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执行蒙特利尔议定书
　多边基金执行委员会
第八十四次会议
2019 年 12 月 16 日至 20 日，蒙特利尔

项目提案：埃及

本文件包括秘书处对以下项目提案的评论和建议：

淘汰

•	氟氯烃淘汰管理计划（第一阶段，最后进度报告）	工发组织和开发计划署
•	氟氯烃淘汰管理计划（第二阶段，第二次付款）	工发组织、开发计划署、环境规划署和德国政府

埃及氟氯烃淘汰管理计划第一阶段（最后进度报告）（工发组织和开发计划署）

背景

1. 工发组织作为牵头执行机构，代表埃及政府提交了以下文件：

(a) 关于埃及氟氯烃淘汰管理计划第一阶段第三次付款执行情况的进度报告；

(b) 关于配方厂家、81 家中小企业和 350 个微型用户转型情况的报告，以及关于临时技术使用状况的报告（第 82/72 号决定(b)（一）和（四）段）；以及

(c) 关于埃及空调业推广低全球升温潜能值制冷剂项目的报告。

氟氯烃淘汰管理计划第一阶段的背景

制造行业

2. 列入第一阶段[1]的所有九家聚氨酯泡沫塑料制造企业都完成了转型，总共淘汰了 92.1 ODP 吨 HCFC-141b。氟氯烃淘汰管理计划第一阶段还包括一个项目，使 81 家中小企业和 350 个微型用户转用甲酸甲酯或其他低全球升温潜能值技术（将在执行期间选定），在其配方厂家和经销商的支持下，淘汰 75.74 ODP 吨 HCFC-141b。为两个第 5 条所有配方厂家的设备转型核准了供资，包括向所有配方厂家和经销商提供技术援助，也为中小企业转型核准了供资。

3. 在第八十二次会议上，据报告，一个当地配方厂家（Technocom）和一个非第 5 条所有配方厂家（Dow）实现了转型。多边基金没有为 Dow 的设备转型提供资金；但为向下游用户引进替代泡沫塑料发泡剂的技术援助提供了资金。一个配方厂家退出了该项目（Obeigi），预计将与另一个配方厂家（Baalbaki）签署协定备忘录。[2]总共有 24 家下游用户得到了援助。剩余的 57 家下游用户预计将在 2019 年底完成转型。

4. 另外，在第八十二次会议上，据报告，两个配方厂家（Dow 和 Technocom）正在开发使用水和氢氟烯烃的低全球升温潜能值配方，而且使用 HFC-245fa、HFC-365mfc 和 HFC-227ea，这些物质是由《基加利修正案》管制的，尽管预计使用高全球升温潜能值替代品只是暂时的，其使用最迟在 2015 年淘汰。开发计划署确认，由于下游用户同意转用低全球升温潜能值技术，因此不会为在第一阶段配方厂家项目下获得援助的下游用户请求进一步援助。开发计划署还确认，根据第 77/35 号决定(a)（六）段，客户不使用低全球升温潜能值技术，没有也不会向其提供增支经营费用。

[1] 包括在第六十五次会议上纳入第一阶段的六家企业（其供资在第六十二次会议上获得核准）。在第六十二次会议上核准了 Delta 电器的 HCFC-141b 淘汰项目，总费用为 422,740 美元，外加机构支助费用；在非第 5 条实体购买该企业之后，项目被取消，核准的供资在第七十次会议上退回基金。

[2] 开发计划署的项目执行安排。

5. 在第八十三次会议上，据报告，与 Baalbaki 签署了使八个客户转型以淘汰 53.7 公吨 HCFC-141b 的协定备忘录。编制了与 Technocom 的协定备忘录增编，使另外 12 个客户转型以淘汰 11.37 ODP 吨 HCFC-141b；预计该协定备忘录将在 2019 年 5 月之前签署。Baalbaki 的替代技术包括水和甲酸甲酯，而 Technocom 的替代技术包括使用水和氢氟烯烃的配方；在这两种情况下，只能临时预见氢氟碳化合物。当时，没有一个微型用户转型；微型用户转型预计将在 2019 年下半年开始。

6. 关于技术使用状况，开发计划署报告称，Dow 和 Technocom 推出了使用水的配方，并得到客户批准用于某些应用；还需要进一步研究氢氟烯烃在多元醇中的性能，因为一些配方厂家报告了编制配方方面存在的问题，包括其稳定性。开发计划署继续监测这方面的情况，并计划于 2019 年 5 月与国家臭氧机构就引入低全球升温潜能值技术的障碍进行磋商。

制冷和空调行业的保障活动

7. 埃及空调业推广低全球升温潜能值制冷剂倡议于 2014 年启动，以评估家用和商用空调行业中的低全球升温潜能值替代品，方法是使用各种氟氯烃替代品建造和测试样机，以比较这些替代品的性能和效率，包括在环境温度高的条件下。该项目测试了制冷量在 12,000 英制热量单位/小时至 24,000 英制热量单位/小时[3]之间的定制空调分体式样机和额定制冷量为 120,000 英制热量单位/小时[4]的中央空调样机，以使用替代制冷剂运行，并将其性能与 HCFC-22 和 R-410A 基准空调机进行比较。

关于氟氯烃消费的报告

8. 埃及政府报告 2018 年消费了 287.45 ODP 吨氟氯烃，比氟氯烃的履约基准低 26%。表 1 列示了 2014-2018 年的氟氯烃消费量。

表 1. 埃及的氟氯烃消费量（2014-2018 年第 7 条数据）

氟氯烃	**2014 年**	**2015 年**	**2016 年**	**2017 年**	**2018 年**	**基准**
公吨						
HCFC-22	3,172.59	4,038.97	4,767.59	4,472.52	3,919.38	4,367.16
HCFC-123	0	9.07	5.00	1.64	2.00	5.25
HCFC-124	0.27	2.70	0.00	2.09	0.00	0
HCFC-141b	1,118.78	1,072.75	731.53	871.01	629.47	1,178.26
HCFC-142b	146.49	42.04	57.53	70.54	40.02	251.69
共计（公吨）	**4,438.13**	**5,165.53**	**5,561.66**	**5,417.80**	**4,590.87**	**5,802.36**
进口预混多元醇中所含 HCFC-141b	120.00	100.00	177.80	87.95	0	894.00*
ODP 吨						
HCFC-22	174.49	222.14	262.22	245.99	215.57	240.19
HCFC-123	0	0.18	0.10	0.03	0.04	0.11
HFC-124	0.01	0.06	0.00	0.05	0.00	0.00

[3] BTU=英制热量单位。有关冷冻吨，12,000-24,000 英制热量单位/小时为 1-2 冷冻吨。
[4] 120,000 英制热量单位/小时=10 冷冻吨。

氟氯烃	2014 年	2015 年	2016 年	2017 年	2018 年	基准
HCFC-141b	123.07	118.00	80.47	95.81	69.24	129.61
HCFC-142b	9.52	2.73	3.74	4.59	2.60	16.36
共计（ODP 吨）	**307.09**	**343.12**	**346.53**	**346.46**	**287.45**	**386.27**
进口预混多元醇中所含 HCFC-141b	13.20	11.00	19.56	9.67	0	98.34*

*2007-2009 年平均消费量。

9. HCFC-22 用于制造和维修制冷和空调设备，并用于制造挤塑聚苯乙烯泡沫塑料。由于使用 HCFC-22 的空调机出口减少，加上维修做法有了改善，制冷和空调制造和维修行业的 HCFC-22 消费量都有了下降。鉴于聚氨酯泡沫塑料制造行业转型，HCFC-141b（纯）在继续减少，同时，按照 2018 年禁令，2018 年未报告进口预混多元醇中所含 HCFC-141b。HCFC-142b 用于制造挤塑聚苯乙烯泡沫塑料，并作为 R-406A（使用 CFC-12 的设备所用的一种无须改造设备的混合物）的一种成分进口。

国家方案执行情况报告

10. 埃及政府根据 2018 年国家方案执行情况报告报告了氟氯烃行业消费数据，这与根据《蒙特利尔议定书》第 7 条报告的数据相一致。

<u>关于氟氯烃淘汰管理计划第三次付款执行情况的进度报告</u>

法律框架

11. 氟氯烃许可和配额制度（进口预混多元醇中所含 HCFC-141b 除外）于 2013 年生效。自 2018 年 1 月 1 日起，埃及政府禁止进口预混多元醇中所含 HCFC-141b。此项禁令是通过与埃及环境事务局和海关总署合作实施的，海关总署在国家臭氧机构协助下，根据多元醇统一制海关编号检查所有进口品。根据第 79/34 号决定(c)（二）段，自 2020 年 1 月 1 日起，政府将禁止进口、使用和出口散装 HCFC-141b，禁止出口预混多元醇中所含 HCFC-141b。

制造行业

12. 81 家中小企业转用低全球升温潜能值技术的项目正在进行，与 Baalbaki、Dow 和 Technocom 三个配方厂家签署了协定备忘录，以使 64 个下游客户转型；预计将在 2019 年 11 月 30 日前与 Baalbaki 签署另外六个客户转型的协定备忘录增编。在 64 个下游客户中，44 个已转型并签署了停用使用氟氯烃的配方的承诺；另有三个客户已转型并正在签署这种承诺，预计到 2019 年底停用。剩余的下游客户确切数量将在执行期间确认；预计所有下游用户将在 2019 年底前完成转型。

13. 大多数微型用户通过分销商不定期地购买配方，而不是直接通过配方厂家购买，这使得查明这些微型用户具有挑战性。2019 年 9 月举办了一次提高认识讲习班，以查明所有微型用户，确保它们在 2020 年 1 月 1 日之前完成转用非氟氯烃替代品。迄今还没有微型用户在转型时得到项目援助。

临时技术使用状况报告

14. Baalbaki、Dow 和 Technocom 三个配方厂家成功地帮助其下游客户转用低全球升温潜能值替代品，包括水、氢氟烯烃和甲酸甲酯。配方厂家还生产了高全球升温潜能值配方，并将这些配方出售给下游客户，但不出售给那些得到项目援助的客户。

15. 一个配方厂家之前曾报告过一种氢氟烯烃的加工问题。配方厂家临时转用一种不同的氢氟烯烃来解决这个问题；然而，那种氢氟烯烃的价格更高，而且，鉴于其刚刚引入该区域，有人担忧不间断交付问题。开发计划署继续监测这一情况，并期望配方厂家能够像其他两个配方那样解决它在使用原氢氟烯烃时遇到的加工问题。

制冷和空调部门的保障活动

16. 使用 Arkema、Chemours、Daikin 和 Honeywell 提供的制冷剂，在当地可利用的经认证实验室中测试了由多家企业提供的 19 台带有专用压缩机的定制的分体式样机。测试结果详情载于本文件附件一。埃及空调业推广低全球升温潜能值制冷剂项目的结果为住宅空调制造行业企业选择低全球升温潜能值替代品提供了依据。

资金发放量

17. 截至 2019 年 10 月，在迄今核准的 6,148,975 美元[5]中，已发放 4,265,938 美元（工发组织 1,255,818 美元，开发计划署 3,010,120 美元），如表 2 所示。2019 和 2020 年将发放 1,883,037 美元余额。

表 2. 埃及氟氯烃淘汰管理计划第一阶段的财务情况报告（美元）

付款		工发组织	开发计划署	共计	发放率（%）
第一次付款	已核准	950,000	2,000,000	2,950,000	98
	已发放	950,000	1,954,628	2,904,628	
第二次付款	已核准	250,000	2,000,000	2,250,000	58
	已发放	250,000	1,055,492	1,305,492	
第三次付款	已核准	232,575	716,400	948,975	6
	已发放	55,818	0	55,818	
共计	已核准	1,432,575	4,716,400	6,148,975	69
	已发放	1,255,818	3,010,120	4,265,938	

[5] 此外，第六十二次会议核准了六个投资项目的 2,371,840 美元外加机构支助费用，并将其列入第一阶段（不包括为随后退出第一阶段的 Delta 电器提供的资金）。

秘书处的评论

对氟氯烃淘汰管理计划第一阶段年度报告的评论

法律框架

18. 埃及政府发布 2019 年氟氯烃进口配额为 289.7 ODP 吨，低于《蒙特利尔议定书》的管制目标，并且符合该国与执行委员会之间的《协定》规定的目标。

关于临时技术使用状况的报告

19. 虽然三个配方厂家成功地帮助其下游客户转用低全球升温潜能值替代品，包括水、氢氟烯烃和甲酸甲酯，但配方厂家也生产高全球升温潜能值配方，并将这些配方出售给不接受项目援助的下游客户。为了确保项目完成后下游客户持续使用低全球升温潜能值替代品，开发计划署的移交议定书程序不允许配方厂家在参与该项目的下游客户中使用高全球升温潜能值替代品。

制冷和空调行业的保障活动

20. 秘书处赞赏地注意到埃及空调业推广低全球升温潜能值制冷剂项目的综合报告。虽然分体式空调机的测试已经完成，但还需要额外的时间完成对已制成中央空调机的测试，以起草将提交第八十六次会议的最终报告，并完成当地制造厂家可能使用的建模工具方面的工作。因此，工发组织要求将氟氯烃淘汰管理计划第一阶段完成日期延长至 2020 年 6 月 30 日，指出第一阶段的所有其他组成部分将在 2019 年 12 月 31 日之前完成，项目完成报告将提交第八十七次会议，工发组织将在 2020 年 6 月 30 日之前退回所有余额，开发计划署将在 2020 年 12 月 31 日前退回余额（与聚氨酯泡沫塑料行业的财务结算日期保持一致）。

21. 鉴于其与空调制造行业选定低全球升温潜能值替代品的相关性，秘书处将埃及空调业推广低全球升温潜能值制冷剂项目报告的摘要以及报告本身均作为附件附在本文件之后。埃及空调业推广低全球升温潜能值制冷剂项目的结果为根据第 79/34 号决定(d)段向本次会议提交的五个住宅空调制造厂家转用低全球升温潜能值替代品的项目的技术选定直接提供依据。最终报告一旦提交，将添加到多边基金网站上。[6]

22. 秘书处要求澄清埃及空调业推广低全球升温潜能值制冷剂项目的结果和结论是否与其他同样测试空调制造行业低全球升温潜能值替代品的测试方案相同，包括多边基金供资的示范项目。埃及空调业推广低全球升温潜能值制冷剂项目没有与关于在沙特阿拉伯使用低全球升温潜能值制冷剂开发窗式和台柜式空调机的空调制造厂家示范项目的最终报告进行比较，也没有与关于哥伦比亚 Industrias Thermotar Ltda 在商用空调设备制造中淘汰 HCFC-22 示范项目的最终报告进行比较；然而，它与三个测试方案进行了比较：

[6] 氟氯烃技术的低全球升温潜能值替代品示范项目的情况说明和最终报告，见 http://multilateralfund.org/ Our%20Work/DemonProject/default.aspx。

AREP-II、[7]ORNL[8]和 PRAHA。[9]埃及空调业推广低全球升温潜能值制冷剂项目特点的介绍以及与三个测试方案的比较载于本文件附件一。

结论

23. 埃及政府正在对氟氯烃进出口实行许可和配额制度，2018 年的消费量低于《蒙特利尔议定书》和与执行委员会的《协定》规定的管制目标。自 2018 年 1 月 1 日起出台了禁止进口预混多元醇中所含 HCFC-141b 的禁令，并将在 2020 年 1 月 1 日之前制定禁止进口、使用和出口散装 HCFC-141b 以及出口预混多元醇中所含 HCFC-141b 的禁令。总发放率为 69%。制冷和空调部门的技术援助活动正在顺利开展，制成了家用和商用空调样机，尽管需要一些额外时间来测试已制成的中央空调机；因此，需要延长至 2020 年 6 月 30 日。三个配方厂家成功地帮助其下游客户转用低全球升温潜能值替代品，泡沫塑料行业将在 2019 年 12 月 31 日之前完成转型。

秘书处的评论

24. 执行委员会不妨：

(a) 注意到 UNEP/OzL.Pro/ExCom/84/49 号文件所载的工发组织提交的下列文件：

（一）关于埃及氟氯烃淘汰管理计划第一阶段第三次付款执行情况的进度报告；

（二）关于埃及空调业推广低全球升温潜能值制冷剂项目的报告；

（三）关于配方厂家、81 家中小企业和 350 个微型用户转型情况的报告，以及关于临时技术使用状况的报告；

(b) 注意到埃及氟氯烃淘汰管理计划第一阶段的所有活动将在 2019 年 12 月 31 日之前完成，任何未付余额将在 2020 年 12 月 31 日之前退回，工发组织维修行业的组成部分除外，该部分将在 2020 年 6 月 30 日之前完成；

(c) 核准将氟氯烃淘汰管理计划第一阶段延长至 2020 年 6 月 30 日，以允许完成(b)分段所述活动；

[7] 美国制冷空调与供暖协会替代制冷剂评价方案，见 http://www.ahrinet.org/arep。

[8] Abdelaziz，2015 年 Abdelaziz O、Shrestha S、Munk J、Linkous R、Goetzler W、Guernsey M 和 Kassuga T，2015 年。“高环境温度环境下的替代制冷剂评价：小型分体式空调的 R-22 和 R-410A 替代品”，ORNL/TM-2015/536。可查阅：https://www.energy.gov/sites/prod/files/2015/10/f27/bto_pub59157_101515.pdf。

[9] PRAHA 项目报告：https://www.unenvironment.org/resources/report/promoting-lowgwp-refrigerants-air-conditioning-sectors-high-ambient-temperature。

(d) 请埃及政府和工发组织向第八十六次会议提交关于埃及空调业推广低全球升温潜能值制冷剂项目的最终报告；以及

(e) 请埃及政府和工发组织向第八十七次会议提交直至项目完成的与第一阶段最后一次付款相关联的工作方案执行情况的年度进度报告以及项目完成报告。

项目评价表——多年期项目

埃及

（一）项目名称	机构
氟氯烃淘汰计划（第二阶段）	工发组织（牵头）、开发计划署、环境规划署、德国

（二）最新第 7 条数据（附件 C 第一类）	年份：2018 年	287.45（ODP 吨）

（三）最新国家方案行业数据（ODP 吨）									年份：2018 年
化学品	气雾剂	泡沫塑料	灭火剂	制冷		溶剂	加工剂	实验室用途	行业消费总量
				制造	维修				
HCFC-22		32.19		85.83	97.54				215.57
HCFC-123					0.04				0.04
HCFC-141b		69.24							69.24
HCFC-142b		2.60							2.60
进口预混多元醇中所含 HCFC-141b		0							0

（四）消费数据（ODP 吨）			
2009-2010 年基准：	386.3	持续削减总量的起点：	484.61
符合资助条件的消费量（ODP 吨）			
已核准：	174.00	剩余：	310.61

（五）业务计划		2019 年	2020 年	2021 年	2021 年后	共计
工发组织	消耗臭氧层物质淘汰量（ODP 吨）	10.13	0	12.54	12.75	35.42
	供资（美元）	807,850	0	1,000,450	1,016,714	2,825,014
开发计划署	消耗臭氧层物质淘汰量（ODP 吨）	24.62	0	10.96	0	35.58
	供资（美元）	1,965,323	0	873,783	0	2,839,106
环境规划署	消耗臭氧层物质淘汰量（ODP 吨）	3.75	0	3.49	3.83	11.07
	供资（美元）	312,894	0	291,064	319,611	923,569
德国	消耗臭氧层物质淘汰量（ODP 吨）	2.78	0	0	0	2.78
	供资（美元）	234,249	0	0	0	234,249

（六）项目数据			2017 年	2018 年	2019 年	2020 年	2021 年	2022 年	2023 年	2024 年	2025 年	共计
《蒙特利尔议定书》的消费限量			347.64	347.64	347.64	251.08	251.08	251.08	251.08	251.08	125.54	暂缺
最高允许消费量（ODP 吨）			347.64	289.70	289.70	251.08	251.08	251.08	251.08	251.08	125.54*	暂缺
商定供资（美元）	工发组织	项目费用	3,356,641	0	755,000	0	935,000	0	755,200	0	195,000	5,996,841
		支助费用	234,965	0	52,850	0	65,450	0	52,864	0	13,650	419,779
	开发计划署	项目费用	1,042,352	0	1,836,750	0	816,620	0	0	0	0	3,695,722
		支助费用	72,965	0	128,573	0	57,163	0	0	0	0	258,701
	环境规划署	项目费用	230,000	0	279,500	0	260,000	0	180,000	0	105,500	1,055,000
		支助费用	27,480	0	33,394	0	31,064	0	21,506	0	12,605	126,050
	德国	项目费用	0	0	207,300	0	0	0	0	0	0	207,300
		支助费用	0	0	26,949	0	0	0	0	0	0	26,949
执行委员会核准供资（美元）		项目费用	4,628,993	0	0							4,628,993
		支助费用	335,410	0	0							335,410
申请本次会议核准供资总额（美元）		项目费用			3,078,550							3,078,550
		支助费用			241,766							241,766

*附件 C 第一类物质的最高允许总消费量，在作为第二阶段组成部分的家用空调行业计划获得核准后，将再减少不超过 10 ODP 吨。

注：经修订的协定将在第八十四次会议上审议。

秘书处的建议	个别审议

项目说明

25. 工发组织作为牵头执行机构，代表埃及政府提交了氟氯烃淘汰管理计划第二阶段第二次付款的供资申请，总费用为3,320,316美元，包括给工发组织的755,000美元外加机构支助费用 52,850 美元，给开发计划署的 1,836,750 美元外加机构支助费用 128,573 美元，给环境规划署的 279,500 美元外加机构支助费用 33,394 美元，以及给德国政府的 207,300 美元外加机构支助费用26,949美元。[10]提交的材料包括关于第一次付款执行情况的进度报告、关于 2018 年氟氯烃消费量的核查报告和 2019 至 2021 年的付款执行计划。

26. 在第七十九次会议上，执行委员会决定作为例外邀请埃及政府，在技术选定后，在2020年1月1日之前提交一份提案，作为第二阶段的一部分，使家用空调行业转用低全球升温潜能值替代品（第 79/34 号决定(d)段）。工发组织代表埃及政府提交了使制造行业HCFC-22 住宅空调转型的项目，总金额为所提交的 11,710,018 美元，外加机构支助费用819,701 美元。一旦获得核准，该项目将被纳入《与执行委员会的氟氯烃淘汰管理计划第二阶段的协定》。[11]

关于氟氯烃消费的报告

27. 如本文件第 8 段所述，埃及政府报告 2018 年的氟氯烃消费量为 287.45 ODP 吨，低于 2018 年该国与执行委员会的《协定》规定的目标，比氟氯烃履约基准低 26%。

核查报告

28. 核查报告确认，埃及政府正在执行氟氯烃进出口许可和配额制度，2018 年氟氯烃的总消费量为 287.48 ODP 吨。核查得出结论认为，埃及遵守了与执行委员会的《协定》中规定的 2018 年所有附件 C 第一类物质的最高允许消费量，而且，核查的消费量和依据《蒙特利尔议定书》第 7 条报告的消费量在四舍五入精确度范围内是一致的。报告指出，在入境港口发现的受控物质可疑货物被海关总署拦截，并相应通知了国家臭氧机构和进出口管制总局。在确认货物与发放的许可证不符，并且进口商有机会要求进一步核实后，进口商必须将货物退回给出口商，费用由进口商负担；此外，出口国通过非正式的事先知情同意机制得到通知，需要核准货物的再进口。2010 年，对两批可疑的消耗臭氧层物质货物采取了这一程序；此后没有查到任何可疑货物，包括含CFC-11或CFC-12的货物。2009年对危险废物法进行修正后，对违反该国受控物质进口条例者的处罚可能包括监禁（最多五年）和罚款 20,000 埃及镑至 40,000 埃及镑（约 1,240 美元至 2,842 美元）。

[10] 根据埃及环境部 2019 年 9 月 18 日给工发组织的信。

[11] 根据埃及环境部 2019 年 9 月 18 日给工发组织的信。

氟氯烃淘汰管理计划第一次付款执行情况的进度报告

制造行业的活动

聚氨酯泡沫塑料制造行业

29. 聚氨酯泡沫塑料制造行业包括：剩余的八家制造家用冰箱的企业转用环戊烷（Bahgat、Fresh、Ocean、Siltal、Star、Top Maker 和 Tredco 得到多边基金的援助；Everest 企业将用自己的资源资助其转型）；两家制造电热水器的企业（Electrostar 和 Kiriazi）转用环戊烷；还有一个小组项目通过配方厂家 Beta 技术和贸易局使 38 家中小企业淘汰转用甲酸甲酯，多边基金为 28 家中小企业提供资金，有 10 家中小企业用自己的资源进行转型。家用制冷制造次级行业核准供资的 HCFC-141b 总淘汰量为 422.50 公吨（46.48 ODP 吨），剩余的聚氨酯绝缘泡沫塑料次级行业的淘汰量为 49.79 公吨（5.48 ODP 吨），共计 472.29 公吨（51.95 ODP 吨）。Everest 和另外 10 家中小企业将利用自己的资源额外淘汰 114.43 公吨（12.59 ODP 吨）。执行委员会注意到，埃及政府将灵活地向聚氨酯泡沫塑料行业中未申请到供资的符合条件企业分配资金，如果在执行期间被认为有必要的话（第 79/34 号决定(e)段）。

30. 访问了八家制造家用冰箱的企业，与每家企业签署了工作安排，[12]并编写了职权范围。七家企业完成了国际招标，多边基金为这些企业提供的资金得到核准，选定了设备供应商，并发出了订购单。已向三家企业（Bahgat、Fresh 和 Star）交付设备，安装和试运行正在进行中；另外两家企业（Siltal 和 Tredco）的设备预计将在 10 月前交付，安装和试运行预计将在 2019 年 12 月 31 日之前完成。Ocean 和 Top Maker 的设备预计将在 2019 年 12 月 31 日之前交付；安装和试运行预计将在 2020 年第一季度完成。这两家企业将自 2020 年 1 月 1 日起停止制造使用氟氯烃的泡沫塑料。供资未得到核准的企业 Everest 的设备预计将在 2019 年底之前交付，安装和试运行预计将在 2020 年第一季度完成。这两家企业承诺自 2020 年 1 月 1 日起停止制造使用氟氯烃的泡沫塑料。

31. 与两家制造电热水器的企业（Electrostar 和 Kiriazi）签署了协定备忘录。[13]完成了国际招标，选定了设备供应商，还发出了订购单。预计将在 2019 年 12 月 31 日之前交付设备；安装和试运行预计将在 2020 年第一季度完成。这两家企业将自 2020 年 1 月 1 日起停止制造使用氟氯烃的泡沫塑料。

32. 与 Beta 技术和贸易局签署了协定备忘录，并在 24 家中小企业完成了甲酸甲酯试验；这些客户签署了关于停止制造使用氟氯烃的泡沫塑料的完成和承诺声明。为其提供资金的剩余四家中小企业的试验正在进行中；预计将在 2019 年 12 月 31 日之前完成转用甲酸甲酯；开发计划署确认，所有 28 家中小企业都符合供资标准。发现剩余的 10 家中小企业不符合供资标准；虽然其转型状态和选定的替代品不得而知，但根据 2020 年 1 月 1 日禁令，其转型将在 2019 年 12 月 31 日前完成。

[12] 工发组织的项目执行安排。

[13] 开发计划署的项目执行安排。

对住宅空调制造行业的技术援助

33. 根据五个住宅空调制造厂家（El-Araby、Fresh、Miraco、Power 和 Unionaire）提供的关于基准空调机和计划转型的数据，对有供验证的性能数据的制冷剂转换进行了评估。国际顾问对不同的制造厂家进行了广泛的建模、验证和性能优化。已为基准设备开发并验证了模型。已使用建议的替代制冷剂作为无须改造设备的制冷剂和软优化制冷剂进行了模拟，以与基准容量相匹配。组织了实地考察，其间举办了关于配方模拟工具（ORNL 热泵设计模型）的培训，还举办了设计讲习班，以进一步提高配方性能，同时将配方制冷剂改为较低全球升温潜能值制冷剂。

制冷维修行业的活动

34. 下述活动已经完成：

(a) 埃及环境事务局与消费者保护局签署议定书，以监测并制止当地市场上的假冒制冷剂产品；为关于制冷和空调行业淘汰氟氯烃和使用替代品的社会经济影响的研究制定职权范围；

(b) 为 30 名消费者保护局检查员举办培训员培训讲习班，并在两个省为培训 140 名消费者保护局检查员举办了八次讲习班，计划于 2019 年 10 月在其余各省再举办 10 次讲习班，以培训 175 名消费者保护局检查员。议题包括立法和监测氟氯烃供应和使用情况；

(c) 与工业和贸易部签署议定书，以审查条例和政策，并采取措施加紧对受控物质的监督；根据世界海关组织修订稿更新受控物质海关编号；

(d) 购买 10 个制冷剂识别器供海关和消费者保护局检查员使用，并对 180 名检查员进行使用培训；

(e) 2019 年 7 月 25 日发布部长决定，更新了受控物质清单，以纳入所有进口的氟氯烃化合物；海关总署 2019 年发布进口监管令，自 2020 年 1 月 1 日起禁止进口 HCFC-141b；更新 HCFC-22 的进口许可证，将进口量限制在 40 公吨以内；

(f) 已启动制定制冷剂市场监测方案的活动，包括通过修正《埃及消费者保护法》（181/2018）的业务程序，将受控物质纳入这些程序，并编制针对贸易商、零售商和消费者的关于欺诈产品的提高认识宣传材料；宣传运动预计将在 2020 年 1 月开始；

(g) 与两所职业培训学校签署合作议定书，以制定国家认证方案，认证计划草案正在最后审查中；与埃及标准和质量组织签署合作议定书，藉此开始编写将

由人力部执行的准则，以便向维修中心和技术员颁发证书；[14]并且发布了关于制冷剂回收和再生服务试点中心的项目建议；

(h) 起草更新版当地技术教育和职业课程，评估培训所需的设备和工具；更新和评估正接受最后审查；

(i) 与住房和建筑研究中心签署合作议定书，以更新国家规范并促进引进低全球升温潜能值替代品；以及

(j) 计划开展关于低全球升温潜能值替代品的全国提高认识运动，在艾因沙姆斯大学环境研究所为 188 名学员举办了三次讲习班，并为大约 50 名研究人员举办了一次关于低全球升温潜能值替代品的技术研讨会。

项目执行和监测机构

35. 项目管理分为两部分，一部分与工发组织有关，另一部分与开发计划署有关，以管理各自的项目活动，前者负责监督所有项目活动和总体协调。工发组织聘请国家顾问协调和监测项目执行情况，包括访问受益人和利益攸关方；组织讲习班、会议和活动；以及起草和分发支助文件和提高认识材料（89,397 美元）。开发计划署聘请一名项目经理负责访问受益人；提供设备规格方面的技术支持，并报告执行进展情况；与国家臭氧机构和开发计划署磋商，为受益人制定合同；氟氯烃淘汰管理计划活动的日常开展；以及财务控制（14,314 美元）。

<u>资金发放量</u>

36. 截至 2019 年 9 月，在迄今已核准的 4,628,993 美元中（工发组织 3,356,641 美元、开发计划署 1,042,352 美元、环境规划署 230,000 美元），已发放 1,523,242 美元（33%）（工发组织 895,028 美元、开发计划署 465,314 美元、环境规划署 162,900 美元）。2020 和 2021 年将发放 3,105,751 美元余额。

<u>氟氯烃淘汰管理计划第二次付款的执行计划</u>

37. 以下活动将在 2020 年 1 月至 2022 年 12 月期间开展：

(a) 继续制定、执行和监测政策，并开展培训，包括关于制冷剂市场监测方案的培训；进一步制定技术员认证计划，更新当地技术教育和职业课程，并启动试点认证方案（环境规划署）（140,000 美元）；

[14] 埃及有三个不同的认证计划，一个由人力部牵头，另一个在职业培训方案下，第三个是教育部牵头的技术教育计划的组成部分。目前，要求提供最低资格证书，但取决于专业和雇主；三个方案中的每一个都根据市场的需要培养合格的技术员；然而，维修最佳做法不属于要求内容，与处理易燃制冷剂有关的最佳做法也是如此。

(b) 继续与住房和建筑研究中心协作，更新国家规范，审查设备和集装箱地方标准，并就规范和标准开展培训和外联（环境规划署）（79,500 美元）；

(c) 为公共部门、咨询小组和顾问提供绿色采购培训（环境规划署）（60,000 美元）；

(d) 购买大约 15 个制冷剂识别器（60,000 美元），并建立两个主培训中心（60,000 美元）（工发组织）；

(e) 建立当地再生中心，包括当地独立的测试实验室（150,000 美元），并通过提供回收装置和钢瓶建立回收和再生网络（150,000 美元）（工发组织）；

(f) 为职业培训中心举办两次关于易燃制冷剂的利益攸关方讲习班；选定职业培训中心及相关能力评估和差距分析；举办四次主培训员培训（包括 A2、A2L 和 A3 制冷剂的工具和设备；钎焊能力和管子压接方法；制冷剂循环操作；制冷剂回收、排放和处置；报告、日志和评估），以及为职业培训中心购买设备、工具、个人防护设备和培训装置（德国政府）（207,300 美元）；

(g) 继续开发可由住宅空调制造厂家用于产品开发的免费的简化建模软件（工发组织）（100,000 美元）；

(h) 为能力低于 10 冷冻吨的应用提供技术援助并在三个低全球升温潜能值的商用空调制造厂家制造样机，对于能力在 12-40 冷冻吨范围内的应用，综合使用间接蒸发冷却和直接蒸发（低全球升温潜能值替代品）（工发组织）（110,000 美元）；

(i) 使四个挤塑聚苯乙烯泡沫塑料制造厂家转用 HFO-1234ze 和二甲醚的 60/40 化合物（开发计划署）（1,761,750 美元）；以及

(j) 项目执行和监测机构将继续协调和监测非投资和投资活动的开展情况，包括访问受益人和利益攸关方，并组织讲习班和会议（工发组织）（125,000 美元）；它将启动挤塑聚苯乙烯泡沫塑料企业的转型，包括定期访问受益人、制定技术规格、提供技术支持、报告资金情况并进行财务控制（开发计划署）（75,000 美元）。

<u>住宅空调机制造中 HCFC-22 的转换</u>

背景

38. 工发组织提交了一份关于在住宅空调机制造中将 HCFC-22 转换为 HFC-32 和 R-454B 的项目提案，总金额为所提交的 11,710,018 美元外加机构支助费用 819,701 美元。

39. 该项目的目标是通过以下措施淘汰住宅空调制造行业中的 HCFC-22：

(a) 调整和重新设计空调设备，以使用低全球升温潜能值替代制冷剂；

(b) 通过以下方式使制造企业转用替代制冷剂：

（一）在不增加生产能力的情况下，视需要购买新的制造设备；

（二）执行可燃制冷剂安全储存和处理的安全制度；

（三）为新设备的重新设计提供技术援助，以维持或提高能效；

（四）为新设备的重新设计提供技术援助，以确保符合相关的国际安全标准；

（五）执行可燃制冷剂安全处理的工作程序；以及

（六）获取符合当前国际标准的安全认证（例如，欧盟指令）。

项目说明

40. 五个制造厂家（El-Araby、Fresh、Miraco、Power 和 Unionaire）是该国仅有的住宅空调制造厂家，并且参与了埃及空调业推广低全球升温潜能值制冷剂项目，它们将淘汰其对 HCFC-22 的使用。虽然上述企业的住宅空调设备大多在当地销售，但它们也向海湾和北非地区出口；它们不向非第 5 条国家出口。除了 Miraco 拥有 37%的非第 5 条所有权外，其余四个制造厂家都 100%归第 5 条所有。一些制造厂家与全球空调供应商签订了协定，因此在设计和部件选择上与它们挂钩，这也影响了它们对制冷剂技术的选择。每个制造厂家都有一家工厂，它们都生产全系列住宅空调设备和电器。除 Power 只使用 HCFC-22 外，其他四家企业都使用 HCFC-22 和 R-410A。以前没有一个制造厂家曾经获得转用氟氯烃技术的资金。表 3 总结了 2016 至 2018 年五家企业的制造情况及其消费量：

表 3. 五家企业的制造情况和 HCFC-22 消费量（公吨）

制造厂家	生产线数量	生产细节	**2016 年**	**2017 年**	**2018 年**
El-Araby	2	这两条生产线以不同的速度和周期运行。室内空调机的泄漏测试是通过加注少量 HCFC-22 和使用卤素检漏仪进行的。	275	198	212
Fresh	2	这两条生产线以相同的速度和周期运行。Fresh 使用氦气检漏室测试室内空调机。	136	142	147
Miraco	3	这三条生产线以相同的速度和周期运行。Miraco 使用氦气检漏室测试室内空调机。	396	359	366

制造厂家	生产线数量	生产细节	2016 年	2017 年	2018 年
Power	1	生产线以大约 70 秒的周期运行。生产室内和室外空调机使用同一条生产线。室内空调机的泄漏测试是通过加注少量 HCFC-22 和使用卤素检漏仪进行的。	50	43	45
Unionaire	2	生产线以大约 40 秒的周期运行。室内空调机的泄漏测试是通过加注少量 HCFC-22 和使用卤素检漏仪进行的。	600	360	240

41. 制造设施中的以下工序和测试区将受到转用易燃制冷剂的影响：泄漏测试（室内空调机生产线）、真空系统（室外空调机生产线）、制冷剂储存和供应系统、制冷剂加注系统（室外生产线）、焊接设备（室外生产线）、最终泄漏检测（室外生产线）、运行测试区（室外生产线）和实验室测试室。人们认为，一般性工厂基础设施，比如支持通风系统、电气接地和防静电保护应由每个制造厂家负责。

项目费用

42. 表 4 汇总了每个制造厂家实现转换所需的设备和增支资本费用。增支资本费用总额为 5,085,410 美元，与热交换器改造相关联的任何费用均由制造厂家承担。

表 4. 所提交的五家企业的增支资本费用（美元）

加工区和设备	制造厂家					共计
	El-Araby	**Fresh**	**Miraco***	**Power**	**Unionaire**	
制冷剂供应系统（供应泵、供应管道和气体传感器）	81,000	118,000	74,340	76,000	118,000	467,340
室内生产线（加注设备、制冷剂回收站、安全系统和通风）	84,000	0	0	0	168,000	252,000
室外生产线（加注设备、制冷剂回收站、安全系统和通风、泄漏检测和流程连接器）	473,500	405,000	494,550	248,000	535,000	2,156,050
运行测试区（测试台改造、安全系统和通风）	122,000	82,000	77,490	30,000	100,000	411,490
实验室测试室（制冷剂回收站、安全系统和通风）	183,000	61,000	38,430	61,000	61,000	404,430
一般性基础设施（备件）	30,000	30,000	28,350	7,500	30,000	125,850
工程、安装、认证和培训	143,000	98,000	118,440	77,000	138,000	574,440
技术援助	50,000	50,000	31,500	50,000	50,000	231,500
或有事项	116,650	84,400	86,310	54,950	120,000	462,310
共计	**1,283,150**	**928,400**	**949,410**	**604,450**	**1,320,000**	**5,085,410**

*已经考虑到 37%的非第 5 条所有权。

43. 在新型制冷剂运行一年的基础上计算增支运行费用时，考虑到了根据 2016-2018 年平均值计算的公司符合资助条件的消费量，以及第 74/50 号决定中规定的 6.30 美元/公斤的增支运行费用阈值。

表 5.　五个制造厂家转型的总费用（美元）

企业	公吨	**ODP 吨**	增支资本费用（美元）	增支运行费用（美元）	共计（美元）	成本效益（美元/公斤）
El-Araby	228.45	12.56	1,283,150	1,439,222	2,722,372	11.92
Fresh	141.67	7.79	928,400	892,502	1,820,902	12.85
Miraco*	373.67	20.55	949,410	1,483,084	2,432,494	6.51
Power	46.00	2.53	604,450	289,800	894,250	19.44
Unionaire	400.00	22.00	1,320,000	2,520,000	3,840,000	9.60
共计	**1,189.78**	**65.44**	**5,085,410**	**6,624,608**	**11,710,018**	**9.84**

*已经考虑到 37%的非第 5 条所有权。

44. 该项目需要修订第七十九次会议核准的《氟氯烃淘汰管理计划第二阶段的协定》。

秘书处的评论和建议

评论

<u>关于氟氯烃淘汰管理计划第一次付款执行情况的进度报告</u>

聚氨酯泡沫塑料制造行业

45. 秘书处注意到在落实聚氨酯泡沫塑料制造行业转型方面取得了相当大的进展，包括受援企业所需的所有设备均已购买，但秘书处也注意到，并非所有设备都已交付，且埃及政府禁止在 2020 年 1 月 1 日之前进口、使用和出口散装 HCFC-141b 以及出口预混多元醇中所含 HCFC-141b。开发署确认，任何尚未交付的设备预计将在 2019 年 12 月 31 日之前交付。设备安装将要求在进行新设备的安装、调试和优化时停止制造聚氨酯泡沫塑料；因此，企业将能够遵守禁令。开发计划署进一步确认将拆除使用氟氯烃的设备，使其无法使用。

<u>住宅空调机制造中 HCFC-22 的转换</u>

技术选择

46. 在第七十九次会议上，秘书处无法评估该行业拟议转型的增支费用，因为当时企业决定在其作出技术选择之前评估仍在进行的埃及空调业推广低全球升温潜能值制冷剂项目和 PRAHA 第二阶段示范项目的结果。

47. 秘书处注意到，该提案吸取了埃及空调业推广低全球升温潜能值制冷剂项目在选定企业将要转用的技术方面的经验教训，并借鉴了 2018 年制冷空调和热泵技术选择委员会

评估报告[15]和其他技术评价。如果成功执行，该项目将进一步促进埃及遵守《蒙特利尔议定书》的控制义务，并将有助于避免将高全球升温潜能值替代品（即 R-410A）引入住宅空调市场。

48. 根据第 74/20 号决定(a)(三)段，秘书处请供应商提供信息，说明如何以及何时向该国提供足够的 HFC-32（全球升温潜能值=675）和 R-454B（全球升温潜能值=490）以及必要的部件（特别是压缩机）。工发组织表示，HFC-32 和 HFC-32 压缩机易于获得，包括适合在高环境温度下使用的压缩机；当地供应商表示，他们能够在 2020 年底之前提供 HFC-32 压缩机。相比之下，R-454B 制冷剂和部件的供应链尚未完全建立：R-454B 制冷剂供应有限，且市场上还没有 R-454B 压缩机。预计制冷剂气体和压缩机将于 2023 年在非第 5 条国家供应，并在两三年后在埃及供应。鉴于当地市场上没有供应 R-454B，而且这种情况可能在完成氟氯烃淘汰管理计划第二阶段之后继续存在，秘书处无法审议转用 R-454B 的费用。因此，商定将在向 HFC-32 过渡的基础上确定增支费用；然而，一旦技术可用，企业也可以灵活选择制造使用 R-454B 的设备。

增支费用

49. 关于增支资本费用的讨论涉及加注机的费用；所需超声波焊接机的数量；与所使用的制冷剂无关的流程连接器申请是否符合条件；与实验室有关的费用，包括气体监测、通风以及是否需要回收机；氦气泄漏检测系统的费用，考虑到其中两家企业测试室内空调机是否有 HCFC-22 泄漏；以及备件、项目工程、安装和培训及安全审计的价格。此外，每家企业要求保持或提高能效的技术援助不符合资助条件，确保安全合规的技术援助已经列入商定的安装和培训费用。但是，根据项目独立技术审查的建议和埃及空调业推广低全球升温潜能值制冷剂项目的结果，秘书处认为需要进一步援助，以优化所制造设备的性能，确保其能够与市场上使用 R-410A 的设备竞争。

50. 如表 6 所示，在考虑到 2007 年 9 月 21 日之后购买的设备不符合资助条件后，将五家企业商定的增支资本费用从 5,085,410 美元调整为 4,253,197 美元。

表 6. 五家企业商定的增支资本费用（美元）

加工区和设备	制造厂家					共计
	El-Araby	**Fresh**	**Miraco**	**Power**	**Unionaire**	
制冷剂供应系统	81,000	118,000	74,340	40,000	118,000	431,340
室内生产线	65,000	0	0	0	130,000	195,000
室外生产线	328,500	304,500	406,035	216,500	448,500	1,704,035
运行测试区	122,000	82,000	77,490	30,000	100,000	411,490
实验室测试室	71,000	31,000	32,130	31,000	31,000	196,130
备件	15,000	15,000	14,175	7,500	15,000	66,675
工程、安装、认证和培训	112,000	72,000	70,560	62,000	112,000	428,560
产品设计和优化	150,000	75,000	94,500	50,000	150,000	519,500

[15] 可查阅 https://ozone.unep.org/sites/default/files/2019-04/RTOC-assessment-report-2018_0.pdf

加工区和设备	制造厂家					共计
	El-Araby	**Fresh**	**Miraco**	**Power**	**Unionaire**	
或有事项	68,250	55,050	60,417	32,500	84,250	300,467
增支资本费用总额	**1,012,750**	**752,550**	**829,647**	**469,500**	**1,188,750**	**4,253,197**

51. 商定增支运行费用的依据包括每台空调机的平均加注量（1.30 公斤/台），由 HCFC-22 转换至 HFC-22 将使加注量减少 30%，HCFC-22（2.95 美元/公斤）与 HFC-32（7.94 美元/公斤）之间的差价，与安全相关的额外费用，以及适用于高环境温度条件的 HFC-32 压缩机价格可能存在着细微差异（3.65 美元/台），从而得出增支运行费用为 6.18 美元/公斤。

52. 此外，在第七十九次会议上，与会者商定，如果住宅空调制造行业提案作为第二阶段的一部分获得核准，则项目执行和监测机构的费用可能增加[16]，工发组织在其项目提案中无意中遗漏了这一点；商定为项目执行和监测机构追加 175,000 美元的供资。

53. 在此基础上商定项目总费用为 10,926,623 美元，如表 7 所示。

表 7. 五家制造商实现转型的商定费用（美元）

企业	公吨	**ODP 吨**	增支资本费用（美元）	增支运行费用（美元）	共计（美元）	成本效益/公斤
El-Araby	228.45	12.56	1,012,750	1,411,809	2,424,559	10.61
Fresh	141.67	7.79	752,550	875,502	1,628,052	11.49
Miraco*	373.67	20.55	829,647	1,454,835	2,284,482	6.11
Power	46.00	2.53	469,500	284,280	753,780	16.39
Unionaire	400.00	22.00	1,188,750	2,472,000	3,660,750	9.15
项目执行和监测机构					175,000	
共计	**1,189.78**	**65.44**	**4,253,197**	**6,498,426**	**10,926,623**	**9.18**

*已经考虑到 37%的非第 5 条所有权。

转型的可持续性

54. 除 Power 外，所有企业都在其生产线上制造使用 HCFC-22 和 R-410A 的设备；特别是，每条生产线（Power 的生产线除外）都可用来制造使用 HCFC-22 的设备或使用 R-410A 的设备。鉴于这些企业制造使用 R-410A 的设备，而这种设备在国际市场上易于获得，价格相对便宜，且埃及也有进口，秘书处认为需要一个有利的框架，以确保淘汰的可持续性。

[16] UNEP/OzL.Pro/ExCom/79/32，第 56 段。

55. 秘书处和工发组织详细讨论了关于这种有利框架的备选方案。秘书处特别建议，这种框架可包括对进口使用 R-407C 和 R-410A 的住宅空调设备提高关税、对当地制造的此类设备征收与关税一致的税款以及对低全球升温潜能值设备发放补贴。工发组织告知，虽然埃及政府正在考虑一系列政策措施，但这些措施可能并不完全属于埃及环境事务局和国家臭氧机构的职权范围，由于执行这些措施需要进行国内磋商，政府需要更多的时间来选定这些措施。因此，商定的结果是埃及政府承诺结合转型项目的进展情况，采取和执行适当的监管措施，从而：确保充分控制进口或投放当地市场的使用 R-410A/R-407C 的家用空调设备；并确保当地市场采用选定的替代技术。

56. 在提交氟氯烃淘汰管理计划第二阶段第三次付款时将提交关于这些措施执行的最新状况。秘书处对付款申请进行审查时将考虑到在执行有利环境框架方面取得的进展。

57. 此外，商定这五家企业将承诺积极参与，努力促进市场接受使用商定技术的住宅空调设备，并承诺确保其为当地市场制造的使用 R-410A 的设备数量逐步减少，直至各企业只使用商定技术或全球升温潜能值较低的技术为当地市场制造设备。

58. 关于今后可能制造使用 HFC-32 和使用 R-454B 的设备的问题，秘书处指出，一旦 R-454B 可用，其费用可能高于 HFC-32。因此，可能存在的一种风险是，需要维修的 R-454B 设备被加注了构成 R-454B 主要成分的 HFC-32，而不是混合物本身。工发组织澄清说，虽然这对该设备造成的后果可能有限，但这种做法可能会影响设备的可靠性，部分原因在于 HFC-32 的排放温度较高。可以考虑取消制造商的保修，以阻止这种可能采取的做法，可能的话，为 R-454B 开发专门的加注口。

59. 注意到这五家企业的转型将导致整个住宅空调制造行业的转型，商定依照第 79/25 号决定，埃及政府将禁止在 2023 年 1 月 1 日之前进口和制造使用 HCFC-22 的住宅空调设备。

60. 关于企业未来的资助条件，与会者达成了一项共识，即五家企业将无资格获得多边基金的进一步资助以淘汰氟氯烃或 R-410A。此外，秘书处认为，依据第 XXVIII/2 号决定第 17 和 18 段，企业也无资格逐步减少其 HFC-32 消费量，埃及政府与各企业就此达成了共识。

对气候的影响

61. 根据修订后的多边基金气候影响指标，空调行业用 HFC-32 替代 HCFC-22 将避免 2,223,435 公吨二氧化碳当量的排放（即排放从 5,797,387 公吨二氧化碳当量的基准降至 3,573,952 公吨二氧化碳当量）。

共同出资

62. 住宅空调行业转型的商定总费用为 10,926,623 美元；其他额外费用，如对转换换热设施的投资（如需要）将由企业承担。埃及政府将通过实物支助共同出资，以执行必要的监管和政策支持措施，从而有助于确保住宅空调行业可持续地转用低全球升温潜能值替代品。

《氟氯烃淘汰管理计划协定》的修订

63. 根据第 79/34 号决定(d)段，该国政府提议修订《氟氯烃淘汰管理计划第二阶段的协定》。根据项目时间表，商定将与项目相关联的资金分为在 2019 年、2021 年和 2023 年三次付款，用于五家住宅空调制造企业实现转型；根据在第七十九次会议上商定的附录 2-A 的脚注，修改第 1.2 行规定的 2023 年、2024 年和 2025 年的目标；[17]从该国符合资助条件的剩余消费量中扣除 65.44 ODP 吨 HCFC-22，将第 1 段中用于受控用途的目标更新为 115.54 ODP 吨，并将新增一个第 17 段，以反映《协定》已经更新，如本文件附件二所示。完全更新的《协定》将附于第八十四次会议的最终报告。

淘汰氟氯烃的可持续性

64. 埃及政府颁布了支持聚氨酯泡沫塑料制造行业转型的法规，包括自 2018 年 1 月 1 日起禁止进口预混多元醇中所含 HCFC-141b，以及禁止在 2020 年 1 月 1 日之前进口、使用和出口散装 HCFC-141b 和出口预混多元醇中所含 HCFC-141b。埃及政府进一步承诺禁止在 2023 年 1 月 1 日之前在挤塑聚苯乙烯泡沫塑料制造中使用氟氯烃和氟氯烃混合物；禁止在 2023 年 1 月 1 日之前进口 HCFC-142b 和 HCFC-142b 混合物；在住宅空调制造行业转型项目获得核准之后，禁止在 2023 年 1 月 1 日之前进口和制造使用 HCFC-22 的住宅空调设备；承诺确保充分管制进口或投放当地市场的使用 R-410A 和 R-407C 的家用空调设备；承诺确保当地市场采用 HFC-32 技术，一旦技术可用，如果企业做出这样的决定，还要确保当地市场采用 R-454B 技术。

结论

65. 氟氯烃淘汰管理计划的执行工作正在取得进展，该国的进口许可和配额制度正在运行，经核查的消费量低于 2018 年目标。聚氨酯泡沫塑料行业的转型正在取得进展，所有企业都能遵守自 2020 年 1 月 1 日起禁止进口、使用和出口散装 HCFC-141b 和出口预混多元醇中所含 HCFC-141b 的禁令。资金发放量为 33%。第二次付款下计划开展的活动将促使挤塑聚苯乙烯泡沫塑料制造行业实现转型，使其能够在第三次付款的资助下完成，这些活动还将进一步建设海关和执法官员的能力，以及强化维修行业，从而有助于确保该国继续履行《议定书》规定的合规义务。如果没有将住宅空调制造行业转换为使用低全球升温潜能值替代品的项目，五家企业中的四家可能会开始在现有生产线上专门制造 R-410A 设备；包括有利环境框架和相关政策措施在内的这一项目对于避免这一结果并向市场发出转用低全球升温潜能值技术的信号至关重要，这可能会改变该行业市场转型的轨迹，促进使用低全球升温潜能值替代品。

[17] 附件 C 第一类物质的最高允许总消费量，在作为第二阶段组成部分的家用空调行业计划获得核准后，将再减少不超过 10 ODP 吨。

建议

66. 执行委员会不妨考虑：

(a) 注意到关于埃及氟氯烃淘汰管理计划第二阶段第一次付款执行情况的进度报告；

(b) 核准 El-Araby、Fresh、Miraco、Power 和 Unionaire 从 HCFC-22 转换为 HFC-32 的项目，并且一旦技术可用，如果企业做出这样的决定，R-454B 将被用于制造住宅空调机，金额为 10,926,623 美元外加给工发组织的支助费用 764,864 美元；

(c) 从符合资助条件的剩余氟氯烃消费量中扣除 65.44 ODP 吨 HCFC-22；

(d) 注意到埃及政府承诺按照《蒙特利尔议定书》时间表在 2025 年 1 月 1 日之前保持 115.54 ODP 吨的持续数量；

(e) 注意到：

（一）埃及政府承诺：

a. 禁止在 2023 年 1 月 1 日之前进口和制造使用 HCFC-22 的住宅空调设备；

b. 确保充分管制进口或投放当地市场的使用 R-410A 和 R-407C 的住宅空调设备；以及

c. 确保当地市场采用 HFC-32 技术，并且一旦技术可用，如果企业做出这样的决定，还要确保当地市场采用 R-454B 技术。

（二）El-Araby、Fresh、Miraco、Power 和 Unionaire 承诺积极参与，努力促进市场接受使用商定技术的住宅空调设备，并承诺确保其为当地市场制造的使用 R-410A 的设备逐步减少，直至各企业只使用商定技术或全球升温潜能值较低的技术为当地市场制造设备；

(f) 基于上文(b)分段中提到的项目提案的核准，以及(c)分段中提到的氟氯烃吨数的扣减，秘书处更新了《埃及政府与执行委员会之间的协定》附录 2-A，将第 1 段中用于受控用途的目标更新为 115.54 ODP 吨，并将新增一个第 17 段，表明本次更新后的《协定》取代在第七十九次会议上达成的《协定》，见本文件附件二。以及

(g) 核准埃及氟氯烃淘汰管理计划第一阶段第二次付款和相应的 2019-2022 年付款执行计划，总金额为 6,991,764 美元，包括：给工发组织的 4,668,214 美元外加机构支助费用 326,775 美元；给开发计划署的 1,836,750 美元外加机构支助费用 128,573 美元；给环境规划署的 279,500 美元外加机构支助费用 33,394 美元；给德国政府的 207,300 美元外加机构支助费用 26,949 美元。

附件一

埃及空调业推广低全球升温潜能值制冷剂项目

1. 使用 Arkema、Chemours、Daikin 和 Honeywell 提供的制冷剂，在当地可利用的经认证实验室中测试了由多家企业提供的 19 台带有专用压缩机的定制的分体式样机。重复测试以进行优化。

2. 结果表明，使用 HCFC-22 和 R-410A 的替代品运行的样机具有提高制冷量和能效的潜力（R-410A 替代品的改进程度更高）。这些改进取决于能够提供所需性能的设备的正确部件的可用性和选择。

3. 需要进行能力建设，使制造厂家能够设计、优化和测试使用易燃制冷剂的空调机，以提高性能并满足能效标准，并在仪器和处理易燃制冷剂方面提升其测试设施。测试结果表明，从热力学角度来看，项目中使用的所有制冷剂都是可行的替代品；然而，与埃及的最低能效标准相比，结果显示，该行业在今后几年提供满足严格要求的高效空调机方面会遇到挑战。此外，在兼容性、商业可用性、安全性和成本等其他标准方面的可行性还需要进一步研究。

4. 秘书处要求澄清埃及空调业推广低全球升温潜能值制冷剂项目的结果和结论是否与其他同样测试空调制造行业低全球升温潜能值替代品的测试方案相同，包括多边基金资助的示范项目。表 1 比较了四个测试方案设计标准、测试协议、测试的制冷剂和限制条件：AREP 第二阶段[1]、埃及空调业推广低全球升温潜能值制冷剂项目、ORNL[2]和 PRAHA[3]：

表 1. PRAHA、埃及空调业推广低全球升温潜能值制冷剂项目、ORNL 和 AREP 第二阶段测试方案比较

	方案	PRAHA	埃及空调业推广低全球升温潜能值制冷剂项目	ORNL – 第一阶段（小型分体空调）	AREP 第二阶段
1	测试类型	定制测试样机，与基准空调机相比：HCFC-22 和 R-410A	定制测试样机，与基准空调机相比：HCFC-22 和 R-410A	软优化测试，与基准空调机相比：HCFC-22 和 R-410A	对基准 R-410A 空调机进行软优化或无须改造设备的单个空调机
2	样机数量	13 台样机，每种具体的性能和制冷剂由一个或两个原始设备制造厂家制造，与基准制冷剂相比：HCFC-22 和 R-410A。样机和基准空调机总数 = 22	28 台样机，每种具体的性能和制冷剂由一个原始设备制造厂家制造，与基准制冷剂相比：HCFC-22 和 R-410A。样机和基准空调机总数 = 37	2 台商业可用的空调机，软修改以与基准制冷剂进行比较：HCFC-22 和 R-410a	22 台来自不同原始设备制造厂家的空调机，范围包括从分体式到水冷式

[1] 美国制冷空调与供暖协会替代制冷剂评价方案，http://www.ahrinet.org/arep

[2] Abdelaziz，2015 年 Abdelaziz O、Shrestha S、Munk J、Linkous R、Goetzler W、Guernsey M 和 Kassuga T，2015 年。“高环境温度环境下的替代制冷剂评价：小型分体式空调的 R-22 和 R-410A 替代品”，ORNL/TM-2015/536。可查阅：https://www.energy.gov/sites/prod/files/2015/10/f27/bto_pub59157_101515.pdf。

[3] PRAHA 项目报告：https://www.unenvironment.org/resources/report/promoting-lowgwp-refrigerants-air-conditioning-sectors-high-ambient-temperature

<table>
<tr><td colspan="2">方案</td><td colspan="4">PRAHA</td><td colspan="4">埃及空调业推广低全球升温潜能值制冷剂项目</td><td colspan="2">ORNL – 第一阶段（小型分体空调）</td><td>AREP 第二阶段</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">类别数量</td><td colspan="2">60 Hz</td><td colspan="2">50 Hz</td><td colspan="4">50 Hz</td><td colspan="2">60 Hz</td><td>60 Hz</td></tr>
<tr><td>窗式</td><td>小型分体式</td><td>有管</td><td>台柜式</td><td>小型分体式</td><td>小型分体式</td><td>小型分体式</td><td>中央</td><td>分体空调机</td><td>分体空调机</td><td rowspan="2">34 MBH 冷却、2x 36 MBH 分体式、48 MBH 台柜式、60 MBH 台柜式、72 MBH 台柜式</td></tr>
<tr><td>18 MBH</td><td>24 MBH</td><td>36 MBH</td><td>90 MBH</td><td>12 MBH</td><td>18 MBH</td><td>24 MBH</td><td>120 MBH</td><td>18 MBH 相当于 R-22</td><td>18 MBH 相当于 R-410a</td></tr>
<tr><td>4</td><td>测试条件</td><td colspan="4">在 T1、T3 和 T3+（50°C）下的 ANSI/AHRI 标准 210/240 和 ISO 5151，以及在 52°C 下持续 2 小时的连续性测试</td><td colspan="4">EOS 4814 和 3795（ISO 5151）T1、T2 和 T3 条件</td><td colspan="2">ANSI/AHRI 标准 210/240 和 ISO 5153 T3（2010）条件</td><td>在 T1、T3 和 125°F 下的 ANSI/AHRI 210/240</td></tr>
<tr><td>5</td><td>提供的样机和进行的测试</td><td colspan="4">在六个原始设备制造厂家制造的样机，在 Intertek 测试</td><td colspan="4">在八个原始设备制造厂家制造的样机，在原始设备制造厂家的实验室进行有人见证的测试</td><td colspan="2">ORNL，一个供应商——就地软优化</td><td>个别供应商，在自己的场所进行测试</td></tr>
<tr><td rowspan="3">6</td><td rowspan="3">测试的制冷剂</td><td colspan="4">相当于 HCFC-22：HC-290、R-444B(L-20)、DR-3</td><td colspan="4">相当于 HCFC-22：HC-290、R-444B(L-20)、DR-3、R-457A (ARM-32d)</td><td colspan="2">相当于 HCFC-22：N-20B、DR-3、ARM-20B、R-444B(L-20A)、HC-290</td><td rowspan="3">相当于 R-410A：HFC-32、DR-5A、DR-55、L-41-1、L-41-2、ARM-71a、HPR2A</td></tr>
<tr><td colspan="4">相当于 R-410A：HFC-32、R-447A(L-41-1)、R-454B (DR-5A)</td><td colspan="4">相当于 R-410A：HFC-32、R-447A (L-41-1)、R-454B (DR-5A)、ARM-71d</td><td colspan="2">相当于 R-410A：HFC-32、R-447A (L-41-1)、DR-55、ARM-71d、HPR-2A</td></tr>
<tr><td colspan="4">最终报告截至 2016 年 3 月</td><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td>7</td><td>限制条件</td><td colspan="4">使用专用压缩机为选定的制冷剂制造新的样机，这些样机与原始设计的箱体尺寸相同，并将性能和效率与使用 HCFC-22 和 R-410A 设备的基准模型进行比较</td><td colspan="4">使用专用压缩机为选定的制冷剂制造新的样机，条件是与 HCFC-22 和 R-410A 空调机相比，能够满足与选定模型相同的设计能力</td><td colspan="2">在“软优化”流程中，更改两个样机的某些部件以适应不同的制冷剂</td><td>-无须改造设备；
-通过调整膨胀装置、调整加注量和改变油种进行软优化；
-使用变速驱动器调节压缩机转速的一种情况</td></tr>
</table>

*MBH = 英制热量单位

5. 虽然埃及空调业推广低全球升温潜能值制冷剂项目在设计上与其他项目相似，但它具有以下显著特点：

(a) 埃及空调业推广低全球升温潜能值制冷剂项目是氟氯烃淘汰管理计划的一个方案，旨在使当地制造厂家参与关于其行业最佳制冷剂替代品的决策。该方案的第二阶段将使制造厂家对优化流程有所了解；

(b) 参与该方案的制造厂家数量仅次于 AREP，并且与其他三个方案相比测试的样机数量更多。使用的八种替代制冷剂涵盖了制造样机时可用的制冷剂；

(c) 埃及空调业推广低全球升温潜能值制冷剂项目不仅关注高环境温度，而且关注埃及可能普遍存在的整个温度范围；以及

(d) 显示的测试结果更易于说明制冷剂、环境温度、设备应用和性能之间的关系。

6. 埃及空调业推广低全球升温潜能值制冷剂项目没有与关于在沙特阿拉伯使用低全球升温潜能值制冷剂开发窗式和台柜式空调机的空调制造厂家示范项目的最终报告进行比较，也没有与关于哥伦比亚 Industrias Thermotar Ltda 在商业空调设备制造中淘汰 HCFC-22 示范项目的最终报告进行比较。

附件二

依照氯氟烃淘汰管理计划第二阶段将被纳入更新后的埃及政府与多边基金执行委员会关于减少氯氟烃消费量的协定草案的文本

（为了便于参考，相关修改以黑体形式出现）

1. 本协定是埃及（“国家”）政府和执行委员会关于按照《蒙特利尔议定书》时间表在 2025 年 1 月 1 日之前将附录 1-A 所列消耗臭氧层物质（“物质”）的控制使用减少到 **115.54** ODP 吨的持续数量的协定。

17. 本次更新后的《协定》取代埃及政府与执行委员会在执行委员会第七十九次会议上达成的《协定》。

附录 2-A：目标和供资

行	详情	2017 年	2018 年	2019 年	2020 年	2021 年	2022 年	2023 年	2024 年	2025 年	共计
1.1	《蒙特利尔议定书》削减附件 C 第一类物质时间表（ODP 吨）	347.64	347.64	347.64	251.08	251.08	251.08	251.08	251.08	125.54	暂缺
1.2	附件 C 第一类物质的最高允许总消费量（ODP 吨）	347.64	289.70	289.70	251.08	251.08	251.08	**241.08**	**241.08**	**115.54**	暂缺
2.1	牵头执行机构（工发组织）议定供资（美元）	3,356,641	0	**4,668,214**	0	**4,664,196**	0	**4,039,413**	0	195,000	**16,923,464**
2.2	牵头执行机构（工发组织）支助费用（美元）	234,965	0	**326,775**	0	**326,494**	0	**282,759**	0	13,650	**1,184,642**
2.3	合作执行机构（开发计划署）议定供资（美元）	1,042,352	0	1,836,750	0	816,620	0	0	0	0	3,695,722
2.4	合作执行机构（开发计划署）支助费用（美元）	72,965	0	128,573	0	57,163	0	0	0	0	258,701
2.5	合作执行机构（环境规划署）议定供资（美元）	230,000	0	279,500	0	260,000	0	180,000	0	105,500	1,055,000
2.6	合作执行机构（环境规划署）支助费用（美元）	27,480	0	33,394	0	31,064	0	21,506	0	12,605	126,050
2.7	合作执行机构（德国）议定供资（美元）	0	0	207,300	0	0	0	0	0	0	207,300
2.8	合作执行机构（德国）支助费用（美元）	0	0	26,949	0	0	0	0	0	0	26,949
3.1	议定总供资（美元）	4,628,993	0	**6,991,764**	0	**5,740,816**	0	**4,219,413**	0	300,500	**21,881,486**
3.2	总支助费用（美元）	335,410	0	**515,690**	0	**414,721**	0	**304,265**	0	26,255	**1,596,342**
3.3	议定总费用（美元）	4,964,403	0	**7,507,454**	0	**6,155,537**	0	**4,523,678**	0	326,755	**23,477,828**

4.1.1	本协定下要完成的议定的 HCFC-22 淘汰总量（ODP 吨）	**135.97**
4.1.2	之前阶段中要完成的 HCFC-22 淘汰量（ODP 吨）	6.13
4.1.3	剩余的符合资助条件的 HCFC-22 消费量（ODP 吨）	**98.09**
4.2.1	本协定下要完成的议定的 HCFC-123 淘汰总量（ODP 吨）	0
4.2.2	之前阶段要完成的 HCFC-123 淘汰量（ODP 吨）	0
4.2.3	剩余的符合资助条件的 HCFC-123 消费量（ODP 吨）	0.11
4.3.1	本协定下要完成的议定的 HCFC-141b 淘汰总量（ODP 吨）	33.92*
4.3.2	之前阶段中要完成的 HCFC-141b 淘汰量（ODP 吨）	95.69
4.3.3	剩余的符合资助条件的 HCFC-141b 消费量（ODP 吨）	0
4.4.1	本协定下要完成的议定的 HCFC-142b 淘汰总量（ODP 吨）	16.36
4.4.2	之前阶段中要完成的 HCFC-142b 淘汰量（ODP 吨）	0
4.4.3	剩余的符合资助条件的 HCFC-142b 消费量（ODP 吨）	0
4.5.1	本协定下要完成的议定的进口预混多元醇中所含 HCFC-141b 淘汰总量(ODP 吨)	26.16
4.5.2	之前阶段中要完成的进口预混多元醇中所含 HCFC-141b 淘汰量（ODP 吨）	72.18
4.5.3	剩余的符合资助条件的进口预混多元醇中所含 HCFC-141b 消费量（ODP 吨）	0

* 包括第七十六次会议核准、并于此纳入本协定的 4.4 ODP 吨淘汰量。

注： 根据第一阶段《协定》第一阶段完成日期：2019 年 12 月 31 日。

EGYPRA – Promotion of Low-GWP Refrigerants for the Air Conditioning Industry in Egypt

2019

Report

Project supported by the Multilateral Fund 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.

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We would like to acknowledge the assistance given by the government and the National Ozone Unit Officers of Egypt for their support in the implementation of the project phases and their assistance in facilitating communication with the different stakeholders.

We also acknowledge the independent International Technical Review Team that assist the project team in reviewing the process, results and the report of the project.

Prof. Roberto Peixoto (Brazil)
Prof. Walid Chakroun (Kuwait)
Dr. Omar Abdel Aziz (USA/UAE)

Acknowledgement also goes to the "Technology Providers" (Refrigerant and Compressor manufacturers) for providing components free of charge.

Refrigerant Providers: Arkema, Chemours, Daikin, and Honeywell.
Compressor providers: Emerson, Highly, and GMCC.

Also the OEM manufacturers who built the prototypes and tested them at their own facilities. The OEMs are listed under item 1.6

Delta Construction Manufacturing (DCM)
Elaraby
Egyptian German Air Treatment Company (EGAT)
Fresh
Miraco
Power
Unionaire
Volta

Project Team

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

The Project Management: UN Environment and UNIDO 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 Dr. Lamia Benabbas, Programme Officer – UNIDO and Mr. Ayman Eltalouny, International Partnership Coordinator, OzoneAction Programme – UN Environment

The Egyptian Organization for Standards: provided guidance on the Egyptian standards for testing as well as the minimum energy performance standards (MEPS).

The Technical Consultant, 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. The Technical Consultant witnessed-testing of all prototypes and baseline units, compiled testing data, and provided analysis of data.

The Coordination Consultant, Mr. Bassam Elassaad provided logistical support and coordination for the project and helped with writing of the final report.

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Acronyms

AHRI	Air Conditioning, Heating, and Refrigeration Institute
ANSI	American National Standards Institute
AREP	Alternative Refrigerant Evaluation Program
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
Btuh	Also denoted as BTU/h or B.t.u/hr = British Thermal Unit per Hour
BV	Burning Velocity
CAP	Capacity
CC	Cooling Capacity
CFC	Chloro Fluoro Carbon
COP	Coefficient of Performance
DB	Dry Bulb
DC	District Cooling
DX	Direct Expansion
EE	Energy Efficiency
EER	Energy Efficiency Ratio
EGYPRA	Egyptian Program for Promoting Low-GWP Refrigerant Alternatives
EN	European Norms (Standards)
EPA	Environmental Protection Agency (US)
GWP	Global Warming Potential
HAT	High Ambient Temperature
HC	Hydro Carbons
HCFC	Hydro Chloro Fluoro Carbon
HFC	Hydro Fluoro Carbon
HFO	Hydro Fluoro Olefins
HPMP	HCFC Phase-out Management Plan
HVACR	Heating, Ventilation, Air Conditioning and Refrigeration
HX	Heat Exchanger
IU	Indoor Unit
IEC	International Electrotechnical Commission
IPR	Intellectual Property Rights
ISO	International Standards Organization
Kg	Kilograms
kW	Kilowatts
LCCP	Life Cycle Climate Performance
LFL	lower Flammability Limit
MEPS	Minimum Energy Performance Standards
MOP	Meeting of Parties
MP	Montreal Protocol
NOU	National Ozone Unit
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
OEM	Original Equipment Manufacturer
PRAHA	Promoting Low-GWP Refrigerants for the Air Conditioning in HAT Countries
PSI	Pounds per Square Inch
RAC	Refrigeration and Air Conditioning
ROWA	UNEP Regional Office for West Africa
RTOC	Refrigeration, Air Conditioning, and Heat pump & Technical Options Committee

SCFM	Standard Cubic Foot per Minute
SHR	Sensible Heat ratio
SNAP	Significant New Alternative Policy
Tdb	Dry Bulb Temperature
Twb	Wet Bulb Temperature
TEAP	Technical & Economic Assessment Panel
TEWI	Total Equivalent Warming Impact
TF	Task Force
TWB	Wet Bulb Temperature
UNEP	United Nations Environment
UNIDO	United Nations Industrial Development Organization
USD	US Dollars
VC	Vienna Convention
VRF	Variable Refrigerant Flow
WB	Wet Bulb
WG	Working Group

Executive Summary

HCFCs are used extensively in the refrigeration and air conditioning industry, in particular in the air-conditioning industry. Parties to the Montreal Protocol, in their 21st meeting, adopted a decision concerning HCFCs and environmentally sound alternatives. The decision calls for further assessment and support work to enable parties to find the best ways of moving forward particularly for those with forthcoming compliance targets related to consumption of HCFC in the air-conditioning sector.

The aim of this program was to individually test custom-built AC split unit prototypes and central unit prototypes, to operate with alternative refrigerants and compare their performance against baseline units. Those baseline units are either HCFC-22 or R-410A. The list of refrigerants used and the split unit categories tested is as per the table below. The project involved building and testing 19 custom built split unit prototypes with dedicated compressors provided by Emerson, GMCC, and Hitachi Highly, and 16 base units by five OEMs. The refrigerants were provided by Arkema, Chemours, Daikin, and Honeywell. All the prototypes and the base units were tested at locally available accredited labs at the time the tests were conducted and witnessed by the project's Technical Consultant who also advised the OEMs during the manufacturing stage. Tests were repeated for optimization by tweaking some of the components. A total of 140 witnessed tests were performed. The central units were built but could not be tested due to lack of locally accredited available labs.

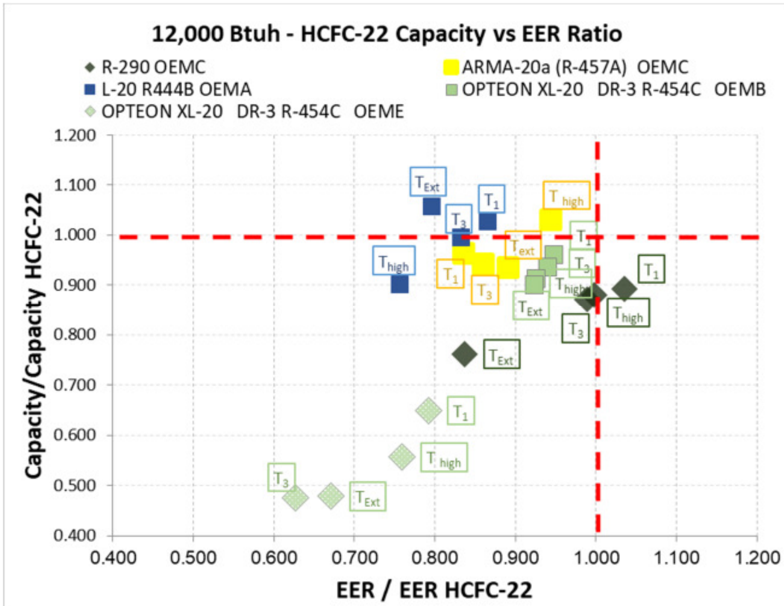
		Split system (mini-split)			Central 120,000 Btuh	
	Replacement for	**12,000 Btuh**	**18,000 Btuh**	**24,000 Btuh**	**Std. coil**	**micro channel**
HC-290	HCFC-22					
HFC-32	R-410A					
R-457C (Arkema ARM-20a)	HCFC-22					
R-459A (Arkema ARM -71a)	R-410A					
R-454C (Chemours DR-3)	HCFC-22					
R-454B (Chemours DR-5A)	R-410A					
R-444B (Honeywell L-20)	HCFC-22					
R-447A (Honeywell L-41)	R-410A					
HCFC-22 baseline						
R-410A baseline						

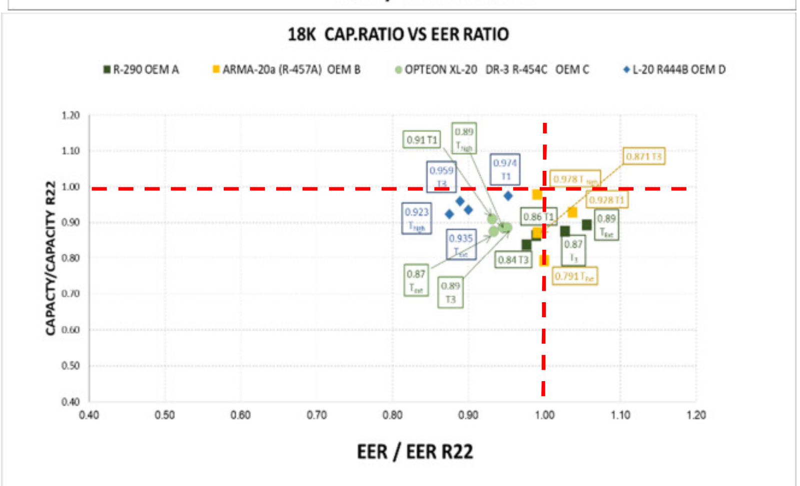
The units were tested at four ambient temperatures: T_1 (35 °C) and T_3 (46 °C) with indoor dry bulb/wet bulb temperatures of 27/19 °C and 29/19 °C respectively, plus two other ambient temperatures of 50 °C termed as T_{High} and 55 °C termed as $T_{Extreme}$ at ISO 5151 specified indoor dry bulb/wet bulb temperature of 32/23 °C (maximum testing condition in ISO 5151). These indoor temperatures are different from the ones used by other testing programs such as AREP and ORNL. The test results gave higher capacities at T_{High} than at T_3.

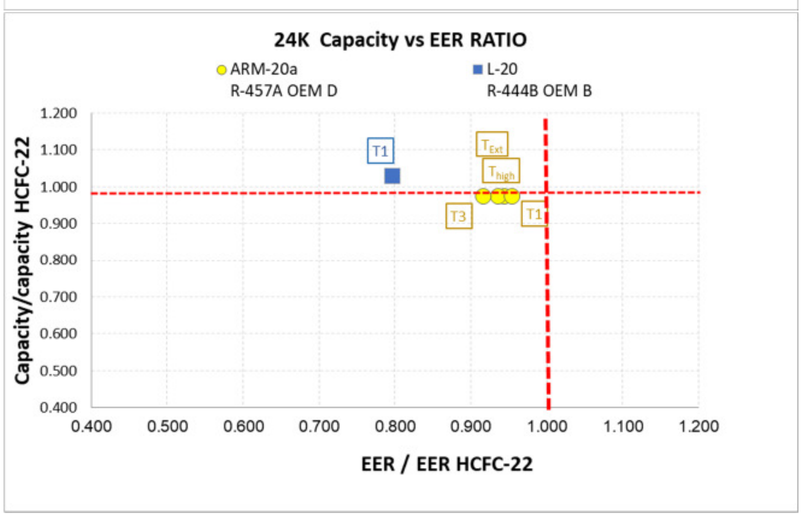
The casual reading of the results may establish confusion, even among specialists, in relation to the increase in capacity and EER at T_{High} compared to T_3. This result is not witnessed in other similar research projects; however, by understanding the impact of changing the dry bulb and wet bulb indoor testing conditions i.e. T_{high} (outdoor 50/24 ^{0}C, indoor 32/24 ^{0}C) compared to T_3 (outdoor 46/24 ^{0}C, indoor 29/19 ^{0}C), the results can be explained. These results were randomly double checked through a simulation exercise. The additional exercise to review the results delayed publishing results.

The test results are presented in comparison to the baseline units and color coded to denote the performance over or below the performance of the comparative baseline units. Scattered charts are plotted for the capacity ratio vs EER ratio for the prototypes vs the baseline units for each of the three unit categories and for the HCFC-22 alternatives and the R-410A alternatives. The red lines denote performance comparable to the base unit

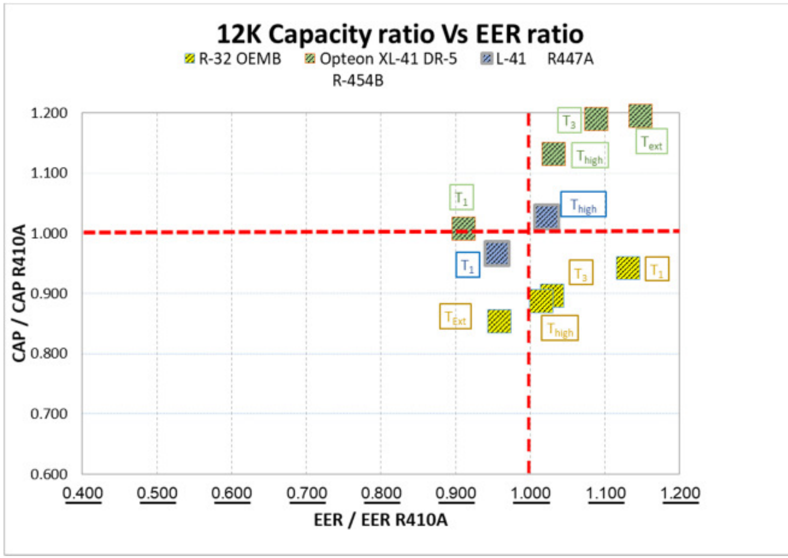
HCFC-22 alternatives

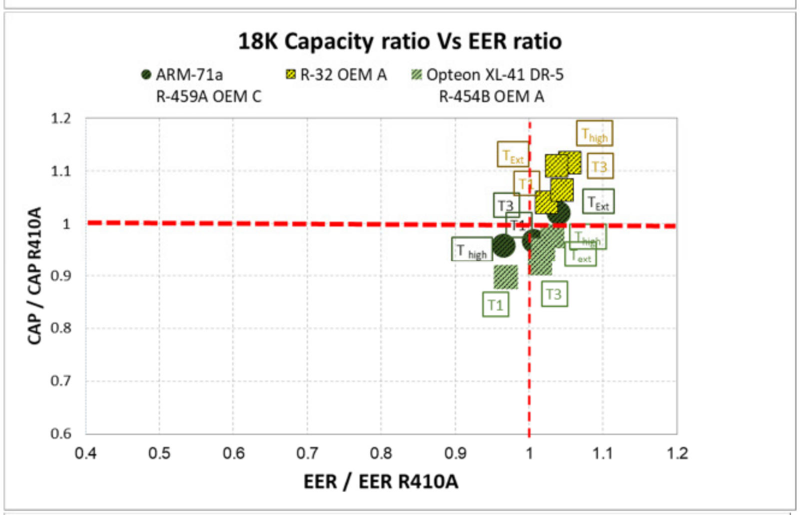


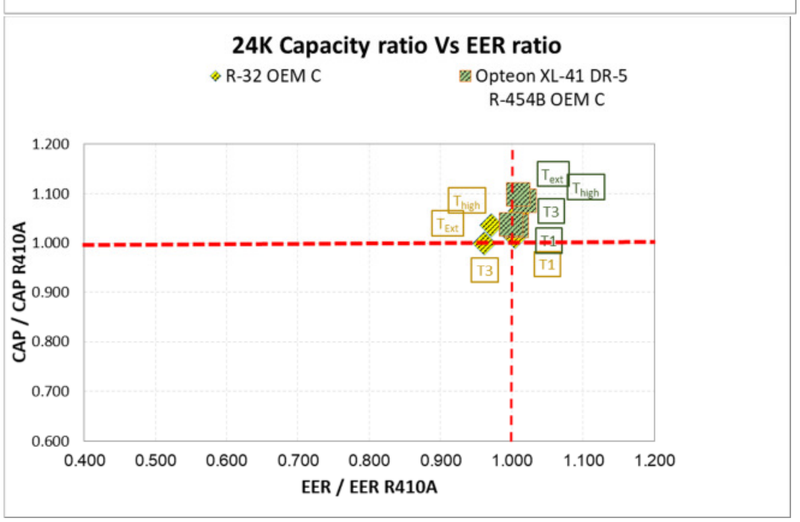




R-410A alternatives







Test results for HCFC-22 alternatives refrigerants demonstrate that:

- Several refrigerant alternatives show 60%, or above, chance for capacity matching or improvement across all categories and at different testing temperatures.
- Most refrigerant alternatives show 50%, or above, chance for EER improvement across all categories and at different testing temperatures.

Test results for R-410A alternatives refrigerants demonstrate that:

- All refrigerants showed improvement in capacity by 25 % to 67 %
- All refrigerants showed improvement in EER by 67 % to 75 %

The results show that there is a potential to improve the capacity and energy efficiency of the prototypes working with alternatives to HCFC-22; however, the potential for improvements for the prototypes working with alternatives to R-410A is better. This conclusion is in line with the outcome of other testing projects shown in Annex 4 and is based on the percentage of test results that were within plus or minus 10% of the results from testing the baseline refrigerants in the same category of equipment. This improvements are dependent on the availability and selection of the right components for units that can deliver the required performance while still be commercially viable.

An outcome of the project is a need for capacity building to enable the participating OEMs to design, optimize, and t test units with flammable refrigerants in order to improve the performance and meet the energy efficiency standards. There is a need to upgrade their testing facilities both in terms of instrumentation as well as to handle flammable refrigerants (refer to Annex 3 for a description of the OEM labs).

Test results show that all refrigerants used in the project are viable alternatives from a thermodynamic point of view; however, when compared to MEPS (Minimum Efficiency Performance Standards) for Egypt - see chapter 4 - results show there are challenges for the industry to provide high efficiency AC units meeting stringent requirements in the coming years. Moreover, the viability in terms of the other criteria like compatibility, commercial availability, safety, and cost among others needs to be further researched.

Chapter 1

1. Introduction

HCFCs are used extensively in the refrigeration and air conditioning industry, in particular in the air-conditioning industry. Parties to the Montreal Protocol, in their 21st meeting, adopted a decision concerning HCFCs and environmentally sound alternatives. The decision calls for further assessment and support work to enable parties to find the best ways of moving forward particularly for those with forthcoming compliance targets related to consumption of HCFC in the air-conditioning sector.

The PRAHA project (*Promoting Low-GWP Refrigerant Alternatives for the Air Conditioning Industry in High Ambient Temperature Countries*) was a pioneer project in testing specially built prototypes by local industries in the Middle East and West Asia region using alternatives refrigerants.

Manufacturers of residential and commercial air conditioning equipment in Egypt met with the Montreal Protocol implementing agencies in July 2014 and agreed on participating in a project to build and test prototypes using various HCFC alternatives at preset conditions in order to compare the performance and efficiency of those refrigerant alternatives.

The project's key elements are to:

a) Asses available low-GWP refrigerant alternatives by building, optimizing, testing and comparing prototypes with those alternatives;
b) Asses local Energy Efficiency (EE) standards and codes and the effect of using low-GWP refrigerant alternatives on those standards;
c) Promoting technology transfer by examining and facilitating technology transfer through the HPMP.

The last two elements are part of the Egyptian HPMP and are not included in this report.

1.1. Egypt HPMP

Egypt's starting point for aggregate reductions in its HCFC consumption is the same as its HCFC baseline consumption of 386 ODP tonnes (ODPt). The analysis of the data by substance and by sector showed that HCFC-22 is used almost entirely in the RAC sector and is the most predominant ODS in metric terms. However, in terms of ODS the use of HCFC-141b is significant, being 35% of the total baseline consumption. Egypt has committed to reduce its consumption by 25% by 2018. The 35% reduction on January 1, 2020 will take the consumption down to 251 ODPt.

The air conditioning manufacturing sub-sector accounts for about 35% of the HCFC-22 consumption. About 56% is used for servicing with RAC manufacturers accounting for the majority of this service consumption, while independent service companies account for just 3% of the HCFC-22 consumption.

The important consumption of HCFC-22 by local AC manufacturers, especially in the RAC sector, is the reason for adopting a project for testing locally built prototypes using low-GWP alternatives in Egypt. The program has been given the name EGYPRA (*Promotion of Low-GWP Refrigerants for the Air-Conditioning Industry in Egypt)*

1.2. Project Objectives

The aim of the program is to individually test especially made prototype split units and central units, to operate with alternative refrigerants and compare their performance against baseline units. Those baseline units are with either HCFC-22 or R-410A refrigerants.

The project objectives were decided upon in agreement with the local stakeholders and can be summarized as follows:

- Orient the Egyptian air conditioning manufacturers to the new medium and low-GWP refrigerants including those with low and high flammability;
- Support technical and policy decisions regarding long-term HCFC alternatives for the air-conditioning industry as part of the of Egypt's HPMP;
- Streamline the HCFC phase-out program with the Energy Efficiency work in Egypt;
- Promote the introduction of relevant standards/codes that ease the adoption of alternatives needing special safety or handling considerations;
- Exchange the experience with other relevant initiatives and programs which aim at addressing long term alternatives;
- Assess the capacity building and training needs for deploying low-GWP alternatives for different groups dealing or handling refrigerants in Egypt.

The outcomes from the above objectives are not presented in this report which only presents the results of the tests that were carried out for the various prototypes

1.3. Selection of Alternative Refrigerants

The selection of the alternative refrigerants was based on the following aspects which are derived from decision XXIII/9 of the Meeting of Parties (MOP):

I. Commercially available;
II. Technically proven;
III. Environmentally sound;
IV. Economically viable and cost effective;
V. Safety consideration;
VI. Easy to service and maintain.

EGYPRA took into consideration the refrigerants that were tested by PRAHA and added new alternatives that were still at an early stage of development when PRAHA was launched in 2012 even though they were still not commercially available at the time the prototype building and testing was done. The refrigerants were selected to replace either HCFC-22 or R-410A as shown in the two tables below, in line with the other testing projects on alternative refrigerants. It is worth noting that EGYPRA is a larger testing program than PRAHA, since it tested 19 specially made split unit prototypes and 16 baseline units, a total 35 units. It also witness-tested all units at the manufacturers' labs. In all 140 tests were made including baseline refrigerants and eight low GWP refrigerants.

Table 1 List of HCFC-22 alternative refrigerants

Refrigerant	ASHRAE classification	GWP (100 years) – RTOC
HC-290	A3	5
R-444B Honeywell L-20A	A2L	310
R-454C Chemours Opteon XL-20	A2L	295
R-457A Arkema ARM-20a	A2L	251

Table 2 List of R-410A alternative refrigerants

Refrigerant	ASHRAE classification	GWP (100 years) – RTOC
HFC-32	A2L	704
R-447A Honeywell L-41-2	A2L	600
R-454B Chemours Opteon XL-41	A2L	510
R-459A Arkema ARM-71a	A2L	466

While not all the selected refrigerants are not commercially available or cost effective at present, they have all received "R" numbers as per ASHRAE standard 34.

1.4. Selection of Capacity Categories

The selection of prototypes to build took into consideration that the majority of the units produced in Egypt are of the mini-split type with capacities of 12,000 Btuh, 18,000 Btuh, and 24,000 Btuh ((equivalent to 1, 1.5, and 2 refrigeration tons). Some of the units are still manufactured with HCFC-22 and some with HFC refrigerants which prompted building prototypes for alternatives to HCFC-22 as well as R-410A. .

Manufacturers also build what is termed as Central or Packaged units. Several manufacturers produce these units in the 10 Tons (120,000 Btuh or 35 kW) capacity but also in larger capacities of 20 and 25 tons. A 10 Ton Central unit was added to the categories to be tested. Only HCFC-22 alternatives were used for this category. The Central category does not include a prototype with HC-290 because of the relatively high amount of charge needed. The stakeholders preferred to wait for the result of further risk assessment work being done in the region.

One of the technology stakeholders (Danfoss) suggested building at least one prototype with condenser micro-channel heat exchangers (HX). Micro-channel HX technology is proven for conventional refrigerants and uses less refrigerant charge. One of the OEMs took up the challenge to build an extra Central unit with micro-channel HX.

Table 3 below shows the matrix of the prototypes that were agreed upon. Green highlighted areas are for units built, while red denotes the unused portion of the central units as mentioned above.

Table 3 Matrix of prototypes showing refrigerants selected for each equipment category

		Split system (mini-split)			Central 120,000 Btuh	
	Replacement for	12,000 Btuh	18,000 Btuh	24,000 Btuh	Std. coil	micro channel
HC-290	HCFC-22					
HFC-32	R-410A					
R-457C (Arkema ARM-20a)	HCFC-22					
R-459A (Arkema ARM -71a)	R-410A					
R-454C (Chemours DR-3)	HCFC-22					
R-454B (Chemours DR-5A)	R-410A					
R-444B (Honeywell L-20)	HCFC-22					
R-447A (Honeywell L-41)	R-410A					
HCFC-22 base						
R-410A						

OEMs were asked to supply from their standard manufacturing line units with baseline refrigerants equivalent in capacity to each prototypes in order to compare units built by the same OEM.

The test results of the central units are not covered in this report.

1.5. Stakeholders:

The project stakeholders:

The Ministry of Environmental Affairs. The following entities at the ministry provided overall supervision and monitoring of the project**:**

- **The Egyptian Environmental Affairs Agency (EEAA):** The Chief Executive Director of EEAA has direct responsibility for the supervision of the activities of the National Ozone Unit.
- **The National Ozone Unit (NOU):** The NOU as an integral part of the Ministry for Environmental Affairs may draw on the legal and technical expertise and resources of the Ministry to undertake its responsibilities. It cooperates with other relevant divisions and field offices of the Ministry and EEAA for carrying out its activities**.**

The Manufacturers (OEMs): Local manufacturers cooperated with Technology Providers to build and test agreed upon prototypes. Eight OEMs participated in the project, listed in alphabetical order:

- **DCM: (Delta Construction Manufacturing):** a manufacturer of central air conditioning equipment;
- **EGAT (Egyptian German Air Treatment Company):** a manufacturer of ducted split and central air conditioners along with airside equipment for commercial and industrial air conditioning;
- **Elaraby Company for Air Conditioning:** a manufacturer of air conditioners and home appliances, Elaraby partners with Sharp on technology for air conditioning equipment;
- **FRESH Electric for Home Appliances:** a manufacturer of air conditioners and home appliances;
- **Miraco Carrier:** a manufacturer of residential and commercial air conditioning equipment. Miraco also partners with Midea;
- **Power Egypt:** a manufacturer of small and central commercial & residential air conditioning equipment;
- **Unionaire:** a manufacturer of air conditioners and home appliances;
- **Volta Egypt:** a manufacturer of central air conditioning equipment.

Note on Confidentiality: To ensure the confidentiality of results, OEMs were given random designations from A to H and the results were reported under this designation.

The Technology Providers: Provide sample raw materials (refrigerants, compressors, and micro-channel coils) in addition to technical support when needed;

- **Chemours (ex-DuPont):** Provided refrigerants R-454C and R-454B;
- **Daikin:** Provided refrigerant HFC-32;
- **Danfoss:** provided micro-channel HX condenser coils for one central unit;
- **Emerson:** provided compressors for some split systems and all central units;
- **GMCC:** Provided compressors for some of the split systems;
- **Hitachi Highly:** provided compressors for some of the split systems;
- **Honeywell:** provided refrigerants R-444B and R-447A.

1.6. Methodology

The local manufacturers volunteered to build a certain number of prototypes each and provided standard units from their production line running on the baseline refrigerants against which the particular prototypes were compared. Baseline units are with either HCFC-22 or R-410A refrigerants.

The assignment of categories and refrigerants to each of the OEMs was based on a questionnaire in which they listed their preferences and their capabilities to take on the work. The questionnaire can be found in Annex 2. Coordination meetings were held with the OEMs in which some of the technology providers were also present. These meetings and the subsequent contacts with the OEMs facilitated the logistics of shipping both the compressors and the refrigerants to the different OEMs

The prototypes were built with the following constraints:

- Using dedicated compressors provided by the project for each type of alternative refrigerant;
- Using the same unit overall dimensions as the base unit, i.e. the heat exchangers could not be oversized in order to compare with the baseline unit. The overall dimensions of the unit were hence kept the same;
- Prototypes needed to meet the MEPS as set out by the Egyptian Organization for Standards EOS 3795:2013 equivalent to ISO 5151 at T_1 conditions as a minimum.
- OEMs provided throttling devices (capillary, flow controls…) according to guidance from refrigerant manufacturers for optimization.

EOS 3795:2013 stipulates for split units less than 65,000 Btuh capacity an EER of 9.5 equivalent to a COP of 2.78 W/W at T_1 conditions.

The OEMs optimized the prototypes by changing the refrigerant charge and the expansion devices. No special coil designs were made for this project except for the micro-channel HX coils used on the central unit. The constraint of keeping the same coils has an effect on the optimization of the prototype; however, since the purpose of the tests is to compare to a baseline unit using HCFC-22 or R-410A refrigerants, this constraint was accepted by the stakeholders.

The Table below shows the number and type of prototype built by each of the OEMs

Table 4 Prototypes and type of refrigerant built by the different OEMs

Category	**12 000 Btuh**		**18 000 Btuh**		**24 000 Btuh**	
OEM	**HCFC-22 Alternatives**	**R-410 A Alternatives**	**HCFC-22 Alternatives**	**R-410 A Alternatives**	**HCFC-22 Alternatives**	**R-410 A Alternatives**
A	R-444B	R-447A	R-290	HFC-32 and R-454B	-	-
B	R-454C	HFC-32	R-457A	-	R-444B	-
C	R-290 and R-457C	-	R-457A	R-459A	-	HFC-32 and R-454B
D	-	-	R-444B	-	R-457C	-
E	R-454C	R-454B	-	-	-	-

1.7. Testing Parameters and Facilities

EGYPRA testing protocol followed the following testing conditions:

Table 5 Testing conditions for outdoor and indoor dry and wet bulb temperatures

	T_1	T_3	T_{High}	$T_{Extreme}$
Outdoor °C db/wb	35/24	46/24	50/24	55/24
Indoor °C db/wb	27/19	29/19	32/23	32/23

The indoor conditions at T_{High} and $T_{Extreme}$ are not the same as those at T_3 conditions, they were chosen in agreement with the OEMs and are in conformity with ISO 5151 which is followed in Egypt. These indoor conditions are also not the same as in the other testing projects shown in Annex 4. Since the objective of EGYPRA is to compare the performance of AC units with medium and low-GWP alternative refrigerants against units with baseline refrigerants, this comparison remains true as long as the conditions of testing are consistent.

EGYPRA testing facilities: The project managers wanted to use one independent testing lab for testing all units in order to provide a continuity and similitude of testing. The government's accredited lab was contacted for that purpose; however, the lab did not have the capability of testing flammable refrigerants. Efforts at upgrading the lab capabilities could not be finished in time for the project timeline and the project adapted the strategy of witness testing at the manufacturers' testing facilities. The Technical Consultant witnessed all the tests and verified the results. A brief description of the OEM testing facilities can be found in Annex 3.

Testing Methodology:

Testing of the units followed the Egyptian standard EOS 4814, non-ducted AC & HP testing and rating performance. The standard is derived from ISO-5151 and is followed by all manufacturers. The standard stipulates that,

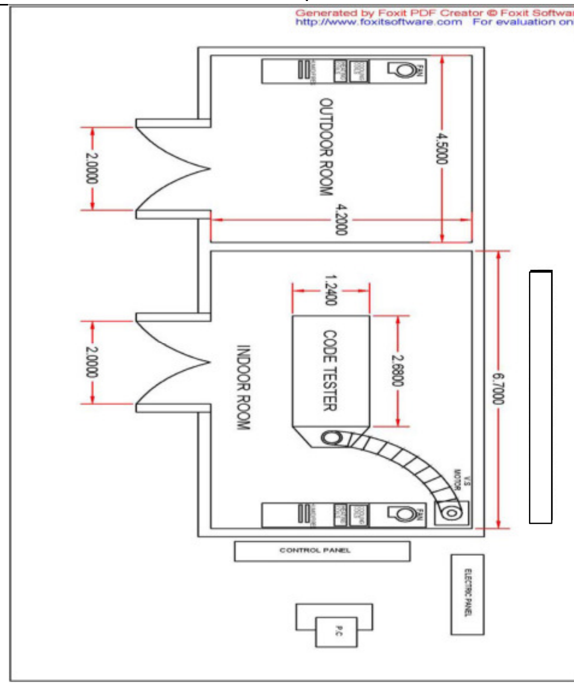
> *"4.1.1.2.5 Machines manufactured for use in more than one of the climatic conditions as T_3, T_2 and T_1 shall be rated and recorded at each of the conditions for which the unit was designed."*

The Egyptian standards do not stipulate testing at temperatures higher than T_3. The T_{High} and $T_{Extreme}$ conditions were derived from ISO 5151 with the agreement of the OEMs.

The tests were witnessed by the Technical Consultant. Re-testing the units was permitted when the results were inconsistent or did not meet the minimum EER stipulated in EOS 3795. The Technical Consultant advised the OEMs on possible remedies and helped them in the determination of the charge and the expansion device setting to achieve better results.

Testing procedure

Table below describes the testing procedure applied by all OEMs

No.	Item	Description
1	Testing lab infrastructure: • Testing chamber description Note: (Typical testing laboratory's testing chambers schematic diagram shown. Dimensions and arrangement of equipment are for indicative purposes only.)	 I. Laboratory is used for measuring capacities less than 1, 1, 1.5, 2 TR. Laboratory of the psychometric type where the air conditioner cooling capacity, heating capacity and unit efficiency (EER, COP) can be measured accurately. II. Other parameters such as unit working pressure, superheat, subcooling and state point's temperature of the refrigeration cycle could also be measured. III. Laboratory consists of two thermally insulated chambers (indoor and outdoor chambers). Both chamber's temperature and humidity can be controlled precisely to achieve the required state point (as per standards) using AC units, humidifiers and electric heater. IV. The accuracy of temperature control for dry and wet bulb temperatures to be 0.01 ^{o}C or better. V. The indoor room to have a thermal insulated code tester to collect all outlet air from the air conditioner, measuring its dry bulb and wet bulb temperatures and air volume
	• Parameters measured & instrumentation used	• All temperature sensors for inlet and leaving air in indoor room as well as outdoor room air temperatures are to be measured. • Surface temperatures to be measured by sensors - accuracy 0.1 ^{o}C or better-for both indoor and outdoor chambers. A minimum of 15 measuring points to be used for each room at various locations on the air conditioner. • All data gathered during an experiment to be read by a computer through a specialized program with multi channels data acquisition to get the required data in a live format fashion. • Factory supplied control panel located outside the chambers space to have all necessary control switches to

		operate the laboratory and set the required conditions with power meters for single phase and 3 phase and all electrical data for tested units. Data to be measured and transferred to computer system.
2	Standards to be used:	All tests for cooling and heating performance to be performed according to the following standards: • EOS 4814 non-ducted AC & HP testing and rating performance • ASHRAE testing standards • ISO 5151 for non-ducted air conditioners • ISO 13253 for ducted type split • EOS 3795-1/2016 • EOS 3795-2/2017
3	Description of the testing procedures: • Description of testing method • Method of selection of capillary tube and choosing refrigerant charge • Achieving steady state for outdoor and indoor conditions (description, time needed…)	• Psychometric testing method is used as per ISO 5151-2017 annex C, G. Air flow rates are to be measured through nozzles for both entering and leaving dry and wet bulb temperatures. • Optimum selection of capillary size, length, number and refrigerant charge to achieve good matching and improved performance for the unit according to the following: i) Select from preliminary capillary chart size, number and length of the required capillary to match the specified load. ii) Accumulated experience plays an important role in determining the preliminary refrigerant charge. iii) Testing the unit based on pervious selections give an indication for system optimization including increasing or decreasing the charge and/or the size of the capillary. iv) System pressure, superheat, subcooling, power consumption, cooling capacity and refrigerant temperature at various points of the cycle give a strong indication on how the matching is proceeding. • 2 hours' time are needed as a minimum to achieve the steady state condition for testing cooling capacity of the unit as well as EER or COP.
4	Calculating EER and capacity: • How the EER is calculated measurements used and formula • How the capacity was calculated measurements used and formula	EER= cooling capacity/ total power consumed by the system in Btuh/W or equivalent. As per ISO 5151 see equations in annex C
5	The air psychometric process: • The cycle on psychometric chart • Explanation of state points at T_1, T_3, T_h and T_{ext}	• Test result to provide all required information to draw the cycle on Psychometric chart: ○ E_{DB},L_{DB},E_{WB},L_{DB} (E=Enthalpy) • Test result to provide all required data to draw and change, when needed, the cycle on the PH diagram: ○ High pressure. ○ Compressor discharge temp. ○ Subcooling amount in condenser. ○ Low pressure. ○ Compressor suction temperature. ○ Superheat amount in evaporator for all required tests T_1, T_3, T_h and T_{ext} .

Chapter 2

2. Results

The results of the various tests were combined under two major headings: results of alternatives to HCFC-22 and results of alternatives to R-410A. The presentation or comparison of results across the two major headings does not lead to tangible conclusions while the separation of the discussion under the two baseline refrigerants leads to a better understanding of the information.

The casual reading of the results may establish confusion, even among specialists, in relation to the increase in capacity at T_{High} compared to T_3. This result is not witnessed in other similar research projects; however, by understanding the impact of changing the dry bulb and wet bulb indoor testing conditions i.e. T_{high} (outdoor 50/24 ^oC, indoor 32/24 ^oC) compared to T_3 (outdoor 46/24 ^oC, indoor 29/19 ^oC), the results can be justified using the modeling approach explained below. The additional exercise to review and validate all results is the reason for the unplanned delay in concluding the project report.

Modeling Using ORNL Heat Pump Design Model

Since the measurements provided by the labs were somehow limited, it was difficult to explain the hypothesis for the increase in performance under T_{High} conditions. As such, a full-scale modeling using the ORNL Flexible Heat Pump Model was performed on a sample packaged air conditioning system and the indoor and outdoor conditions were changed according to the EGYPRA conditions: T_1, T_3, T_{Hot}, and T_{High}. Table 5 above provides a summary of the indoor and ambient conditions for the four simulations along with the capacity ratio (capacity/capacity at T_1), compressor mass flow rate, compressor power, sensible heat ratio (SHR), and evaporator overall area integral heat transfer for the vapor (UA_vap) and the 2 phase (UA_2-ph) portions respectively.

The T_{Hot} condition was selected to simulate the same ambient conditions as that tested by the OEMs but with the same indoor conditions as T_1 and T_3. The results for this simulation follows the simple intuition that as the ambient temperature increases, the performance degrades at a rough order of magnitude of 1% point per 1°C of outdoor temperature increase. However, when examining the performance of the T_{High} condition; we notice a sudden increase in capacity – coupled with an increase in refrigerant mass flow rate, and reduction in SHR. The simulation results show that for T_1, T_3 and T_{Hot} conditions, the suction saturation temperature change was less than 1°C, while when the indoor conditions were changed to the T_{High} condition, the suction saturation temperature changed by more than 4°C. This has an impact on the compression ratio, compressor suction density, and compressor performance (volumetric and isentropic efficiencies). Furthermore, the higher humidity associated with the T_{High} condition induces the evaporator coil to become wetter and as such results in higher airside performance and higher SHR.

Table 6: Conditions and relevant results for the rooftop unit simulated using the ORNL Flexible HPDM simulation tool

Condition	EDB	EWB	Ambient	Capacity/Capacity at T1	Compressor mass flow rate	Compressor Power	SHR	Evaporator vapor UA	Evaporator 2-ph UA
	°C	°C	°C	%	g/s	W	%	W/K	W/K
T1	29	19	35	100%	379.8	14,074.9	88%	5.6	265.7
T3	29	19	46	89%	383.7	16,952.9	93%	6.7	265.1
T_{Hot}	29	19	50	86%	384.6	18,077.2	95%	6.7	265.2
T_{High}	32	23	50	94%	433.9	18,693.8	78%	9.4	261.3

Hypothesis summary

When the indoor dry bulb and wet bulb temperatures are increased from the T_3 conditions to the T_{High} conditions; the sensible heat ratio of the AC system is reduced, and a large portion of the evaporator is wetted by the condensate. This results in heat transfer enhancement due to reduced free flow area and increased surface velocity and the concurrence of heat and mass transfer at the tubes and fin surfaces. From further analysis provided by the detailed study from OEM C; the evaporator log mean temperature difference is also increased due to the increased air inlet temperature. Hence on the air side, both the increase in overall heat transfer coefficient along with the increased evaporator LMTD and increased latent capacity contribute directly to the increased heat capacity between T_3 and T_3 with elevated indoor conditions (subsequently also the increased capacity at the T_{High} conditions).

At the refrigerant side, when the indoor conditions are changed from the T_3 to the T_{High} conditions – the compressor pressure ratio is reduced while the compressor inlet density is increased. The refrigerant flow rate also increases which further justifies the increased cooling capacity from the refrigerant side analysis.

2.1 Presentation and Analysis of Results

The analysis of the results is presented in table form. The complete results and comparative bar charts are found in Annex 1.

The Results for capacity in Btuh and energy efficiency in EER (energy efficiency ratio in MBH output/ kW input) are given for the four testing temperatures. The tables show the test results and the percentage increase or decrease in capacity and EER compared to the baseline unit. As a reminder, each OEM was asked to test a baseline unit from their own standard production for each prototype built in order to compare with the results.

The analysis uses shades of color to denote the comparison level to the baseline unit as follows:

No shading	Performance is same as base unit – for capacity and EER
Green	**Increase** in EER or cooling capacity over baseline unit
Yellow	**Decrease** in EER or cooling capacity by **- 0.01 % to - 5 %**
Orange	**Decrease** in EER or cooling capacity from **-5 % to - 10 %**
Red	**Decrease** in EER or cooling capacity over **-10 %**

The results are then plotted on a scattered chart for the ratio of capacity of the prototype to that of the baseline unit vs. the EER ratio at the four testing temperatures. The baseline unit performance is denoted by the two red dotted lines at a ratio of one for both capacity and EER.

The analysis is presented for the alternatives of HCFC-22 and R-410A separately. Some results for inconclusive tests mentioned in the Annex were not used in the analysis.

2.1.1. Analysis of Capacity and EER Performance for HCFC-22 Alternatives

The tables in this section are for alternatives to HCFC-22 for the three categories of mini-split units: 12,000 Btuh, 18,000 Btuh, and 24,000 Btuh.

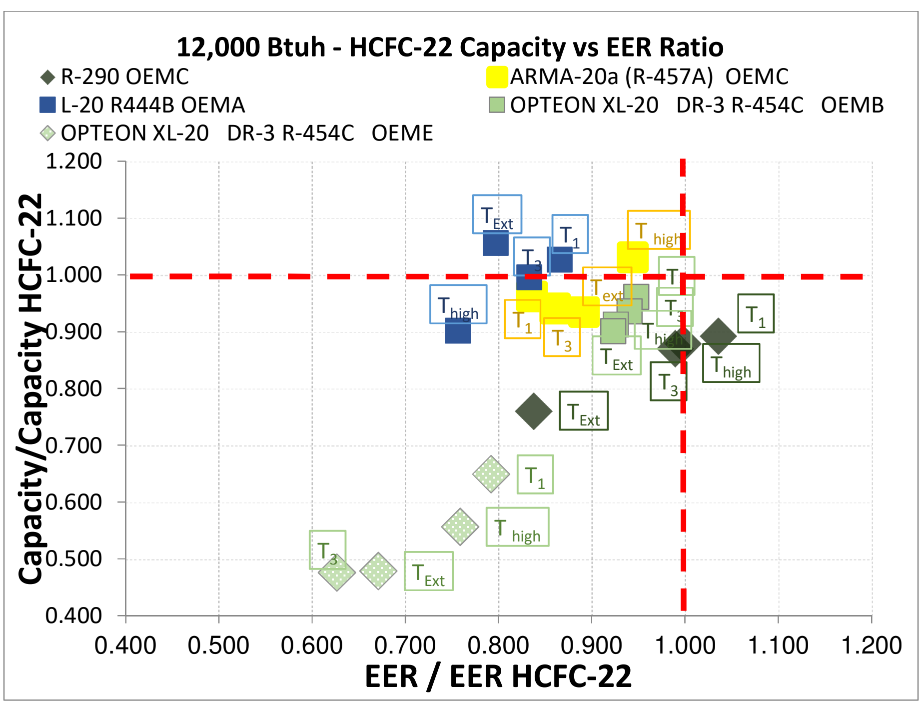
Results for the 12,000 Btuh category

Table 7 Comparison of HCFC-22 alternatives for 12,000 Btuh split units

HFCF-22 12,000 Btuh	T_1	T_3	T_{High}	$T_{Extreme}$	T_1	T_3	T_{High}	$T_{Extreme}$
	Capacity in Btuh				EER			
Base Units								
R-22(OEM C)	11,452	9,960	10,560	10,181	10.0	7.25	6.98	6.23
R-22(OEM B)	11,410	9,988	10,900	10,035	8.41	6.38	6.33	5.47
R-22(OEM A)	11,479	9,699	11,353	8,407	9.74	6.88	7.31	5.61
Prototypes								
HC-290 (OEMC)	10,219 (-10.77%)	8,677 (-12.88%)	9,289 (-12.04%)	7,747 (-23.91%)	10.36 (+3.53%)	7.17 (-1.1%)	6.96 (-0.23%)	5.22 (-16.2%)
R-457A (OEM C)	11,023 (-3.75%)	9,376 (-5.86%)	10,892 (+3.14%)	9,517 (-6.52%)	8.36 (-16.44%)	6.24 (-13.93%)	6.58 (-5.63%)	5.56 (-10.83%)
R-454 C (OEM B)	10,968 (-3.87%)	9,349 (-6.40%)	9,946 (-8.75%)	9,042 (-9.90%)	7.97 (-5.23%)	6.00 (-5.96%)	5.86 (-7.42%)	5.05 (-7.68%)
R-444 B (OEM A)	11,790 (+2.71%)	9,661 (-0.39%)	10,241 (-9.79%)	8,881 (+5.64%)	8.43 (-13.45%)	5.73 (-16.72%)	5.53 (-24.35%)	4.47 (-20.32%)

The table shows that for HC-290, the capacity of the prototype at all four temperatures is less than that of HCFC-22 baseline, while the EER is higher at T_1 and within 1% at T_3 and $T_{High.}$ The results for R-457A and R-454C show results for capacity up to 10% less than the baseline with R-457A showing a better capacity at Thigh which is not the case for R-454C. For R-444B, capacity is better than the baseline at both T_1 and $T_{Extreme}$ but 10% worse at T_{High} which cannot be explained. EER for R-444B is more than 10% worse than the baseline. Plotted on a scattered chart as follows

Figure 1 Capacity vs. EER ratio for HCFC-22 alternatives in 12,000 Btuh split units



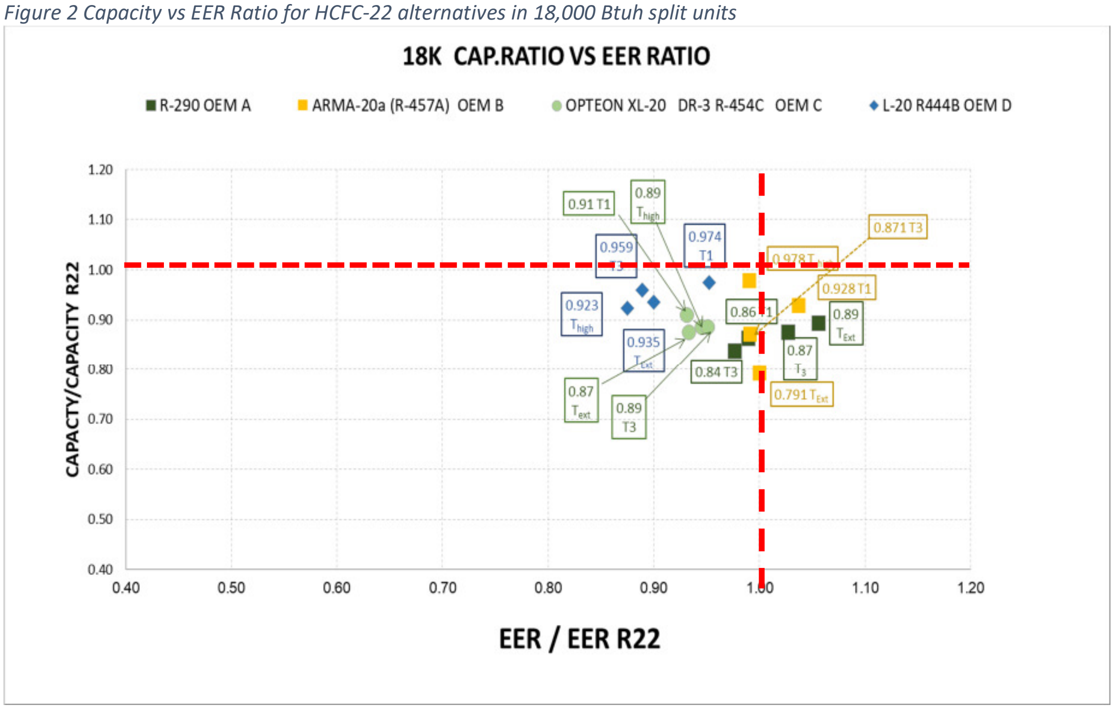
Results for 18,000 Btuh Splits

Table 8 Comparison of HCFC-22 alternatives for 18,000 Btuh split units

18,000 Btuh	T_1	T_3	T_{High}	$T_{Extreme}$	T_1	T_3	T_{High}	$T_{Extreme}$
Refrigerant	Capacity				EER			
Baseline Units								
HCFC-22								
OEM A	18,659	16,799	17,543	15,046	9.41	7.20	6.98	5.55
OEM B	16,433	14,545	13,718	15,350	8.93	6.65	6.37	5.33
OEM C	18,160	16,182	17,632	16,292	10.00	7.37	7.37	6.45
OEM D	17,548	16,422	14,624	13,948	10.50	8.75	7.22	6.00
Prototypes								
R-290 (OEM A)	*16,111 (-13.66%)*	*14,067 (-16.26%)*	*15,343 (-12.54%)*	*13,442 (-10.66%)*	9.31 (-1.06%)	7.090 (-2.34%)	7.170 (+2.72%)	5.860 (+5.59%)
R-444 B (OEM D)	*17,098 (-2.56%)*	*15,746 (-4.12%)*	*13,498 (-7.70%)*	*13,047 (-6.46%)*	10.00 (-4.76%)	7.78 (-11.01%)	6.32 (-12.47%)	5.40 (-10.00%)
R-454 C (OEM C)	*16,510 (-9.09%)*	*14,327 (-11.46%)*	*15,619 (-11.42%)*	*14,250 (-12.53%)*	9.31 (-6.88%)	6.97 (-5.43%)	7.01 (-4.88%)	6.02 (-6.67%)
R-457 A (OEM B)	*15,257 (-7.16%)*	*12,672 (-12.88%)*	*13,418 (-2.19%)*	*12,149 (-20.85%)*	9.26 (+3.70%)	6.59 (-0.90%)	6.31 (-0.94%)	5.33 (0.00%)

The results for HC-290 for capacity are consistent with the results of the 12,000 Btuh category, while the EER shows better results than the baseline at T_{High} and $T_{Extreme}$. The results for R-457C capacity compared to the 12,000 Btuh category show a further degradation compared to the baseline for the 18,000 Btuh category, while the EER results at the four temperatures are better than the 12,00 Btuh category. The same can be said about R-454C, while R-444B has comparable results with the 12,000 Btuh category with a variation with temperature. The results of this category show higher values for both capacity and EER for T High results compared to T3 in line with the discussion at the beginning of this chapter.

Figure 2 Capacity vs EER Ratio for HCFC-22 alternatives in 18,000 Btuh split units



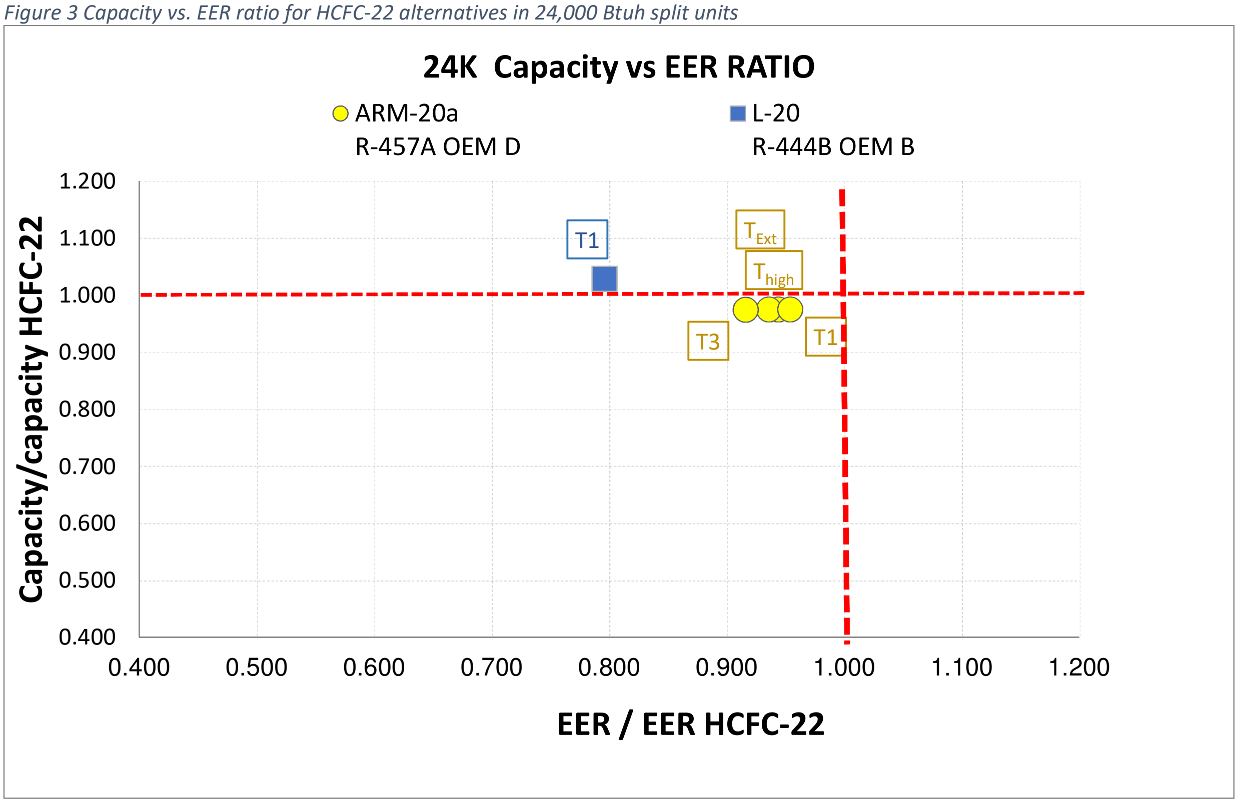
Results for 24,000 splits

Table 9 Comparison of HCFC-22 alternatives for 24,000 Btuh split units

24,000 Btuh	T_1	T_3	T_{High}	$T_{Extreme}$	T_1	T_3	T_{High}	$T_{Extreme}$
Refrigerant	Capacity				EER			
Baseline								
HCFC-22 OEM B OEM D	 22,782 22,318	 N/A 21,202	 N/A 20,144	 N/A 19,148	 9.27 9.30	 N/A 7.32	 N/A 6.10	 N/A 5.73
Prototypes								
R-444 B (OEM B)	23,436 (+2.87%)	N/A	N/A	N/A	7.38 (-20.39%)	N/A	N/A	N/A
R-457 A (OEM D)	21,758 (-2.51%)	20,670 (-2.51%)	19,636 (-2.52%)	18,657 (-2.56%)	8.78 (-5.59%)	6.85 (-6.42%)	5.82 (-4.59%)	5.25 (-8.38%)

Unfortunately, the data for R-444B at temperatures other than T_1 were not available. Data for R-457A as a percentage of the baseline by the same OEM show a better trend than for the other two categories; however, in absolute terms the EER of the baseline of the 24,000 Btuh category is lower than the other two categories which explains the higher percentage.

Figure 3 Capacity vs. EER ratio for HCFC-22 alternatives in 24,000 Btuh split units



Note that the results for the capacity for R-457A at the four temperatures are similar and hence the yellow circle label points seem almost concentric.

2.1.2. Analysis of Capacity and EER Performance for R-410A Alternatives

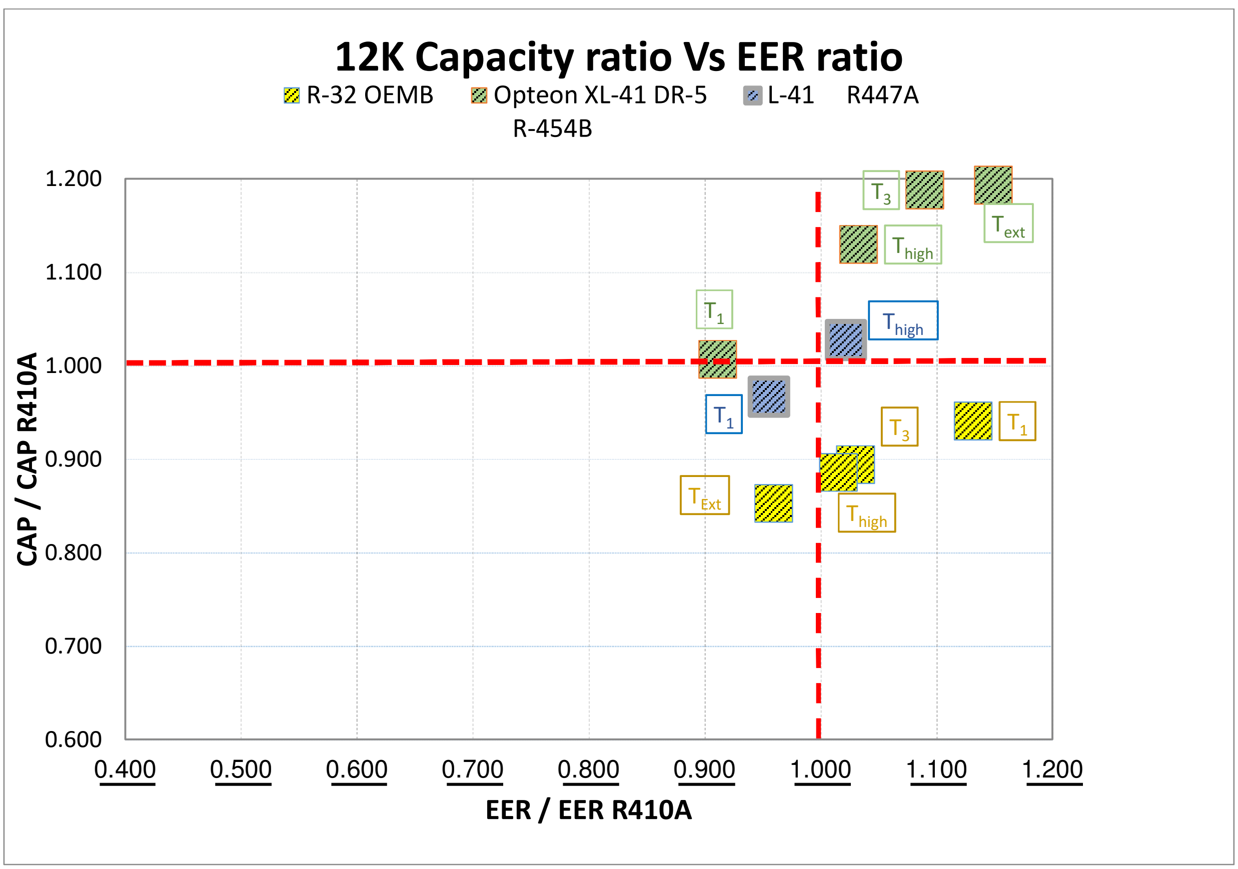
Results for 12,000 Btuh splits

Table 10 Comparison of R-410A alternatives for 12,000 Btuh split units

12,000	T_1	T_3	T_{High}	$T_{Extreme}$	T_1	T_3	T_{High}	$T_{Extreme}$
Refrigerant	Capacity				EER			
Baseline								
R-410A OEM A OEM B OEM E	 10,307 12,068 11,905	 N\A 10,343 9,369	 8,313 11,089 10,848	 N\A 9,968 9,299	 8.77 10.17 10.88	 N\A 7.31 7.29	 5.43 7.15 7.42	 N\A 5.93 5.89
Prototype								
HFC-32 (OEM B)	11355 (-5.91%)	9,249 (-10.58%)	9,822 (-11.435)	8,499 (-14.74%)	11.51 (+13.18%)	7.53 (+3.01%)	7.26 (+1.54%)	5.69 (-4.05%)
R-454B (OEM E)	11,987 (+0.69%)	11130 (+18.8%)	12,257 (+12.99%)	11,094 (+19.30%)	9.92 (-8.82%)	7.95 (+9.05%)	7.66 (+3.27%)	6.7 (+14.90%)
R-447A (OEM A)	9963 (-3.34%)	N\A N\A	8539 (+2.72%)	N\A N\A	8.38 (-4.45%)	N\A N\A	5.55 (+2.21%)	N\A N\A

The results for R-454B compared to the baseline is better except for the EER at T_1. Results for HFC-32 compared to the baseline show a higher performance for EER but lower for capacity.

Figure 4 Capacity vs EER ratio for R-410a alternatives in 12,000 Btuh split units



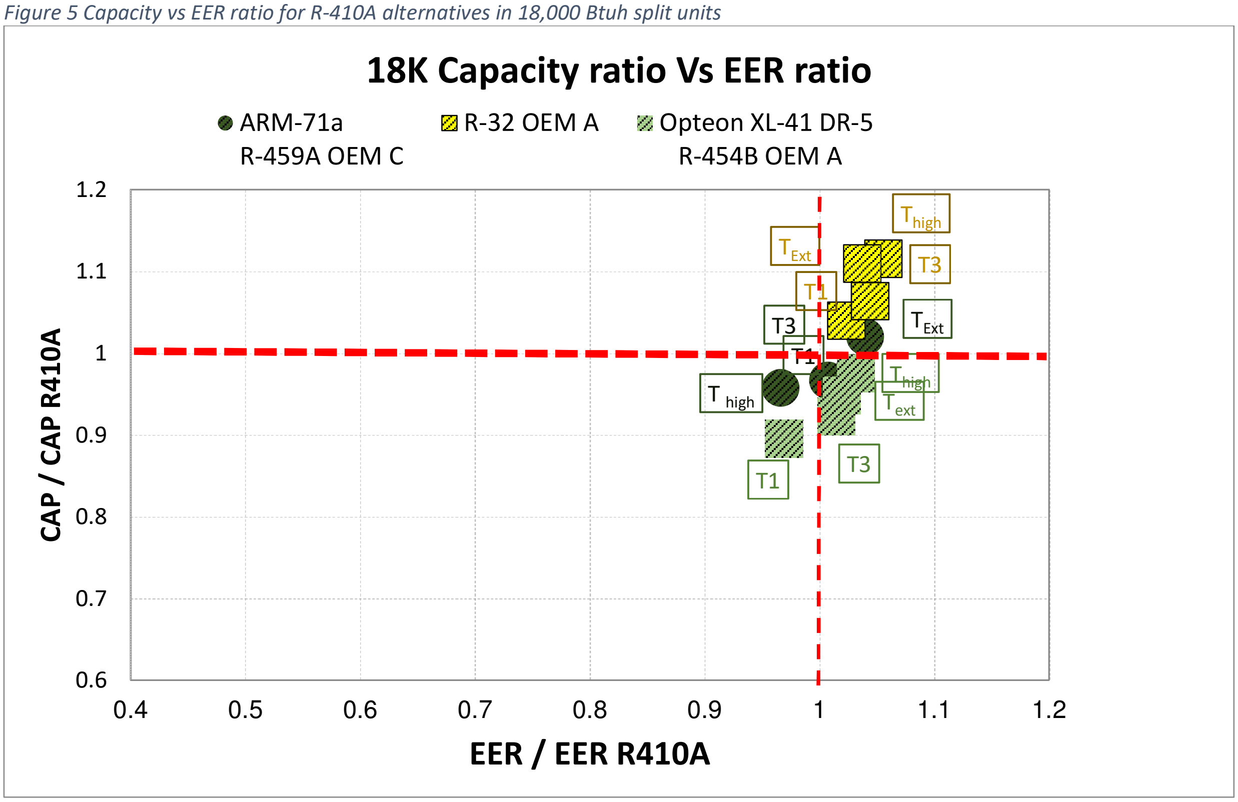
Results for 18,000 Btuh

Table 11 Comparison of R-410A alternatives for 18,000 Btuh split units

18,000	T_1	T_3	T_{High}	$T_{Extreme}$	T_1	T_3	T_{High}	$T_{Extreme}$
Refrigerant	Capacity				EER			
Baseline								
R- 410 A								
OEM A	16,938	14,337	14,123	12,441	9.8	6.8	6.3	5.1
OEM C	17,800	14,924	16,075	13,746	9.15	6.50	6.49	5.12
Prototype								
R-459A (OEM C)	17,115 (-3.85%)	14,430 (-3.31%)	15,392 (-4.25%)	14,023 (+2.02%)	9.28 (+1.42%)	6.54 (+0.72%)	6.27 (-3.39%)	5.32 (+3.99%)
HFC-32 (OEM A)	17616 (+4.00%)	15,255 (+6.40%)	15,761 (+11.60%)	13,809 (+11.00%)	10.03 (+2.35%)	7.10 (+4.41%)	6.65 (+5.56%)	5.29 (+3.73%)
R-454B (OEM A)	15,167 (-10.46%)	13,229 (-7.73%)	13,782 (-2.41%)	11,800 (-5.15%)	9.5 (-3.06%)	6.90 (+1.47%)	6.50 (+3.17%)	5.20 (+1.96%)

The results for R-454B show a similar trend of higher values against the baseline to the 12,000 Btuh category for EER but lower for capacity. Results for HFC-32 are higher than the baseline for both capacity and EER, which is different from the 12,000 Btuh category.

Figure 5 Capacity vs EER ratio for R-410A alternatives in 18,000 Btuh split units



The plot shows that most of the results are on the positive side when compared to the baseline units for EER with some results for capacity showing lower values.

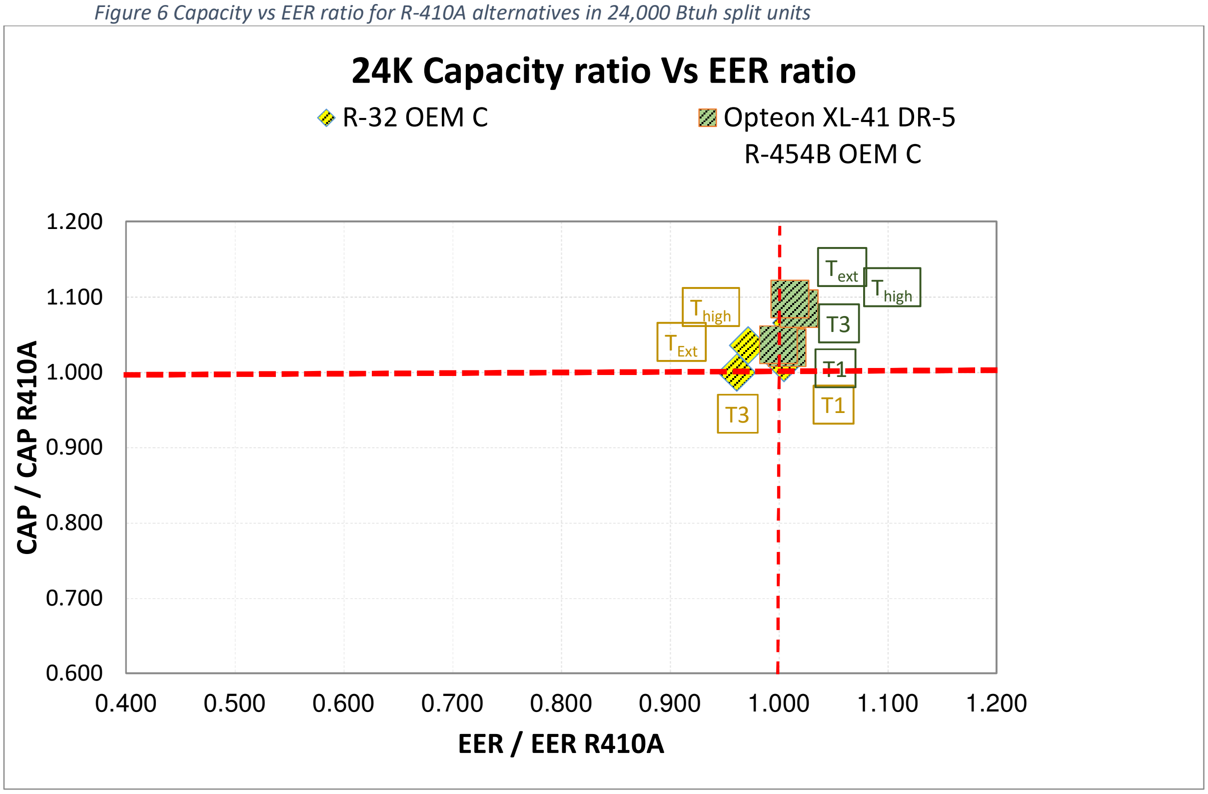
Results for 24,000 Btuh

Table 12 Comparison of R-410A alternatives for 24,000 Btuh split units

24,000	T_1	T_3	T_{High}	$T_{Extreme}$	T_1	T_3	T_{High}	$T_{Extreme}$
Refrigerant	Capacity				EER			
Baseline								
R- 410 A OEM C	23022	19531	20534	18379	10.57	7.518	7.376	6.161
Prototype								
HFC-32 (OEM C)	23310 (+1.25%)	19522 (-0.05%)	21876 (+6.54%)	19035 (+3.57%)	10.62 (-0.47%)	7.228 (-3.86%)	7.459 (+1.13%)	5.988 (-2.81%)
R-454B (OEM C)	23766 (+3.23%)	20241 (+3.64%)	22268 (+8.44%)	20160 (+9.69%)	10.653 (+0.79%)	7.516 (-0.03%)	7.515 (+1.88%)	6.224 (+1.02%)

Results are mostly positive for the two refrigerants tested at this category.

Figure 6 Capacity vs EER ratio for R-410A alternatives in 24,000 Btuh split units



Chapter 3

3. Analytical comparison & way forward

The purpose of the comparative analysis in this section is to determine the potential for improvement for the different alternative refrigerants at the different testing temperatures and for the three categories. Since we have three variables: refrigerants, testing temperatures, and category of equipment, the analysis fixed one of the variables and then calculated the percentage of incidence of cases where either the capacity or the EER are compared to the base unit falls in the five color categories defined earlier and repeated here for ease of reference.

No shading	Performance is same as base unit
Green	**Increase** in performance or cooling capacity over base unit
Yellow	**Decrease** in performance or cooling capacity by **- 0.01 % to - 5 %**
Orange	**Decrease** in performance or cooling capacity from **-5 % to - 10 %**
Red	**Decrease** in performance or cooling capacity over **-10 %**

As an example, consider the 12,000 Btuh category for all refrigerants and at all testing temperatures for the capacity comparison. We come up with the following table:

Table 13 Example of calculation of the comparative pie charts

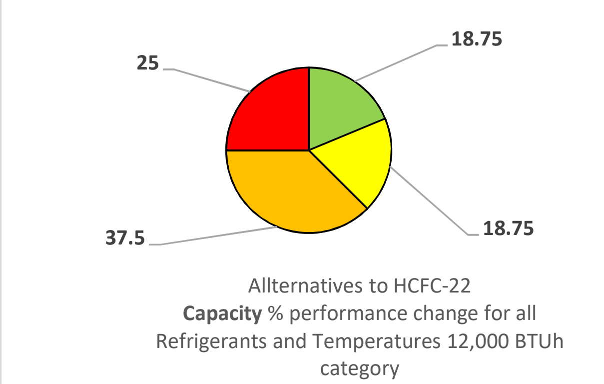
12,000 Btuh category	**Capacity**				
Refrigerant	T_1	T_3	T_{High}	$T_{Extreme}$	
R-290	10219	8677	9289	7747	
(OEM C)	(-10.77%)	(-12.88%)	(-12.04%)	(-23.91%)	
R-457 A	11023	9376	10892	9517	
(OEM C)	(-3.75%)	(-5.86%)	(+3.14%)	(-6.52%)	
R-454 C	10968	9349	9946	9042	
(OEM B)	(-3.87%)	(-6.40%)	(-8.75%)	(-9.90%)	
R-444 B	11790	9661	10241	8881	
(OEM A)	(+2.71%)	(-0.39%)	(-9.79%)	(+5.64%)	
	Calculation of incidence percentage				
	Green	Yellow	Orange	Red	No shading
Incidence: number of entries per color	**3**	**3**	**6**	**4**	**0**
Percentage of the 16 entries	**18.75%**	**18.75%**	**37.5%**	**25%**	**0%**

And the respective pie chart will look as in Figure 7 with the percentage of each incidence marked on the respective color. The pie chart is telling us that when we consider all the HCFC-22 refrigerant alternatives at all testing temperatures for the 12,000 category, there is

- 18.75% certainty that the result is better than the base,
- 18.75% that the result is up to 5% less compared to the base,
- 37.5% that the result between 5 and 10% less, and
- 25% that the results is over 10% less than the base.

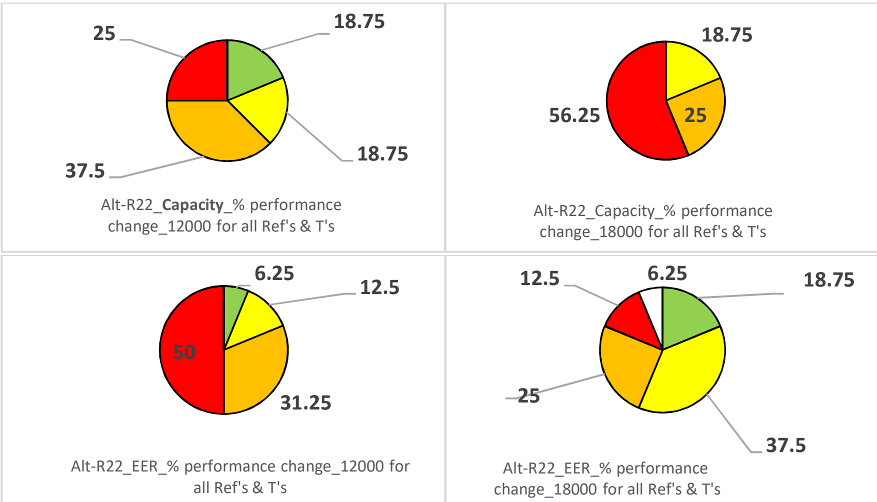
Similar comparative analysis will be made for the different cases for HCFC-22 alternatives and R-410A alternatives. The analysis clarifies the way forward and recommendations can be made for all the cases.

Figure 7 Example of pie chart for HCFC-22 alternatives in the 12,000 Btuh category



3.1. Capacity and EER behaviour of HCFC-22 Alternatives for each category across all refrigerants and testing temperatures

Figure 8 capacity and EER Performance of HCFC-22 alternatives for each category across all refrigerants and all testing temperatures



This analysis shows the following key observations:

For 12,000 Capacity:

- There is, certainly, potential to improve the capacity across 75% of refrigerants and at different testing temperatures
- On the EER side, the potential improvement drops down to 50%

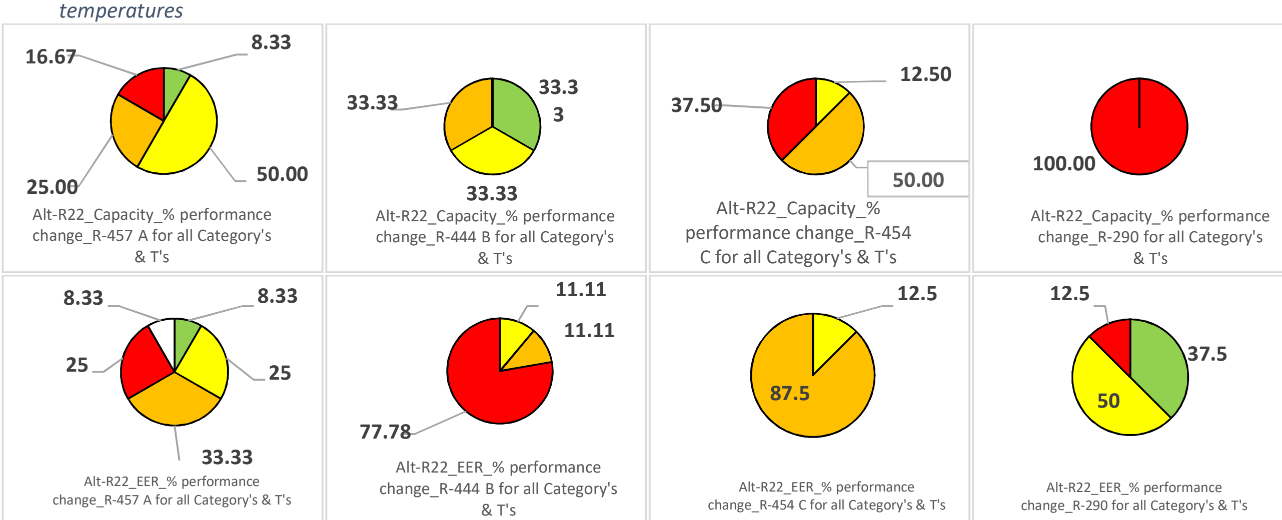
For 18,000 Capacity:

- There is less potentiality to improve capacity across all refrigerants and at different testing temperatures compared to the 12,000 category.
- However, opportunities to improve EER is much higher reaching over 85% across all refrigerants and at different testing temperatures

The 24,000 prototypes results were disregarded, since only one OEM tested one refrigerant across all test temperatures conditions. The other OEM tested another refrigerant at only one testing temperature condition. Therefore, a comparison of the results would be misleading.

3.2. Capacity and EER behaviour of HCFC-22 Alternatives for each refrigerant across all categories and testing temperatures

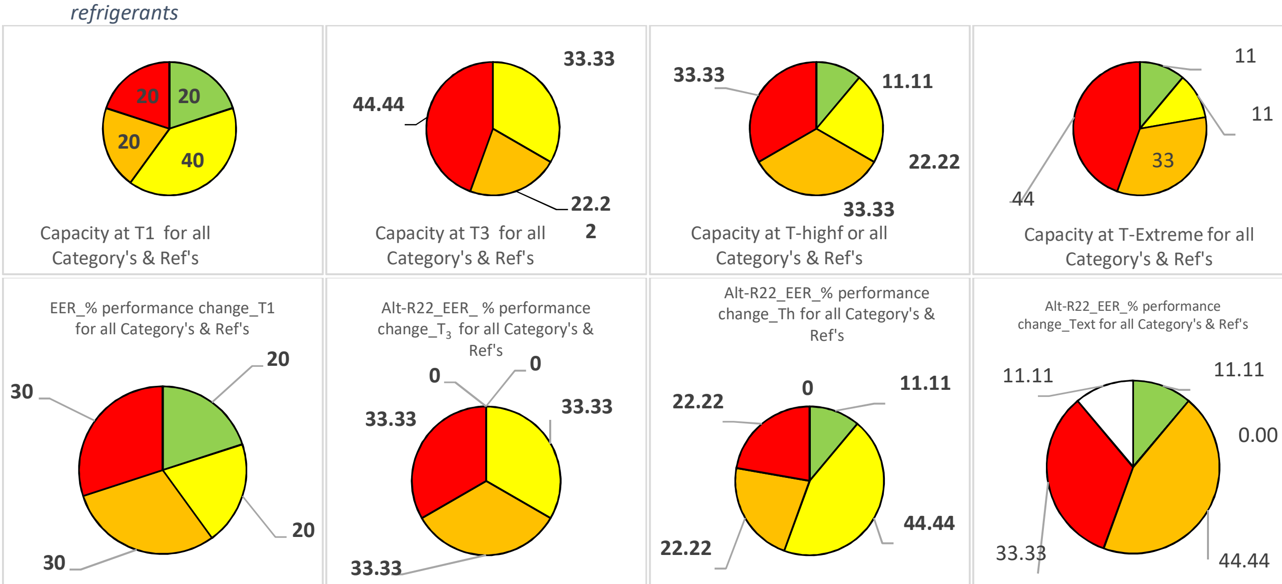
Figure 9 capacity and EER performance for HCFC-22 alternatives for each refrigerant across all categories and all testing temperatures



- Several alternatives to R-22 shows 60%, or above, chance for Capacity matching or improvement across all categories and at different testing temperatures.
- Most alternatives to R-22 shows 50%, or above, chance for EER improvement across all categories and at different testing temperatures.

3.3. Capacity and EER behaviour of HCFC-22 Alternatives for each testing temperature across all categories and refrigerants

Figure 10 Capacity and EER performance of HCFC-22 alternatives for each testing temperature across all categories and all refrigerants

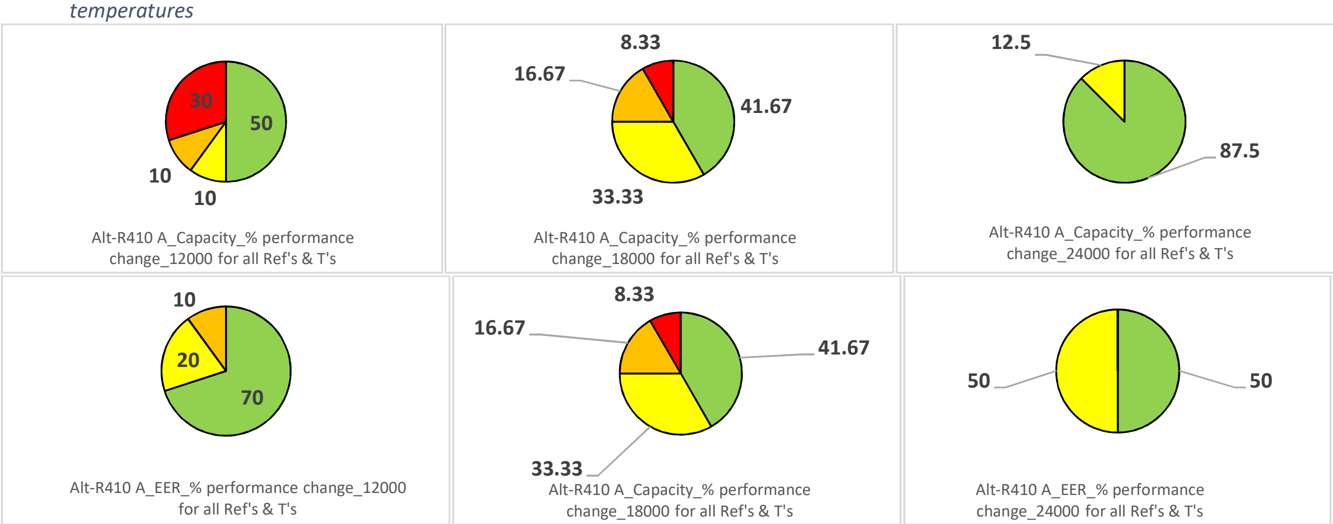


- As expected, moving from T1 to T3 testing temperatures, both capacity and EER deteriorate, at different levels, across all categories and refrigerants
- At T_{High}, the increased indoor wet bulb testing condition, as per EOS & ISO-5151, leads to better results for EER and capacity compared to T3

- Since $T_{Extreme}$ testing condition is similar to T_{High}, with regard to indoor wet bulb testing condition, both EER and capacity re-deteriorate.
- In general, there are candidates with potential improvement, more than 50%, across all categories at all high temperature testing conditions i.e. T_3, T_{high} & $T_{extreme}$.

3.4. Capacity and EER behaviour of R-410A Alternatives for each category across all refrigerants and testing temperatures

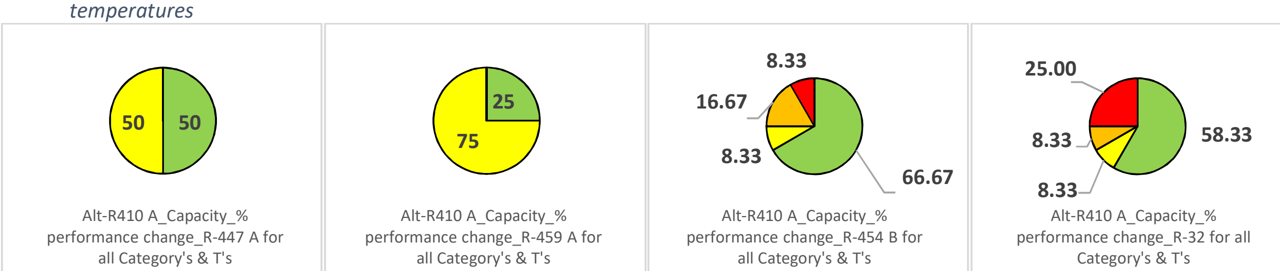
Figure 11 capacity and EER performance of R-410A alternatives for each category across all refrigerants and all testing temperatures

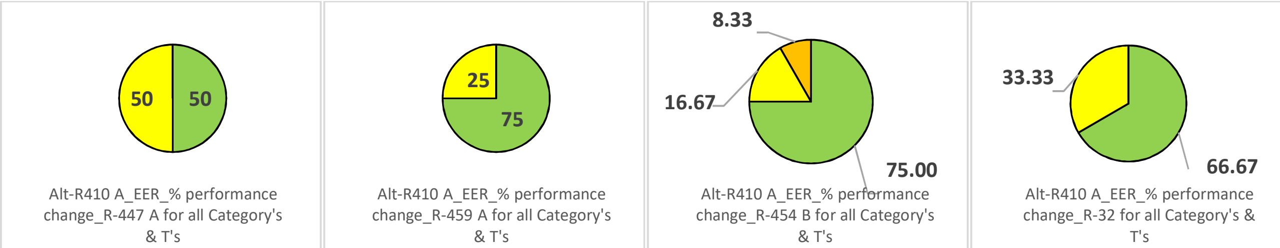


- Increase in capacity as category size increases, across all refrigerants and all testing temperate conditions.
- Capacity increases are from 50 % to 87.5 %.
- However, EER decreased as category size increases.
- EER improvement decreases from 70 % to 50 %.
- 18,000 showed capacity readings for all ranges similar to EER readings.
- 18,000 in the range (-0.1 % to - 5 %) readings for both capacity and EER were the same, 33.33 % instead of 10 % and 20 % in 12,000 size.
- The possibility of improving by optimization capacity and EER compared to R-410A are high

3.5. Capacity and EER behaviour of R-410A Alternatives for each refrigerant across all categories and testing temperatures

Figure 12 Capacity and EER performance of R-410A alternatives for each refrigerant across all categories and all testing temperatures

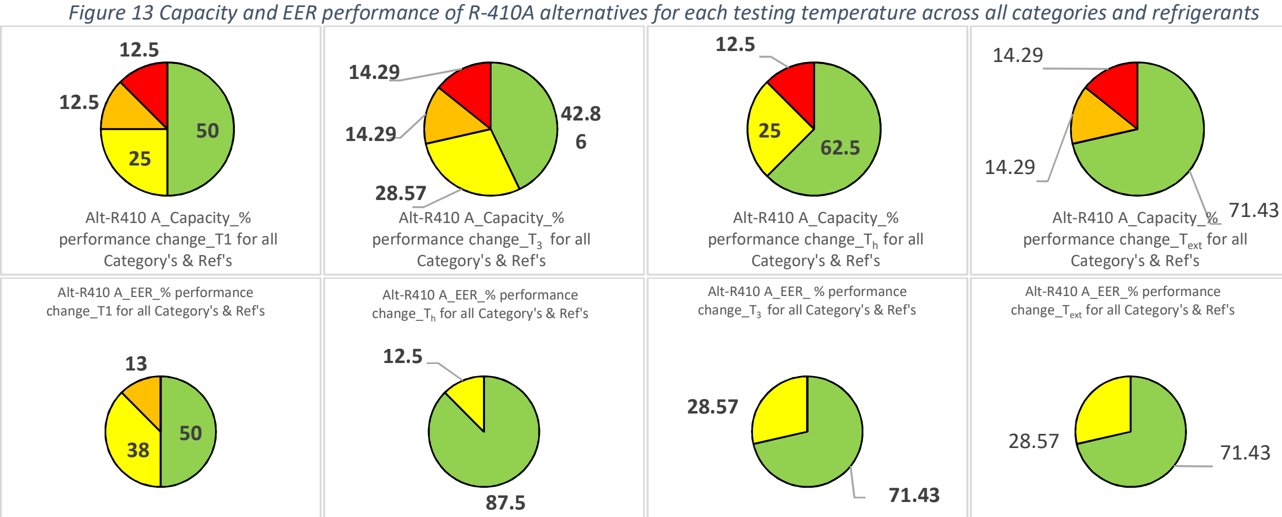




- All refrigerants showed improvement in capacity by 25% to 67 % and 50 % to 75 % in EER.
- One refrigerant was excluded from the comparison because of lack of data.
- All refrigerants have excellent chances of improvement in capacity and EER by optimization.

3.6. Capacity and EER behaviour of R-410A Alternatives for each temperature across all categories and refrigerants

Figure 13 Capacity and EER performance of R-410A alternatives for each testing temperature across all categories and refrigerants



- At $T_{1:}$ 50 % of all test readings show better capacities than R-410 A for all refrigerants and categories and 50% better EER.
- At $T_{3\,:}$ 42.86 % decrease in capacity improvement to 42.86% and then improvement rose to 62.5% and 71.43 % at T_h and T_{ext}.
- At T_3 : 87.5 %improvement in EER. Improvement diminished slightly to 71.43 % for both T_h and T_{ext}.

Excellent prospects for improvement in capacity and EER by optimization compared to R-410 A across all temperature testing conditions for all categories and all refrigerants.

Chapter 4

4. Energy Efficiency and Progressive Changes in MEPS for Egypt

Egypt's MEPS (Minimum Energy Performance Standards) energy efficiency label requirement for mini split air conditioning units and window type, ES: 3795-/2013 and ES: 3795-/2016 Part 1-for constant speed compressors- define EER (BTU/W.hr) at T_1 condition (ISO 5151) across several efficiency classes, A 5+ to E as listed in the tables below according to regulation years, 2014 to 2021.

MEPS progression across the years:

The standards, starting June 2014, lists EER values for energy efficiencies that define a certain class, termed calibration level, starting from E to A^{++}, see table below.

Table 14: Egypt Energy Ratings per 2014 Standard

Calibration	Energy Efficiency ratio of a room air conditioner (Split AC)	
	Watt/ Watt	**B.T.U/ Watt/h**
A^{++}	Higher or equal to 4,1	Higher or equal to 14
A+	Higher than or equal to 3, 81 and less than 4,1	Higher or equal to 13 and less than 14
A	Higher than or equal to 3, 51 and less than 3, 81	Higher or equal to 12 and less than 13
B	Higher than or equal to 3, 22 and less than 3, 51	Higher or equal to 11 and less than 12
C	Higher than or equal to 3, 08 and less than 3, 22	Higher or equal to 10, 5 and less than 11
D	Higher than or equal to 2, 93 and less than 3, 08	Higher or equal to 10 and less than 10, 5
E	Higher than or equal to 2, 78 and less than 2, 93	Higher or equal to 9, 5 and less than 10

Those EER classes' changes to become progressively stricter, as of June 2017, see table shown below, new class created **A^{+++}** and class **E** removed:

Table 15: Egypt Energy Ratings per 2017 Standard

Calibration	Energy Efficiency ratio of a room air conditioner (Split AC)	
	Watt/ Watt	**B.T.U/ Watt/h**
A^{+++}	Higher or equal to 4,4	Higher or equal to 15
A^{++}	Higher than or equal to 4,1 and less than 4,4	Higher or equal to 14 and less than 15
A+	Higher than or equal to 3, 81 and less than 4,1	Higher or equal to 13 and less than 14
A	Higher than or equal to 3, 51 and less than 3, 81	Higher or equal to 12 and less than 13
B	Higher than or equal to 3, 22 and less than 3, 51	Higher or equal to 11 and less than 12
C	Higher than or equal to 3, 08 and less than 3, 22	Higher or equal to 10, 5 and less than 11
D	Higher than or equal to 2, 93 and less than 3, 08	Higher or equal to 10 and less than 10, 5

And in June 2019 as shown below, new class created **A^{++++}** and class D removed:

Table 16: Egypt Energy Ratings per 2019 Standards

Calibration	**Energy Efficiency ratio of a room air conditioner (Split AC)**	
	Watt/ Watt	**B.T.U/ Watt/h**
A^{++++}	Higher or equal to 4,69	Higher or equal to 16
A^{+++}	Higher or equal to 4,4 and less than 4,69	Higher or equal to 15 and less than 16
A^{++}	Higher than or equal to 4,1 and less than 4,4	Higher or equal to 14 and less than 15
A+	Higher than or equal to 3, 81 and less than 4,1	Higher or equal to 13 and less than 14
A	Higher than or equal to 3, 51 and less than 3, 81	Higher or equal to 12 and less than 13
B	Higher than or equal to 3, 22 and less than 3, 51	Higher or equal to 11 and less than 12
C	Higher than or equal to 3, 08 and less than 3, 22	Higher or equal to 10, 5 and less than 11

Finally in June 2021 it becomes as shown below, new class created **A^{+++++}** and class **C** removed:

Table 17: Egypt Energy ratings per 2021 Standard

Calibration	**Energy Efficiency ratio of a room air conditioner (Split AC)**	
	Watt/ Watt	**B.T.U/ Watt/h**
A^{+++++}	Higher or equal to 4,98	Higher or equal to 17
A^{++++}	Higher or equal to 4,69 and less than 4, 98	Higher or equal to 16 and less than 17
A^{+++}	Higher or equal to 4,4 and less than 4,69	Higher or equal to 15 and less than 16
A^{++}	Higher than or equal to 4,1 and less than 4,4	Higher or equal to 14 and less than 15
A+	Higher than or equal to 3, 81 and less than 4,1	Higher or equal to 13 and less than 14
A	Higher than or equal to 3, 51 and less than 3, 81	Higher or equal to 12 and less than 13
B	Higher than or equal to 3, 22 and less than 3, 51	Higher or equal to 11 and less than 12

When the EER values are tabulated according to efficiency class (calibration) versus the year(s) when standards come into operation, the below table is obtained, where the most efficient class for each year(s) is in red followed by green, violet, sky blue, orange, light blue and navy blue as the class of efficiency becomes less and less . For all years there are 7 classes of efficiency.

The highest EER in 2014-2016 was 14 for class A^{2+} while in 2021 the highest EER will be 17 and a new classis created; A^{5+}. This continuous progression to more efficient systems is reflected in the graph below, where EERs are plotted across all years from 2014 to 2021. The top line denotes the highest EER for each regulation year, while the other lines are in descending order. The colors of the rows in the table correspond to the colors of the lines in the graph, 7 classes of efficiency for each year(s).

Table 18: EER Values at T1 according to the Egyptian Standard ES: 3795/2016

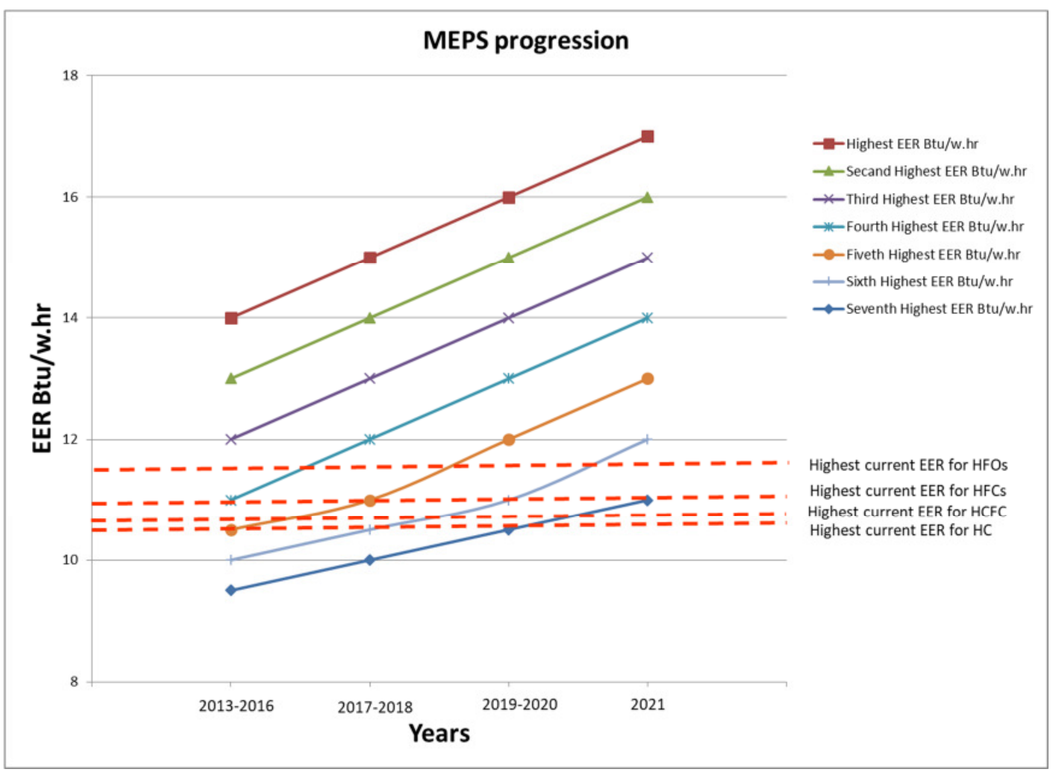
Eff. class /yr.	2014-2016	2017-2018	2019-2020	2021
A^{5+}				17
A^{4+}			16	16
A^{3+}		15	15	15
A^{2+}	14	14	14	14
A^{+}	13	13	13	13
A	12	12	12	12
B	11	11	11	11
C	10.5	10.5	10.5	
D	10	10		
E	9.5			

The table shows how the energy efficiency classes are increasing progressively with the years.

EER versus years:

The graph below shows the highest to lowest EER plotted against the years it came/coming into effect. The graph shows the progression to higher EER with the years. The values are taken from the table above. Seven classes are represented for each year.

Figure 14: EER curves for the highest in each class plotted vs. the standard regulation year



When the results of the Egyptian program for testing alternative low-GWP refrigerants for the Egyptian air conditioning industry, EGYPRA, are plotted on the graph as straight lines showing the best EER achieved for HCFCs, HFCs, HC and HFO, the following is shown:

- The highest EER of prototypes using HC-290 refrigerant is 10.35
- The highest EER of tested units using HCFC refrigerant is 10.5
- The highest EER of tested units using HFC refrigerant is 10.88
- The highest EER of prototypes using HFO refrigerant is 11.5

EGYPRA prototypes, especially made for the program, were optimized by choosing an optimum refrigerant charge and suitable selection of capillary tube (expansion device). No changes were made to either evaporator or condenser.

The best EER of alterative refrigerants cannot achieve at current optimization more than class B (light blue) for MEPS 2019-2020 and class B (navy blue) for 2021.

However, there is potential for improvement. The potential for improvement is based on the fact that the prototypes were built with many constraints (size and type of heat exchangers, size if the units, etc…). In future further optimization through the selection of compressors better suited to alternative refrigerants and the selection of heat exchangers that can improve the efficiency of the units will increase EER of the systems.

Can EER improvement be made from the current 11.5 to 16 in 2019 and 17 in 2 years? This remains to be seen, although it is unlikely. How far can EERs improve is related to the optimization process itself which requires research and development capabilities and capital cost and time. This might be beyond the capability of the majority of the manufacturers.

Further results of this correlation is as follows:

- Shifting to variable speed split units is inevitable if the higher efficiency EER standards are to be achieved by 2019 and beyond, with the resultant additional incremental costs associated with this shift, in manufacturing equipment and end product cost (USD 50 to 100).
- The introduction of Not-In-Kind cooling technology must be accelerated, if energy efficiency rates are to be improved for the air conditioning sector.

Chapter 5

5. Conclusion

EGYPRA is funded from Egypt's HCFC Phase-out Management Plan (HPMP) as an enabling activity for the benefit of the Egyptian air conditioning industry to help local manufacturers experiment working with new alternative lower-GWP refrigerants.

EGYPRA tested refrigerants with medium pressure characteristics similar to HCFC-22 and others with high pressure similar to R-410A in split system units. Testing of central units with higher capacity was not finalized in time for this report due to lack of testing facilities for flammable refrigerants at those capacities. Results will be reported in the future once testing and evaluation is done.

This conclusion is in two parts: technical and institutional regarding capacity building requirements.

5.1. Technical Conclusion

EGYPRA results lead to the following conclusions:

- As expected, and for all refrigerants, moving from T_1 to T_3 testing temperatures, both capacity and EER deteriorate, at different levels, across all categories and refrigerants;
- At T_{High}, the increased indoor wet bulb testing condition, as per EOS & ISO-5151, leads to better results for EER and capacity compared to T_3;
- Since $T_{Extreme}$ testing condition is similar to T_{High}, with regard to indoor wet bulb testing condition, both EER and capacity re-deteriorate;
- In general, there are candidates with potential for improvement; however, since high pressure refrigerants show better results vs. R-410A, the potential for improvement is higher.

Almost all of the OEMs who have participated in EGYPRA have already introduced R-410A units into the market. One uncorroborated study shows that more than 10% of the units sold in 2017 were with R-410A. This might make it easier for OEMs to leap-frog solutions for HCFC-22 and pass directly to high pressure alternatives to R-410A as the possibility for performance and EER improvement is higher for those alternatives.

Results also show that the potential for improvement applies also at higher ambient temperatures, an important factor for some of the regions in the south of Egypt that experience higher ambient temperatures than 35 °C. This is also important for the export market as some manufacturers export to neighboring HAT countries in the region.

5.2. Capacity Building Requirements

The conclusion from chapter 4 is clear: at the current optimization level, none of the prototypes tested will be able to meet more than class B of the 2021 MEPS values; however, the fact is that prototypes were built with many constraints

- The prototypes could be further optimized through the selection of compressors better suited to the tested refrigerants and the selection of heat exchangers that can improve the efficiency of the units;
- Variable speed technology would improve the Seasonal EER of the units where applicable;
- The optimization process requires research and development capabilities that might go beyond those available at some of the manufacturers;

- A further conclusion concerns the testing facilities of the EGYPRA OEMs. Witness testing has enabled the Technical Consultant to carefully assess the capabilities of each lab, especially for testing flammable refrigerants. For confidentiality purposes, the general description of the lab facilities given in Annex 2 does not aim to critique the individual labs or divulge where the individual labs need to be upgraded; however, the fact remains that some of the labs could benefit from an upgrade program;
- The lack of an accredited independent lab to test larger than 65,000 Btuh units using flammable refrigerants was the reason for the delay in testing central units which are part of the EGYPRA project. These units were built by the respective manufacturers; however, the arrangement for testing them independently and with good certainty could not be made on time for this report.
- Test results show that all refrigerants used in the project are viable alternatives from a thermodynamic point of view. The viability in terms of the other criteria like commercial availability, cost, and safety – among others - needs to be further researched.

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Annex 1: Test Results

The annex includes tables and charts from the test results. All OEMs results were compiled by category, for HCFC-22 equivalent refrigerants and for R-410A equivalent refrigerants.

The tables show the results for capacity in Btuh and EER at the four testing temperatures. The tables are per category of 12,000 Btuh split units, 18,000 split units and 24,000 Btuh split units. They include all alternatives refrigerant tested by each OEM.

The equivalent bar charts reflect the results in the tables: one bar chart for capacity and one bar chart for EER.

The sequence in which they are presented is:

- Table and bar chart equivalents for HCFC-22 alternatives in the 12,000 Btuh category;
- Table and bar chart equivalents for HCFC-22 alternatives in the 18,000 Btuh category;
- Table and bar chart equivalents for HCFC-22 alternatives in the 24,000 Btuh category;
- Table and bar chart equivalents for R-410A alternatives in the 12,000 Btuh category;
- Table and bar chart equivalents for R-410A alternatives in the 18,000 Btuh category;
- Table and bar chart equivalents for R-410A alternatives in the 24,000 Btuh category.

Table 19 A1: Capacity and EER Results for HCFC-22 alternatives in 12,000 Btuh category

HCFC-22 eq. 12,000 Btuh		OEM A				OEM B				OEM C				OEM E			
Ambient		T_1	T_3	T_{high}	T_{Ext}	T_1	T_3	T_{high}	T_{Ext}	T_1	T_3	T_{high}	T_{Ext}	T_1	T_3	T_{high}	T_{Ext}
R-22	CAP	11479	9699	11353	8407	11410	9988	10900	10035	11452	9960	10560	10181	10753	10415	10352	9381
	EER	9.74	6.88	7.31	5.61	8.410	6.380	6.330	5.470	10.002	7.249	6.975	6.231	10.290	8.300	7.380	6.230
R-290	CAP									10219	8677	9289	7747				
	EER									10.355	7.171	6.959	5.217				
ARM-20a R-457A	CAP									11023	9376	10892	9517				
	EER									8.358	6.239	6.582	5.556				
Opteon XL-20 R-454C	CAP					10968	9349	9946	9042					6980.6	4958.27	5762.15	4489.25
	EER					7.970	6.000	5.860	5.050					8.150	5.200	5.600	4.180
L-20 R-444B	CAP	11790	9661	10241	8881												
	EER	8.43	5.73	5.53	4.47												

Figure 15 A1 - Equivalent capacity charts for HCFC-22 alternatives in 12,000 Btuh category plotted vs HCFC-22 results

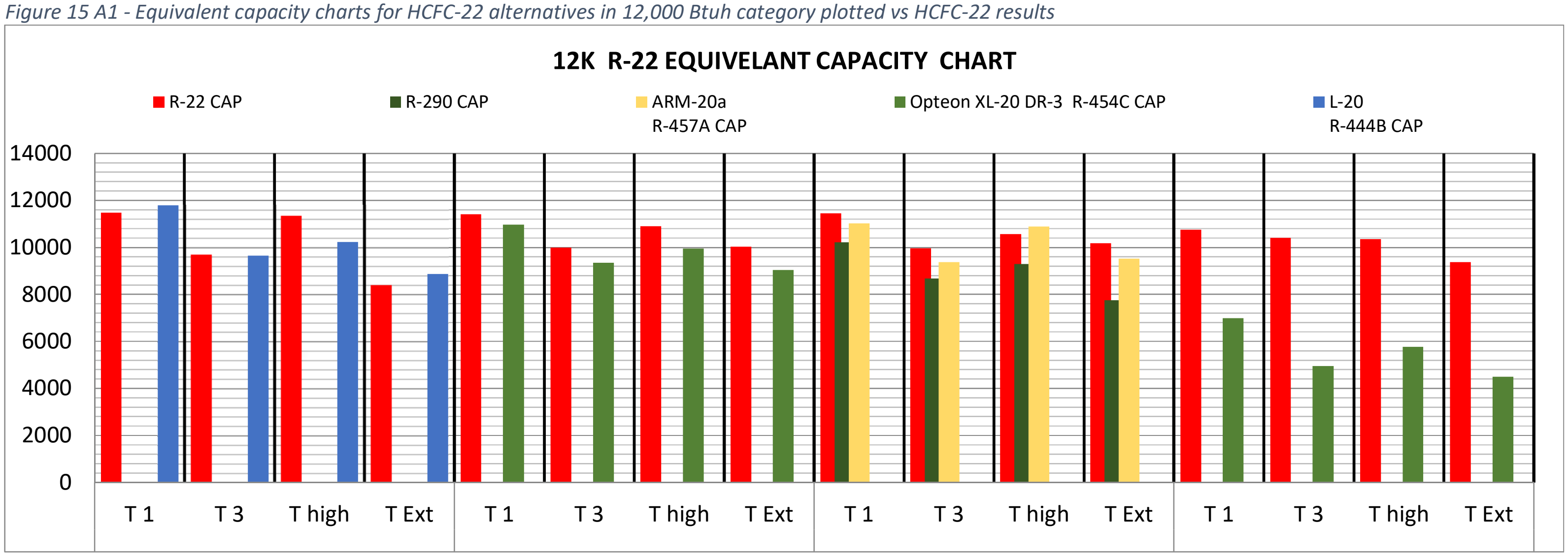


Figure 16 A1 - Equivalent EER chart for HCFC-22 alternatives in 12,000 Btuh category plotted vs HCFC-22 results

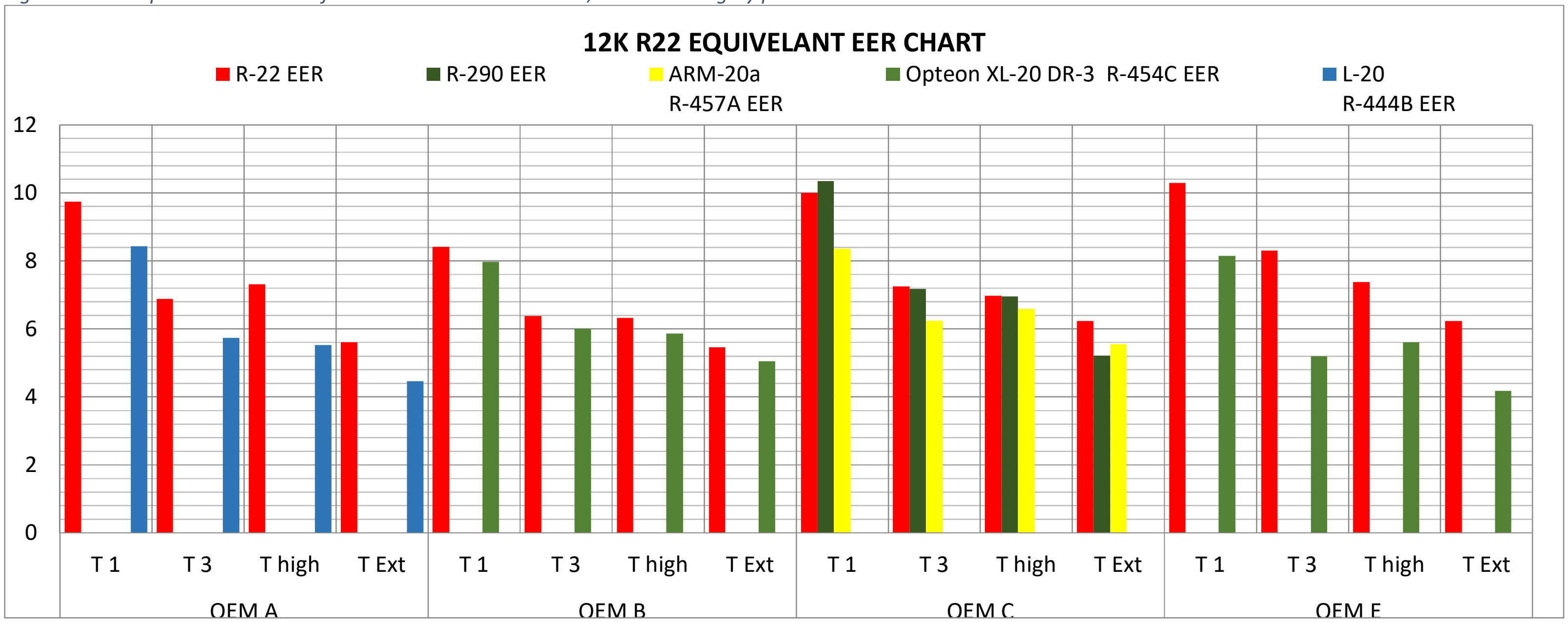


Table 20 A1- Capacity and EER results for HCFC-22 alternatives in 18,000 Btuh category

HCF-22 eq. 18,000 Btuh		OEM A				OEM B				OEM C				OEM D			
Ambient		**T 1**	**T 3**	**T high**	**T Ext**	**T 1**	**T 3**	**T high**	**T Ext**	**T 1**	**T 3**	**T high**	**T Ext**	**T 1**	**T 3**	**T high**	**T Ext**
R-22	CAP	18659	16799	17543	15046	16433	14545	13718	15350	18160	16182	17632	16292	17548	16422	14624	13948
	EER	9.410	7.260	6.980	5.550	8.930	6.650	6.370	5.330	10	7.372	7.371	6.445	10.500	8.750	7.220	6.00
R-290	CAP	16111	14067	15343	13442												
	EER	9.310	7.090	7.170	5.860												
R-457A	CAP					15257	12672	13418	12149								
	EER					9.260	6.590	6.310	5.330								
R-454C	CAP									16510	14327	15619	14250				
	EER									9.312	6.972	7.011	6.015				
R-444B	CAP													17098	15746	13498	13047
	EER													10.000	7.780	6.320	5.400

Figure 17 A1 - Equivalent capacity charts for HCFC-22 alternatives in 18,000 Btuh category plotted vs HCFC-22 results

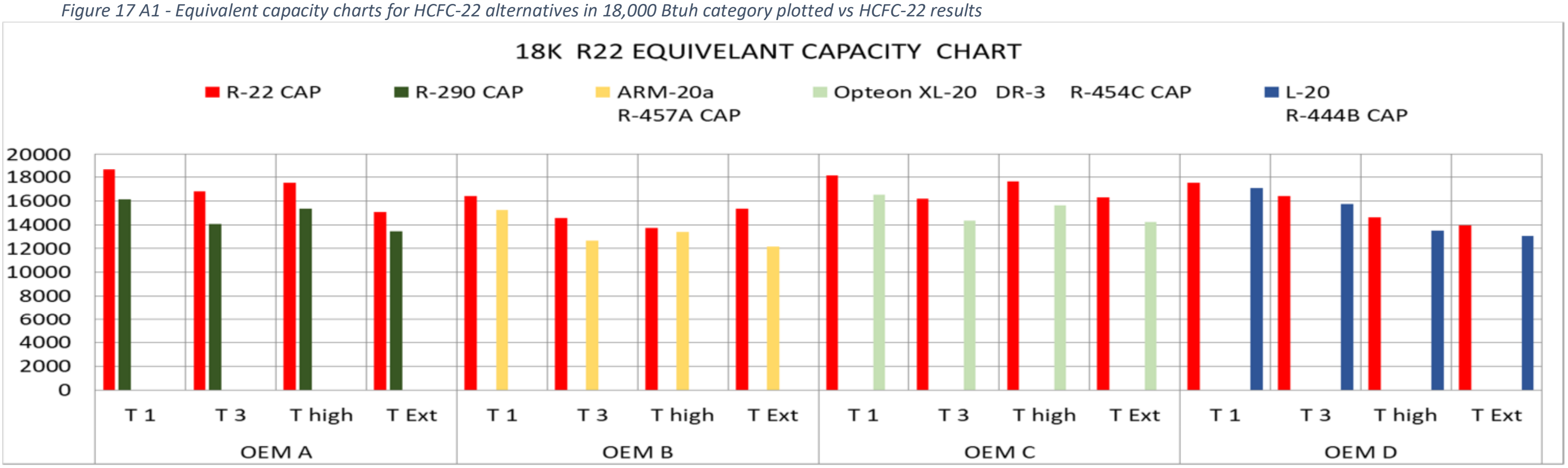


Figure 187 A1 - Equivalent EER charts for HCFC-22 alternatives in 18,000 Btuh category plotted vs HCFC-22 results

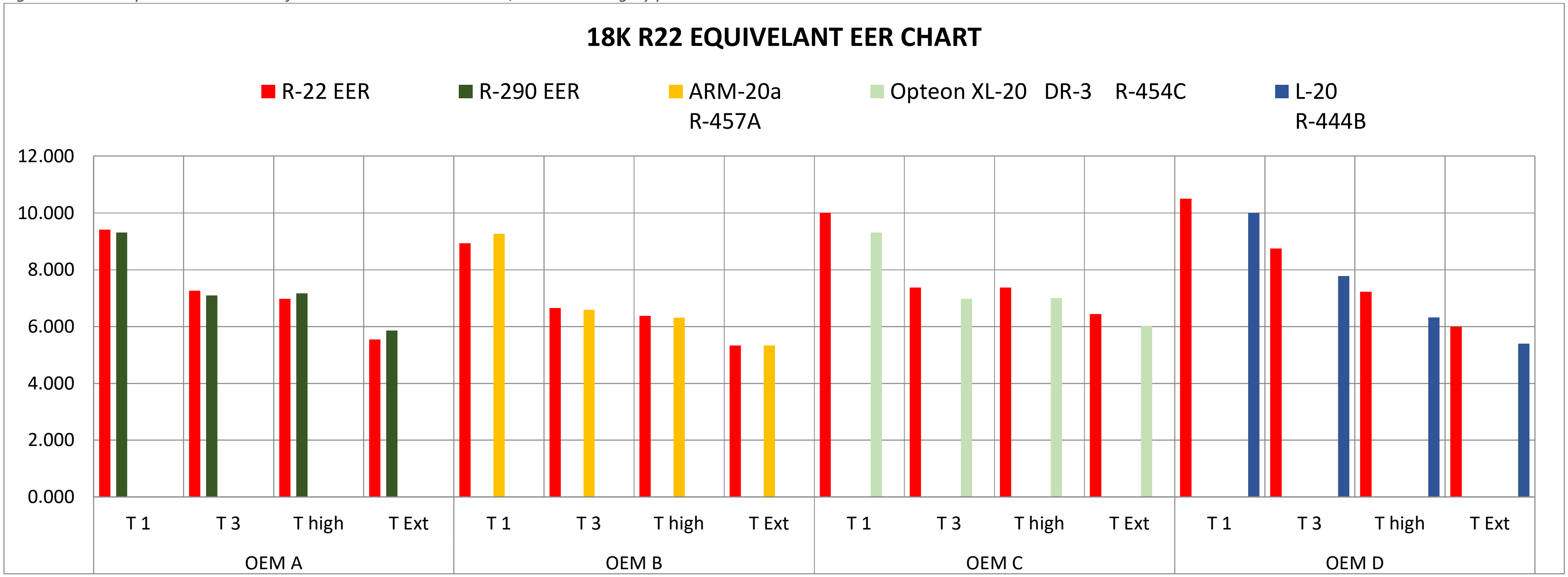


Table 21 A1 - Capacity and EER results for HCFC-22 alternatives in 24,000 Btuh category

HCFC-22 eq. 24,000 Btuh		OEM B				OEM D			
Ambient		**T 1**	**T 3**	**T high**	**T Ext**	**T 1**	**T 3**	**T high**	**T Ext**
R-22	CAP	22782				22318	21202	20144	19148
	EER	9.270				9.300	7.320	6.100	5.73
R-290	CAP								
	EER								
ARM-20a R-457A	CAP					21758	20670	19636	18657
	EER					8.78	6.85	5.82	5.25
Opteon XL-20 DR-3 R-454C	CAP								
	EER								
L-20 R-444B	CAP	23436							
	EER	7.38							

Figure 19 A1 - Equivalent capacity charts for HCFC-22 alternatives in 24,000 Btuh category plotted vs HCFC-22 results

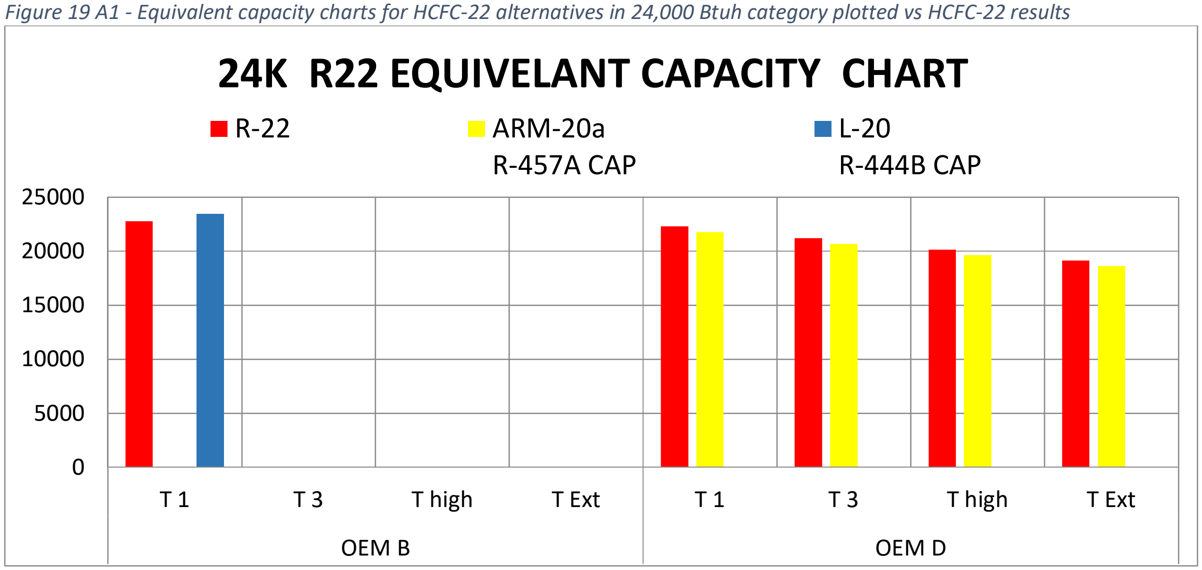


Figure 20 A1 - Equivalent EER chart for HCFC-22 alternatives in 24,000 Btuh category plotted vs HCFC-22 results

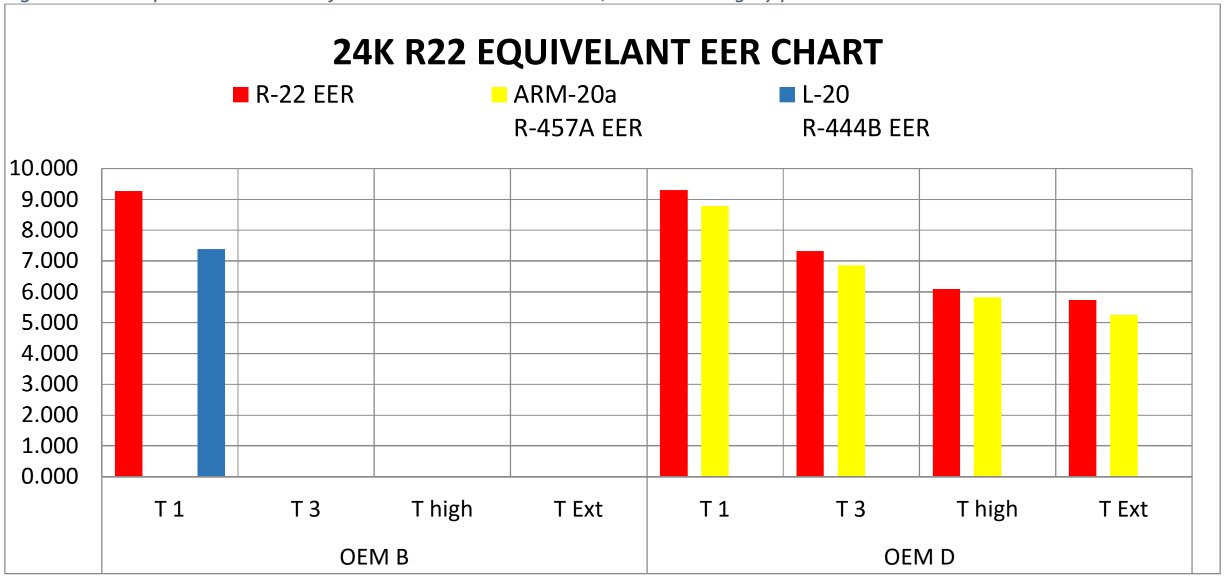


Table 22 A1 - Capacity & EER results for R-410A alternatives in 12,000 Btuh category

R-410 A eq.		OEM A				OEM B				OEM E			
12,000 Btuh Ambient		T 1	T 3	T high	T Ext	T 1	T 3	T high	T Ext	T 1	T 3	T high	T Ext
R-410A	CAP	10307	-	8313	-	12068	10343	11089	9968	11905	9369	10848	9299
	EER	8.77	-	5.43	-	10.17	7.31	7.15	5.93	10.88	7.29	7.42	5.89
ARM-71a R-459A	CAP												
	EER												
R-32	CAP					11355	9249	9822	8499				
	EER					11.51	7.53	7.26	5.69				
Opteon XL-41 DR-5 R-454B	CAP									11987	11130	12257	11094
	EER									9.92	7.95	7.66252	6.7676
L-41 R447A	CAP	9963	-	8539	-								
	EER	8.38	-	5.55	-								

Figure 21 A1 - Equivalent capacity chart for R410A alternatives in 12,000 Btuh category plotted vs R-410A results

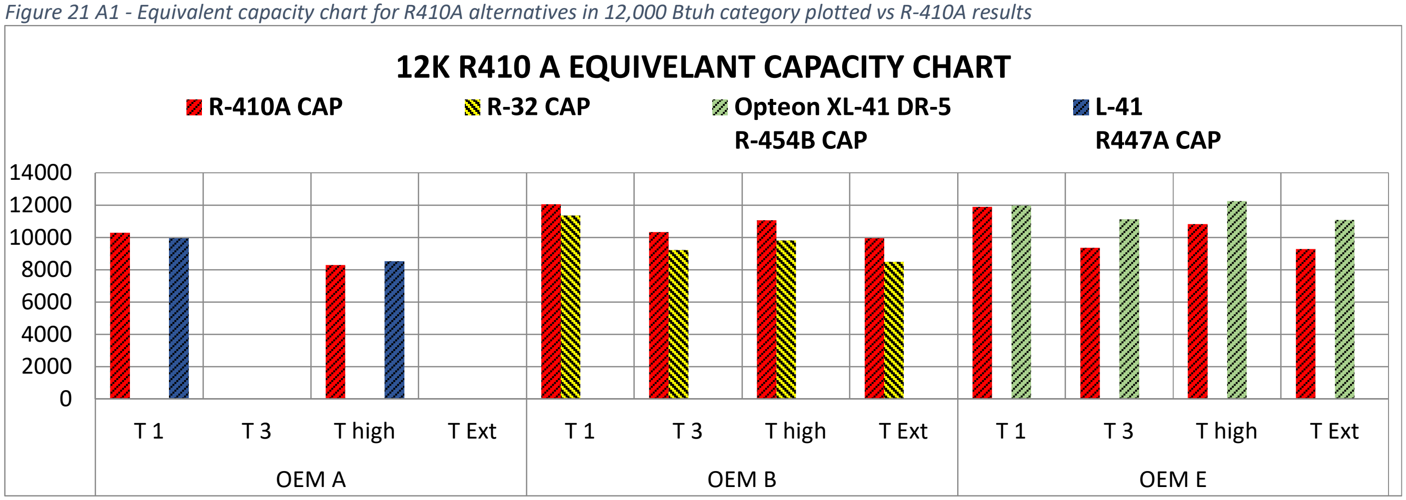


Figure 22 A1 - Equivalent EER chart for R-410A alternatives in 12,000 Btuh category plotted vs R-410A results

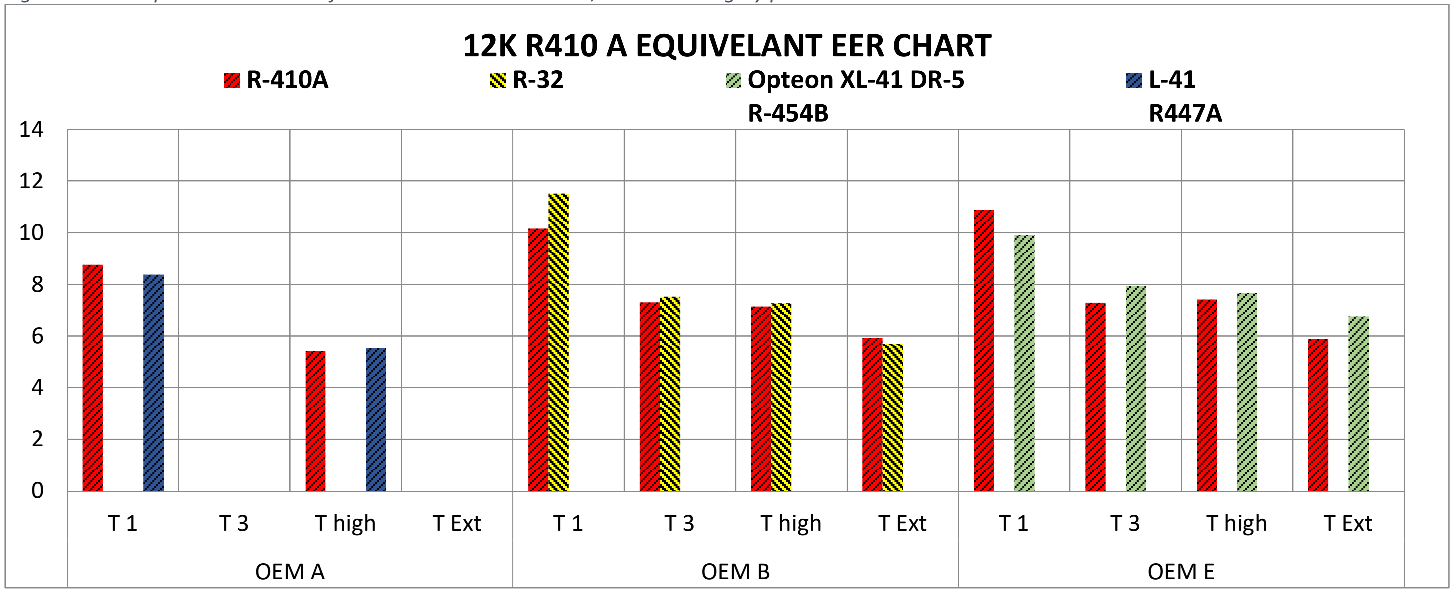


Table 23 A1 - Capacity & EER results for R-410A alternatives in 18,000 Btuh category

R-410 A eq. 18,000 Btuh		OEM A				OEM C			
Ambient		**T 1**	**T 3**	**T high**	**T Ext**	**T 1**	**T 3**	**T high**	**T Ext**
R-410A	CAP	16938	14337	14123	12441	17800	14924	16075	13746
	EER	9.8	6.8	6.3	5.1	9.152	6.497	6.485	5.116
ARM-71a R-459A	CAP					17115	14430	15392	14023
	EER					9.282	6.544	6.265	5.32
R-32	CAP	17616	15255	15761	13809				
	EER	10.03	7.1	6.65	5.29				
Opteon XL-41 DR-5 R-454B	CAP	15167	13229	13782	11800				
	EER	9.5	6.9	6.5	5.2				
L-41 R447A	CAP								
	EER								

Figure 23 A1- Equivalent capacity charts for R-410A alternatives in 18,000 Btuh category plotted vs R-410A results

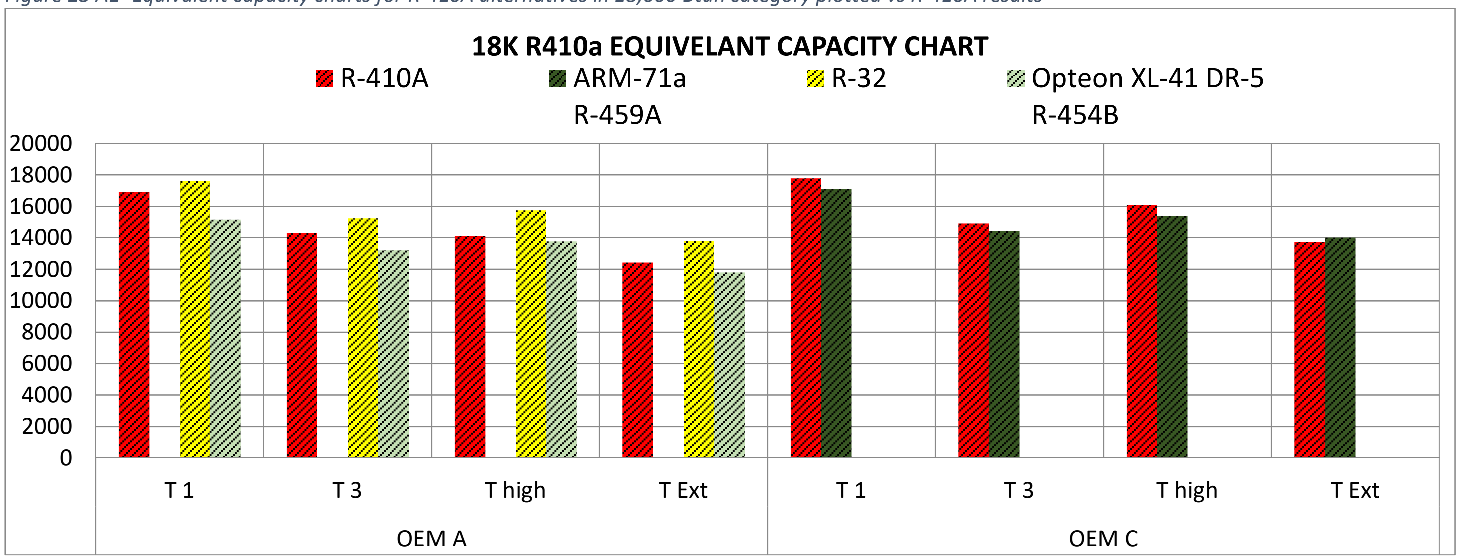


Figure 24 A1 - Equivalent EER chart for R-410A alternatives in 18,000 Btuh category plotted vs R-410A results

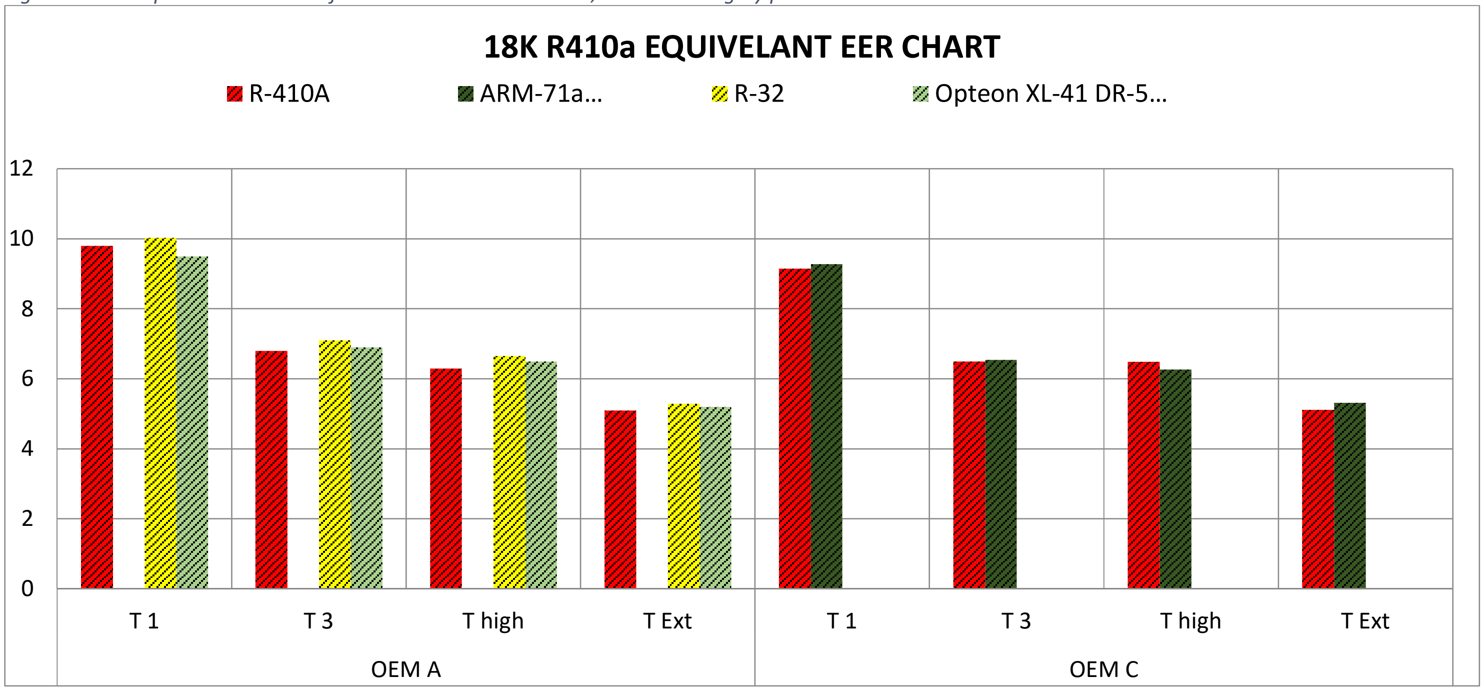


Table 24 A1 - Capacity & EER results for R-410A alternatives in 24,000 Btuh category

R-410 A eq. 24,000 Btuh		OEM C			
Ambient		T 1	T 3	T high	T Ext
R-410A	CAP	23022	19531	20534	18379
	EER	10.57	7.518	7.376	6.161
ARM-71a R-459A	CAP				
	EER				
R-32	CAP	23310	19522	21876	19035
	EER	10.62	7.228	7.459	5.988
Opteon XL-41 DR-5 R-454B	CAP	23766	20241	22268	20160
	EER	10.653	7.516	7.515	6.224
L-41 R447A	CAP				
	EER				

Figure 25 A1 - Equivalent capacity charts for R-410A alternatives in 24,000 Btuh category plotted vs R-410A results

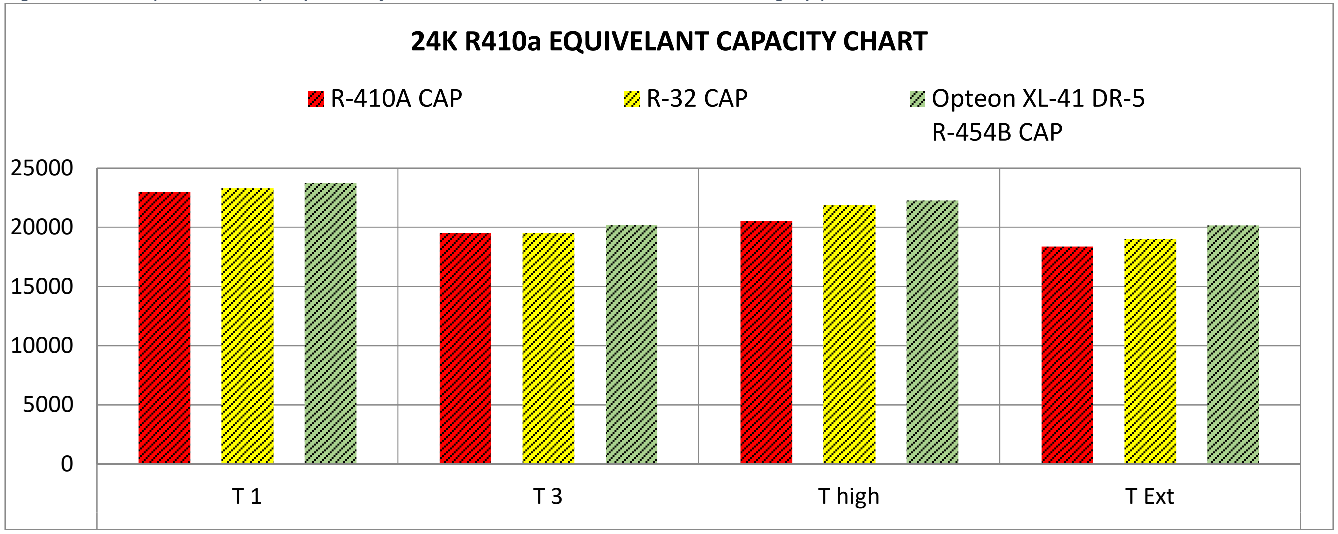
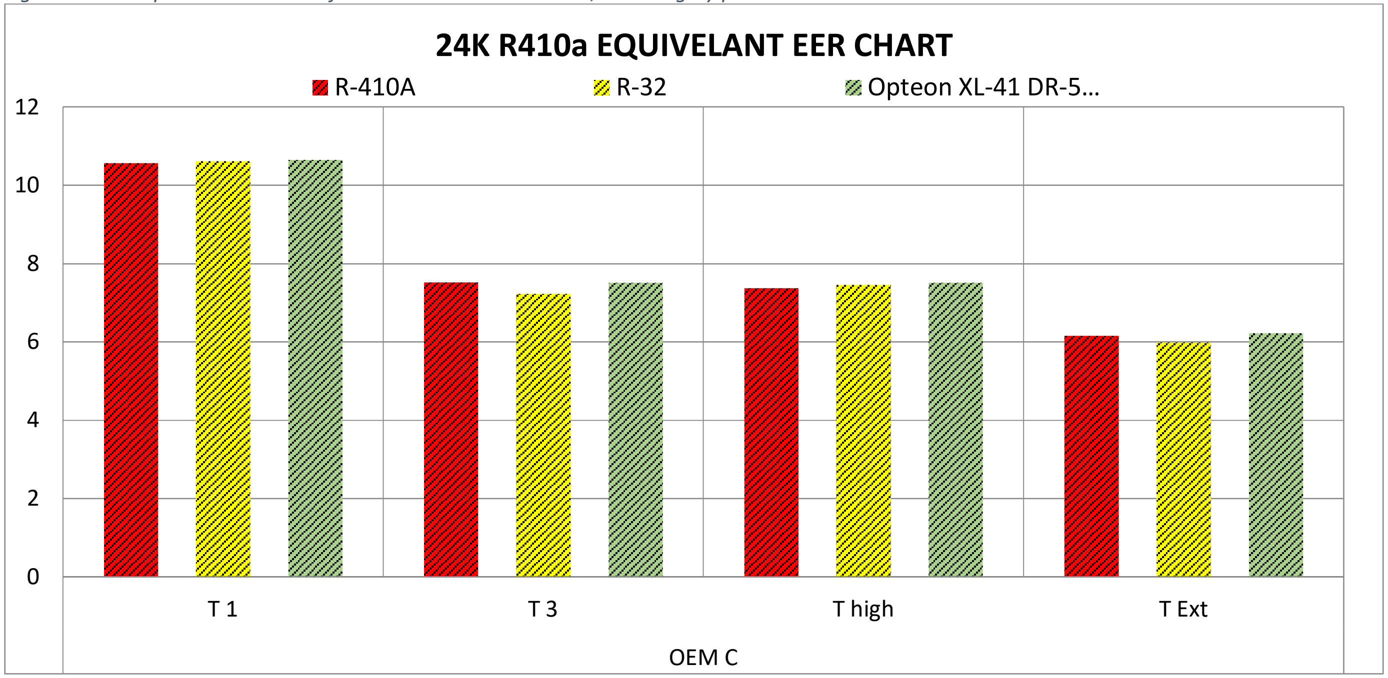


Figure 26 A1 - Equivalent EER chart for R-410A alternatives in 24,000 category plotted vs R-410A results



Annex 2: Sample Questionnaire for Local Manufacturers

Goal:

The Initiative objective is to test prototype air-conditioning units using low-GWP alternative technologies and share recommendations with manufacturers and decision makers in Egypt

Questionnaire:

This questionnaire is aimed at selected air-conditioning manufacturers in Egypt. The purpose of the questionnaire is to ask the preferences of the selected manufacturers in as far as technology selection and partnership with other stakeholders as well as getting a confirmation on their willingness to participate. All information complied of this questionnaire will be treated as confidential.

A. General Conditions	**Participant response**	
My company is willing to participate in the project. If you answer YES, please proceed to rest to questionnaire.	YES	NO

B. Technology Selection	**Participant response**	
1. Do you have a preference for the alternative refrigerant?	YES	NO
2. Alternative refrigerant choice (*you can provide more than one selection by deleting what is not applicable)*	➢ HFO Honeywell ➢ HFO DuPont ➢ R-32 ➢ Hydrocarbon	
3. Do you have a preference for the compressor manufacturer?	YES	NO
4. Provide name of compressor manufacturer(s)		

C. Application Selection	**Participant response**	
5. Do you have a preference for the type and capacity of equipment for which you will build the prototype?	YES	NO
6. My selection of equipment: (*you can provide more than one selection)*	➢ Decorative split ➢ Ducted split ➢ Rooftop package ➢ Self-contained	
7. My selection of cooling capacity	➢ 1 – 5 tons ➢ 6 – 10 tons ➢ No preference	

D. Building Prototypes	**Participant response**	
8. My company can design and/or build prototypes	YES	NO
9. How many prototypes are you willing to build?	➢ One ➢ More (*pls specify number)*	

E. Testing Prototypes	**Participant response**	
10. Which type of testing do you prefer?	➢ Independent 3rd party Testing ➢ Witness Testing at own premises	
11. If you answered **3rd Party Testing**, are you willing to pay the cost for the test?	YES	NO

12. If you answered **Witness Testing**, is your lab certified and by whom?	YES NO Certified by:

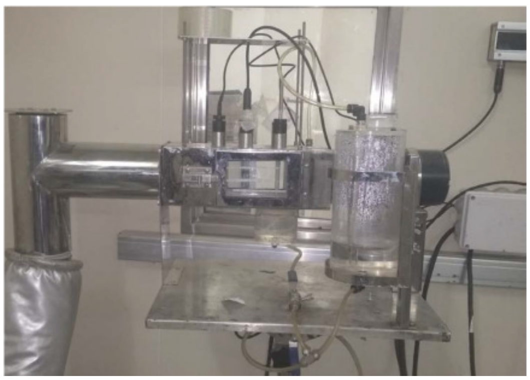
F. Logistics	Participant response
13. My company will allow independent consultants appointed by UNEP/UNIDO to oversee the development of the prototypes.	YES NO
14. If NO, pls describe what limitations you want to impose.	
15. My company will allow independent consultants appointed by UNEP/UNIDO to oversee the testing of the prototypes.	YES NO
16. If NO, pls describe what limitations you want to impose.	

G. Information about the Company	Participant response
17. Company Name	
18. Brand names used in market	
19. Company headquarters location	
20. Manufacturing location where prototype will be built	
21. Ownership percentage pertaining to the nationality where prototype is manufactured (*This information is needed to determine whether the limitations for project participation set by the Ozone Secretariat of the Montreal Protocol are applicable)*	
22. Name and title and Contact details of designated contact person for this project	

Annex 3: Brief description of Manufacturers' testing labs

The test labs of the different OEMs had varying capabilities. The best equipped labs have the following characteristics:

- Psychrometric type laboratory in which the air enthalpy test method is used to determine the cooling and heating capacities from measurements of entering and leaving wet-and dry-bulb temperatures and the associated airflow rate;
- Air sampling devices in each room (indoor room, code tester and outdoor room) are used to measure an average temperature. The airflow induced using blower through the tree (photo on left) and insulated duct passing over the temperature instruments (photo on the right) at velocity of 4-5 m/s.




- Air flow measuring apparatus (code tester) is attached to air discharge of UUT by insulated duct. The first section (receiving chamber) delivers air from UUT and contains the static pressure measuring instrument. The air is then mixed by a mixer in next section to measure its temperature by the air sampling device installed inside the code tester.

- Nozzles section, consisting of a receiving chamber and a discharge chamber separated by a partition in which four nozzles are located (see photo below). Air passes through the nozzles and is then exhausted to the test room. The pressure drop across the nozzles is measured using differential pressure transmitter. Air flow rate is calculated according to ISO 5151:2017.

- Voltage stabilizer(photo on left) is used to adjust the applied voltage for UUT, and the Power meter device is used to measure electrical parameters for it like applied voltage, power consumption, current consumption and power factor.

- Most labs are capable of testing up to 5 TR capacity (17.5 kW of cooling) measuring unit working pressure, super-heat, sub-cooling, and various temperature points on the refrigeration cycle;
- Lab consists of two well thermally insulated rooms: indoor room and outdoor room. In both rooms, temperature and humidity can be controlled preciously to achieve the required environment, as per different standards, thru refrigeration units, humidifiers and electric heaters;
- The accuracy of temperature control for dry and wet bulb temperature is 0.01 °C;
- In the indoor room there is a thermal insulated code tester where outlet air dry bulb, wet bulb and volume are measured;
- Wires sensors with accuracy of 0.1 °C are used for measuring surface temperatures at various points;
- Information gathered during the test are monitored on a computer screen;

The table below shows the parameters that are shown on the monitor

Table 25 A3: Typical parameters shown on a testing lab monitoring screen

Test Screen Display
Inlet DB
Inlet WB
Inlet Enthalpy
Outlet DB
Outlet WB
Outlet Enthalpy
Enthalpy Differential
Specific Density
Air velocity
Air volume
Standard air volume
Atmospheric pressure
Differential pressure
Heat Loss
Total capacity
Capacity ratio
EER
EER ratio
COMPRESSOR
FM surface temperature
high pressure
low pressure
Super-heat
Sub-cooling
ADDITIVE TEMP.
Accumulator outlet temp
Outlet air temperature
Evaporator coil sensor temp
Compressor inlet
O/D Motor surface
OUTDOOR UNIT
Inlet DB
Inlet WB
POWER
Voltage
Current
Wattage
Power Factor
Frequency

Research at High Ambient Temperature

The dedicated research on the performance of refrigerants at High Ambient Temperatures (HAT) was driven by the need to find low-GWP alternative refrigerants that have a better degradation of capacity and efficiency than the commercial HFCs that are replacing HCFCs in the HAT countries. The need to meet higher Minimum Efficiency Performance Standards (MEPS) while phasing out the current production of HCFC-based units was a challenge facing both the local industry in the HAT countries and the global exporters to those markets.

Three research programs were announced and completed in the time period between 2013 and 2016. While the three programs had a common goal in testing the refrigerant alternatives at temperatures higher than the standard T1 testing conditions, they were distinct in their protocols, approach, and the entity who was behind the project.

The PRAHA program mentioned in Chapter 1 is a Multilateral Fund financed project to test custom-built prototypes in four equipment categories that built by manufacturers located in HAT countries and testing them all at one independent lab. The results were compared to base units running with HCFC-22 and R-410A refrigerants.

The AREP (Alternative Refrigerant Evaluation Program) is an industry association program by the Air Conditioning, Heating, and Refrigeration Institute (AHRI) to test various categories of equipment, by various manufacturers, at their own labs by either dropping in the refrigerant or "soft" optimizing the unit.

The Oak Ridge National Laboratory (ORNL) program by the United States Department of Energy (DoE) tested two similar capacity standard units running with HCFC-22 and R-410A and soft optimizing them for the various alternative refrigerants. All tests were carried on at ORNL labs.

A comparison of the three program design criteria and testing protocols is found in table xx below. In the next sections of this chapter is a resume of the test results for the three programs and a comparison of these results.

PRAHA program

Six local Original Equipment Manufacturers (OEMs) built 14 prototypes running with five refrigerant alternatives and shipped 9 other "base units' operating with HCFC or HFC for direct comparison purposes. Testing was done at 35, 46, and 50 °C ambient temperatures with an "endurance" test at 55 °C ambient to ensure no tripping for two hours when units are run at that temperature. The indoor conditions will be kept the same for all tests; dry bulb temperature of 27 ^{o}C and a relative humidity of 50 % as per AHRI test procedures for T1 conditions (35 ^{o}C), and 29 ^{o}C and 50% for T3 (46 ^{o}C and 50 ^{o}C) conditions. A memorandum of understanding (MOU) was signed with AHRI (Air-Conditioning, Heating and Refrigerating Institute) for exchanging experience on the testing methodology benefiting of AHRI relevant research project known as AREP.

The project compares the following refrigerants: R-290, HFC-32, R-444B (herein referred to as L-20), R-447A (L-41), and DR-3 to HCFC-22 or R-410A. Prototypes operating with R-290, R-444B, and DR-3 are compared with HCFC-22 as they portray similar characteristics to HCFC-22, while HFC-32, and R-447A are compared with R-410A.

All the prototypes in every category were built to have the same cooling capacity and fit in the same box dimensions as their respective base units, and they were all required to meet the minimum energy efficiency (EER) of 7 at 46 °C. Tests were performed at an independent reputable lab for result consistency; Intertek was selected through competitive bidding. Verification for repeatability was performed to ensure that results are within the acceptable accuracy levels.

Table 26 A4 - Results for PRAHA-I program

Equipment type	Baseline refrigerant	Refrigerant tested	COP % comp to baseline @ 35°C	Capacity % comp to baseline @ 35°C	COP % comp to baseline @ 50°C	Capacity % comp to baseline @ 50°C
18,000 Btu/hr. Window Unit	HCFC-22 COP = 3.14 (35°C), 2.26 (50°C) for OEM A COP = 2.76 (35°C), 2.02 (50°C) for OEM B	L-20 (OEM A)	-11%	9%	-10%	7%
		L-20 (OEM B)	-2%	-6%	-5%	-10%
		DR-3 (OEM A)	-9%	2%	-2%	1%
24,000 Btu/hr. split system	HCFC-22 COP = 2.75 (35°C), 1.94 (50°C) for OEM C COP = 2.52 (35°C) for OEM D	HC-290 (OEM C)	4%	8%	-2%	5%
		L-20 (OEM D)	-19%	7%	-76%	-78%
		DR-3 (OEM D)	-27%	-33%	-28%	-31%
24,000 Btu/hr. split system	R-410A COP = 3.52 (35°C), 2.30 (50°C) for OEM E COP = 3.08 (35°C), 2.02 (50°C) for OEM F	HFC-32 (OEM E)	-1%	15%	-2%	16%
		HFC-32 (OEM F)	-9%	8%	-22%	-1%
		L-41 (OEM E)	-10%	20%	-7%	22%
36,000 Btu/hr. Ducted Split	HCFC-22 COP = 2.83 (35°C), 1.91 (50°C) for OEM G	L-20 (OEM G)	0%	-7%	2%	-5%
		DR-3 (OEM G)	-18%	-25%	-13%	-21%
36,000 Btu/hr. Ducted Split	R-410A COP = 2.79 (35°C), 1.84 (50°C) for OEM G	HFC-32 (OEM G)	-1%	-4%	-12%	-18%
90,000 Btu/hr. Rooftop	HCFC-22 COP = 2.95 (35°C), 2.07 (50°C) for OEM H	L-20 (OEM H)	1%	6%	-3%	5%
		DR-3 (OEM H)	-3%	-1%	-6%	-4%

AREP Program

The Alternative Refrigerant Evaluation Program (AREP) by the Air Conditioning, Heating, and Refrigeration Institute (AHRI) tested several refrigerants either as a drop-or in soft optimized units built and tested at various manufacturers who are members of AHRI (AREP 2014). Testing was done in two phases for several applications including refrigeration and at various temperatures.

Table 27 A4 - Results for the AREP program

Equipment type	Base-line refrigerant	Modifications (test-type)	Refrigerant tested	COP % compared to baseline @ 35 °C	Capacity % compared to baseline @ 35 °C	COP % compared to baseline @ 51.6 °C	Capacity % compared to baseline @ 51.6 °C
36,000 Bu/hr. Split heat pump. AREP report 52(6)	R-410A COP = 3.55 at 35C and 1.87 at 51.6C	Criteria: Drop-in. Matching superheat and sub cooling to base unit. Charge level determined by criteria and held constant for all temperatures tested.	ARM-71A	-1%	-8%	7%	-3%
			R-454A (DR-5A)	-1%	-6%	6%	-1%
			HPR2A	-4%	-11%	3%	-4%
			R-446A (L-41-1)	-2%	-10%	-1%	-3%
			R447A (L-41-2)	-1%	-7%	-1%	-4%
48,500 Btu/hr. Rooftop AREP report 56(11)	R-410A COP = 3.31 at 35C, 2.00 at 48.9C and 1.80 at 51.6C	Soft optimization. Adjustable expansion device, Variable Frequency drive matching the capacity with base unit. Varying indoor conditions.	DR-55	4%	0%	3%	0%
			HFC-32	6%	1%	NA	NA
			DR-5A	5%	1%	7%	3%
72,000 Btu/hr. Rooftop AREP report 55(10)	R-410A COP = 3.57 at 35 C and 2.06 at 51.6C	Soft Optimization. Same superheat and sub cooling as base, changing expansion devise and adjusting charge. Oil is also different.	HFC-32	2%	9%	10%	16%
34,000 Btu/hr. split AREP Report 42(5)	R-410A COP = 3.53 at 35C and 1.82 at 51.6C	Tested HFC-32 unit with POE oil and withy prototype oil for the same expansion devise and charge determined by superheat.	HFC-32 with prototype oil	3%	7%	13%	14%
60,000 Btu/hr. Rooftop AREP reports 47 & 53 (8, 9)	R-410A COP = 3.87 at 35C and 2.07 at 51.6C	Soft optimization. Matching superheat and sub cooling.	L-41-2	3%	-7%	10%	-1%
			ARM-71A	3%	-4%	10%	2%
			HPR2A	1%	-5%	8%	1%
			DR-5A	1%	-4%	2%	-3%
			HFC-32	-10%	-4%	-9%	-1%

ORNL Program

The Oak Ridge National Laboratory (ORNL) program consisted of testing alternatives of HCFC-22 and R-410A in two units of the same capacity (Abdelaziz 2015). Testing was done at the ORNL labs at various temperatures. Table below shows the criteria and a comparison of the result.

Table 28 A4 - Results for the ORNL program

Equipment Type	Lab utilized	Baseline Refrigerant	Equipment Criterion	Refriger. Tested	COP % comp to baseline @ 35°C	Capacity % comp to baseline @ 35°C	COP % comp to baseline @ 52°C	Capacity % comp to baseline @ 52°C
18,000 Btu/hr. Split unit (Carrier)	ORNL	HCFC-22 COP = 3.07 at 35°C and 1.98 at 52°C	Same machine to test all refrigerants. Criteria: matching superheat and sub cooling to base unit. Changing expansion devise. Charge level optimized at 35C	N-20B	-13%	-14%	-11%	-15%
				DR-3	-16%	-12%	-14%	-12%
				ARM-20B	-12%	-3%	-11%	-3%
				R-444B (L-20A)	-11%	-9%	-7%	-4%
				HC-290	7%	-8%	7%	-4%
18,000 Btu/hr. split unit (Carrier)	ORNL	R-410A COP = 3.4 at 35°C and 2.07 at 52°C	Same machine to test all refrigerants. Criteria: matching superheat and sub cooling to base unit. Changing expansion devise. Charge level optimized at 35C	HFC-32	4%	5%	5%	11%
				DR-55	3%	-3%	3%	0%
				R-447A (L-41)	-5%	-14%	3%	-6%
				ARM-71a	-1%	-8%	2%	-4%
				HPR-2A	-2%	-9%	5%	-1%