polarity as marked inside.
KEW6310
– 8 –


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
POWER QUALITY ANALYZER
KEW 6310
KYORITSU
– 9 –
KEW6310



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
Each setting
1. Select a setting item – Wiring
2. Select a proper wiring configuration
3. Confirm the selected wiring configuration
Setting completes.
KEW6310 – 10 –
Basic Setting SET UP KEW6310
Basic Setting
Setting item
Details of Setting
Wiring
Voltage Range
VT Ratio
Clamp / Current Range
Power Clamp sensor
Leakage Clamp sensor
CT Ratio
Filter
DC V
Frequency
Wiring Configuration
– 11 – KEW6310
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
QUALITY
Flicker
Capacitance
* Default values are highlighted in gray
– 13 – KEW6310
KEW6310 SET UP Save / Other Setting
Measurement Setting
Setting Item
Details of Setting
Interval
Save Setting
Setting Item
Details of Setting
Recording method
Recording starts
Recording ends
Destination to save data
Destination to save screenshot
Formatting CF Card
Deleting data in the CF Card
Formatting internal memory
Deleting data in the internal memory
Data transfer
Load setting
Save setting
Other Setting
Setting Item
Details of Setting
Language*
Date format
Time and date*
Buzzer
CSV File
ID number
LCD contrast
CH Color*
Auto-power-off
LCD auto-off
Battery charge
System reset
* Items listed with "*" mark won't restore to default after system reset.
KEW6310 – 14 –
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
List
Zoom
Save data
– 15 – KEW6310


KEW6310 — Instantaneous value measurement

Header of the saved data

AVG_A1[A]_1

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

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.

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.

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

KEW6310 — 16 —

6. Integration value measurement

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 — 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.

— 17 — KEW6310

KEW6310 — Integration value measurement

Header of the saved data

INTEG_WP+[Wh]_1

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

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 / Saving / Stop steps as on page 16.)

KEW6310 — 18 —

7. Demand measurement

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

DATE	TIME	ELAPSED TIME		Integration	INTEG_WP	INTEG_WS	INTEG_WQ	DEM	TARGET
				Variation in interval	INTVL_WP	INTVL_WS	INTVL_WQ		
yyyy/mm/dd	h:mm:ss	h:mm:ss			(±)x.xxxxxE±nn			(±)x.xxxxE±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.

— 19 — KEW6310

KEW6310 — Demand measurement

Header of the saved data

INTVL_WP+[Wh]_1

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

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 / Saving / Stop steps as on page 16.)

KEW6310 — 20 —

Measurement Screen

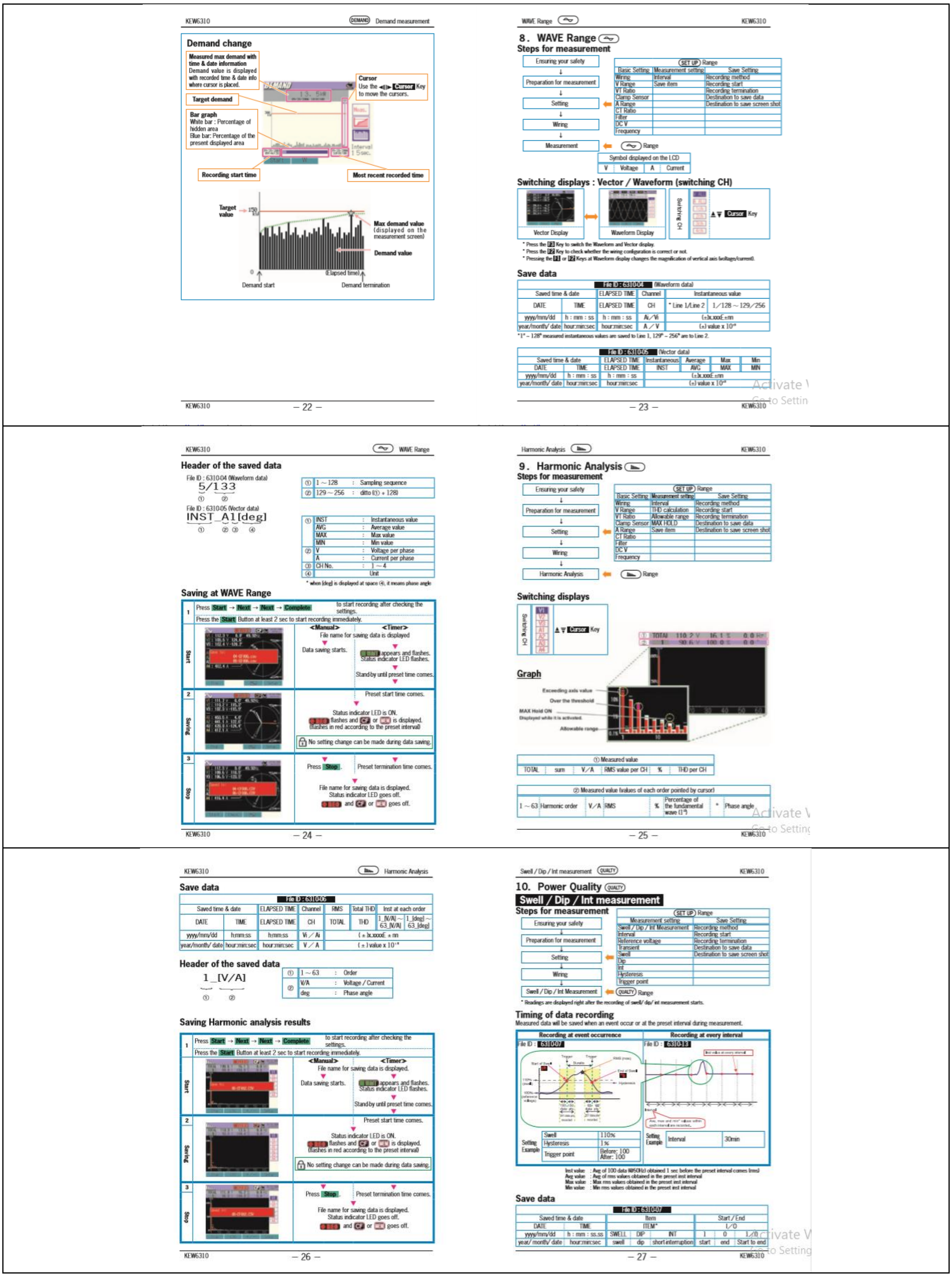
Remaining time (Time left): Demand interval is counted down.
Target value: Should be set for each measurement.
Predicted value: Predicted demand value when preset demand interval elapses under present load. (Present value) x (preset interval) / (elapsed time)
* Integration and calculations are done as 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+)x(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.

— 21 — KEW6310



KEW6310 — 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

Cursor: Use the ◄► Cursor Key to move the cursors.

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

Recording start time — Most recent recorded time

Target value — Max demand value (displayed on the measurement screen) — Demand value — Demand start — (Elapsed time) — Demand termination

KEW6310 — 22 —

WAVE Range — KEW6310

8. WAVE Range

Steps for measurement

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

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

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 : 631004 (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	A/V		(±)x.xxxE±nn
year/month/ date	hour:min:sec	hour:min:sec	A / V		(±) value x $10^{\pm n}$

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

File ID : 631005 (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 $10^{\pm n}$		

— 23 — KEW6310

KEW6310 — WAVE Range

Header of the saved data

File ID : 631004 (Waveform data)

5/133 — ① ②

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

File ID : 631005 (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> Data saving starts. <Timer> File name for saving data is displayed. [icon] appears and flashes. Status indicator LED flashes. Standby until preset time comes.
2. Saving: Preset start time comes. Status indicator LED is ON. [icon] flashes and [icon] or [icon] 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. [icon] and [icon] or [icon] goes off.

KEW6310 — 24 —

Harmonic Analysis — KEW6310

9. Harmonic Analysis

Steps for measurement

Ensuring your safety → Preparation for measurement → Setting → Wiring → Harmonic Analysis

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

Switching displays

Switching CH — ▲▼ Cursor Key

Graph

Exceeding axis value — Over the threshold — MAX Hold ON: Displayed while it is activated. — Allowable range

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

— 25 — KEW6310

KEW6310 — Harmonic Analysis

Save data

File ID : 631006

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	V/A		(±)x.xxxE±nn		
year/month/ date	hour:min:sec	hour:min:sec	V / A		(±) value x $10^{\pm n}$		

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> Data saving starts. <Timer> File name for saving data is displayed. [icon] appears and flashes. Status indicator LED flashes. Standby until preset time comes.
2. Saving: Preset start time comes. Status indicator LED is ON. [icon] flashes and [icon] or [icon] 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. [icon] and [icon] or [icon] 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

SET UP Range: Measurement setting (Swell / Dip / Int Measurement, Interval, Reference voltage, Transient, Swell, Dip, Int, Hysteresis, Trigger point); Save Setting (Recording method, Recording start, Recording termination, Destination to save data, Destination to save screen shot)

* 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 : 631007) — Recording at every interval (File ID : 631013)

Setting Example: Swell 110%; Hysteresis 1%; Trigger point Before: 100, After: 100 — Interval 30min

Inst value: Avg of 100 data (RMS) obtained 1 sec before the preset interval comes (ms)
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 : 631007

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

— 27 — KEW6310

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$^{\pm nn}$

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$^{\pm nn}$			

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> File name for saving data is displayed. ▼ Data saving starts. <Timer> File name for saving data is displayed. ▼ [STATUS] 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 [SD] 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 [SD] 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	

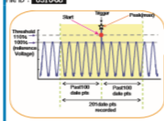
Transient Measurement ← (QUALITY) Range

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

Timing of data recording

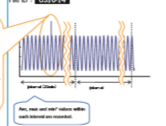
Measured data will be saved when an event occur or at the preset interval during measurement.

Recording at event occurrence — File ID : 6310-08



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

Recording at every interval — File ID : 6310-14



Setting Example	
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$^{\pm nn}$

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$^{\pm nn}$			

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> File name for saving data is displayed. ▼ Data saving starts. <Timer> File name for saving data is displayed. ▼ [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 [SD] 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 [SD] 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	

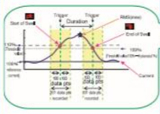
Inrush Current Measurement ← (QUALITY) Range

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

Timing of data recording

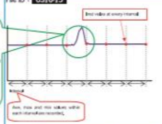
Measured data will be saved when an event occur or at the preset interval during measurement.

Recording at event occurrence — File ID : 6310-09



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

Recording at every interval — File ID : 6310-15



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 : 6310-09								
Saved time & date		Start / End			Duration		Max / Min	Data
DATE	TIME	1/0			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$^{\pm nn}$

File ID : 6310-15						
Saved time & date		ELAPSED TIME	Instantaneous	Avarage	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			

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> File name for saving data is displayed. ▼ Data saving starts. <Timer> File name for saving data is displayed. ▼ [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 [SD] 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 [SD] 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: (11), (13), (13).

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	LOAD	◀▶ Cursor Key
Select an item	Inst / Avg / Max / Min	▲▼ 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$^{\pm nn}$			

KEW6310 (QUALTY) Unbalance Ratio

Header of the saved data

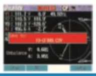
AVG_A1[A]_1

① ②③④ 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: [REC] 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 [M] 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 [M] goes off.

KEW6310 — 34 —

Flicker (QUALTY) KEW6310

Flicker

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

Steps for measurement

Ensuring your safety ↓ Preparation for measurement ↓ Setting ← ↓ 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 : 631012

Saved time & date		ELAPSED TIME	Frequency	Voltage			Short time intensity (for 1 min)	Short time intensity	Long time intensity
				Average	Max	Min			
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.xxxxE±nn	(±)x.xxxxE±nn				(±)x.xxxE±nn	
year/month/date	hour:min:sec	hour:min:sec	(±) value x 10^n						

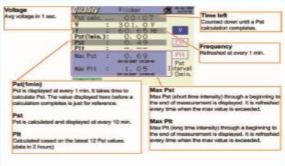
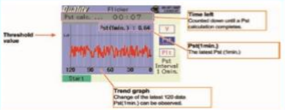
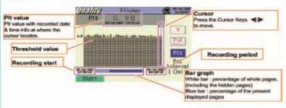
* Data is saved at every 1 min, but Pst is saved at every 10 min and Plt at every 10 min in 2 hours later.

Saving Flicker data

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

— 35 — KEW6310

KEW6310 (QUALTY) Flicker

V	
Pst (1min)	
Plt	

KEW6310 — 36 —

Capacitance Calculation (QUALTY) KEW6310

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

Steps for measurement

Ensuring your safety ↓ Preparation for measurement ↓ Setting ← ↓ 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	Total measured values / Measured values per CH — List → Zoom
Select an item	▲▼ Cursor Key	

* 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^n			

— 37 — KEW6310

KEW6310 (QUALTY) Capacitance Calculation

Header of the saved data

AVG_A1[A]_1

① ②③④ 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: [REC] 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 [M] 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 [M] goes off.

KEW6310 — 38 —

CF Card / Saved data KEW6310

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
Caiacity		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.

— 39 — KEW6310

Data transfer

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

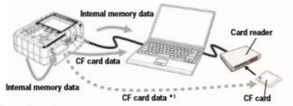
	Transfer to PC via:	
	USB	Card reader
CF card data (file)	△*1	○
Internal memory data (file)	○	—*2

*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

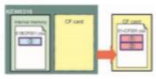
①	Save item	PS : Print screen
②	Save in	CF : CF card
		ME : Internal memory
③	File No	001 ~ 999
④	Extension	BMP

Backup Memory

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

Saving

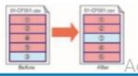
①. A file is created in the CF card, when CF card is selected as a destination for saving data, and measurement data is saved to the CF card.



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.

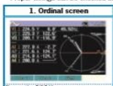
③. When inserting the CF card again during a data saving, further data will be saved to the last available space in CF card ①or ②.

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) WAVE Range.

1. Ordinal screen	2. Checking wiring	3. Check completes
		
Press the F2 Key.	Wiring check starts. Check  [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

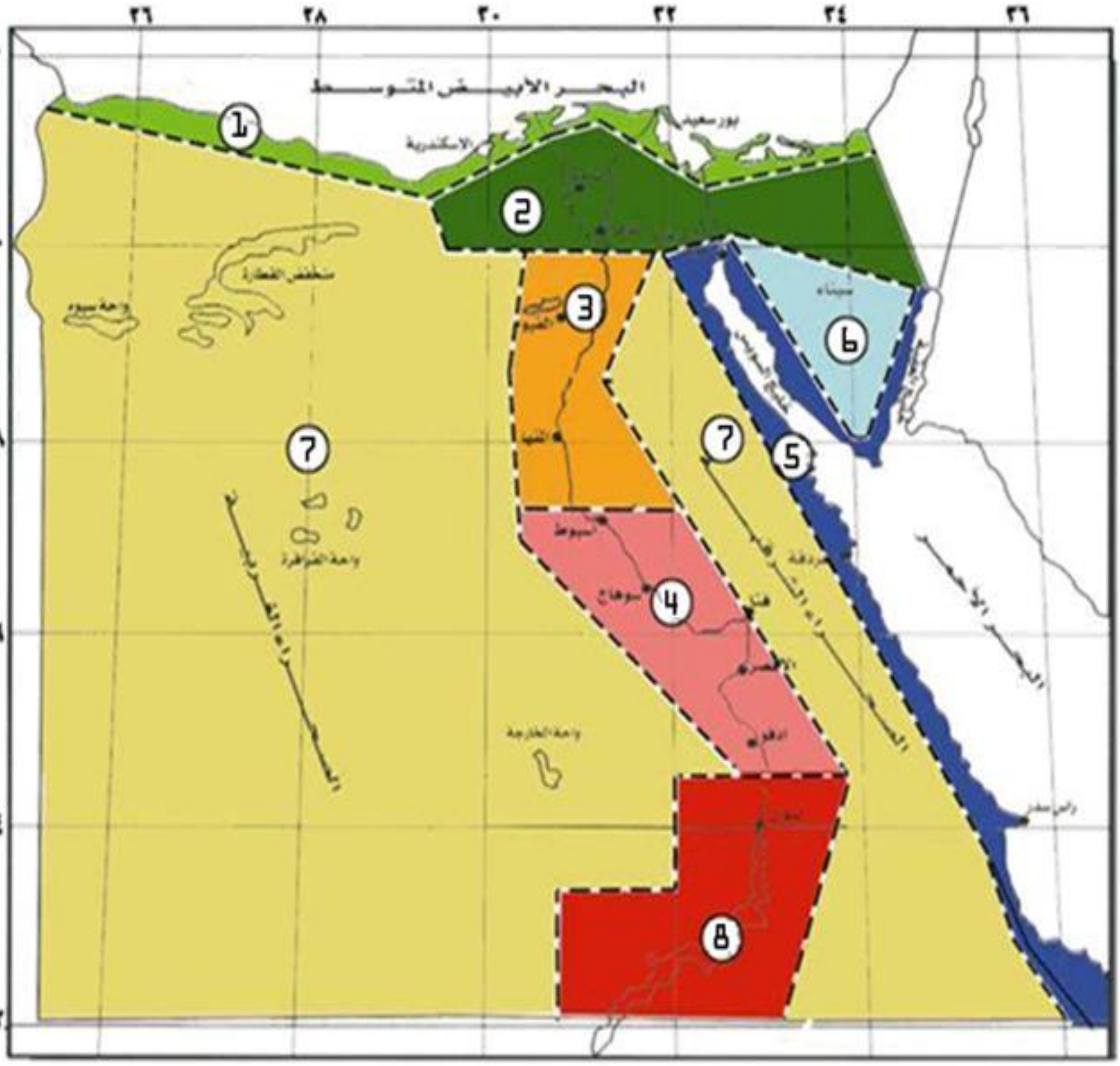
EUROVENT:

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.

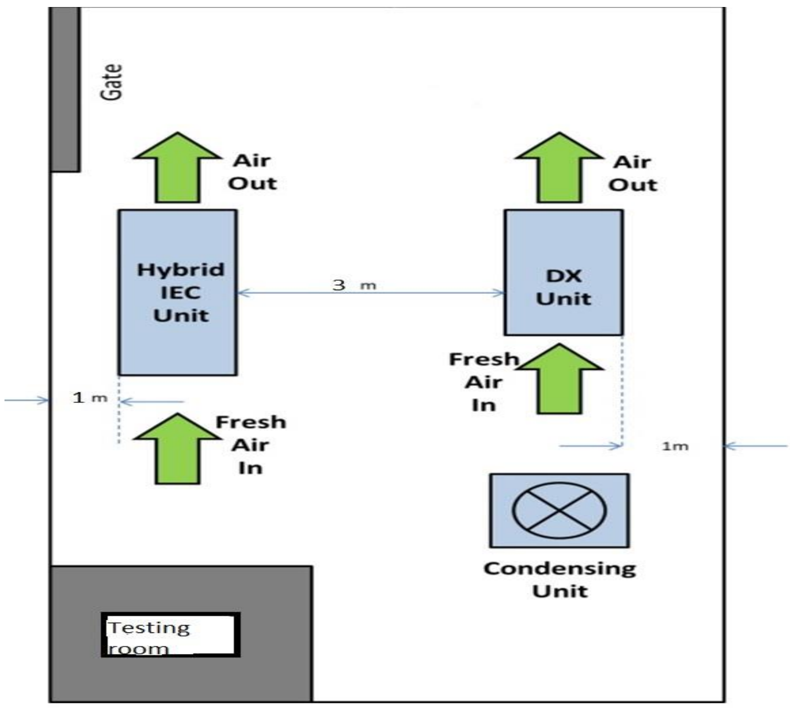
The first testing batch will start on the 15th of June 2022 in Climate Zone 2 (Delta Cairo and middle Sinai Region) followed by a second testing batch starting in the second half of July 2022 at Climatic Zone 5 or 8.

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:

$$EER = \frac{q_{tot}}{W}$$

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.

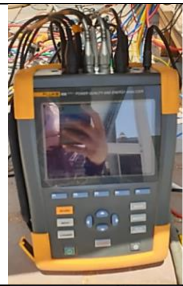
Accuracy of measurements is guaranteed by following the posterior steps:

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

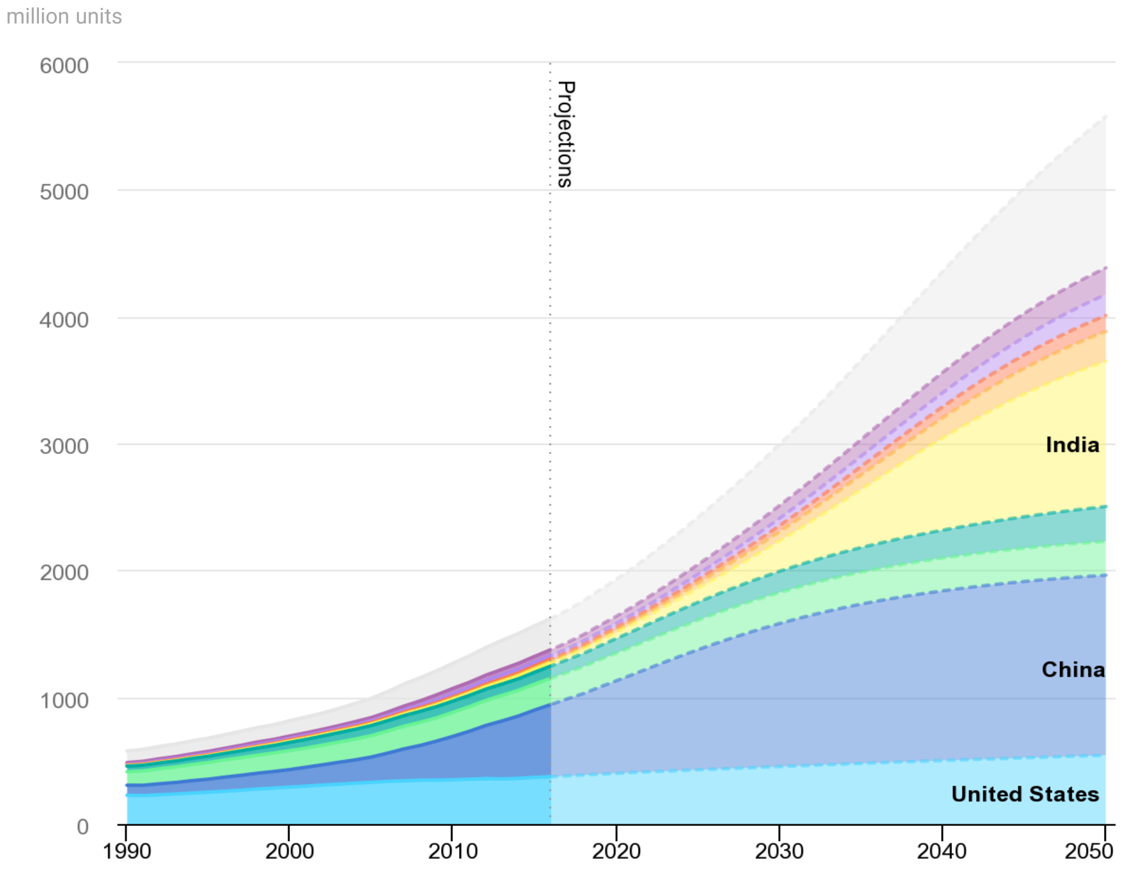
- Renewables

- Innovation and Smart Operations

- Sustainable Consumption of Materials

Population Growth & Energy Bill

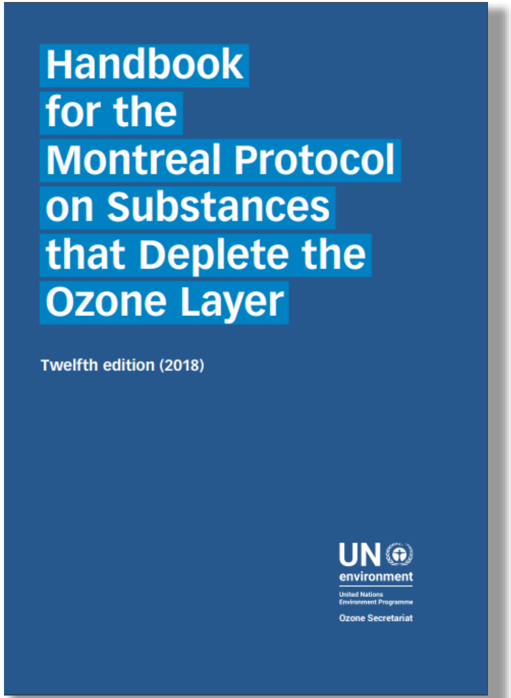
- Cooling is the fastest growing use of energy in buildings
- Cooling will drive peak electricity demand, especially in hot countries
- Most homes in hot countries have not yet purchased their first AC
- Investing in more efficient ACs could cut future energy demand in half



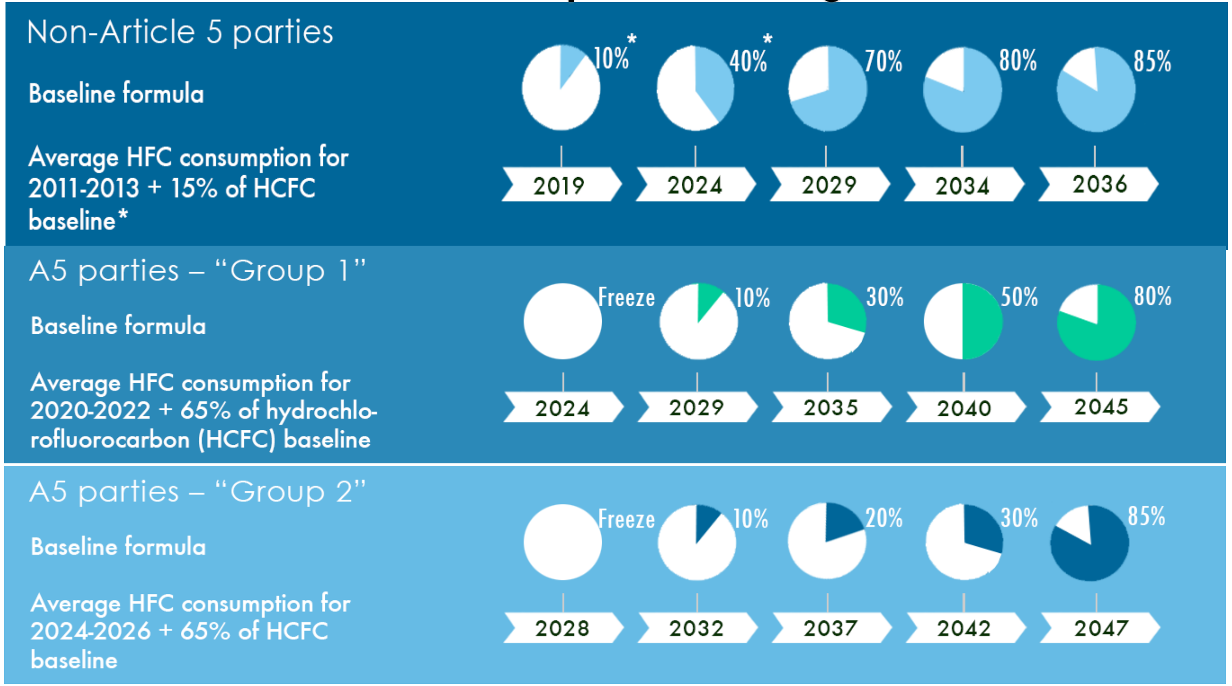
Global air conditioner stock, 1990-2050

IEA Future of Cooling Report (2018) updated 19-Nov-2019

Montreal Protocol –
A tool to protect ozone & climate

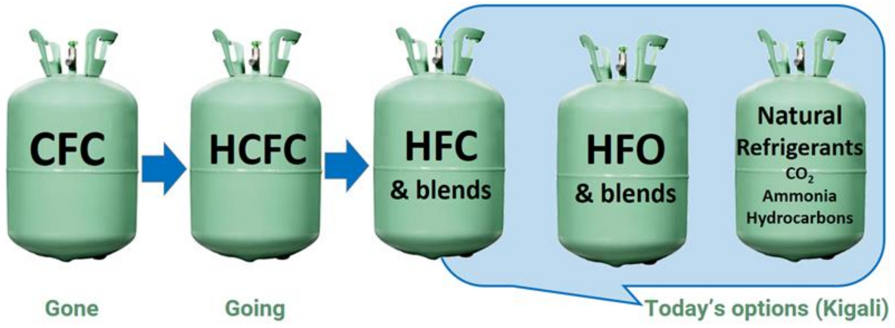


HFC control measures as per the 2016 Kigali Amendment



Refrigerant (re)evolution – transition to low-GWP

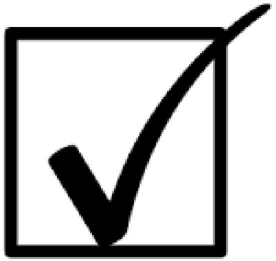
- **1830s-1930s** – **whatever worked**: primarily familiar solvents and other volatile fluids including ethers, ammonia (NH3), carbon dioxide (R-744), sulphur dioxide (R-764) and others
- **1931-1990s** – **safety and durability**: primarily chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), 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

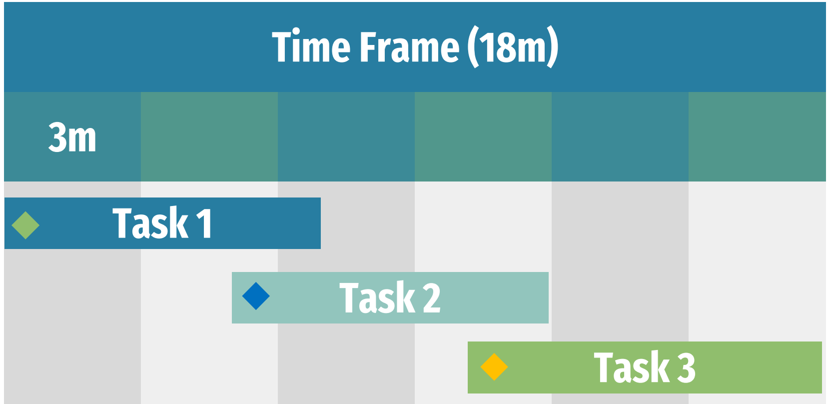
Presented by:

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

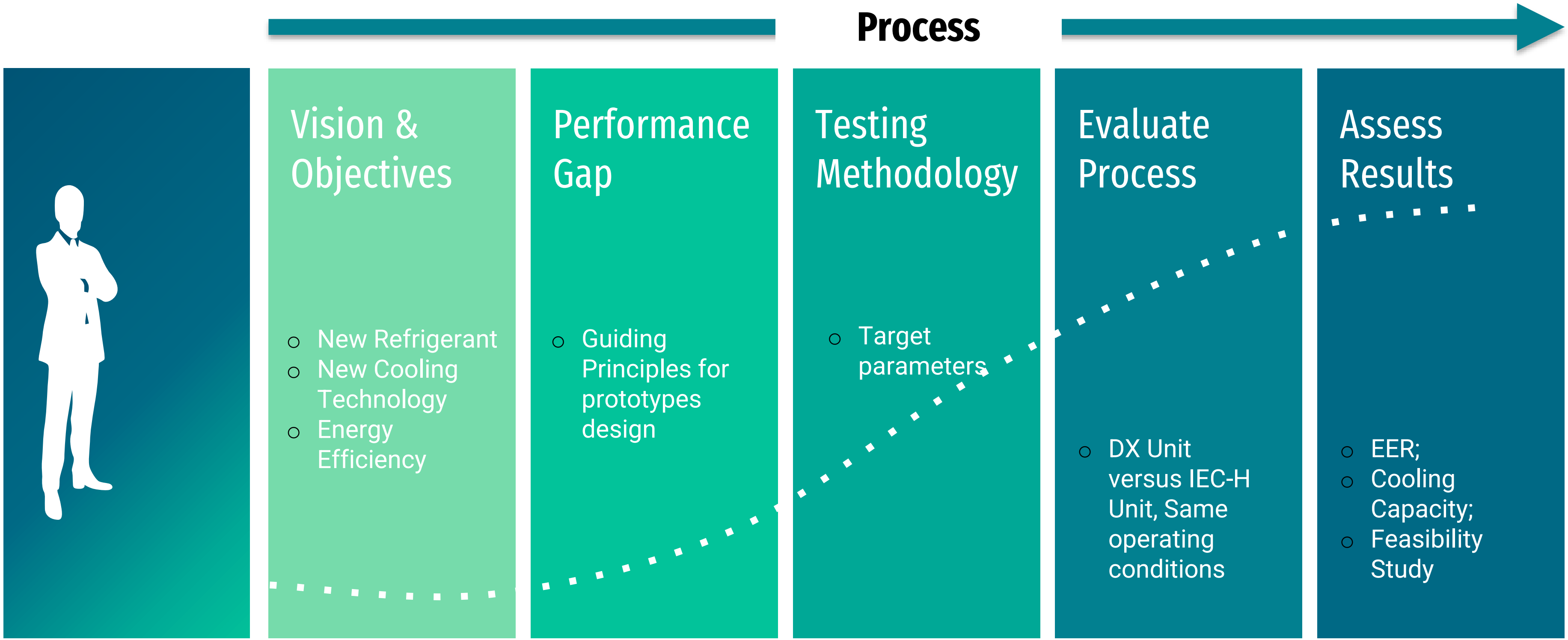
Milestones

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

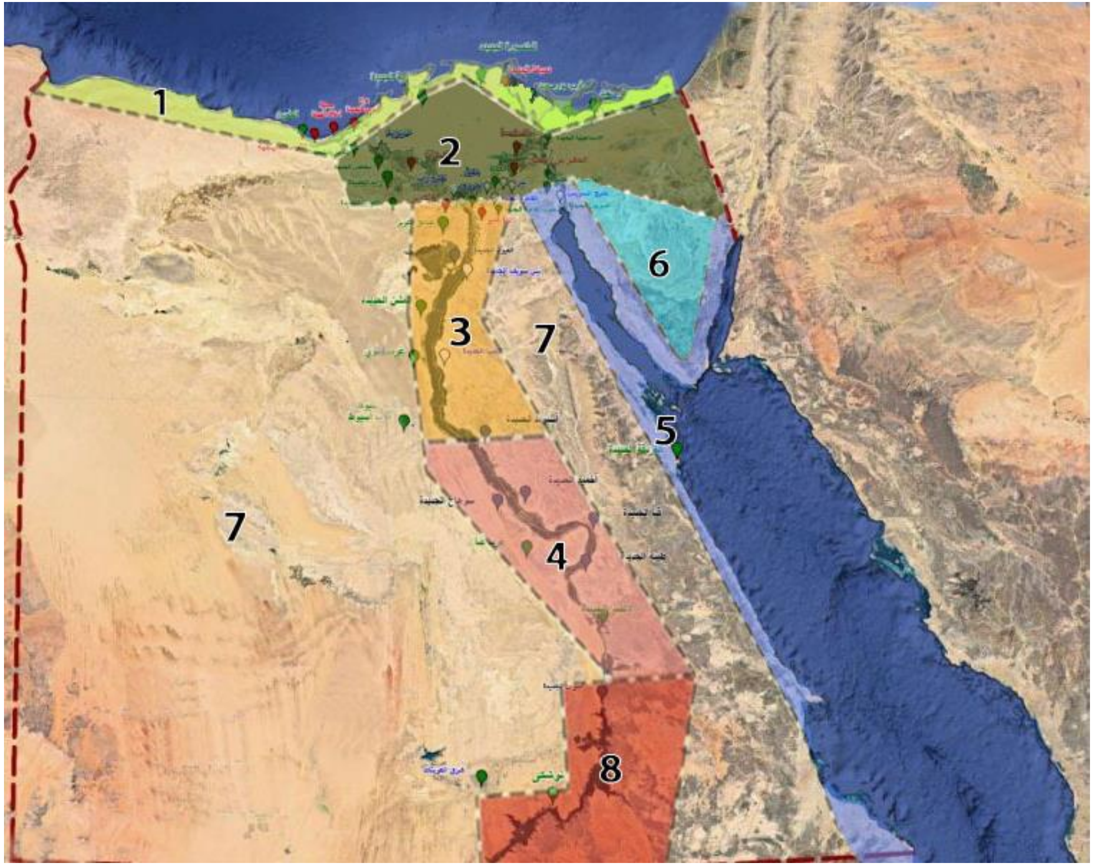
Testing Locations, and Used Apparatuses

Analyzing Data

Provide technical parameters obtained from field testing

Climatic Zones and the New Cities of Egypt

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	



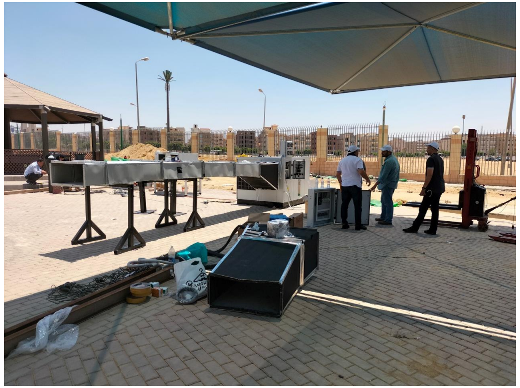
First Location - Climatic Zone 2 (Egyptian Russian University - Badr)

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

Step 1

Setup prototypes in testing location

Step 2

Adjust Airflow

Step 3

Connect Measuring Apparatuses

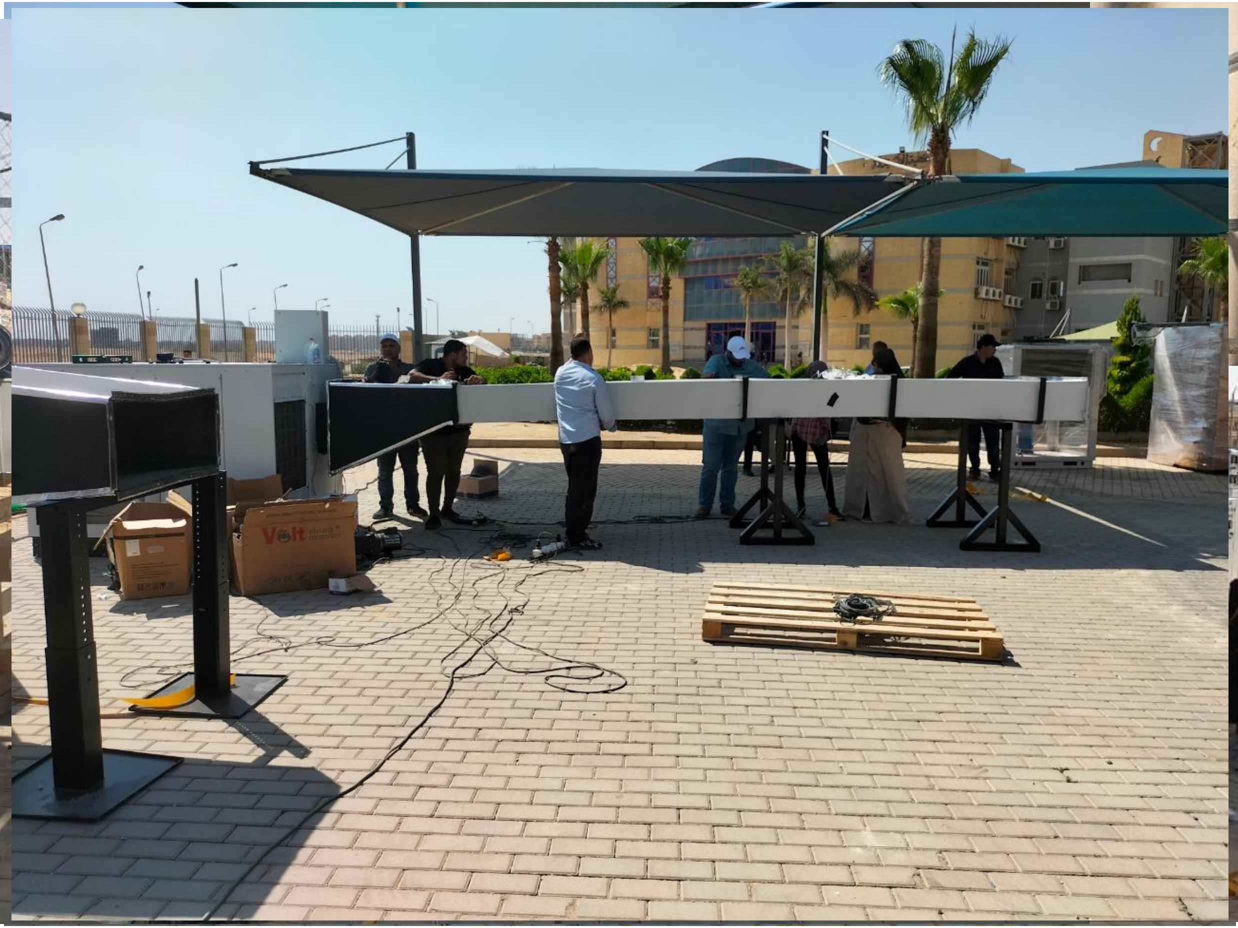
Step 4

Record measurements for 24 hours

Setup prototypes in testing location – CZ2

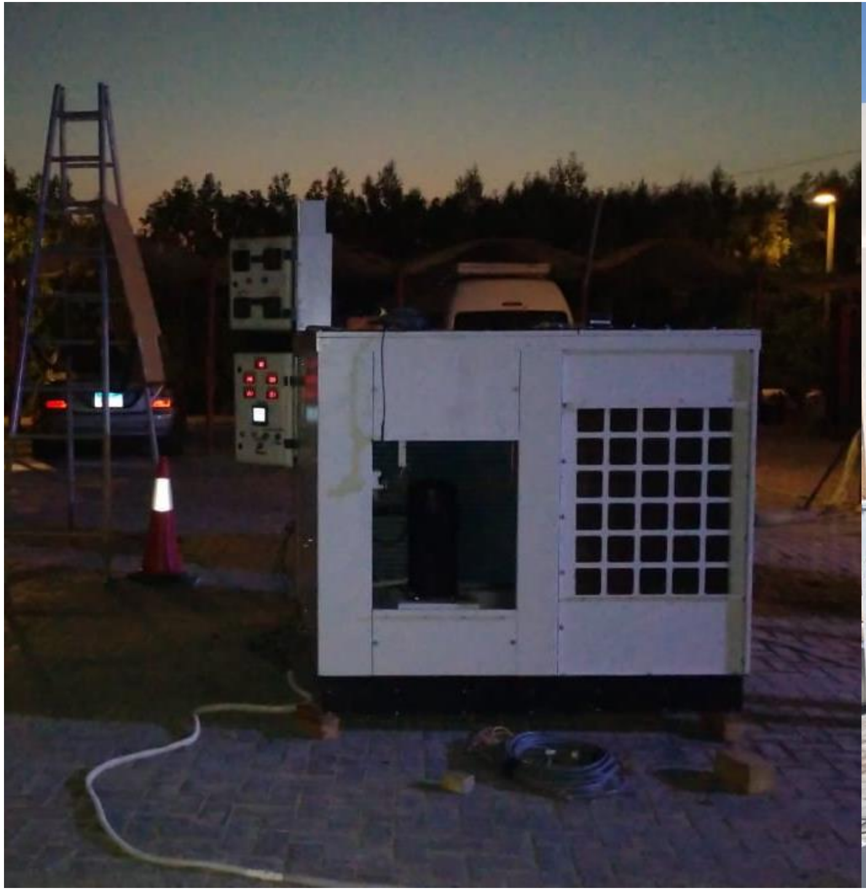
Setup prototypes in testing location – CZ5

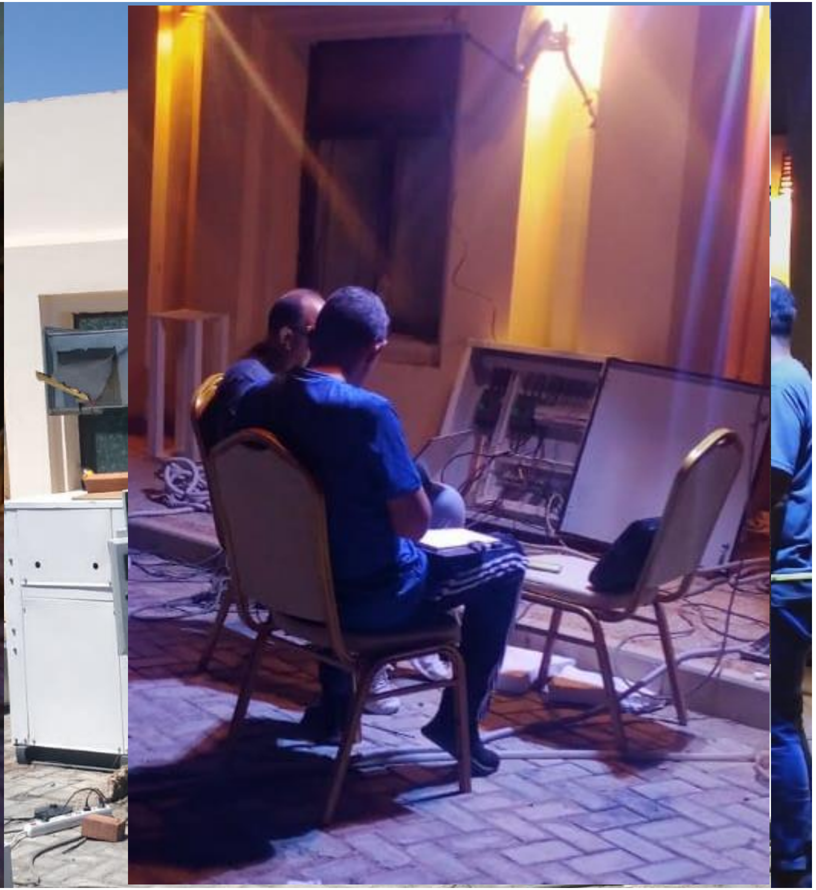
Airflow Setup

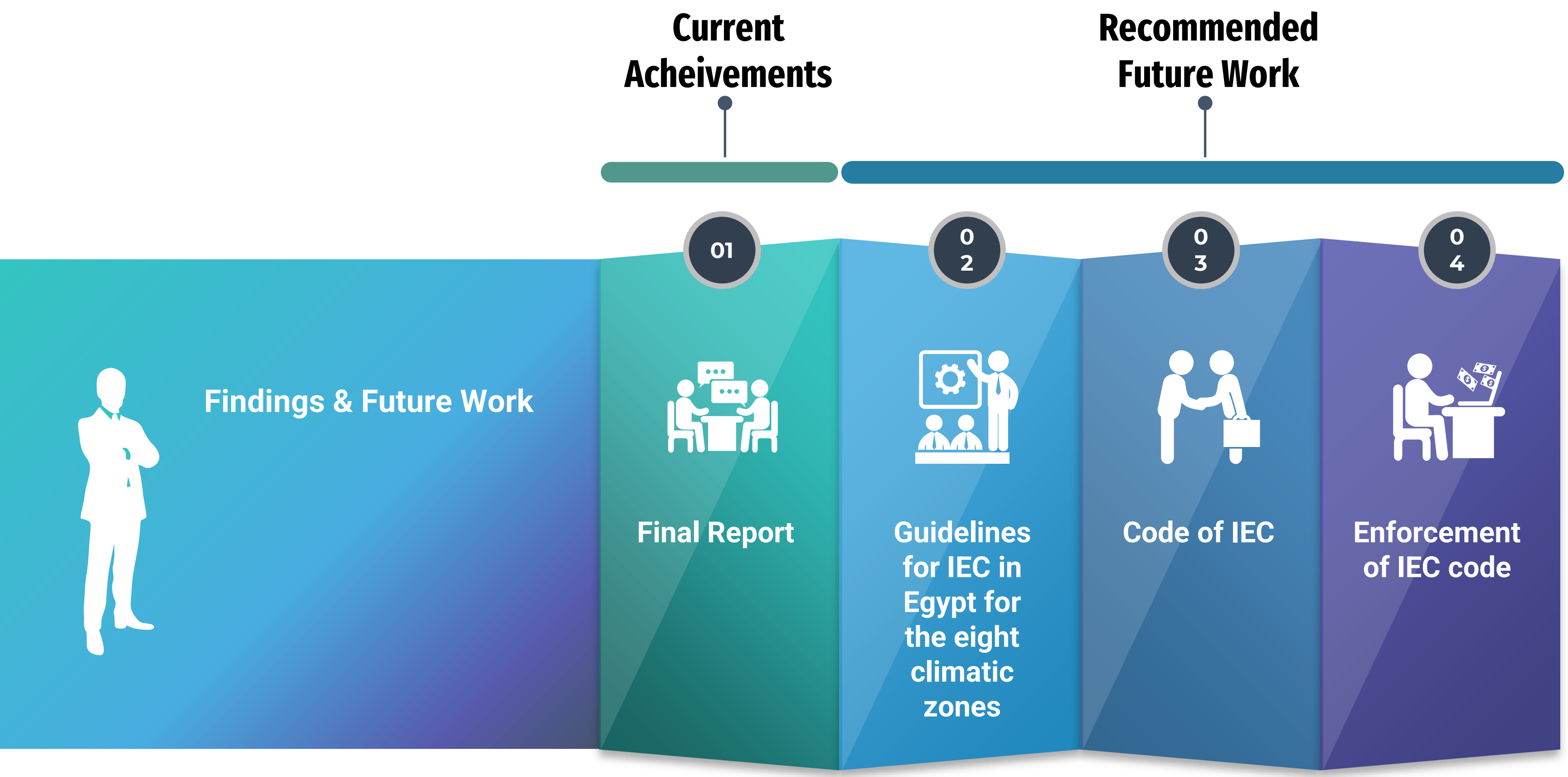


Record Measurement for 24 hours – CZ2

Record Measurement for 24 hours – CZ5





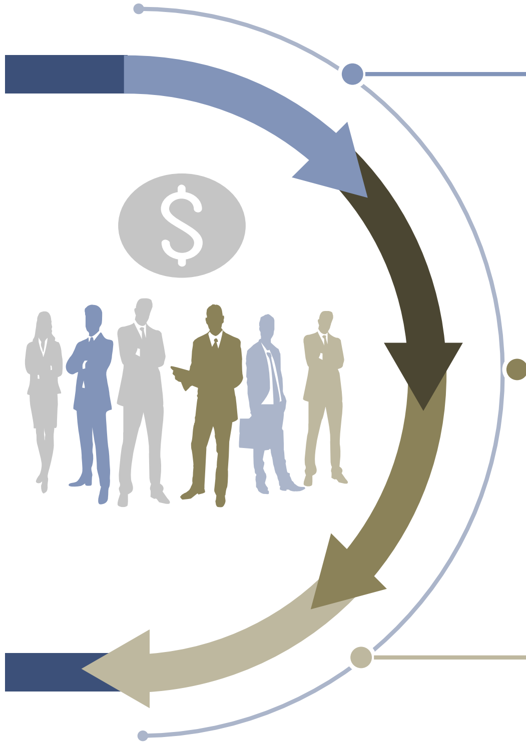

Current Acheivements
Recommended Future Work
Findings & Future Work
01
Final Report
0 2
Guidelines for IEC in Egypt for the eight climatic zones
0 3
Code of IEC
0 4
Enforcement of IEC code

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**

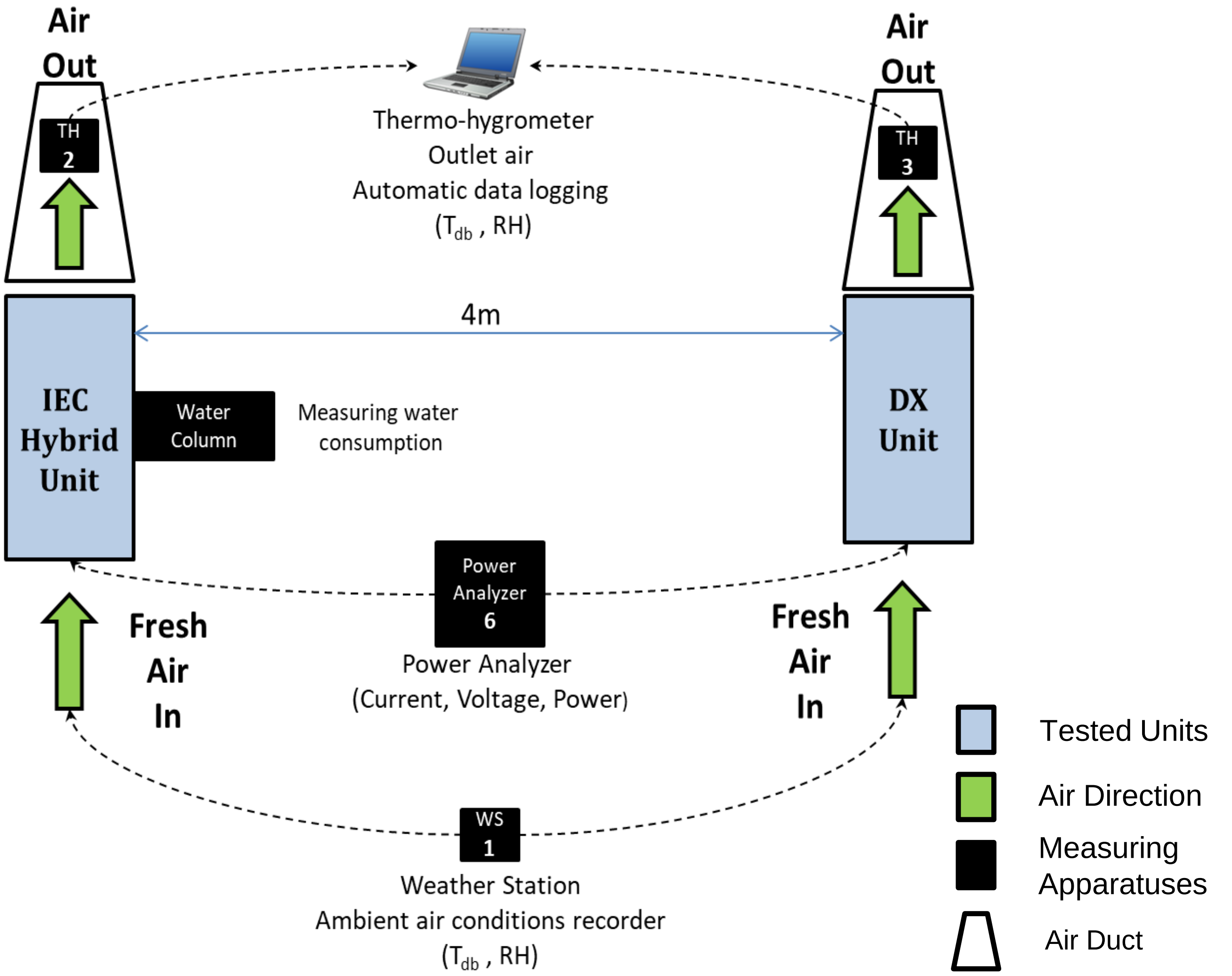
Results
&
Technical Analysis

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.

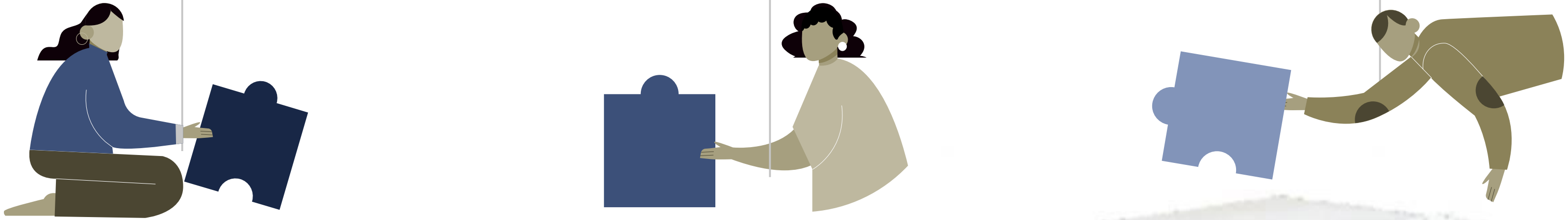
Primary Air Outlet

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**

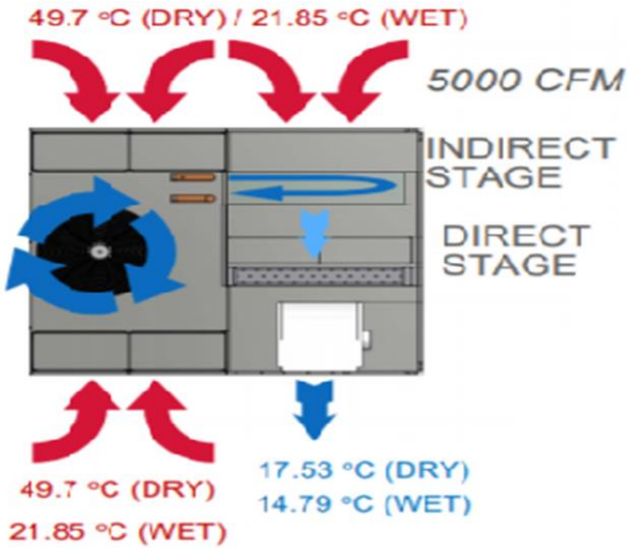


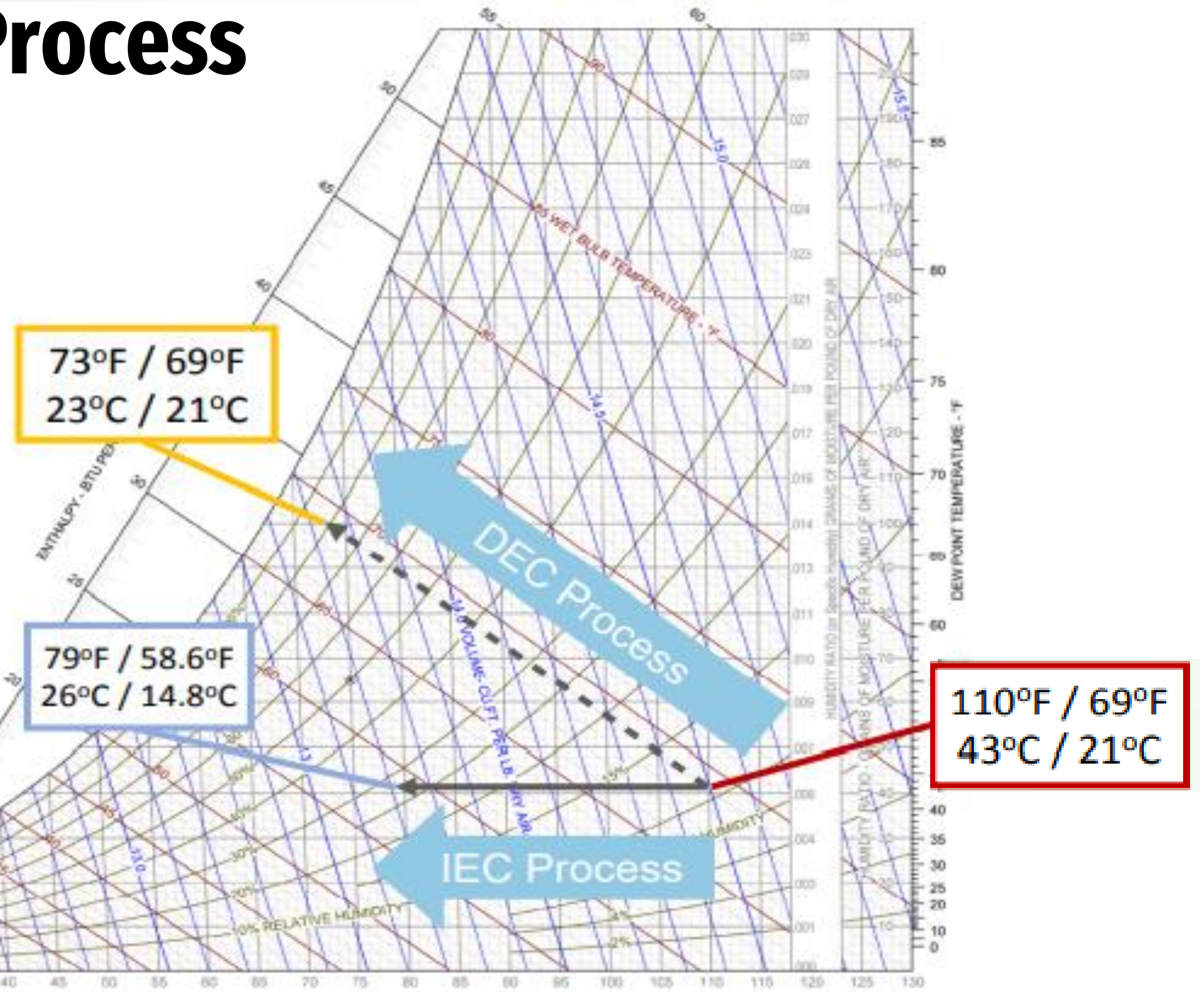
1st Stage — Cooling Tower

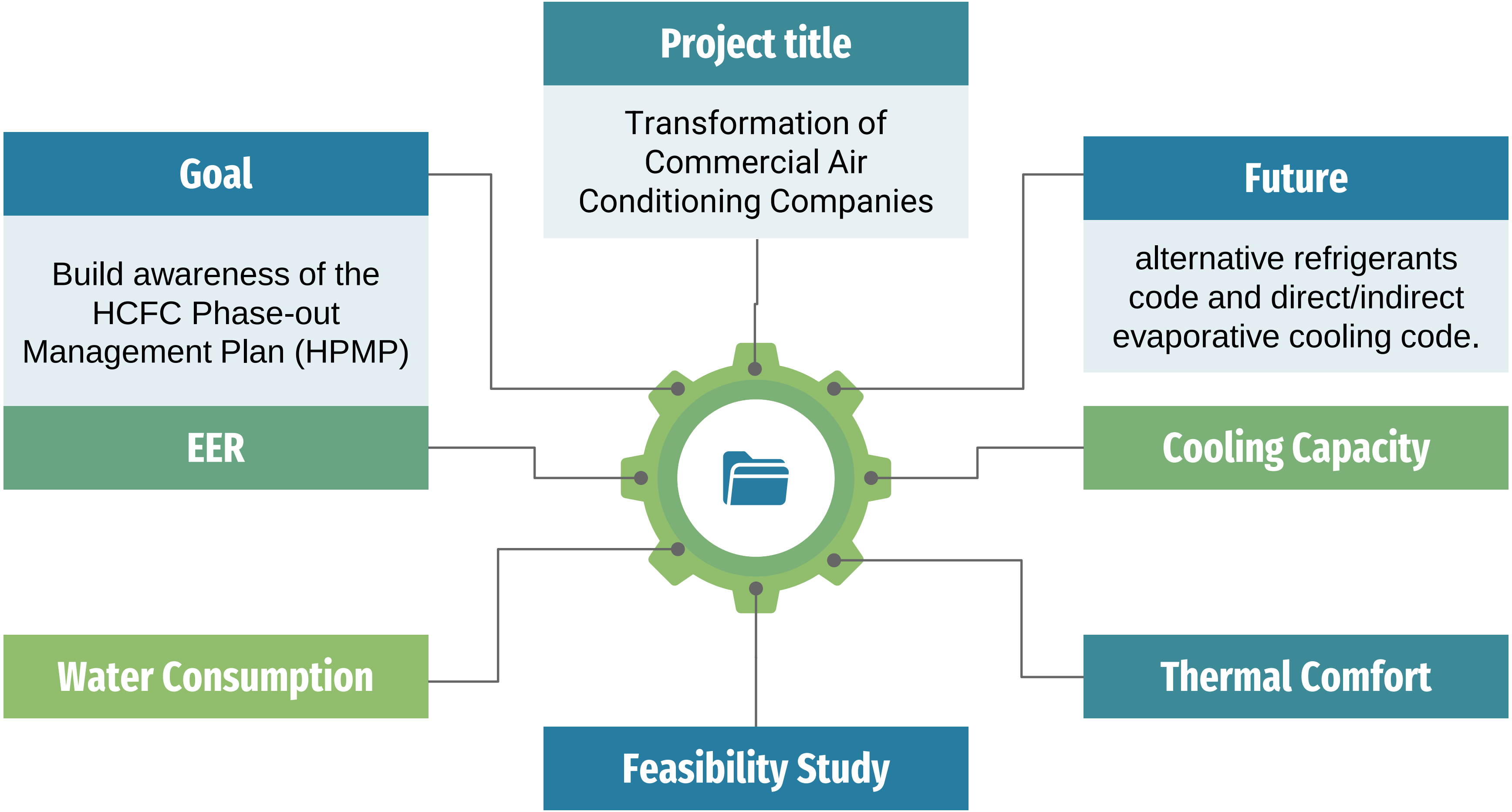
2nd Stage — Serpentine and air being cooled through it

3rd Stage — Evaporation of water in the stream

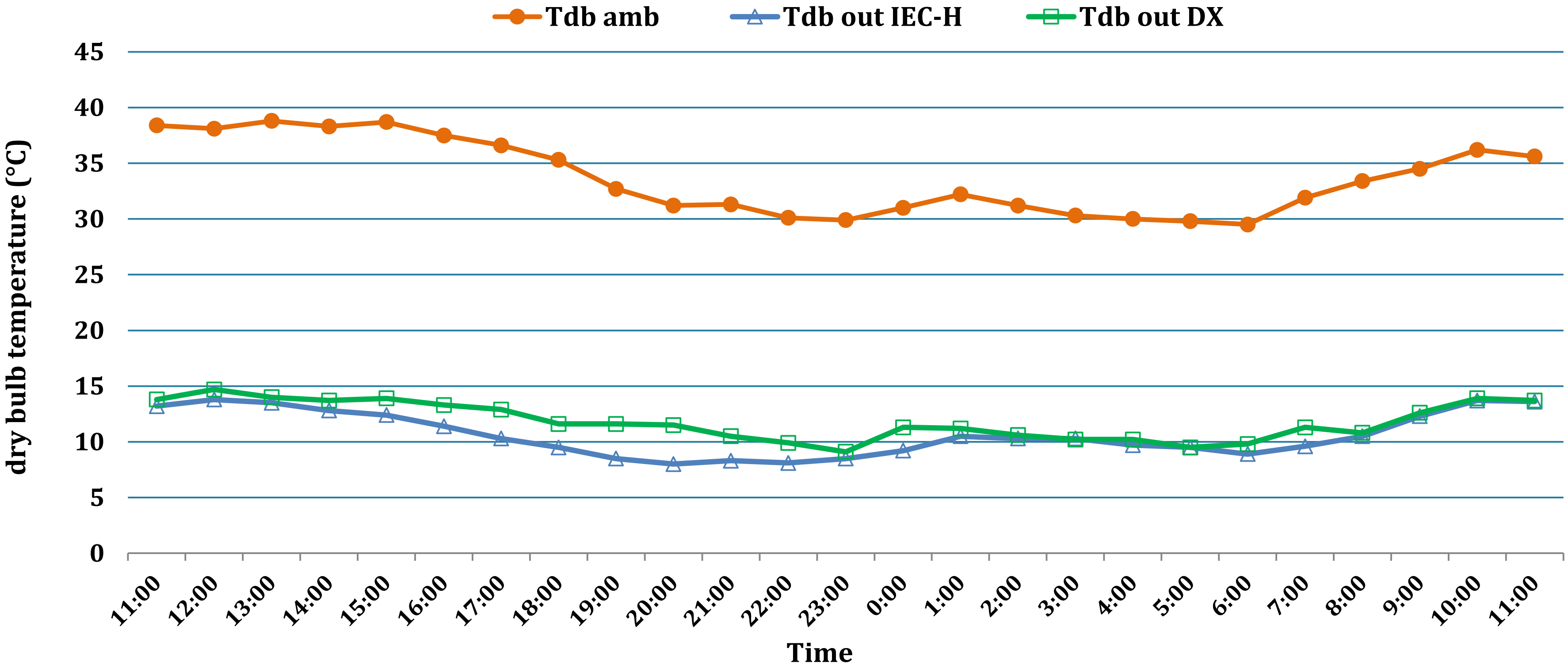
Psychrometric Process





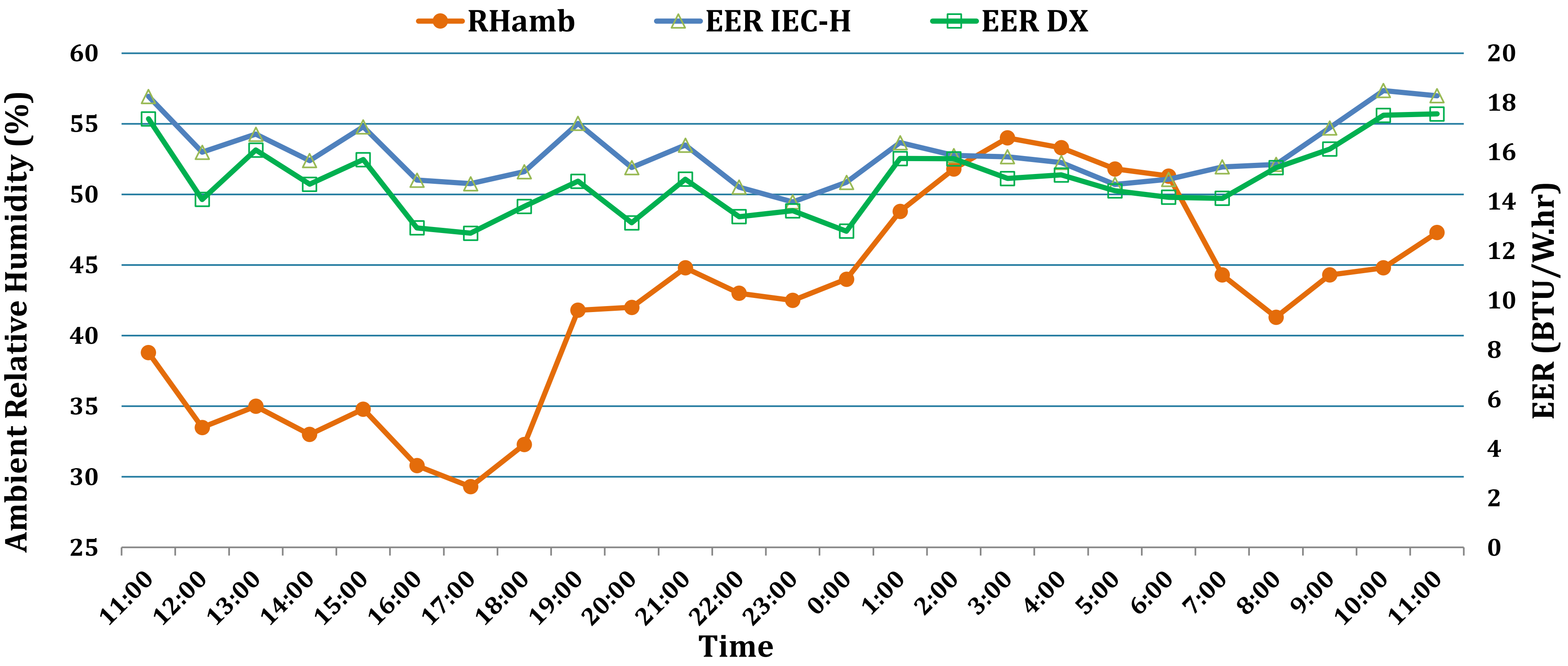

Project title
Transformation of Commercial Air Conditioning Companies
Goal
Build awareness of the HCFC Phase-out Management Plan (HPMP)
Future
alternative refrigerants code and direct/indirect evaporative cooling code.
EER
Cooling Capacity
Water Consumption
Thermal Comfort
Feasibility Study

Results Sample – Inlet Versus Outlet Temperature



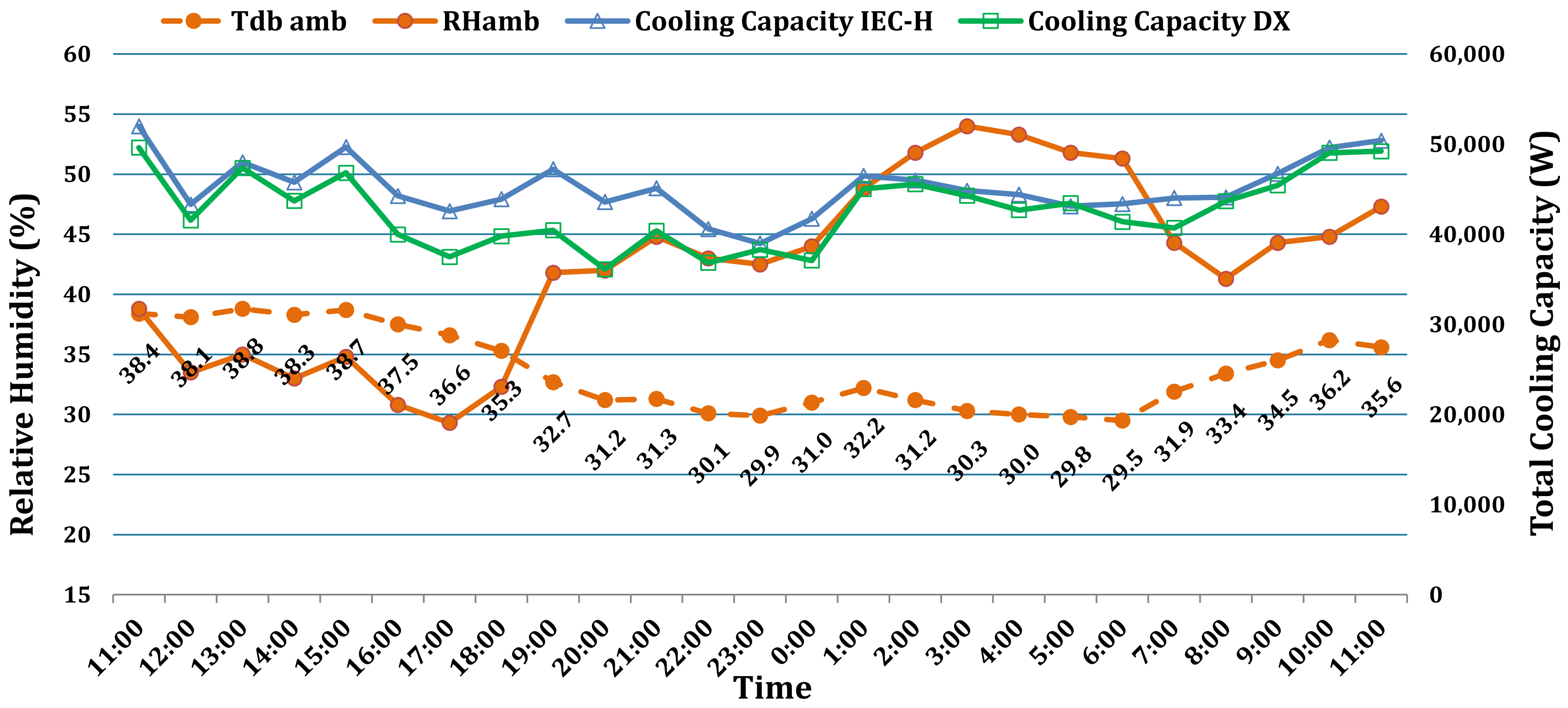
Inlet Ambient Temperature Versus Outlet Temperature of IEC Hybrid and DX units for OEM2 at CZ5

Results Sample – EER



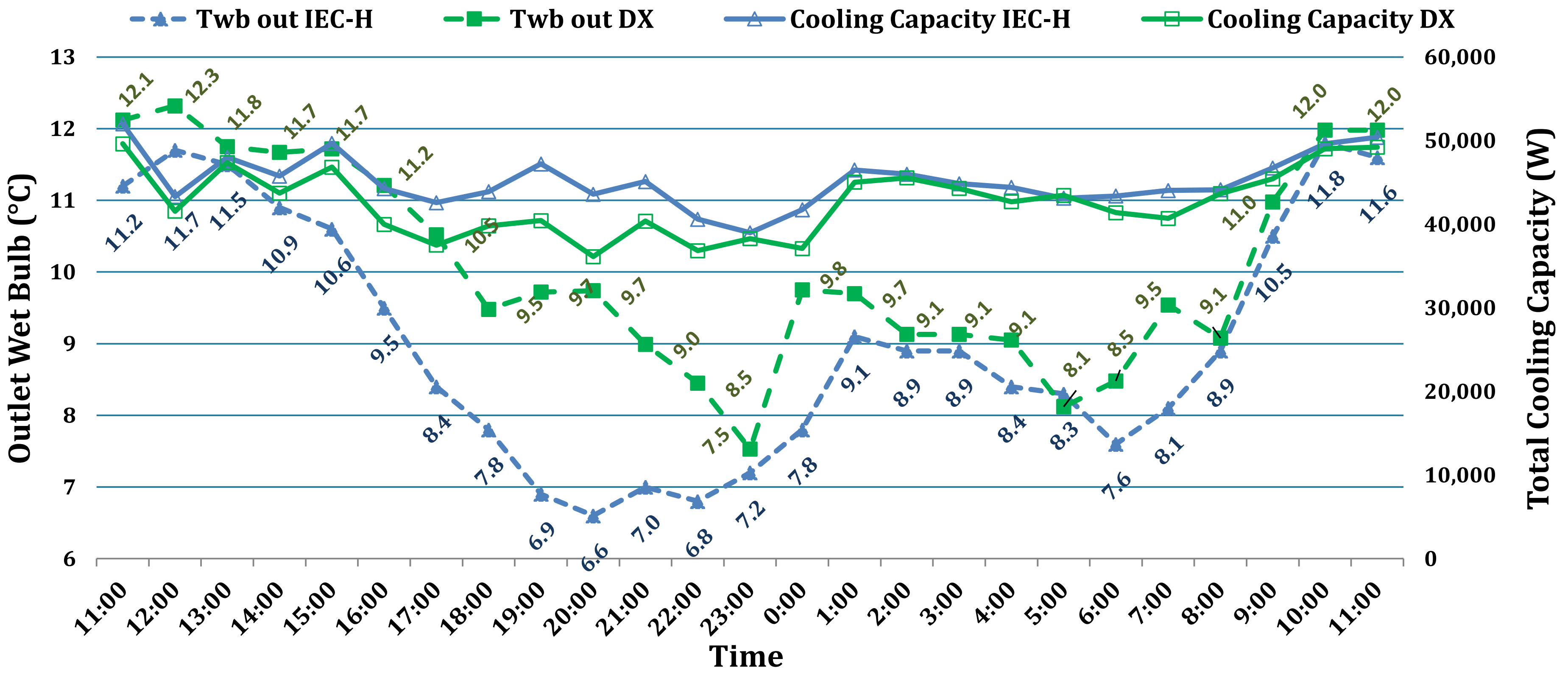
EER for IEC Hybrid Unit Versus DX unit for OEM2 at CZ5

Results Sample – Cooling Capacity



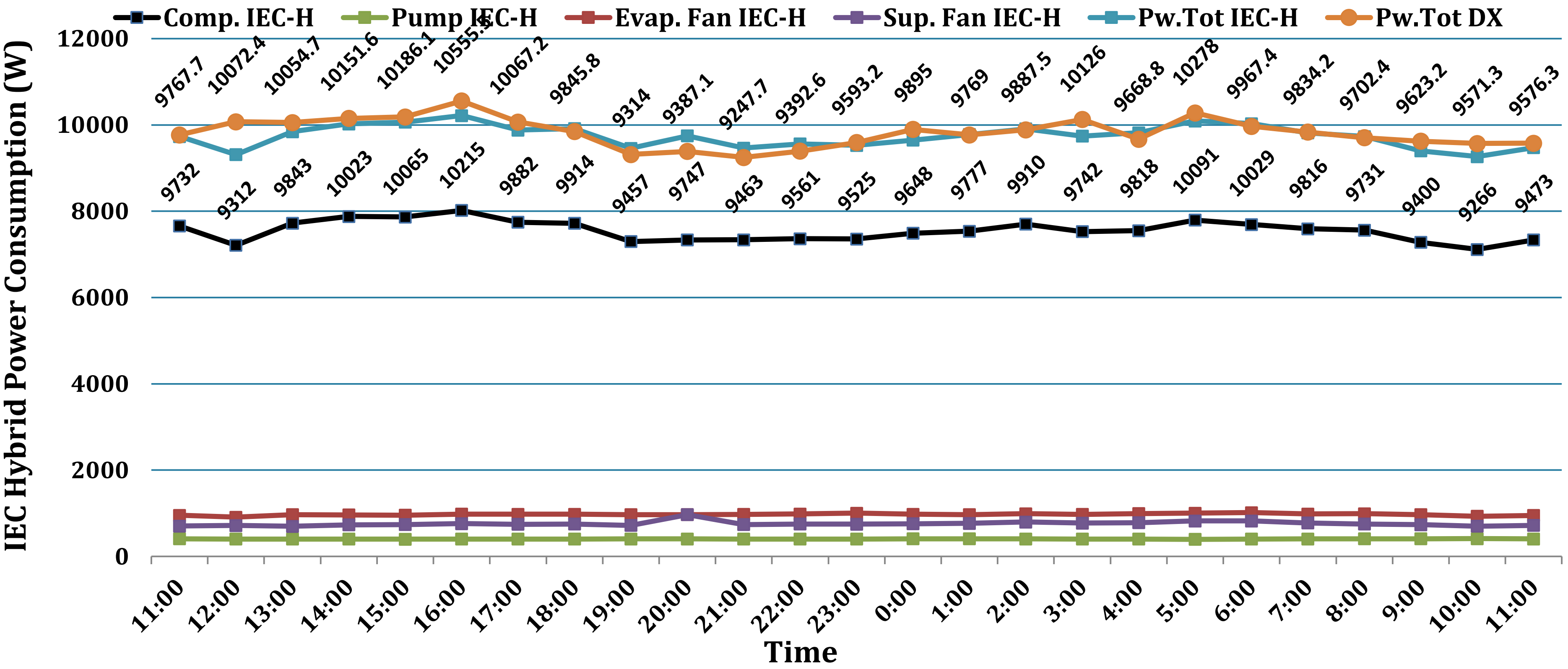
Cooling Capacity for IEC Hybrid Unit & DX Unit Versus Ambient Conditions for OEM2 at CZ5

Results Sample – Wetbulb



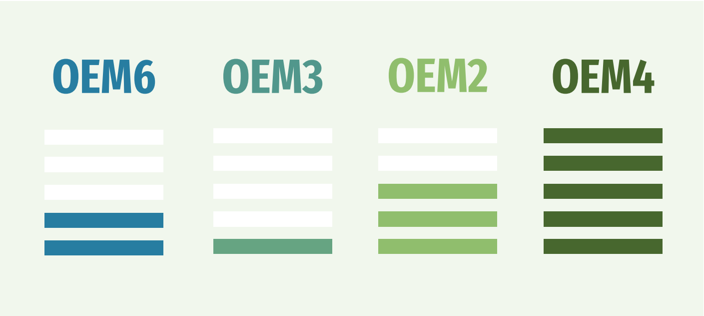
Cooling Capacity versus Outlet Wet Bulb Temperature for IEC Hybrid Unit & DX Unit for OEM2 at CZ5

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



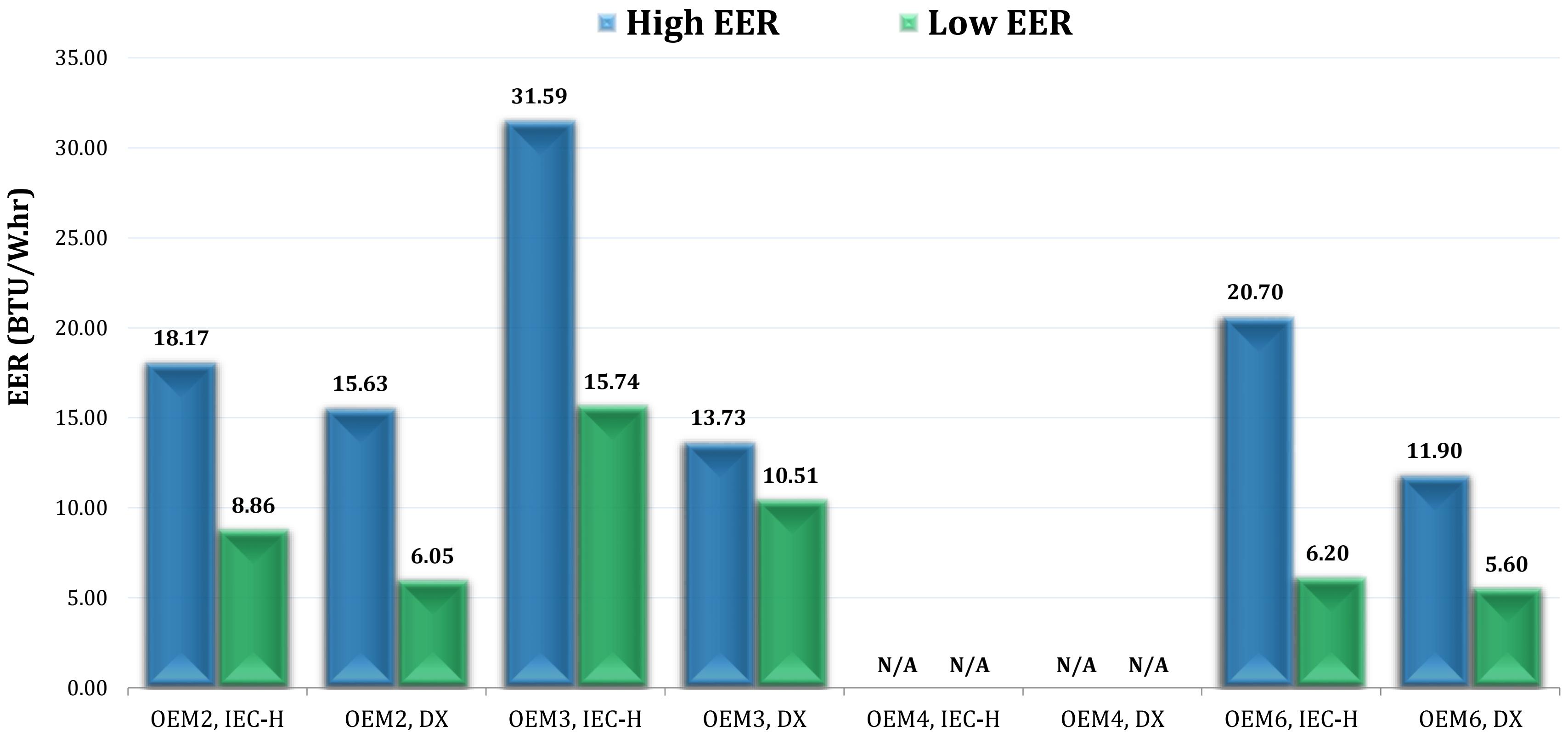
- IEC Compressor smaller by 60% → Lower cooling capacity
- IEC Compressor smaller by 70% → Lower cooling capacity
- IEC Compressor equal to DX Compressor → Equal cooling capacity
- IEC compressor larger by 20% → Equal cooling Capacity

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

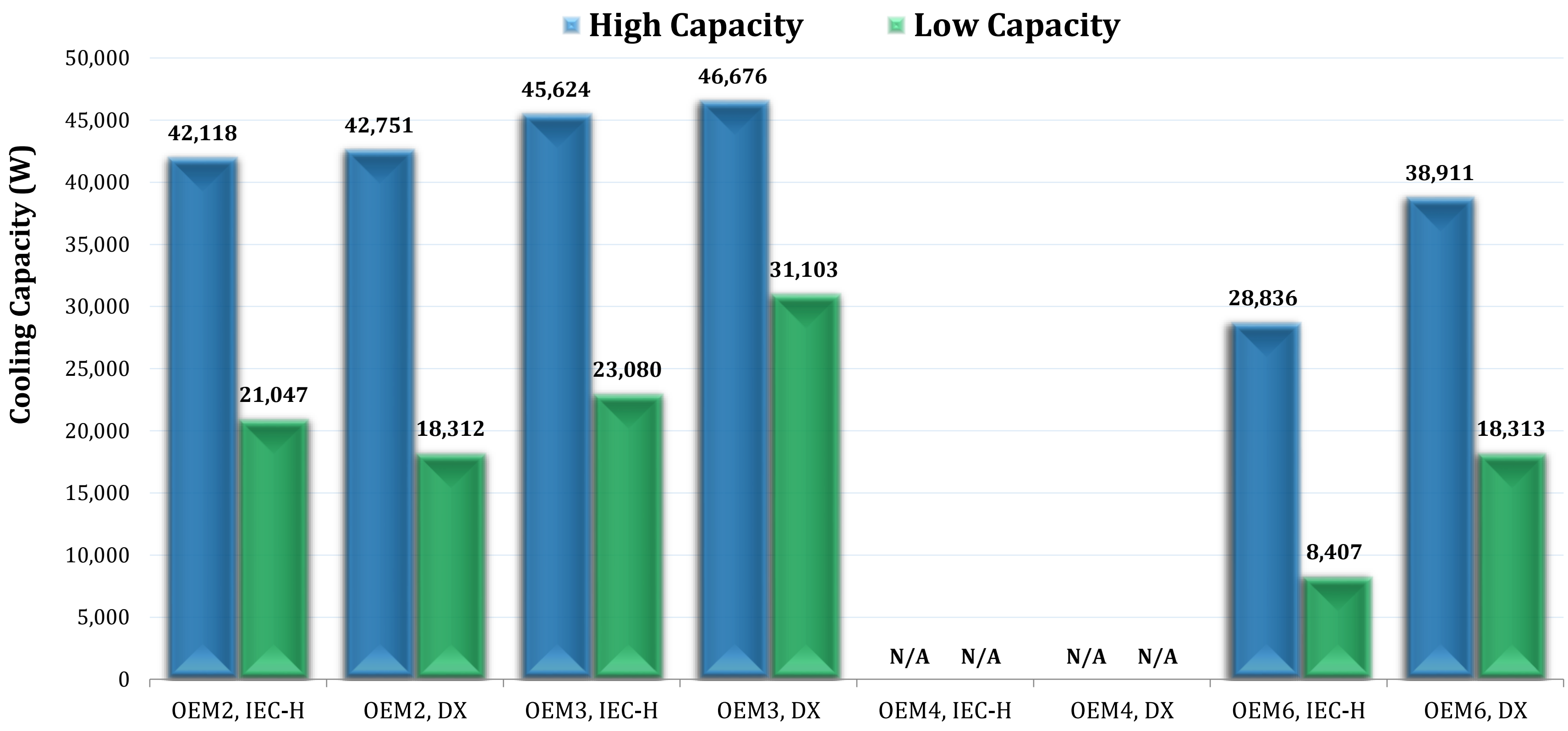
Important point that needs further investigation!

EER in CZ2

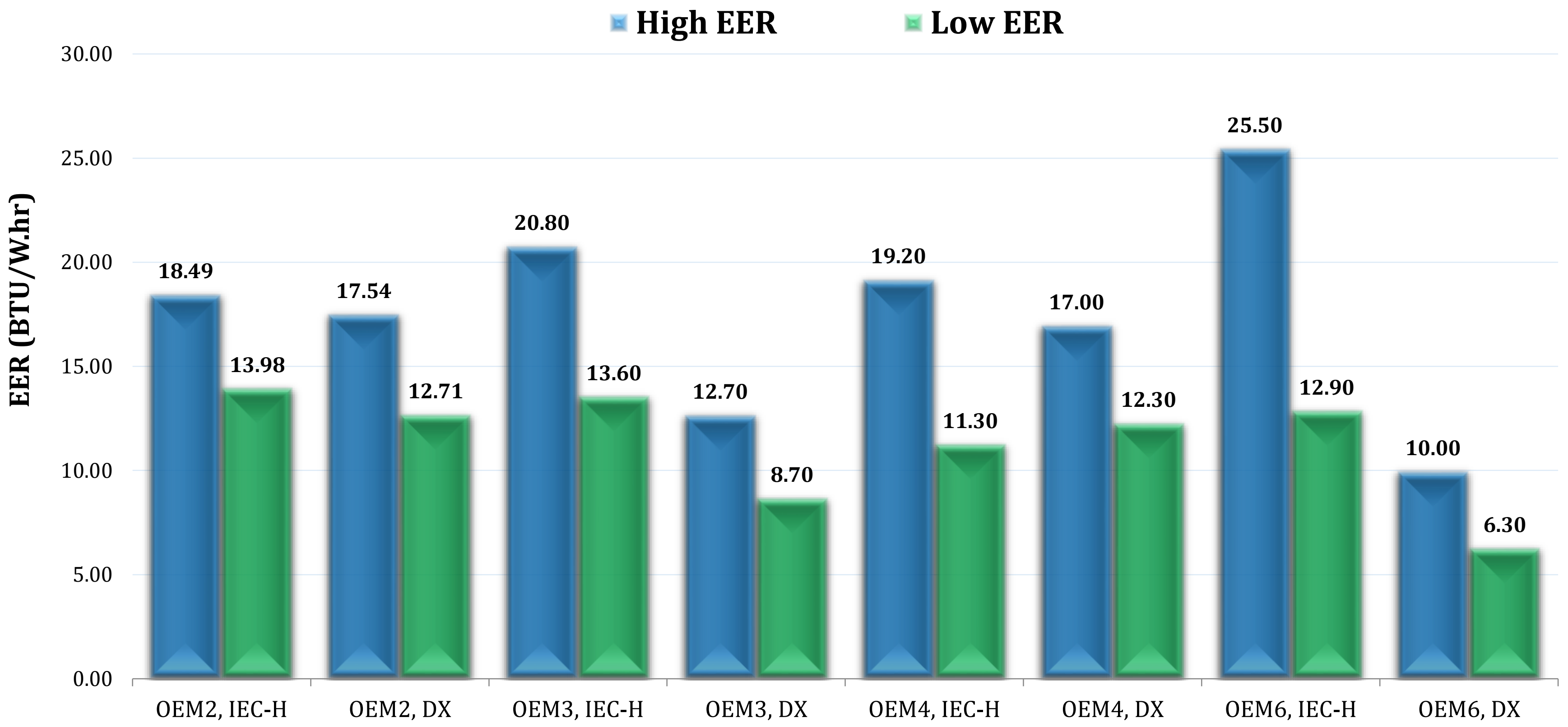


High EER
Low EER
EER (BTU/W.hr)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
18.17
8.86
15.63
6.05
31.59
15.74
13.73
10.51
N/A
N/A
N/A
N/A
20.70
6.20
11.90
5.60
OEM2, IEC-H
OEM2, DX
OEM3, IEC-H
OEM3, DX
OEM4, IEC-H
OEM4, DX
OEM6, IEC-H
OEM6, DX

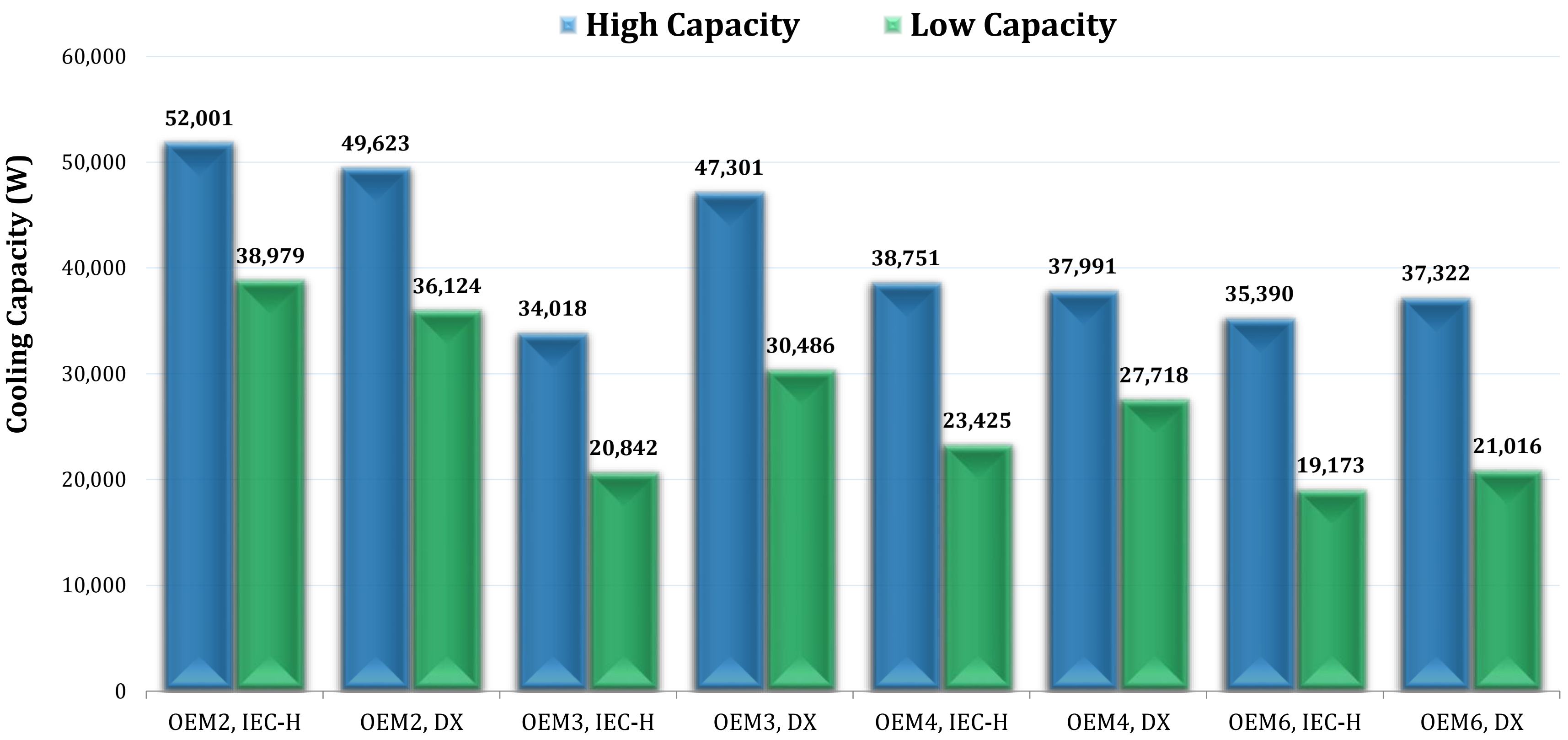
Cooling Capacity in CZ2



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