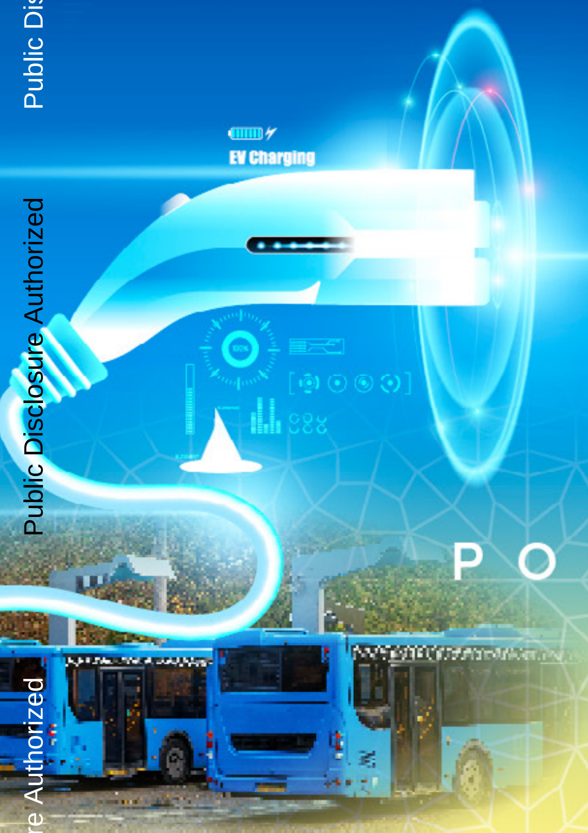

UNLOCKING ELECTRIC MOBILITY POTENTIAL IN MENA

Executive Summary – Mobile Cooling

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This summary captures key findings from the Mobile Cooling report of the World Bank MENA Regional Advisory Services and Analytics on E-Mobility. The Mobile Cooling Study has been led by Maria Rodriguez De La Rubia Gassol, with contributions from Adam Stone Diehl, Rahul Srinivasan, Ashok Sarkar, Yanchao Li, Tarek Keskes, and Yao Zhao. The analysis underpinning this Summary was commissioned by the World Bank and conducted by a consulting team of Siemens AG.

Background and Motivation

The air conditioning systems of transport vehicles, also known as mobile air-conditioning (MAC) systems, pose a challenge to a smooth transition toward transport electrification in hot regions, since these systems constitute one of the biggest auxiliary electrical loads during the operation of an electric vehicle (EV). Climatic conditions, such as ambient temperature, relative humidity, and solar radiation affect the thermal comfort of drivers and passengers, determining their demand for cabin cooling and thus MAC energy consumption (IEA 2019). A recent study (Lahlou et al. 2020) shows that within the range of 29°C to 38°C, a 1°C increase in ambient temperature results in a 10 percent to 18 percent increase in power requirement from the MAC system. For every 10 percent increase in relative humidity, MAC power consumption increases by 5 percent, and for every 10 watts per square meter increase in solar radiation, the MAC power consumption increases by 2 percent to 9 percent (Lahlou et al. 2020). Drivers' and passengers' characteristics, such as gender, age, incomes, and clothing level, also affect their thermal comfort preference and hence cumulative MAC energy consumption (Zhou, Lai, and Chen 2019).

The electricity required for MAC systems can reduce the driving range of EVs by up to 50 percent on hot days (Jeffers, Chaney, and Rugh 2015). Experience in other locales suggests that energy demand for mobile cooling in hotter regions like the Middle East and North Africa results in a significant drain of the vehicle battery and hence substantial reduction in the EV's actual driving ranges. This range reduction is further impaired during times of traffic congestion when the air conditioning loads persist through intermittent traffic flows with stop-and-go conditions.

Mobile cooling is therefore expected to play a crucial role in the upcoming transformation of the mobility sector toward comprehensive electrification. MAC not only has a significant impact on the available driving range of the vehicle and battery life, but it may also result in the need for additional EV charging infrastructure with considerable costs and associated implications for energy generation, transmission, and distribution. Furthermore, the requirement of maintaining mobile cooling within acceptable parameters leads to high greenhouse gas (GHG) emissions from energy consumption where grids rely on fossil fuels, as well as potential leakage of refrigerants from the air conditioning components. Mobile cooling interventions based on technical innovations, alternative technologies, and efficient equipment are fundamental to minimize cooling demand and optimize MAC systems.

Objective and Scope of the Study

This report analyzes the impact of MAC systems on the energy demand and associated GHG emissions derived from the electrification of buses and taxis in selected cities of Egypt, Jordan, and Morocco. The findings not only apply to these three countries, but also to other countries with a similar hot climate throughout the Middle East and North Africa. To evaluate this impact, four scenarios were modeled: the business-as-usual (BAU) scenario represents current EV models operating in these countries, which integrate conventional MAC systems and were not designed considering cooling demand optimization, and three efficient scenarios (ES1, ES2, ES3), where e-buses and e-taxis would integrate energy-efficient MAC systems and would be designed to minimize their cooling load.

The efficient scenarios comprise interventions built on international best practices and emerging global experiences. Each intervention is evaluated through a qualitative assessment considering its applicability, implementation complexity (including labor and material costs, hurdles, and barriers), and maturity. Benefits and impact mechanisms for each of the interventions are also detailed.

The study assesses barriers and gaps faced by the three countries and outlines mitigation strategies for promoting MAC optimization. The mitigation strategies interlink policy regimes and market-enabling instruments to the countries' regulatory context, and they prioritize interventions defined in efficient scenarios based on each country's unique hurdles and strengths.

Technical Analysis: Energy Consumption from MAC in E-Buses and E-Taxis

There are some parameters that need to be identified to derive energy consumption and associated GHG emissions from MAC systems: (i) the temperature set point of the cabin to ensure passengers' thermal comfort, (ii) vehicle characteristics, (iii) thermal load of the cooling requirements needed to keep the cabin temperature under the set point, (iv) mobility patterns, and (v) routes analyzed per city.

The optimal temperature set point of the cabin in buses and taxis that would provide thermal comfort (Tartarini et al. 2020) was found to be similar in all three countries: a setting at around 22°C, owing to their similar weather conditions (temperature and humidity) and cultural preferences for clothing. The main parameters used for the thermal modeling (length, breadth, vehicle volume, glass area, etc.) of the two vehicle types—e-bus and e-taxi—derive from each specific country analysis for Egypt, Jordan, and Morocco. These are presented in separate reports and match the specifications of current e-buses and e-taxis in these countries. This model represents the BAU scenario, which serves as the baseline for the cooling load and energy consumption of MAC systems. Based on the thermal comfort analysis and vehicle profiles, cooling load requirements and distributions across metabolic, radiation, ambient, and ventilation loads (assuming a set point of 22°C) were calculated using the Heat Balance Method. Results indicated little variation occurs across the three countries by EV type, as presented in figure ES.1. Thermal load analysis resulted in total cooling load of around 33 kWth[1] for e-buses and 7 kWth for e-taxis.

The largest thermal load components of a full-capacity e-bus[2] are contributed by the metabolic load of the passenger cabin and the ambient load due to temperature difference between the ambient and cabin air, that will consume over two-thirds of the overall cooling capacity. The large surface area of the bus also contributes to a significant amount of radiation load—over 25 percent of the total load.

The share of the metabolic load of a standard e-taxi[3] is relatively small (about 8 percent), as its cooling capacity is mainly used to balance the heat from solar radiation and ambient hot air. Air conditioning systems stay on throughout each complete journey as the EVs operate in dense urban traffic during times of traffic congestion, bus stops (as passengers board and alight from the bus), or during idle parking and waiting times when the only occupant is the taxi driver. The overall cooling demand of vehicles, therefore, has a strong correlation with the overall driving time.

FIGURE ES.1. • Summary of Thermal Load Modeling

	E-bus: Egypt	E-bus: Jordan	E-bus: Morocco	E-taxi: Morocco	E-taxi: Jordan	Key Findings
Metabolic Load	36%	35%	36%	8%	8%	Metabolic load is significantly higher in e-buses than in e-taxis because buses have been modeled with a large number of passengers, i.e., as fully-occupied seats in addition to standing passengers
Ventilation Load	3%	5%	8%	11%	7%	Ventilation load is similar in both types of vehicles as the share of fresh air require is the same (in %) in both cases.
Radiation Load	27%	22%	27%	49%	42%	Although radiation load from reflection, diffusion, and direct loads is proportional to vehicle surface area, it is a smaller part of overall load for buses because of higher total cooling load of the buses
Ambient Load	33%	38%	29%	33%	44%	Ambient load across the two types of vehicles varies slightly because of the similar external temperatures, which are higher in Jordan, and required internal temperatures in both cases. Another reason is the similar material used in the construction of both vehicles.
	100%	100%	100%	100%	100%	

Source: Original compilation.

1 kWth indicates thermal capacity.
2 100 passengers.
3 Five occupants: four passengers plus driver.

The performance of MAC systems is therefore very dependent on mobility patterns, which are determined by trip distance, hours of operation, number of stops, number of passengers, or average velocity of each specific route. Routes selected per city are described in detail in the country-specific reports. The main characteristics are as follows:

- **Great Cairo, Egypt:** Nine existing bus routes of the Cairo Transportation Authority (CTA), covering around 1.2 million kilometers (km) per year, at an average velocity between 18 and 45 km/hour (h), and an average daily driving time between 11 and 15 hours. The total fleet of 3,000 buses owned by CTA would be electrified.
- **Amman, Jordan:** Two existing bus routes of the Greater Amman Municipality (GAM), covering around 141,000 km per year, at an average velocity between 16 and 22 km/h, and an average daily driving time around 10 hours. The total fleet of 490 buses operated by GAM would be electrified.
- **Amman, Jordan:** Routes of the existing yellow/Al-Mumayyaz taxi fleet, covering 15.3 million km per year, 25 trips of 6 km per day, with e-taxi trips averaging a duration of 30 minutes, and a total wait time per day between rides estimated as 150 minutes (out of a 16-hour workday). The total fleet of 10,700 taxis in Amman would be electrified.
- **Rabat, Morocco:** Four existing bus routes, covering around 300,000 km per year, at an average velocity between 24 and 43 km/h, and an average daily driving time between 6 and 7 hours. The total fleet of 5,100 buses in Rabat would be electrified.
- **Casablanca, Morocco:** Three routes from an existing taxi fleet, covering around 15 million km per year, 30 trips of 8 km per day, with e-taxi trips averaging a duration of 20 minutes, and a total wait time between rides of 240 minutes (out of the work day). The total fleet of 84,000 taxis in Casablanca would be electrified.

Results of cooling demand (kWhth) and MAC electricity consumption (kWhel) per year, on average per vehicle and across the total fleet for different cities and modes of transport are summarized in table ES.1.

TABLE ES.1. • Cooling Demand and MAC Electricity Consumption Average of E-Bus and E-Taxi Modes in Four Cities

		Cooling demand per year	Electricity consumption per year	GHG emissions per year	MAC share of total EV electricity consumption (%)	MAC share of total EV electricity peak load (%)
Cairo (Egypt)	Average per e-bus	126,022 kWhth	9,574 kWhel	4.7 tCO_2e	**7**	**11**
	Total 3,000 e-buses	378 GWhth	**28.7 GWhel**	**14 $ktCO_2e$**		
Amman (Jordan)	Average per e-bus	118,028 kWhth	8,970 kWhel	6.1 tCO_2e	**16**	**17**
	Total 490 e-buses	58 GWhth	**4.4 GWhel**	**3 $ktCO_2e$**		
	Average per e-taxi	19,195 kWhth	5,092 kWhel	3.2 tCO_2e	**34**	**25**
	Total 10,700 e-taxis	206 GWhth	**54.5 GWhel**	**35 $ktCO_2e$**		
Rabat (Morocco)	Average per e-bus	83,413 kWhth	6,339 kWhel	4.7 tCO_2e	**9**	**17**
	Total 5,100 e-buses	426 GWhth	**32.3 GWhel**	**24 $ktCO_2e$**		
Casablanca (Morocco)	Average per e-taxi	14,781 kWhth	3,921 kWhel	2.8 tCO_2e	**31**	**25**
	Total 84,000 e-taxis	1,242 GWhth	**329.3 GWhel**	**240 $ktCO_2e$**		

Source: Original compilation.
(tCO_2e) tons of CO_2 equivalent

The electricity consumption of MAC across the different modes of transport analyzed in the four selected cities shows the importance of optimizing MAC, as it can have significant implications. The share of MAC electricity consumption from the e-bus battery varies from 7 percent to 16 percent on average per city but may be up to 20 percent on specific routes in Amman. The contribution is even higher in e-taxis, where the average per city shows that MAC could consume between 31 percent and 34 percent of the total battery capacity, rising to 37 percent on certain routes in Amman. The charging infrastructure should be designed and built accordingly, as well as distribution, transmission, and generation infrastructure, though this will put more stress on the national grids.

Results of this analysis reveal that the electricity consumption of MAC systems due to the electrification of the current fleet of taxis and buses in the cities analyzed may lead to very different increases in the total electricity consumption of the city, from 0.1 percent in Cairo[4] to above 8 percent in Casablanca. These differences derive from assumptions made, like the number of vehicles to be electrified per city and the current size of the local grids. However, they show that MAC can have a fundamental impact on the electricity grids of countries across the Middle East and North Africa.

Potential for MAC Systems' Optimization

There are many parameters that influence MAC system energy consumption; consequently, several interventions can be implemented to optimize MAC. One of them is the definition of the temperature set point inside the cabin. The BAU analysis was based on the consideration that this set point is 22°C. However, increasing this value to 27°C, which was the upper limit derived from the thermal comfort analysis, would generate a significant reduction of the energy demand for MAC, greater than 20 percent in Egypt and Jordan and about 45 percent in Morocco.

Yet a set point of 22°C would provide thermal comfort to the majority of passengers and may facilitate gender inclusivity, so that women with heavy clothing or traditional attire also feel comfortable. Given the significant impact of this parameter on the cooling demand and electricity consumption due to MAC, the selection of the AC set point should be carefully assessed by the e-bus and e-taxi operators.

This study analyzes three different efficient scenarios (ES) to estimate the potential of MAC optimization. Each scenario considers different combinations of 16 interventions, based on international best practices and emerging global experiences. Each intervention has been evaluated through a qualitative assessment considering its applicability, implementation complexity (including labor and material costs, hurdles, and barriers), and maturity. A comprehensive description of each measure is included in the full report on Mobile Cooling. Table ES.2 describes the interventions selected per ES and their degree

4 Small percentage is due to the fleet size, i.e., 3,000 buses in Cairo compared to a large population with a huge energy demand.

of implementation. Selected interventions were evaluated as having *medium* or *high* implementation complexity. Those evaluated as *very high* were not considered in the ES.

TABLE ES.2. • Definition of Efficient Scenarios Based on Implementation Complexity

ID	Interventions	Implementation complexity	Implementation degree (%)		
			ES1	ES2	ES3
Technical Interventions					
TI-1	Window glazing	M	20	50	50
TI-2	Zonal cooling	M	20	50	50
TI-3	Seat cooling	H	0	0	20
TI-4	Heat exchangers	H	0	0	20
TI-5	Variable capacity compressor optimization	H	0	0	20
TI-6	Refrigerant leakage prevention	M	20	50	50
TI-7	Solar reflective paint	M	20	50	50
TI-8	Default recirculation controls	M	20	50	50
TI-9	Condenser subcooling	H	0	0	20
TI-10	Secondary loop (R1234yf or R152a refrigerant)	H	0	0	20
Alternative and innovative technologies					
AIT-1	Magnetocaloric air conditioners	VH	0	0	0
AIT-2	Thermoacoustic air conditioners	VH	0	0	0
AIT-3	Vacuum-cooled water refrigeration	VH	0	0	0
Nontechnical measures					
NTM-1	Preconditioning	M	20	50	50
NTM-2	Shaded parking and charging	M	20	50	50
NTM-3	Ride sharing	H	0	0	20

Source: Original compilation.
Note: VH = very high; H = high, M = medium.

Results of MAC electricity consumption and potential savings under the ES, presented in table ES.3, vary from 7 percent to 30 percent, showing the wide potential for MAC optimization and the relevant impact that it could have, not only on the driving range of e-buses and e-taxis in Egypt, Jordan, and Morocco, but also on respective charging infrastructure and national grids. Table ES.4 depicts how potential energy savings from efficient MAC would translate from 75 megawatts (MW) (ES1) to 307 MW (ES3) reduced peak load capacity, which in ES3 would generate over US$6 million savings[5] in distribution network infrastructure upgrades every year in the three countries.

TABLE ES.3. • MAC Electricity Consumption in Great Cairo, Amman, Rabat, and Casablanca

Countries	Vehicles	Electricity consumption (GWh/year)				Savings (%)		
		BAU	ES 1	ES 2	ES 3	ES 1	ES 2	ES 3
Cairo, Egypt	3,000 e-buses	28.7	26.7	23.7	20.3	7	17	29
Amman, Jordan	490 e-buses	4.4	4.1	3.6	3.1	7	18	30
	10,700 e-taxis	54.5	50.5	54.5	38.3	7	18	30
Rabat, Morocco	5,100 e-buses	32.3	30.1	26.6	22.7	7	18	30
Casablanca, Morocco	84,000 e-taxis	329.3	305.1	268.8	231.6	7	18	30

Source: World Bank 2022.

TABLE ES.4. • MAC Peak Load in Great Cairo, Amman, Rabat, and Casablanca

Countries	Vehicles	Peak load (MW)	Peak load savings (MW)			Distribution network savings (US$/year)
		BAU	ES 1	ES 2	ES 3	ES 3
Cairo, Egypt	3,000 e-buses	22.4	1.6	3.9	6.6	**131,681**
Amman, Jordan	490 e-buses	5.3	0.4	0.9	1.6	**31,128**
	10,700 e-taxis	107	7.9	19.7	31.8	**635,429**
Rabat, Morocco	5,100 e-buses	56.6	4.1	10.4	17.4	**348,095**
Casablanca, Morocco	84,000 e-taxis	840	61.8	154.5	249.4	**4,988,312**

Source: Original compilation.

5 The estimated value of reduced capacity requirements is US$20/kW-year.

MAC systems' Optimization and Mitigation Strategies

The implementation of interventions aimed at increasing the efficiency of MAC systems and reducing their energy consumption and greenhouse footprint require enabling regulatory frameworks supported by market-enabling instruments. Based on a thorough assessment of global best practices, this report interlinks regulatory measures and market-enabling instruments to overcome the barriers that the three countries under analysis are currently facing. The description of each regulatory measure and market-enabling instrument is included in the full report on Mobile Cooling.

The regulatory measures identified outline mandatory legal requirements and obligations set and enacted at a legislative level; sets of rules and legal obligations that reflect the vision, mission, and long-term objectives of legislative authorities; and the initiation of upstream transformational changes that ripple downstream to government bodies, ministries, and further down to involved sectors and end customers. The market-enabling instruments proposed cover mandatory and voluntary schemes and programs designed in line with the regulatory regime. Table ES.5 summarizes the specific instruments evaluated, and table ES.6 shows the interlinks between them, along with the implementation priority level recommended per country. Tables ES.7, ES.8, and ES.9 present main barriers and mitigation strategies per country.

As reflected in tables ES.7 to ES.9, one persistent barrier across the three countries is the lack of technical capacity or investigation on the issues of MAC. This is correlated with the nascent stage of the efficient MAC market around the world, so national and regional capacity should be developed as the international market grows. However, international market on e-mobility is currently more advanced in Europe, USA and China where the weather is quite different from the MENA region. Heating and cooling needs differ, and consequently technical solutions developed for these counties may not be fully adequate for the MENA countries. Therefore, technical capacity in countries with very hot weather like MENA should be boosted to allow the region taking the lead on the acceleration of efficient MAC systems' market development.

TABLE ES.5 • Regulatory Regimes and Market-Enabling Instruments Evaluated

Regulatory measures		Market enabling instruments	
RG-1	Mandatory equipment labeling	MI-1	Mechanism to update vehicle emission testing standards
RG-2	Reporting obligations	MI-2	Incentive scheme for retrofitting inefficient equipment
RG-3	Regulatory approval for new technologies	MI-3	Training and certification programs for mobile air-conditioning technicians
RG-4	Maximum GWP limit for refrigerants	MI-4	Punitive measures for noncompliance
RG-5	Import regulations to include emissions standards	MI-5	Incentive scheme for vendors and car manufacturers
RG-6	Updated standards for testing	MI-6	Updated policy guidelines for fuel economy regulation testing

Regulatory measures		Market enabling instruments	
RG-7	Import regulations to penalize indirect HFCs	MI-7	Sectorwide implementation of Minimum Energy Performance Standards
		MI-8	Guidelines for GWP recycling
		MI-9	Guidelines for mandating upper limits for refrigerant leakage
		MI-10	Policy instrument to regulate maximum thermal transmittance for vehicle windows and glass surfaces
		MI-11	Establish a funding initiative for MAC innovation
		MI-12	Establish an incentive scheme to retrofit MACs with specific interventions
		MI-13	Awareness campaign for best practices through multiple channels
		MI-14	Policy guidelines to promote parking shades

Source: Original compilation.

TABLE ES.6 • Priority Implementation Level Recommended per Country and Interlinks Between Regulatory Measures and Market-Enabling Instruments

	RG-1	RG-2	RG-3	RG-4	RG-5	RG-6	RG-7	Priority		
								Egypt	Jordan	Morocco
MI-1		E			E	E		H	H	H
MI-2			S		S			H	H	H
MI-3		S				S		H	H	H
MI-4		E		E			E	H	L	L
MI-5			S	S				L	L	L
MI-6						E		L	L	H
MI-7	E							H	H	H
MI-8				E				L	H	H
MI-9		E			E	E		L	L	H
MI-10		E				E		L	L	L
MI-11			S					L	H	L
MI-12			S					L	H	H
MI-13	S							H	H	H
MI-14								H	H	H
Priority: Egypt	H	L	L	L	H	H	L			
Priority: Jordan	H	L	L	H	H	H	L			
Priority: Morocco	H	H	L	L	H	H	H			

Source: Original compilation.

Note: RG = regulatory measure; MI = market-enabling instrument; E = essential MI required for the implementation of RG; S = supplementary MI facilitating a better implementation of RG; H = high priority, short- to medium-term implementation; L = low priority, long-term implementation.

TABLE ES.7 • Mitigation Strategies for Promoting MAC Energy Efficiency in Egypt.

	Barriers	Mitigation strategy
Technical capacity	Through the efforts of the Ministry of Higher Education and Scientific Research (MoHE), a pool of local EV and transport energy efficiency experts is slowly forming in Egypt, but most of them do not cover MAC. Events, competitions, as well as research grants have been offered to attract universities' and students' interest in MAC and support local research on EV technology and its application in Egypt. In addition, various international and local institutions have provided training and certifications for technicians to perform energy-saving retrofits of vehicles. However, when it comes to MACs, education and training still focus mostly on function without much consideration of energy efficiency.	MAC systems to be integrated into existing vehicle training and certification programs for local technicians, e-mobility-related campaigns, and research grants; and higher education curriculums at technical institutions and universities. These efforts will produce a pool of local skilled workers and experts in MAC to implement future MAC technical interventions, and to develop technologies to further improve MAC energy efficiency. Training and certification programs on MAC systems for local technicians to be launched in partnership with international and local institutions to develop a local skilled workforce to implement MAC technical interventions. MoHE to incorporate MAC energy efficiency in future e-mobility–related events, competitions, and research campaigns. MoHE to collaborate with technical institutions and universities to add MAC systems into higher education curricula in relevant disciplines to ensure the long-term availability of a skilled MAC workforce and experts.
Policy and regulation	The MAC industry in Egypt (suppliers, vendors, installers, maintainers, testers, certifiers, etc.) functions with a central industry body, supervising regulator, and compliance to national standards through the Egyptian Organization for Standardization (EOS). There is, however, a lack of both mature market players with enough experience and of neutral agencies that could test and certify equipment. Egypt has made progress in EE in sectors like transport—where EOS regulates the EE of vehicles entering the domestic market—and of buildings, through minimum energy performance standards and mandatory labeling schemes for home appliances. But MAC EE is yet to be integrated in both schemes.	MAC systems to be included in existing or new EE regulations and measures, standardization, and testing procedures, and license renewal requirements. Adoption of MAC-related interventions are to be included in Traffic Law 66/193 as a requirement for license renewal; MAC systems are to be added to vehicle emission testing standards. Minimum energy performance standards (MEPS) for compressors and fans, regulation of the MAC efficiency of imported vehicles, and testing procedures and energy performance of MAC systems are to be monitored by developing low-cost, reliable, and reproducible standard testing procedures. Manufacturers of MAC and e-vehicles should comply with these reguations even when vehicle purchasers will look at energy performance of the vehicle as a whole. However, the energy efficiency label of the MAC system may be available too if the customer is interested, especially in countries with extreme weather.
Information and awareness	There are no studies or official statistics on the energy consumption of MAC systems in public and private transport. There is a lack of market availability of efficient MAC technologies and interventions because of an unclear business case evaluation by vendors and suppliers.	Public awareness campaigns on MAC EE can use multiple channels like social media. Mandatory labeling for MAC. Adding MAC to the existing EE labeling scheme would provide easily comprehensible information, encouraging customers and EV operators to incorporate MAC efficiency into their purchasing decisions.
Finance	Lack of financing for emerging technologies, like MAC EE, at favorable terms. Lack of understanding of the technology leads to higher interest rates to accommodate associated risks. Lack of incentives and mitigation mechanisms.	Map risk-mitigation mechanisms (such as guarantees, grants, and fiscal incentives) to encourage private sector financing, particularly targeting institutional investors. Map the full range of financial instruments available to facilitate investment in mobile cooling, at different stages of the project life cycle and across the entire risk-return spectrum. This may focus on new forms of equity and debt investment. Understand opportunities and challenges of financing instruments alternative to traditional debt, in different economic and regulatory environments and in light of ongoing financial reforms. Increase awareness of banking institutions and provide training to bankers on MAC technologies.

TABLE ES.8. • Mitigation Strategies for Promoting MAC Energy Efficiency in Jordan.

	Barriers	Mitigation strategy
Technical capacity	Local technicians are able to implement (or retrofit) certain technical interventions like solar reflective paints but lack the requisite skills, training, and certifications for interventions like variable capacity compressor optimization.	Implement vocational training programs at organizations such as VTC (Vocational Training Centers) and LTUC (Luminus Technical University College) to build capacity in MAC EE interventions. Training and certification programs on MAC systems for local technicians to be launched in partnership with international and local institutions to develop local skilled workforce to implement MAC technical interventions. Incorporate MAC EE in future e-mobility–related events, competitions, and research campaigns. Collaborate with technical institutions and universities to add MAC systems into higher education curricula in relevant disciplines to ensure the long-term availability of a skilled MAC workforce and experts.
Policy and regulation	There are no regulations or standards specific to MAC.	Identify and revise regulations that are applicable for common types of vehicles imported into the country. Build an incentive and penalty structure for transport operators (such as public transport and taxi operators) to reduce MAC loads. Amend Traffic Law No. 49 to introduce stricter environmental and emissions standards for vehicles, including those emitted from MAC systems. Amend the Vehicle Licensing and Registration Bylaw No. 104 to condition the initial licensing and license renewal of vehicles on the adoption of certain technical interventions. This could be limited—at least initially—to vehicles with a commercial license (such as public transport and taxis). Introduction of new standards by the Jordan Standards and Metrology Organization (JSMO) specific to MAC systems.
Information and awareness	Beyond general awareness on vehicle exhaust emissions, there is no awareness or information sharing on matters related to MAC.	Build awareness through partnerships with international agencies in various entities, such as the Ministry of Interior (and associated departments), municipalities and transport regulators, the JSMO, VTC and other vocational training centers and technical universities, and the Royal Scientific Society (RSS) and other testing labs.
Finance	Lack of financing for emerging technologies, like MAC EE, at favorable terms. Lack of understanding of the technology by financial institutions leads to higher interest rates to accommodate associated risks. Lack of incentives and mitigation mechanisms.	Map risk-mitigation mechanisms (such as guarantees, grants, and fiscal incentives) to encourage private sector financing, particularly among institutional investors. Map the full range of financial instruments available to facilitate investment in mobile cooling, at different stages of the project life cycle and across the entire risk-return spectrum. This may focus on new forms of equity and debt investment. Understand opportunities and challenges of financing instruments that are alternatives to traditional debt, in different economic and regulatory environments and in light of ongoing financial reforms. Increase awareness of banking institutions and provide training to bankers on MAC technologies.

TABLE ES.9. • Mitigation Strategies for Promoting MAC Energy Efficiency in Morocco

	Barriers	Mitigation strategy
Technical capacity	Although many avenues exist for technical and vocational training in Morocco for air-conditioning, such as Ecole Hassania des Traveaux Public (EHTP) and the University of Science Semlalia-Marrakech, both schools do not specialize in MAC-related training and certification for electric vehicles. There is a similar lack of a standardized testing, training system, and professional certificate programs and professional licenses in MAC systems.	Expand the current training programs on EE to include MAC systems to develop the local workforce for undertaking the MAC technical intervention. Develop training and certification programs on the MAC system for local technicians to be launched in partnership with international and local institutions to develop local skilled workforce to implement the MAC technical interventions. Incorporate MAC EE as a part of future e-mobility–related events, competition, and research campaigns. Collaborate with technical institutions and universities to add MAC systems into higher education curriculum in relevant disciplines to ensure long-term availability of skilled MAC workforce and experts.
Policy and regulation	Regulations do not consider the major impact of MAC on vehicles. Lack of standards and agencies to test and approve MAC equipment. No available agencies or laboratories specialized in testing and certifying MAC equipment. While the thermal regulation code specifies the rules of EE in buildings, the decrees related to the deployment of EE in industry and transport have yet to be developed.	Include MAC into the scope of Energy Efficiency Law 47-09. Include MAC interventions as part of Traffic Law n°52-05. Set up standards and rules on MAC EE and enforce them with penalties for noncompliance. Standardize test methods to measure MAC energy consumption. Open up a testing agency or laboratory for local research and development for innovative testing method and MAC technologies. Expand the existing programs like audit scheme and thermal regulation code to incorporate MAC systems; introduce reporting obligations for MAC load in public and private transport fleet operations and limit the maximum thermal transmittance in vehicle glass. Develop a thermal regulation code for MAC that would involve defining the minimum annual cooling requirements of vehicles, the thermal properties of the various components of the envelope of the vehicle, and the minimum energy performance standards for MAC equipment. Speeding up the phase-out of R-22 refrigerant (Freon) in the country by setting up a regulatory framework prohibiting the import of AC systems using it.
Information and awareness	Every year, AMEE organizes awareness campaigns for the public and training for professionals to promote eco-friendly driving but does not cover efficient options for MAC. Limited awareness of the negative impact of AC on climate change and environment in general. Lack of awareness of the negative impact of HFC refrigerants on climate change and environment in general.	Organizing awareness campaigns for the public to encourage customers to go for alternative and innovative technologies for MAC, as well as nontechnical interventions such as parking in the shade (and possibly encourage shaded parking areas) and promoting window glazing as a way to decrease heat from the sun.
Finance	Lack of financing for emerging technologies, like MAC EE, at favorable terms. Lack of understanding of the technology leads to higher interest to accommodate associated risks. Lack of incentives and mitigation mechanisms.	Map risk mitigation mechanisms (such as guarantees, grants, and fiscal incentives) to encourage private sector financing, particularly targeting institutional investors. Map the full range of financial instruments available to facilitate investment in mobile cooling, at different stages of the project life cycle and across the entire risk-return spectrum. This may focus on new forms of equity and debt investment. Understand opportunities and challenges of financing instruments that are alternatives to traditional debt, in different economic and regulatory environments, and in light of on-going financial reforms. Increase MAC technologies awareness and training in banking sector.

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