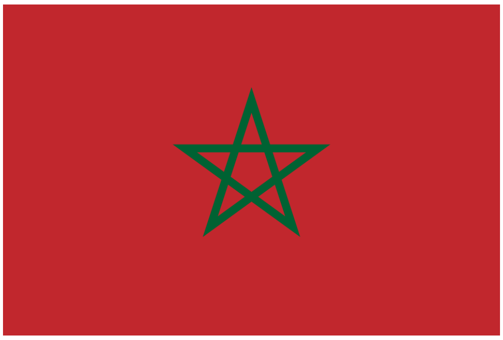
Morocco



EPIC Deploy: Morocco Cooling assessment[1]

[1] **Scope and use:** This report provides contextual and screening-level information to support the preparation of applications. It is not a technical design standard, legal opinion, official national inventory or substitute for site-specific due diligence. Applicants remain responsible for validating demand, baseline conditions, equipment sizing, regulatory compliance and expected emission reductions for the proposed project.

Cooling Demand Taxonomy

Morocco's cooling landscape is shaped by a steep Mediterranean-to-Saharan climatic gradient, a near-universal but still fossil-dominated electricity system, a comparatively developed energy-efficiency and refrigerant-policy framework, and a rapidly expanding appliance stock. The binding constraints are not basic electricity access, which is essentially universal, but the decarbonisation of a coal-heavy grid, the management of rising summer peaks, the affordability and efficiency of new equipment, and the quality of the building stock. The key country framework conditions are summarised in Table 1 as a quick reference. The sections that follow develop each dimension in greater detail.

Table 1 – Morocco: key cooling taxonomy data

Economics and demographics		**Climatic conditions**	
Nominal GDP (2024; 2025 estimate)	approx. USD 160.6 B (2024, current US$); latest World Bank 2025 estimate approx. USD 182.4 B [1]	Avg. Cooling Degree Days (18°C base)	approx. 1,470 °C·day/yr (2020) [2]
GDP per capita (2024; 2025 estimate)	approx. USD 4,300-4,700, depending on 2024/2025 series [1]	Mean annual temperature range	approx. 5–38 °C, zone-dependent [3]
GDP growth (medium-term)	approx. 3.5%/yr [4]	Coastal relative humidity	approx. 70–80% [3]
Total population (2024 census)	36.83 M [5]	Warming since 1960	approx. +0.9–1.0 °C [3][6]
Population growth rate	0.85%/yr [5]	Projected warming by 2050s (BAU)	approx. +1.5–1.8 °C [6]
Urban population share	62.8% [5]	Cooling Degree Days trend	rising; CDDs increased by an average of 3.5%/yr over the past two decades (CDD base 21 °C; IEA/CMCC Weather for Energy Tracker) [6]
Urban growth rate	1.24%/yr [5]	Hot-day / heat-wave trend	hot days about 20% more frequent per month in autumn (since 1960); heat waves projected about 26 days longer by 2100 [7]
Growth-driving sectors	phosphates, automotive, aerospace, agri-food, tourism, offshoring [1][4]	Water stress	severe; <620 m^3/capita/yr [6]
Energy infrastructure		**Regulatory framework**	
National electrification rate	approx. 100% [8]	Cooling-appliance efficiency and labelling requirements	Mandatory energy labelling and minimum-performance requirements for listed air-

			conditioner and refrigerator categories; effective 12 March 2025 under the applicable ministerial orders and NM standards [9]
Urban electricity access	approx. 100% [8]	R22 / HCFC phase-out	HPMP Stage II; completion end-2026 [10]
Rural electricity access	approx. 99.9% (PERG) [8]	HFC phase-down (Kigali)	Ratified 2022; in force [11]
Renewable share of generation	approx. 21.0% of electricity generation in 2023 [12]	National Cooling Action Plan	Under development (RCREEE/UNEP/CCAC) [13]
Grid reliability	Generally reliable nationally; site-level continuity and voltage quality must be checked [14]	NDC emissions target	NDC 3.0: −21.6% unconditional / −53% total by 2035 [15]
Residential electricity tariff	approx. USD 0.12/kWh [16]	Product-specific CMIM marking and/or Certificate of Conformity (CoC) via PortNet; CE marking alone is not sufficient [9][17]	Product-specific CMIM marking and/or Certificate of Conformity via PortNet; CE documentation alone is not sufficient [9][17]
Total electricity production (2024)	approx. 43.7 TWh/yr [8]	Building thermal code	RTCM, in force since 2015 [18]
Adopted IFI combined-margin reference factor	0.83 kg CO_2eq/kWh (2020), used consistently in the sector estimates [16]	Energy-efficiency law	Law 47-09 [18]

General Overview

Geography and climate

Morocco lies on the north-western edge of Africa, with coastlines on both the Mediterranean Sea and the Atlantic Ocean [5]. Boundaries and names shown in the maps follow the source datasets used for the assessment and do not imply a position on legal status or international boundaries. The country spans a pronounced climatic gradient: a temperate Mediterranean and Atlantic coastal fringe where most of the population and economic activity concentrate; the Rif and Atlas mountain chains, which receive significant rainfall and experience cold winters; and a hot, arid pre-Saharan and Saharan interior to the south and east [3]. Morocco's building-energy regulation formally recognises six climatic zones, each defined by a representative city and used to set differentiated thermal-performance requirements.

The geographic and climatic context described above is illustrated in Figure 1.

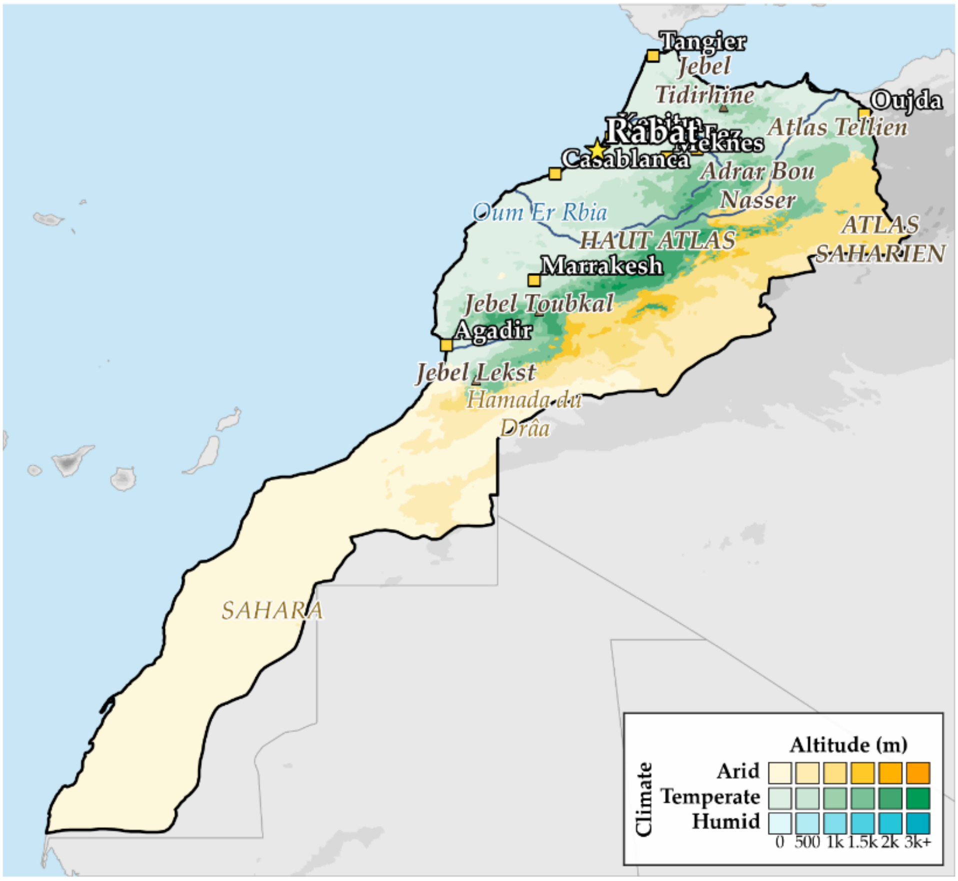


Figure 1 – Morocco: geography and climate

This six-zone structure, summarised in Table 2, is the natural reference framework for cooling demand and is used throughout this chapter.

Table 2 – Morocco: climatic zones (RTCM reference framework) [18]

Zone (reference city)	Climatic character	Key cooling relevance
Z1 – Agadir	Mild Atlantic coastal; small annual amplitude	Moderate cooling loads; humidity-driven comfort on the coast
Z2 – Tangier	Mediterranean coastal / northern	Moderate; rising summer peaks; tourism-driven demand
Z3 – Fès	Continental interior; hot summers, cool winters	High summer cooling and winter heating; dual demand
Z4 – Ifrane	Mountain; cold winters, mild summers	Heating-dominated; limited cooling need
Z5 – Marrakech	Semi-arid; hot, dry summers	High cooling demand; large built-up tourist stock
Z6 – Errachidia	Pre-Saharan / desert; very hot	Highest cooling demand; extreme summer peaks

The corresponding climatic gradient is mapped in Figure 1, and the resulting distribution of cooling degree days is shown in Figure 2.

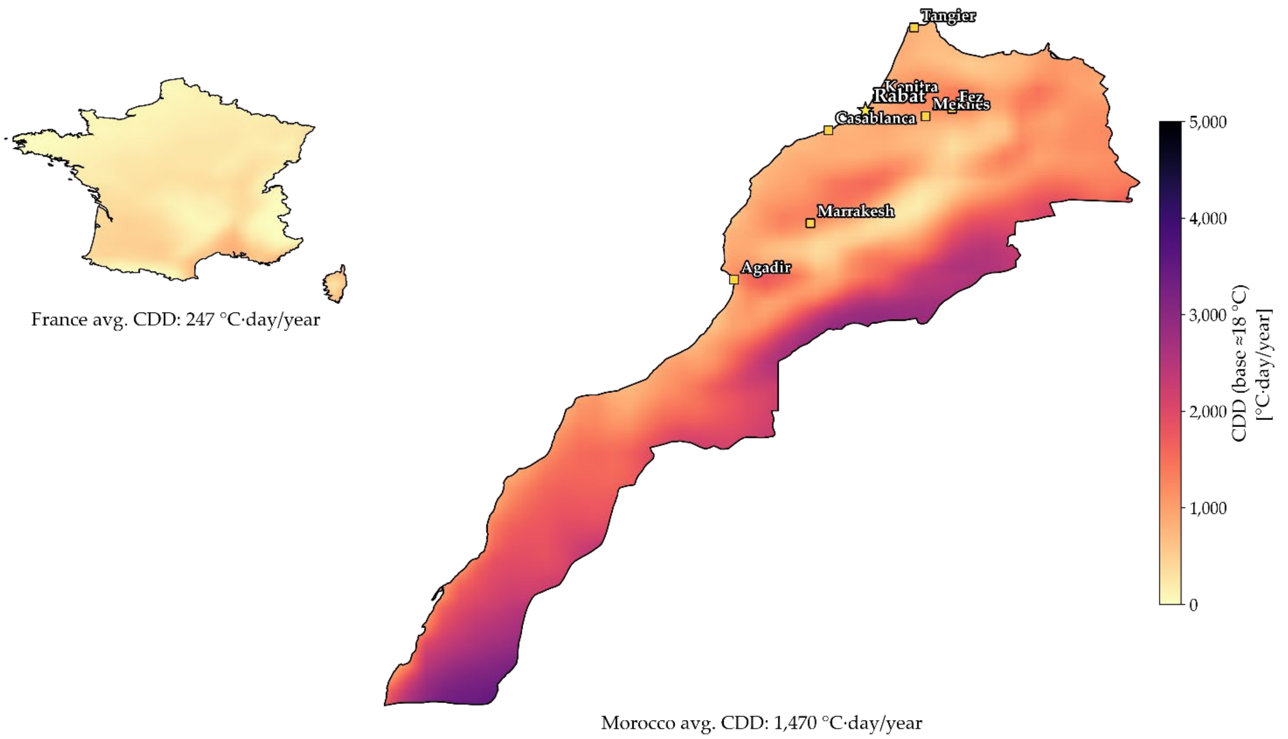


Figure 2 – Morocco: cooling degree days (18 °C) spatial distribution

Climate projections compound the cooling challenge. Mean annual temperatures have risen by approximately 0.9-1.0 °C since the 1960s [3][6], and under business-as-usual scenarios a further increase of about 1.5-1.8 °C is projected by the 2050s, with higher-emission pathways reaching +2 to +3 °C or more by end-century [6]. Published sources point to a clear increase in cooling degree days. The 3.5%/yr trend is reported as an indicative secondary-source estimate and is not used as a calibration parameter in the sector models. Critically, Morocco's defining climate vulnerability is water stress rather than electricity access: renewable water availability has fallen below about 620 m³ per capita per year, deep into the absolute-scarcity range [6][7]. This constrains cooling directly. It caps the role of evaporative cooling, which is thermodynamically well suited to the dry interior and the south but consumes water precisely where it is scarcest, so its deployment in schools and public buildings must be assessed against local water budgets rather than climate alone. It also raises the stakes for the food cold chain: irrigation-dependent horticulture is the most water-intensive use of the resource, which makes every tonne of produce lost after harvest a loss of embodied water as well as of embodied carbon. And it exposes the coal-and-water nexus of the grid itself, since thermal generation requires cooling water in a drying climate.

Population, urbanisation and vulnerability

The 2024 census (RGPH 2024) counted 36,828,330 inhabitants and indicated an urbanisation rate of 62.8% [5]. Population growth has slowed to 0.85% per year nationally, with urban areas growing at 1.24% and rural areas nearly static [5]. Population is highly concentrated: the five most populous regions hold 71.2% of the national total, led by Casablanca-Settat (7.69 M) and Rabat-Salé-Kénitra (5.13 M) [5].

Key demographic and vulnerability indicators are reported in Table 3.

Table 3 – Morocco: general demographic data

Indicator	Value	Source
Total population (Sept 2024 census)	36.83 M	[5]
Population growth rate	0.85%/yr	[5]
Urban population share	62.8% (2024)	[5]
Urban growth rate	1.24%/yr	[5]
Rural growth rate	approx. 0.22%/yr	[5]
Median age	approx. 30 years	[5]
Average household size	3.9 persons	[5]
Share in five most populous regions	71.2%	[5]
Urban pop. in informal settlements (bidonvilles)	approx. 3.3% of urban households	[5]
Population > 10 km from nearest primary care facility	approx. 11%	[19]

The spatial distribution of population, which concentrates along the Atlantic littoral and in the north-west and largely determines where cooling demand accumulates, is mapped in Figure 3.

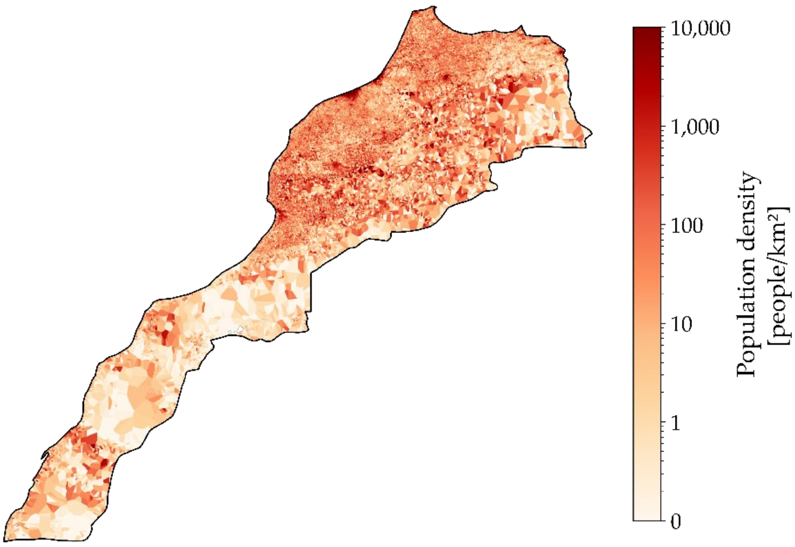


Figure 3 – Morocco: population density

Building stock and thermal exposure

The built environment is a primary determinant of cooling demand. Buildings account for roughly one third of national final energy consumption, of which about 25% is residential and 8% tertiary, and the national thermal regulation estimates an energy-saving potential of about 40% for the sector [18]. The building stock combines a vernacular tradition of high thermal mass and passive ventilation, exemplified by thick-walled earthen ksour and riad courtyard houses, with a dominant trend in new urban construction toward lightweight concrete-frame buildings, large glazed areas and limited insulation, a combination that raises cooling loads as the newer stock expands [18][20]. Urban heat-island effects in dense centres such as

Casablanca and Marrakech are expected to intensify summer peaks, although a city-level quantification of the heat-island effect for Moroccan cities was not identified in the available literature.

Economy and cooling affordability

Morocco is a lower-middle-income economy. The World Bank series used here places nominal GDP at about USD 160.6 billion for 2024, while the latest 2025 current-US-dollar estimate is about USD 182.4 billion [1]. GDP per capita is therefore reported as a range of approximately USD 4,300-4,700, depending on the 2024/2025 series used [1]. Services account for roughly half of GDP, industry about a quarter (phosphates, automotive, aerospace), and agriculture around 11% while still employing close to 30% of the labour force, highlighting its continued social and economic importance despite its declining contribution to national output [1][21]. Near-universal electrification removes the basic access barrier, but no national indicator directly measuring cooling affordability was identified; equipment purchase cost, electricity expenditure and poor building performance can still constrain adequate cooling. Climate exposure is also a material macroeconomic risk. The World Bank's Country Climate and Development Report records around 20 major flood events over the past two decades causing average direct losses of roughly USD 450 million per year, and warns that a 25% reduction in water supply could reduce GDP by about 6.5% [22].

Selected economic indicators relevant to cooling-market potential are reported in Table 4.

Table 4 – Morocco: main economic indicators

Indicator	Value	Source
Nominal GDP (2024; 2025 estimate)	approx. USD 160.6 B (2024, current US$); World Bank 2025 estimate approx. USD 182.4 B	[1]
GDP per capita (2024; 2025 estimate)	approx. USD 4,300-4,700, depending on the 2024/2025 series	[1]
Medium-term growth rate	approx. 3.5%/yr	[4]
Services / industry / agriculture (share of GDP)	approx. 54% / 25% / 11%	[1]
Agriculture share of workforce	approx. 30%	[21]
Average flood-related direct losses	approx. USD 450 M/yr	[22]
GDP loss from a 25% water-supply cut	approx. 6.5%	[22]

Electricity system

Morocco's electricity system is defined by access rather than structural supply scarcity. Electricity access is essentially universal, at about 100% nationally and 99.9% in rural areas after the PERG rural-electrification programme [8]. National supply is generally reliable, although continuity and voltage quality still need to be checked at individual project sites, particularly for critical healthcare and cold-chain loads [14]. The defining feature for cooling is therefore the generation mix. ONEE reports that renewable technologies represented about 45% of national installed electrical capacity in 2024, while actual generation remained more fossilintensive [8][23]. In the 2023 IEA generation series, hydropower, wind, solar PV and solar thermal supplied about 21.0% of generation and coal supplied about 62.1% [12]. The result is a high adopted project-reference emission factor and a strong summer peak-demand profile as air-conditioning spreads. Key system indicators are reported in Table 5.

Table 5 – Morocco: electricity system key indicators

Indicator	Value	Source
National electrification rate	approx. 100%	[8]
Rural access (PERG)	approx. 99.9%	[8]
Renewable share of installed capacity (2024)	approx. 45% of installed electrical capacity	[8][23]
Renewable share of generation (2023)	approx. 21.0% of electricity generation in 2023	[12]
Coal share of generation (2023)	approx. 62.1%	[12]
Total electricity production (2024)	approx. 43.7 TWh/yr	[8]
Electricity sales (2024)	approx. 35.3 TWh/yr (2024)	[8]
Residential electricity tariff	approx. USD 0.12/kWh	[16]
Industrial electricity tariff	approx. USD 0.10/kWh	[16]
Transmission and distribution losses (reference series)	approx. 14.7%	[16]
Adopted IFI combined-margin reference factor	approx. 0.83 kg CO_2eq/kWh (2020)	[16]

The generation mix behind these electricity-system indicators is visualised in Figure 4, which highlights the continuing predominance of coal and the still limited contribution of hydropower, wind and solar to actual electricity generation.

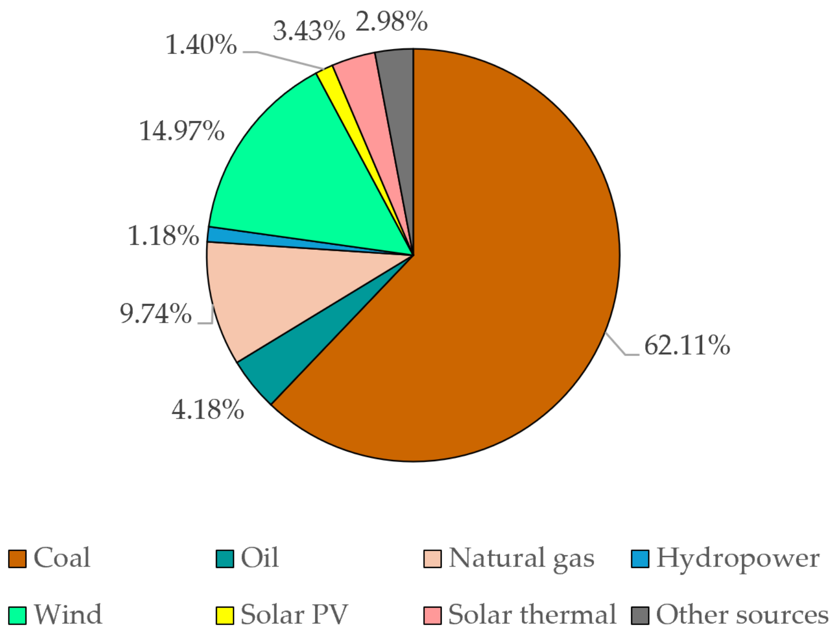


Figure 4 – Morocco electricity generation mix [12]

Regulatory Framework

Key legislation

Morocco has one of the more developed energy-efficiency and refrigerant-policy frameworks in North Africa. Its foundations are Law 47-09 on energy efficiency (enacted 2011), which mandates energy audits, appliance labelling and thermal regulation, and the Règlement Thermique de Construction au Maroc (RTCM), introduced by Decree 2-13-874 and in force since 2015, which sets differentiated envelope requirements across the six climatic zones and establishes reference comfort set-points of about 20 °C for heating and 26 °C for cooling [18].

The principal instruments are summarised in Table 6.

Table 6 – Morocco: list of administrative key provisions

Instrument	Year	Key provision
Law 47-09 on energy efficiency	2011	Framework law: mandatory audits, appliance labelling, thermal regulation
Decree 2-13-874 (RTCM)	2014 / in force 2015	Thermal building code; six-zone envelope requirements; tertiary buildings (health, education, tourism, commerce) covered
Order MEMEE 2148-11 / NM 14.2.300	2011	General energy-labelling framework for electrical products and household appliances
NM 14.2.302 – air conditioners	2022 standard; mandatory application to listed products from 12 March 2025	Product-specific air-conditioner energy-efficiency and labelling requirements under the applicable ministerial order and NM 14.2.302 [9]

Instrument	Year	Key provision
National Cooling Action Plan (NCAP)	Under development (2025) [13]	Multi-sectoral cooling strategy; aligned with the Global Cooling Pledge

Cooling-appliance standards and labelling requirements

Morocco distinguishes between a general appliance-labelling framework and product-specific mandatory standards. Energy labelling and minimum-performance requirements became mandatory from 12 March 2025 for the air-conditioner and refrigerator categories listed in the applicable ministerial instruments, with NM 14.2.302 providing the air-conditioner requirements and NM 14.2.300 forming part of the broader framework [9]. Applicants must confirm the exact product classification, applicable test method and whether the requirement covers household or commercial equipment with AMEE, IMANOR and the Ministry of Industry and Trade. CE, EN and ISO documentation can support the technical file but does not replace Moroccan requirements where a mandatory national standard, CMIM marking or a Certificate of Conformity applies [17]. Applicable instruments are set out in Table 7.

Table 7 – Morocco: cooling-appliance efficiency and labelling requirements

Product	Instrument	Key requirement
Room air conditioners	NM 14.2.302; NM 14.2.300 framework	Mandatory energy label and minimum-performance requirements under NM 14.2.302 for the listed air-conditioner categories; confirm the exact product classification before procurement [9]
Refrigerators & freezers	NM 14.2.300 framework	Energy labelling and minimum-performance requirements apply from 12 March 2025 to the listed refrigerator categories; confirm the scope for household versus commercial equipment [9]

Refrigerant transition timeline

Morocco is comparatively advanced on refrigerants. It operates an HCFC Phase-out Management Plan (HPMP), now in Stage II. The second-tranche project document reports 2022 HCFC consumption of 19.84 ODP tonnes, 61% below the compliance baseline [10]. The fourth-tranche submission reports 2023 Article 7 consumption of 17.30 ODP tonnes, 66% below baseline, and verified HCFC-22 consumption of 17.20 ODP tonnes for 2024; it confirms completion of Stage II by 31 December 2026 [24]. HCFC-141b consumption in pure form has been zero since 2014 and imports have been banned since 2015; phase-out of HCFC-141b contained in imported pre-blended polyols remains part of the implementation programme [24]. Morocco ratified the Kigali Amendment in 2022 and is preparing implementation of the HFC phase-down [11][45]. The available KIP-preparation survey identifies R-404A and HFC-134a among the leading bulk HFCs and notes that R-410A enters largely in pre-charged air-conditioning equipment; it does not support a precise national installed-stock percentage split [11]. A Moroccan AC Buyers Club initiative links high-efficiency equipment and lower-climate-impact refrigerants, with programme documentation reporting indicative electricity savings of up to 70% in a replacement-room-AC demonstration [25]. Transition milestones are set out in Table 8.

Table 8 – Morocco: refrigerant transition targets [10][11]

Milestone	Target / status
HCFC reduction vs baseline (2025)	67.5% cut (Article 5 schedule) [10]
HCFC reduction vs baseline (2030)	97.5% cut [10]
HPMP Stage II completion	31 December 2026 [10]
HCFC-141b in pre-blended polyols	Banned from 1 January 2025 [10]
Kigali Amendment	Ratified 2022; HFC phase-down ongoing [11]
Leading HFCs identified in available survey data	R-404A and HFC-134a among leading bulk imports; R-410A mainly associated with pre-charged AC equipment. No precise installed-stock percentage split is asserted [11]

Key institutions

Regulatory oversight for cooling is shared across several authorities, summarised in Table 9. Project developers should engage AMEE, IMANOR and the National Ozone Unit early, as conformity and refrigerant requirements apply before market entry.

Table 9 – Morocco: cooling key authorities

Authority	Role for cooling
AMEE – Agence Marocaine pour l'Efficacité Énergétique	Energy-efficiency policy, MEPS technical basis, RTCM support (Binayate), audits [18]
ONEE – Office National de l'Électricité et de l'Eau Potable	Electricity generation/transmission/distribution; rural electrification [8]
MASEN – Moroccan Agency for Sustainable Energy	Utility-scale renewable energy (solar, wind) [14]
IMANOR – Institut Marocain de Normalisation	National standards (NM), conformity certification, labelling [9]
Ministère de la Transition Énergétique et du Développement Durable	Energy and climate policy; NCAP host [13]
National Ozone Unit (Dept. of Environment)	HCFC/HFC controls, Montreal Protocol & Kigali implementation [10][11]
ADII / Douanes – customs administration	Customs classification, duties, VAT, DUM and clearance [26]
Ministry of Industry and Trade	Technical regulations, CMIM marking, controlled-product lists and industrial-product conformity controls [17]
PortNet	Import formalities, import-title/DUM workflows, CoC platform and digital import documentation [17][26]

Market Entry

Market entry for cooling equipment is product-specific. European CE/EN/ISO documentation is useful supporting evidence, but it does not replace Moroccan conformity requirements where CMIM marking, mandatory Moroccan standards or origin-control Certificates of Conformity apply [17]. Depending on the controlled-product category, conformity may be verified at origin or at destination. The principal steps are:

I. confirm the ten-digit tariff code and whether the product is subject to a technical regulation, CMIM marking, a mandatory NM standard, energy-labelling/MEPS requirements or origin-control CoC requirements [9][17];
II. prepare the technical dossier, including the Moroccan declaration of conformity where applicable, relevant NM/EN cross-references, accredited laboratory or test reports, product datasheets, energy-label documentation and Arabic user information where required [9][17];
III. submit the applicable CoC, import title and DUM together with the shipment documentation through PortNet, and document refrigerant type and charge as well as electrical, electromagnetic-compatibility, pressure-equipment and safety compliance where relevant [10][17][26];
IV. confirm customs duty, VAT, TPI and preferential origin before shipment. For preliminary costing, qualifying EU-origin industrial goods may be assumed to enter at 0% customs duty only where the exact tariff line is covered and accepted proof of preferential origin is provided; otherwise the applicable national tariff may be materially higher. No automatic donor-funded customs or VAT exemption is assumed [26][27].

The main import and budgeting requirements are summarised in Table 10. A 0% customs-duty assumption is appropriate only for qualifying EU-origin goods with accepted origin proof; the exact rate and conformity route must be checked at ten-digit tariff-line level and against the Ministry of Industry and Trade's current controlled-product list before shipment and final budgeting [17][26][27].

Table 10 – Morocco: import charges for cooling equipment [26][27]

Charge	Working assumption
Import duty (droit d'importation)	Working assumption for qualifying EU-origin industrial goods: likely 0% if the exact tariff line is covered and accepted proof of preferential origin is provided. Otherwise the rate from the ADII ten-digit integrated tariff applies and may be materially higher [26][27]
VAT (TVA)	Standard import VAT: 20% on the customs value plus duty [26]
Parafiscal import tax (TPI)	Taxe Parafiscale à l'Importation (TPI): 0.25% of the CIF value [26]
Other import and transaction costs	Allow for customs-broker fees, PortNet/DUM processing, CoC or conformity assessment, port handling and storage, translation and labelling, and possible laboratory testing [17][26]
EU–Morocco Association Agreement	Preferential treatment requires accepted proof of EU origin, such as EUR.1 or an origin declaration where applicable, and confirmation of the exact tariff line [27]

Charge	Working assumption
Refrigerant notification	Required for controlled substances; specify type and charge and do not specify HCFCs for new equipment [10]
Donor-funded exemptions	No automatic donor-funded customs or VAT exemption has been identified. Any exemption, VAT suspension or relief must have a specific customs regime, investment agreement or project basis and be confirmed with ADII, the Ministry of Finance and the project host [26]
Product conformity / CoC	Check the current controlled-product list and applicable route before shipment. CMIM marking or a CoC may apply depending on the equipment; conformity may be verified at origin or destination, and CoC applications and supporting evidence are managed through PortNet where origin control applies [17]

Core import documentation generally includes the commercial invoice, packing list, bill of lading/airway bill/CMR, import commitment or import title, DUM, PortNet tracking documentation, proof of preferential origin, CoC and CMIM documentation where applicable, CE declaration and the supporting EN/ISO technical file, technical datasheets, test reports, energy-label/MEPS documentation, and refrigerant and pressure-equipment documentation [9][17][26][27].

Application-specific checks remain necessary: room AC, packaged AC and VRF systems may be subject to CMIM/CoC and energy-labelling requirements; chillers and heat pumps require product-by-product electrical, pressure and refrigerant-safety checks; wireless controls may require telecommunications approval; cold rooms and industrial refrigeration are generally subject to product-specific conformity rather than household-appliance labelling; and complete refrigerated vehicles may also require vehicle homologation.

For first-time imports, applicants should allow schedule contingency for conformity assessment and PortNet processing before shipment. As a procurement and implementation requirement, proposals should identify a Moroccan partner for import, installation, commissioning, warranty, spare parts and local operation and maintenance, with refrigerant-specific technician training where low-GWP or natural refrigerants are proposed.

Behavioural Context

Demand for cooling in Morocco is increasingly perceived as a comfort and productivity need as summer temperatures rise, particularly in the hot interior and southern zones and across a large tourism-sector building stock. The U4E 2022 country assessment estimated an installed air-conditioner stock of about 1.4 million units and annual sales above 210,000 units; these values are used as a dated market baseline rather than as a current 2026 inventory [16]. Morocco is named explicitly among the 54 high-impact countries in the global access-to-cooling analysis, meaning those facing sustained high temperatures alongside significant populations exposed to a lack of cooling access, with on the order of 20 million people in the medium-risk group [28].

Tertiary-Sector Cooling

Healthcare

Morocco operates a predominantly public healthcare system financed through taxation and social health insurance, under the stewardship of the Ministry of Health and Social Protection. The system is organised around an extensive primary care network (Réseau des Soins de Santé Primaires) and a hospital network (Réseau Hospitalier). The 2022 baseline used in the energy model includes five autonomous University Hospital Centres (Centres Hospitaliers Universitaires, CHU) reported separately from the general hospital network, alongside a sizeable private clinic sector [29][30]. More recent CHUs at Tangier and Agadir expand the high-specification estate but are outside the 2022 stock baseline [31]. The 2021-2022 reform of compulsory health insurance (AMO) expanded coverage to approximately 75% of the population, increasing demand for hospital services and pressure on healthcare infrastructure [29].

System infrastructure and facility inventories

Hospital capacity is recorded in the Ministry's annual Santé en chiffres yearbook and in the Carte Sanitaire. The public hospital network holds 27,539 existing beds, of which 22,938 are reported as functional [32]. The central energy model uses the existing-bed figure because it is intended to approximate the installed physical estate; this should be read as an upper estimate of actively served capacity. A functional-bed sensitivity would reduce electricity, cooling demand and associated emissions proportionally by about 17%. Private clinics, numbering around 453 facilities, add a further roughly 14,500 beds, bringing total national inpatient capacity to approximately 42,000 beds across all sectors [30][31]. Inpatient capacity in Morocco outside of hospitals and clinics is negligible [33]. Against the 2024 census population of 36.83 million [5], total provision stands at approximately 1.1 beds per 1,000 inhabitants and public-sector provision at about 0.75 beds per 1,000, both well below the global average of about 3.3 [34]. The deficit is concentrated in rural provinces and in the fast-growing peripheries of the large cities [35][36].

The estate is strongly hierarchical. The primary-care network comprises 3,224 establishments (urban and rural health centres and dispensaries) that provide first-contact and preventive care [33]. The public hospital network contains about 170 entries classified as proximity, provincial/prefectural, regional, inter-regional, oncology and psychiatric establishments [36]. Above this network, the 2022 baseline includes the five CHU complexes in Rabat, Casablanca, Marrakech, Fès and Oujda [30][36][37][38][39]. The official Ibn Rochd presentation reports 1,685 beds across three hospitals in Casablanca [38]. Since the baseline year, the CHU Mohammed VI in Tangier was inaugurated with 797 beds and the CHU Mohammed VI in Agadir entered service with 867 beds [31]. These two facilities are excluded from the 2022 energy model but materially enlarge the near-term high-specification cooling estate. The rebuilt Ibn Sina hospital in Rabat is a further major central-hospital project [37].

Because per-facility bed counts are not published in disaggregated form, Table 11 represents a modelled size-band aggregation rather than as the official administrative inventory. The official 2022 Carte Sanitaire hospital-infrastructure table reviewed for this study lists 170 public hospital entries by category: 74 provincial/prefectoral (HP), 37 proximity (HPr), 25 inter-regional (HIR) and 18 regional (HR) hospitals, which together form the 154-facility general curative network, plus 5 regional oncology centres (CRO) and 11 psychiatric establishments (5 university psychiatric centres CPU, 4 provincial and 2 regional psychiatric hospitals) [36]. This list does not include the five CHU teaching hospitals, which have separate legal status under Law 37-80 and are reported outside the Carte Sanitaire hospital network [40]. The energy model adds them from the CHU capacity data [31]. The 161 energy-node count reconciles with this inventory as follows: the four general-network size bands reproduce the 154 curative hospitals (156 modelled nodes, within about 1%), and the fifth band adds the 5 CHU. The 5 oncology and 11 psychiatric establishments are not represented as separate size-band nodes, but their bed stock is already contained in the 27,539 existing beds on which the model is calibrated, so it is captured at the level of installed capacity even though these facilities are not counted individually among the 161 nodes. The 161 value is therefore an energy-node count aligned with the official inventory, not a published administrative total [36]. The size estimates are anchored on individually verified CHU capacities and on the small scale of proximity hospitals (for example Aït Ourir at 45 beds and Beni Mgada at 25 beds) [31]. Within each band, a typical size is selected inside the band's bed range and calibrated so that the implied total reproduces with good approximation the official capacity reported in the Carte Sanitaire [32]. The estimates are therefore appropriate for national energy sizing, but they should not be read as a reconstruction of individual facilities.

Table 11 – Morocco: public healthcare facilities classification by administrative category [31][32][35][36]

Public healthcare Facility Type	Description	Facilities	Est. typical size [beds]	Composition
Proximity hospital (HPr)	Hospital beds ≤ 50	official HPr: 37; model: 40	45	Proximity hospitals (hôpitaux de proximité), included in the energy model; the 3,224 primary-care units are not hospital establishments and sit outside the estate
Small district hospital	50 < beds ≤ 150	55	90	Smaller provincial hospitals
Medium hospital	150 < beds ≤ 300	48	195	Provincial / inter-regional hospitals
Large hospital	300 < beds ≤ 500	13	365	Regional hospitals (CHR)
Referral / Tertiary (CHU)	beds > 500	2022 model baseline: 5; commissioned since baseline: 2	1,369	Baseline CHUs: Rabat, Casablanca, Marrakech, Fès and Oujda; Tangier (2023) and Agadir (2025) are outside the 2022 model stock

The representation of the location of these facilities against thermal stress is provided in Figure 5.

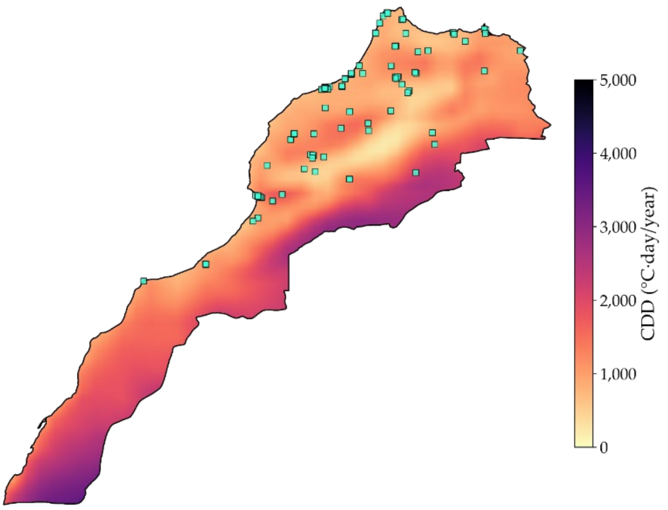


Figure 5 – Morocco: public hospital estate by region

As can be seen, the geography of provision matters for cooling because the regions of highest thermal stress, the pre-Saharan south and the continental interior, are also those with the thinnest hospital infrastructure and the tightest provincial budgets, whereas the cooler Atlantic littoral concentrates the CHU and private capacity.

Any capacity built or rehabilitated in the hot interior will embed new cooling load, and the efficiency and refrigerant standards adopted at the design stage will govern operating costs and emissions for decades.

The cooling deficit and clinical consequences

In healthcare, cooling is an operational enabler rather than a matter of comfort, and its functions fall into three domains summarised in Table 12. Morocco's distinctive feature is that the binding constraint is not access to the cold chain but the maintenance, resilience and modernisation of an established but ageing installed base [11][41].

Table 12 – Morocco: healthcare cooling applications

Domain	Requirement	Evidence / response in Morocco
Vaccine cold chain (2–8 °C)	Continuous temperature control from regional stores to vaccination rooms	Morocco's National Immunization Programme (launched as EPI in 1981, now covering 12 vaccine-preventable diseases) sustains high routine coverage, with almost all children vaccinated through the public centre-de-santé network [41][42]; the Ministry expanded and modernised cold-chain capacity with international partners during the COVID-19 campaign, benefiting the routine programme thereafter [41]. Given travel distances and the thinner technician network in remote provinces, the dispersed rural endpoints remain the points of greatest operational fragility [29].
Medical storage & laboratories	24-hour climate control for pharmaceuticals, blood products and reagents	Hospital pharmacies, blood-transfusion centres and laboratories require documented, uninterrupted temperature control. Refrigeration failure interrupts pharmacy, laboratory and transfusion services. Provision is facility-level given the absence of dense centralised cold storage [29].
Clinical thermal comfort	Stable temperature and humidity in wards, ICU and operating theatres	Operating theatres, intensive-care and isolation rooms require controlled temperature, humidity and air-change rates. Summer heat in the interior and pre-Saharan provinces (Marrakech, Errachidia, the south) drives high sensible cooling loads, while the Atlantic littoral is milder. Reported hospital electricity use of about 6,300 kWh per bed per year is low by international standards, where hospital energy intensities of 20,000 kWh per bed in fully developed countries are common, reflecting both a mild-to-hot climate and a comparatively low level of mechanical-cooling sophistication [43].

Morocco's near-universal electrification [8] and high immunization coverage, with routine DTP3 coverage around 99% [42], make the vaccine cold chain comparatively robust, so the binding constraint is reliability at the most remote endpoints rather than basic access. The priority is therefore the renewal of ageing chillers and split units, the resilience of rural endpoints, and the embedding of efficient, low-GWP equipment in the large rehabilitation and CHU-construction pipeline now under way [29][31].

Current market conditions and technology

Large Moroccan hospitals and the CHU complexes rely on central chilled-water plants serving operating blocks, intensive-care units and main wards, with variable-refrigerant-flow and direct-expansion split systems widespread in smaller hospitals, clinics and administrative areas [43]. The installed base is dominated by fixed-speed, lower-efficiency equipment, in line with the broader national room-air-conditioner market, and the refrigerant stock is still weighted toward higher-GWP HFCs [11][16]. Reference efficiencies for the dominant equipment classes are given in Table 13. The table distinguishes the measured current market average for split units [16] from new-equipment reference classes for central plant and VRF [44].

Table 13 – Morocco: healthcare cooling technology benchmark

Technology	COP	EER [W/W]	Notes
Modern centrifugal / screw chillers	> 5.5	> 5.0	New-equipment reference class (ASHRAE 90.1 / AHRI minimum-efficiency levels) for CHU and large-hospital central plants [44]
Inverter VRF	4.0–5.0	3.5–4.5	New-equipment reference class [44]; strong part-load performance in wards and clinics
Conventional split (on/off)	3.0–3.4	2.8–3.2	Current market average: mean EER of new units sold in Morocco in 2022 was 2.84 W/W, dominated by fixed-speed R-410A units [16]
Automation / predictive control	+15–20%	+15–20%	Operational optimisation of chiller and pump dispatch; emerging in CHUs [43]

Morocco's national renewable-energy programme (notably the Noor solar complexes) and its energy-efficiency agenda create a favourable backdrop for on-site solar and efficiency retrofits in the hospital estate. The very low reported specific consumption per bed [43] indicates substantial scope to raise comfort and clinical air quality without proportionate energy growth, meaning that efficient equipment should be included at the design stage rather than retrofitted later.

Infrastructure demand projections

Future cooling load in the hospital estate depends on how fast bed capacity grows, and two scenarios bracket the range. The first holds today's provision ratio constant and lets the bed stock grow only with population, which is the more realistic near-term path. The second is an illustrative convergence scenario in which provision rises toward the global average of about 3.3 beds per 1,000 [34], well above Morocco's current level of about 0.75 public beds and 1.1 total beds per 1,000 inhabitants. Neither is a development target, but together they bound the additional capacity, and therefore the additional cooling load, that the system may have to serve.

new facilities = population growth × current beds per capita × current facility-type ratio ÷ average facility size

Under the first scenario, population is projected to rise to about 38.8 million in 2030 and 43.2 million in 2050 [5], so holding provision constant adds roughly 17% to the bed stock by 2050, a modest increment concentrated wherever new population settles. Under the convergence scenario, reaching 3.3 beds per 1,000 by 2050 would require roughly tripling today's stock, a build-out distributed across the size bands at the current mix and falling disproportionately in the under-served, hotter interior, as illustrated in Figure 6.

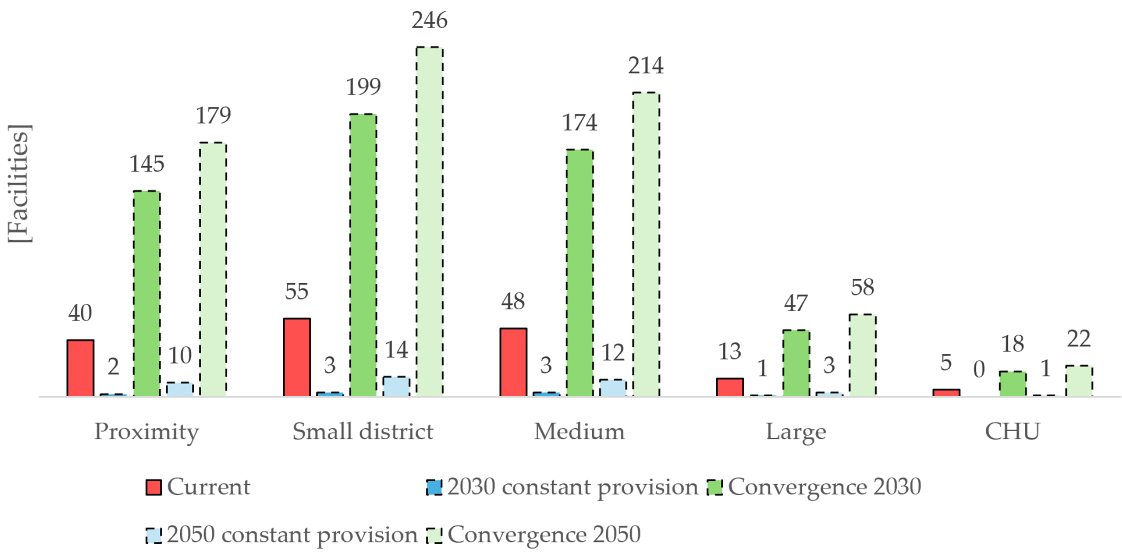


Figure 6 – Morocco: current and additional facility number by size

Technology baseline and refrigerant mix

Morocco is a Party to the Montreal Protocol and has ratified the Kigali Amendment, implementing the HCFC phase-out and preparing the HFC phase-down with support from the Multilateral Fund [10][11][45]. Available KIP-preparation data indicate continued reliance on high-GWP HFCs, with R-404A and HFC-134a important in bulk consumption and R-410A associated mainly with pre-charged air-conditioning equipment [11]. R-134a remains a common reference refrigerant for existing water chillers, while split and VRF markets have historically relied on R-410A and are transitioning toward R-32 and other lower-GWP options, consistent with international technology assessments and the Moroccan room-air-conditioner market [16][46].

Key indicators are summarised in Table 14.

Table 14 – Morocco: healthcare cooling technology indicators

Indicator	Value	Source
Specific electricity consumption (hospital benchmark)	≈ 6,300 kWh/bed·yr (low by international standards)	[43]
Hospital share of tertiary-sector electricity	≈ 33%	[43]
Dominant plant type, medium & large hospitals / CHUs	Central chilled-water plants	[43]
Dominant technology, wards & small units	DX split & VRF on R-410A; transition to R-32	[11]
National HFC context	R-404A and HFC-134a important in surveyed bulk HFC use; R-410A mainly linked to pre-charged AC equipment	[11]
Reference refrigerant used in the central-chiller screening model	R-134a (GWP 1,430)	[46][47]

Energy implications

Applying a bottom-up model to Morocco's 2022 public hospital estate, total hospital electricity consumption, with private clinics and the subsequently commissioned Tangier and Agadir CHUs excluded, is estimated at about 175 GWh per year. Cooling accounts for roughly 70 GWh per year, equivalent to about 0.16% of national electricity generation on the 2023 IEA denominator [12]. The emissions perimeter used here includes only cooling-related electricity and refrigerant leakage. At the consistently adopted reference grid factor of 0.83 kg CO_2eq/kWh [16], indirect cooling emissions are about 0.058 Mt CO_2eq per year and direct refrigerant leakage about 0.012 Mt CO_2eq per year, for a total cooling footprint of about 0.070 Mt CO_2eq per year.

The model is parameterised on hospital bed count, the standard proxy for hospital scale. At national level, beds per 1,000 inhabitants indicates system development, while at facility level bed numbers correlate with clinical complexity and with electricity use per bed. The perimeter is the hospital estate itself. The model uses 161 energy nodes derived from Table 11, while the official 2022 facility list contains about 170 entries; the difference reflects model aggregation and should be validated in a facility-level audit before procurement use [36]. Primary-care units and pharmacies are excluded because they are not hospital establishments and their loads, dominated by lighting, small equipment and pharmaceutical refrigeration, are not comparable with inpatient care. Sector electricity is estimated as the product of the bed stock and the Moroccan literature benchmark of about 6,300 kWh per bed per year, adopted here as the national screening value [43]. Because this literature value is applied as a system-wide screening average, the product determines the sector total directly, so the estimate rests on the two best-documented quantities available: official bed capacity and a Moroccan literature benchmark. The per-band ladder of Table 15 serves a complementary purpose: it disaggregates the total to indicate the order of magnitude of consumption in facilities of each size class. Its gradient follows hospital energy-benchmarking studies that relate consumption to facility complexity [48]. The proximity band, for which no measured Moroccan value exists, extends that gradient one step below the district-hospital level, with consecutive bands differing by a factor of about 1.34 on average, which places the proximity band at about 75% of the district-hospital intensity. The ladder is normalised so that its bed-weighted average over the 27,700-bed estate reproduces the adopted literature benchmark exactly. The band values are therefore indicative allocations consistent with that benchmark, not independent measurements, and the sector totals do not depend on them. Heating, ventilation and air-conditioning is the largest single end-use in hospitals, with the international literature placing it in a broad 30 to 65% range of hospital electricity and measured warm-climate fleets clustering near half [43]. In the absence of a measured Moroccan end-use breakdown, cooling electricity is taken at 40% of total hospital electricity as a central assumption. Because the emissions perimeter includes only cooling electricity, this share affects both the indirect and direct terms. At a 30% cooling share, cooling electricity would be about 52 GWh and installed capacity about 447 MW, giving about 43 kt CO_2eq of indirect emissions and 9 kt CO_2eq of direct emissions, or about 53 kt CO_2eq in total. At a 50% share, cooling electricity would be about 87 GWh and installed capacity about 744 MW, giving about 73 kt CO_2eq indirect and 15 kt CO_2eq direct, or about 88 kt CO_2eq in total. The 40% central case gives about 70 GWh, 58 kt CO_2eq indirect and 12 kt CO_2eq direct, for a cooling total of about 70 kt CO_2eq per year.

Table 15 – Morocco: healthcare reference specific energy consumption (indicative per-band disaggregation: gradient from [48], normalised to the Moroccan literature benchmark adopted as the national screening value [43])

Healthcare Facility Type	Level	Electricity [kWh/bed·yr]	Cooling [kWh/bed·yr]	Notes
Proximity hospital	1	2,942	1,177	First-referral inpatient care; minimal clinical technology;

Healthcare Facility Type	Level	Electricity [kWh/bed·yr]	Cooling [kWh/bed·yr]	Notes
				intensity extrapolated below the district band
Small district hospital	2	3,933	1,573	Lower end; reduced technological sophistication
Medium hospital	3	5,572	2,229	Representative hospital; near national benchmark
Large hospital	4	7,011	2,805	Higher complexity; regional hospitals
Referral / Tertiary (CHU)	5	9,397	3,759	Highest complexity; teaching hospitals

Facility-level cooling emissions are the sum of indirect contributions from cooling electricity and direct contributions from refrigerant leakage. Indirect emissions are therefore calculated from the cooling share of hospital electricity, not from all hospital electricity. This assessment consistently uses the U4E/IFI combined-margin factor of 0.83 kg CO_2eq/kWh as the project-oriented reference factor [16]. Morocco's grid remains coal-dominated: in the 2023 IEA generation data, coal, oil and natural gas account for about 76.0% of electricity generation, hydropower, wind and solar for about 21.0%, and other sources for about 3.0% [12].

Direct emissions are estimated from the installed cooling stock through an explicit sizing convention. The cooling capacity of each band is obtained from its annual cooling electricity as capacity [kW] = cooling electricity [kWh per year] × efficiency ÷ 500. The 500 equivalent full-load hours are a conservative capacity-sizing case reflecting seasonal concentration, not a measured national utilisation value. The efficiency term is differentiated by plant type: proximity and small district hospitals are assigned the measured stock-average split-unit efficiency of 2.84 W/W [16], while medium, large and CHU hospitals are assigned a central-plant COP of 4.5, below the new-equipment reference classes of Table 13 [44]. Refrigerant charge (0.14 kg/kW) and annual service leakage (10%) follow conservative IPCC/RTOC factors [49], with R-134a (GWP 1,430) as the reference refrigerant [47]. The capacity result is sensitive to the utilisation convention: at 1,000 and 1,500 equivalent full-load hours, the same annual cooling energy would imply about 298 and 198 MW of installed capacity, approximately 42 and 28 tonnes of refrigerant charge, and about 6 and 4 kt CO_2eq per year of direct emissions, while indirect emissions would remain about 58 kt CO_2eq. Facility-level load profiles should therefore be validated before procurement. Reference plant characteristics for the 500-hour sizing case are given in Table 16.

Table 16 – Morocco: reference healthcare facility cooling plant characteristics

Healthcare Facility Type	Level	Typical cooling system	Cooling capacity [MW]	Charge [kg/kW]	Leakage
Proximity hospital	1	DX split units; standalone refrigerated cabinets for pharmacy and vaccine storage	0.30	0.14	10%

Healthcare Facility Type	Level	Typical cooling system	Cooling capacity [MW]	Charge [kg/kW]	Leakage
Small district hospital	2	VRF / DX split; small modular chillers for the operating block and ICU	0.80	0.14	10%
Medium hospital	3	Chilled-water plants	3.91	0.14	10%
Large hospital	4	Chilled-water plants	9.21	0.14	10%
Referral / Tertiary (CHU)	5	Large multi-plant chilled-water systems	46.3	0.14	10%

Under the 500-hour reference sizing case, summing the capacities over the facility counts of Table 11 gives about 595 MW of installed refrigeration capacity and about 83,400 kg of refrigerant charge. Direct refrigerant emissions are about 12 kt CO_2eq per year. Applying the adopted 0.83 kg CO_2eq/kWh factor to the 70 GWh cooling-electricity estimate gives about 58 kt CO_2eq per year of indirect emissions, for a total cooling footprint of about 70 kt CO_2eq per year. Proximity hospitals operate on split units charged with R-410A rather than on R-134a chillers; retaining a single reference refrigerant for the estate is a documented simplification that changes the sector total only marginally. The large reference plant size of the referral band reflects the multi-hospital scale of the five CHUs in the 2022 baseline.

In the central case, indirect cooling-electricity emissions account for about 83% of the cooling footprint and direct refrigerant emissions about 17%. Energy efficiency and on-site renewable generation are therefore the first-order mitigation levers, while low-GWP refrigerants, leak prevention and recovery remain material complementary measures. The result is an installed-estate screening estimate rather than a facility inventory: the functional-bed sensitivity reduces both terms by about 17%, and the full-load-hour sensitivity affects the direct term and capacity sizing but not annual cooling electricity.

Structural barriers to investment

The principal barriers to efficient cooling in the Moroccan health sector, and the levers that follow, are summarised in Table 17.

Table 17 – Morocco: barriers to the deployment of cooling technologies in the healthcare sector

Barrier	Detail
Ageing, low-efficiency installed base	Fixed-speed splits and older chillers dominate the stock; as HCFC supply tightens under the HPMP, servicing costs rise and replacement becomes unavoidable [11].
Constrained provincial capital budgets and lowest-price procurement	Provincial and regional hospitals procure under tight budgets and lowest-price rules, which select against higher-efficiency equipment with lower life-cycle cost [29].
Cooling-electricity emissions dominate under the adopted coal-intensive reference factor	The assessment uses 0.83 kg CO_2eq/kWh consistently [16]. Indirect emissions are calculated only on cooling electricity, giving about 58 kt CO_2eq/yr in the central case, versus about 12 kt CO_2eq/yr from refrigerant leakage. Efficiency and on-site solar are therefore primary levers, complemented by low-GWP refrigerants and leak control.

Barrier	Detail
Rural cold-chain resilience and technician capacity	Dispersed rural endpoints and a limited pool of refrigeration-and-air-conditioning technicians expose the most remote vaccine and pharmaceutical stores to maintenance gaps, even though national electrification is near-universal [41].
Concentration of load in a few CHUs	The five CHU complexes carry a large share of installed cooling capacity, so plant renewal and efficiency upgrades in these sites alone can move sector-level energy and emissions materially.

Technology pathways

Morocco's National Cooling Action Plan is still under development. Pending its consolidation, the directions below draw on the Montreal Protocol and Kigali instruments [11][45], on the national energy-efficiency and renewable-energy agenda (Law 47-09, the RTCM and the AMEE Binayate tool), and on current sector practice. For project developers they provide a procurement reference and a basis for demonstrating regulatory alignment in climate-finance applications. The recommended pathways are summarised in Table 18.

Table 18 – Morocco: technology pathway for healthcare cooling applications

Application	Recommended technology direction
General space cooling: wards, clinics, administrative areas	Inverter-driven splits, VRF, mini-chillers; R-32 and other low-GWP refrigerants
Central plants & critical areas (ICU, operating theatres) in medium/large hospitals & CHUs	Semi-centralised systems with heat recovery, enthalpic recuperators and thermal storage; target 21–23 °C, 40–60% RH
Medical & pharmaceutical storage, laboratories	High-efficiency units, R-290 or CO_2, digital monitoring, 2–8 °C continuous
Vaccine cold chain, remote & outage-prone units	Grid-powered, WHO PQS-prequalified ice-lined refrigerators with voltage regulation and continuous remote temperature monitoring [50]; solar direct-drive units only for the small residual set of genuinely off-grid or outage-prone points [50].
Building envelope (new build & rehabilitation)	Cool roofs, shading and natural ventilation, especially in the hot interior and pre-Saharan provinces; on-site PV matched to the cooling peak

Quick summary

The key barriers and enablers for sustainable cooling investment in the Moroccan health sector are summarised in Table 19.

Table 19 – Morocco: healthcare cooling quick summary

Dimension	Barriers	Enablers
Technology	Stock dominated by fixed-speed splits and ageing chillers	Inverter VRF, high-efficiency chillers, low-GWP refrigerants (R-32, R-290, CO_2)
Economics & finance	Constrained provincial budgets; lowest-price procurement	Cooling-as-a-service, life-cycle-cost criteria, development & climate finance

Dimension	Barriers	Enablers
Regulation	National cooling plan not yet consolidated	Kigali Amendment ratified; HPMP in force; energy-efficiency agenda
Infrastructure & resilience	Rural cold-chain endpoints and technician shortages; ageing plant	Near-universal electrification; high immunization coverage; solar-backed cold chain
Energy & emissions	Coal-heavy grid; central estimate sensitive to the cooling share and installed-capacity convention	approx. 175 GWh/yr total hospital electricity; 70 GWh/yr cooling; approx. 70 kt CO_2eq/yr cooling footprint (58 indirect + 12 direct)
Data	Per-facility bed and refrigerant microdata not published	Carte Sanitaire & Santé en chiffres; CHU-level capacity data; submetering programmes

Education

Morocco's 2024–2025 primary and secondary system enrolled 8,018,890 pupils in the public and private sectors combined. The public system enrolled 6,771,263 pupils in 12,258 establishments and employed 289,245 teachers; the private system enrolled 1,247,627 pupils [51]. Higher education enrolled about 1.24 million students, including about 1.11 million in public university education [52]. The sector's distinctive cooling problem is not a lack of electrification but low mechanical-cooling penetration in public classrooms within a system marked by large class sizes and a building stock that is, for the most part, thermally unregulated. Energy and emissions are quantified with a bottom-up classroom thermal model.

System structure and context

Public basic and secondary education is organised in three cycles under the Ministry of National Education, Preschool and Sports. In 2024–2025, public enrolment was 3,643,510 in primary education, 1,943,201 in lower secondary and 1,184,552 in qualifying secondary education; private enrolment across the same cycles was 1,247,627 [51]. Primary participation is close to universal, while progression and completion weaken at the secondary levels and remain less favourable in rural areas [53].

The public estate comprised 12,258 establishments in 2024–2025: 8,397 primary, 2,297 lower-secondary and 1,564 qualifying-secondary establishments [51]. The ministry reported 182,791 rooms in use and 233,421 classes; earlier ministry reporting also identified 25,605 multi-level classes, concentrated in small rural primary schools [51]. Class sizes are large by international standards: an analysis based on PISA 2022 places the Moroccan average near 37 pupils and estimates an educationally optimal class size around 23–24 [54]. This overcrowding is directly relevant to cooling because internal heat gains scale with occupancy [55]. Higher education adds 1,241,032 students, including 1,106,225 in public university education, across 162 public university establishments and approximately 591,573 physical study places [52].

Core indicators describing the education estate and its exposure to cooling demand are summarised in Table 20.

Table 20 – Morocco: education sector key indicators

Indicator	Value	Source
Basic and secondary enrolment (2024–2025)	8,018,890 total; 6,771,263 public; 1,247,627 private	[51]
Public establishments (primary / lower secondary / qualifying)	12,258 (8,397 / 2,297 / 1,564)	[51]
Rooms used / classes (2024–2025)	182,791 rooms / 233,421 classes	[51]
Average class size (public)	≈ 37 pupils (optimal would be 23–24)	[54]
School participation pattern	Primary participation near universal; weaker progression and completion at secondary levels, especially in rural areas	[53]
Higher-education students / physical places / public university establishments	1,241,032 / 591,573 / 162	[52]
Mechanical cooling penetration, public schools	Low (assessment assumption; no national equipment inventory identified)	Model

The thermal problem

Two factors combine to produce classroom overheating in Morocco. First, much of the school stock is lightweight and thermally unregulated: the national building thermal regulation (Réglementation Thermique de Construction au Maroc, RTCM), introduced by Decree 2-13-874 and in force since 2015, sets envelope performance requirements for tertiary buildings including schools, but applies essentially to new construction, leaving the large existing stock uninsulated [18]. Second, the large class sizes typical of Moroccan public schools generate high internal heat loads that compound solar gains through poorly insulated roofs and glazing. Evidence linking classroom heat to reduced cognitive performance is well established internationally, including for African school buildings, although Morocco-specific classroom-heat and learning-outcome studies remain scarce [56][57].

A distinctive Moroccan feature mitigates the headline cooling load: the hottest months, July and August, fall almost entirely within the summer break, so the period of peak ambient heat largely coincides with school closure. Significant classroom cooling demand is therefore concentrated in September and in the late-spring weeks of May and June, and is most acute in the continental interior (Marrakech, Fès, Meknès) and the pre-Saharan south (Errachidia, Ouarzazate, the southern provinces), while the densely populated Atlantic littoral (Casablanca, Rabat, Tangier) is comparatively mild. Mechanical cooling is largely absent from public classrooms, where natural ventilation and fans are the norm, and the near-term active-cooling market is concentrated in private schools, urban institutions and the hottest zones.

This overlap between the education estate and thermal exposure is mapped in Figure 7, showing where schools and tertiary institutions coincide with the highest cooling degree-day zones.

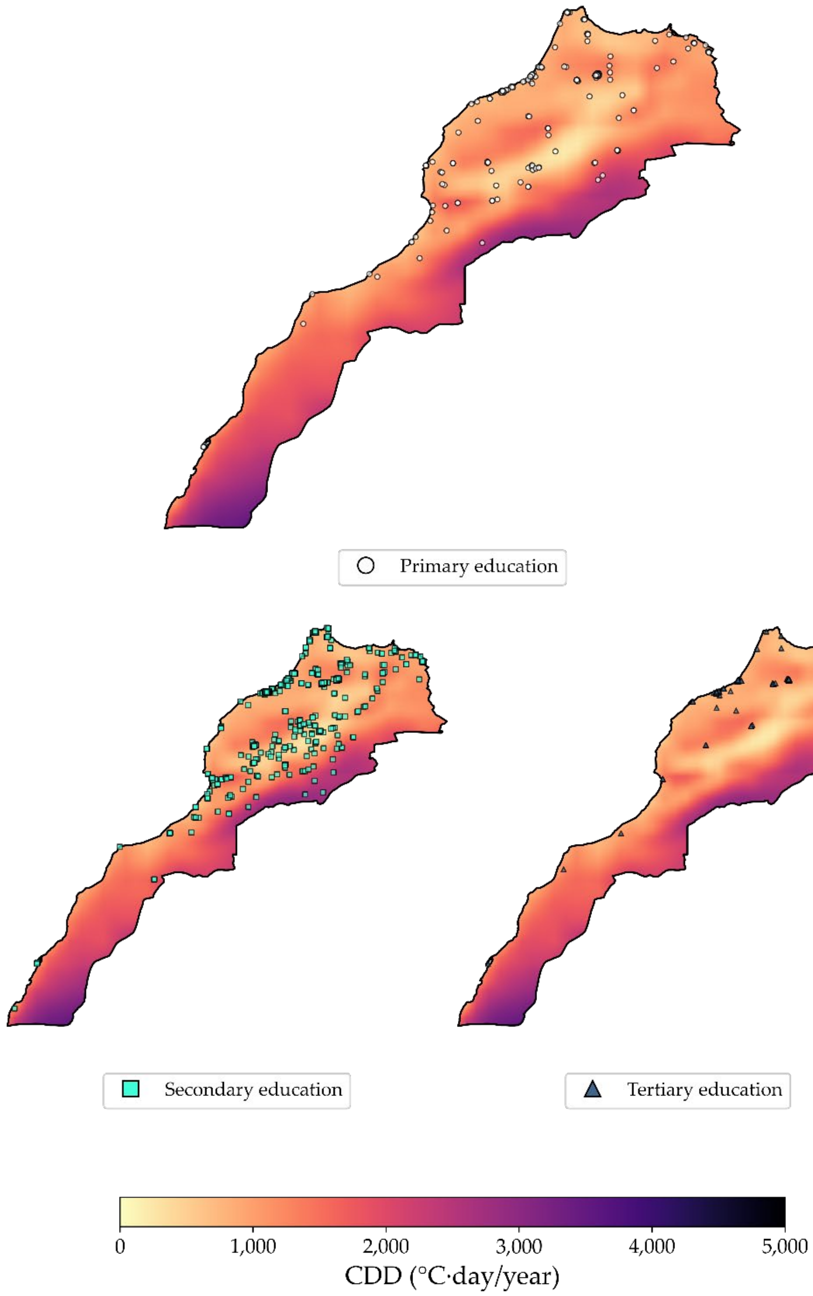


Figure 7 – Morocco: education facilities location vs cooling degree-days (18 °C) distribution

Market trajectory

Mechanical-cooling adoption in Moroccan public schools is at an early stage. The near-term trajectory is concentrated in private schools, urban institutions and the hottest interior and southern zones, where summer-shoulder heat and institutional procurement capacity make active cooling more likely; this qualitative expectation is consistent with the rapid growth of the national air-conditioner market, which is adding more than 210,000 units per year [16]. Indicative efficiencies for the relevant equipment classes are given in Table 21. Conventional-split values reflect the measured current market average, while inverter values are new-equipment references consistent with the national MEPS trajectory [16].

Table 21 – Morocco: education cooling technology benchmarks (current market average vs new-equipment reference) [16]

Technology	EER [W/W]	Notes
Modern inverter split	3.5–4.2	Up to ~40% less energy than conventional units; preferred for urban schools
Conventional split (on/off)	2.6–3.0	Common in lowest-price tenders; locks in low efficiency (market average EER of new units sold in 2022: 2.84 W/W [16])

Demand estimation methodology

Cooling energy demand is estimated with a bottom-up model structured around Morocco's education system. Universities are represented with a centralised-chiller approach. Schools are assessed under two explicitly different per-classroom cases: (i) a recirculating split-unit case, in which the unit serves occupant and envelope loads but does not mechanically condition outdoor ventilation air; and (ii) a comfort-compliant case that includes the outdoor-air load associated with 5 L/s per person + 0.6 L/s per m2 (7.4 L/s per person at 4.0 m2/person). The first better represents the service delivered by typical stand-alone splits; the second represents a classroom system designed to meet the stated outdoor-air condition. In both cases the thermal load is divided by the system COP to obtain electrical plant size. The common design parameters are listed in Table 22.

Table 22 – Morocco: assumed design parameters for an education plant

Parameter	Value	Reference
Ventilation rate	5 L/s per person + 0.6 L/s per m2 (7.4 L/s per person at 4.0 m2/person)	[58]; comfort-design outdoor-air load, not evidence that typical split units mechanically condition ventilation air
Indoor set-point temperature	26 °C, 50% RH (model design assumption)	The RTCM reference summer condition is 26 °C and 60% RH [18]; 50% RH is a more stringent model assumption used only for the comfort-compliant case
Outdoor design temperature (by zone)	32 / 40 / 42 °C (coastal / interior / south)	Read from the RTCM summer dry-bulb design-temperature isolines (Annexe 3), aggregated to the three zones of Table 2 [18]
Outdoor design relative humidity (by zone)	60 / 25 / 18%	Derived from the RTCM summer wet-bulb design-temperature isolines (Annexe 4), aggregated to the three zones of Table 2 [18]
Building envelope U-value (average)	2.0 W/m²K (blend of pre- and post-RTCM stock)	[18]
Average split system COP	2.84	2022 market-average EER of new AC units in Morocco, used as the

Parameter	Value	Reference
		COP-equivalent for the school split-unit model [16]

Table 23 reports the load components for the comfort-compliant case at a zone-weighted outdoor-air enthalpy difference of about 20.8 kJ/kg. Occupant gains use a standard classroom value of about 0.12 kW per person from the ASHRAE Handbook - Fundamentals [55], and the outdoor-air load uses the ASHRAE 62.1 breathing-zone formula of 5 L/s per person plus 0.6 L/s per m2 [58], equivalent to 7.4 L/s per person at the explicit screening assumption of 4.0 m2 per occupant. Because stand-alone split units generally recirculate room air, Table 24 also reports a recirculating-split case that excludes the ventilation term while retaining occupant and envelope loads. The two cases use the same classroom counts, adoption rates, utilisation and part-load factor; they differ only in the cooling service delivered.

Table 23 – Morocco: classroom characteristics (zone-weighted averages from the classroom thermal model)

Level	Occupants	Occupant load [kWth]	Ventilation load [kWth]	Transmission [kWth]	Total [kWth]	Electrical [kWel]
Primary	36	4.32	6.63	1.02	11.98	4.22
Secondary	40	4.80	7.37	1.27	13.44	4.73

The two classroom cooling-load service cases used in the school model are compared in Table 24.

Table 24 – Morocco: classroom cooling-load cases used in the school model

Level	Recirculating split case	Comfort-compliant outdoor-air case
Primary	5.34 kWth; 1.88 kWel	11.98 kWth; 4.22 kWel
Secondary	6.07 kWth; 2.14 kWel	13.44 kWth; 4.73 kWel

The number of physical classrooms is obtained by dividing public enrolment per cycle by the zone-weighted occupancy (about 104,600 primary and 75,400 secondary, totalling about 180,000, consistent with the official 182,791 rooms used in 2024–2025). Annual cooling hours are estimated by weighting three climatic zones by their share of classrooms and assigning each zone an AC-adoption rate and an active-cooling fraction of school days [51]. No official statistics on classroom air-conditioning penetration exist, so the rates in Table 25 are explicit model assumptions. They define a current-low-penetration scenario rather than a measured equipment inventory. The same penetration and utilisation assumptions are applied to both school cooling cases, allowing the effect of outdoor-air treatment to be isolated.

Table 25 – Morocco: current-low-penetration scenario, assumed cooling adoption and utilisation (model assumptions)

Climatic zone	Share of classrooms	AC adoption rate	Days with active cooling
Coastal / temperate	50%	4%	10% of school days
Continental interior	38%	12%	25% of school days
Pre-Saharan / south	12%	25%	40% of school days
Derived current scenario	**100%**	**9.56%**	**≈ 303 h per cooled classroom; ≈ 28.96 equivalent hours across total stock**

The zonal calculation must retain the correlation between adoption and utilisation. Summing classroom share × adoption rate × active-cooling fraction × 1,140 annual school hours gives about 28.96 equivalent full-load hours across the entire classroom stock. This is equivalent to about 303 operating hours per cooled classroom at the weighted adoption rate of 9.56%; multiplying the separately weighted adoption rate by the unconditioned 220-hour average would understate school electricity demand.

School electricity is therefore calculated zone by zone and then summed, rather than by multiplying separately averaged adoption and utilisation values:

Energy [GWh] = Σz (classrooms × adoption × electrical plant size × active cooling hours × load factor)

A load factor of 0.7 is applied, reflecting that compressors cycle below nameplate output across the cooling period rather than running continuously at full load; this is the standard part-load diversity allowance used in building cooling-load estimation [55].

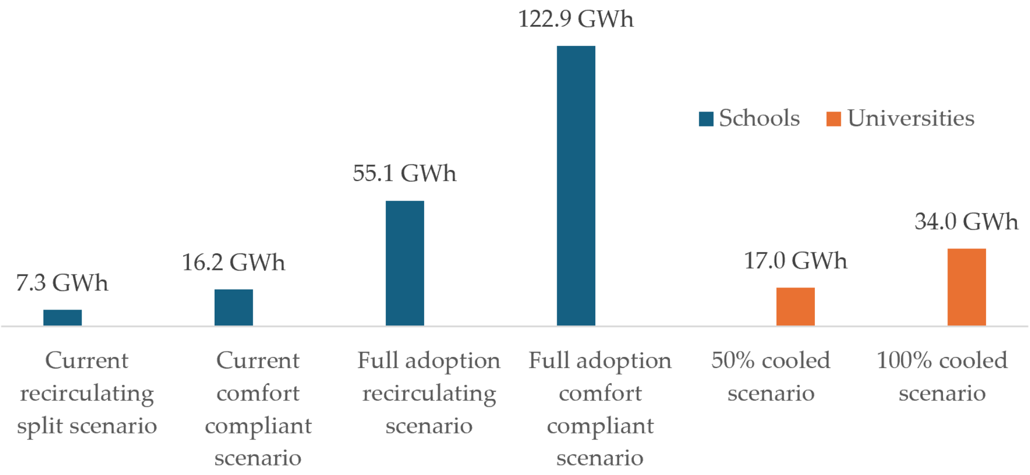
For the university sector, consumption is estimated from the physical capacity of about 591,573 places [52]. The specific load of 200 W per place combines occupant gains of about 120 W per person with lighting, equipment and envelope allowances typical of teaching spaces [55]. The annual equivalent occupancy of 630 hours reflects the overlap of the academic calendar with the cooling season. A design oversizing of 1.15 and a distribution efficiency of 0.9 are assumed as engineering allowances. The centralised-plant COP of 2.8 represents an ageing-stock screening assumption rather than a measured university-fleet average [16], while the cooled fraction of 50% is explicit. At 25%, 50% and 75% cooled, university electricity demand is about 8.5, 17.0 and 25.5 GWh per year.

At current low penetration, public primary and secondary schools consume about 7.3 GWh per year in the recirculating-split case and about 16.2 GWh per year in the comfort-compliant outdoor-air case. Adding the central university estimate of 17.0 GWh gives total education cooling demand of about 24.3 and 33.2 GWh per year respectively, equivalent to roughly 0.06% and 0.08% of 2023 national electricity generation [12]. Both are parametric scenarios, not measured equipment inventories.

A separate full-adoption scenario quantifies latent demand rather than forecasting uptake. If every public classroom were cooled over the same zone-specific school-calendar hours, school electricity demand would be about 55 GWh per year with recirculating splits and about 123 GWh per year with comfort-compliant outdoor-air treatment. If university cooled space simultaneously rose from the central 50% assumption to 100%, university demand would rise from about 17 to 34 GWh; total latent education demand would therefore be about 89 GWh in the recirculating case and 157 GWh in the comfort-compliant case.

The current and latent demand cases are summarised in Figure 8.

Figure 8 – Morocco: education cooling energy demand by service case and adoption level.



Emissions estimation

Indirect emissions use the adopted reference grid factor of 0.83 kg CO_2eq/kWh [16]. Direct emissions are calculated transparently as: annual direct emissions = installed thermal capacity × refrigerant charge per thermal kW × annual leakage fraction × refrigerant GWP. School installed capacity is calculated from the number of cooled classrooms and the per-classroom thermal loads in Table 24. Universities use the modelled central-plant capacity derived from places, cooled fraction, specific load, oversizing and distribution efficiency.

The school direct-emissions calculation uses an explicit assessment-assumed refrigerant mix because no Morocco-specific survey of refrigerants installed in public-school split systems was identified. The shares are reported in Table 26; national KIP documentation is used only to establish the broader HFC context [11].

Table 26 – Morocco: assessment-assumed current-stock refrigerant shares for school split and multi-split systems

Refrigerant	Assessment-assumed current-stock share	GWP (AR4) [47]
R-410A	70%	2,088
R-32	25%	675
R-22 (legacy)	5%	1,810
Weighted average GWP	**100%**	**≈ 1,721**

The corresponding direct-refrigerant-emission calculation is presented in Table 27.

Table 27 – Morocco: education direct-refrigerant-emission calculation (central assumptions)

Subsector / case	Installed thermal capacity	Charge	Leakage	Reference GWP	Direct emissions
Schools – recirculating split	97.2 MWth	0.25 kg/kW	10%/yr	1,721 (weighted)	4.2 kt CO_2eq/yr
Schools – comfort-compliant	216.7 MWth	0.25 kg/kW	10%/yr	1,721 (weighted)	9.3 kt CO_2eq/yr

Subsector / case	Installed thermal capacity	Charge	Leakage	Reference GWP	Direct emissions
Universities – 50% cooled	75.6 MWth	0.14 kg/kW	10%/yr	1,430 (R-134a)	1.5 kt CO_2eq/yr

The school charge assumption represents packaged split and multi-split systems, while the lower university charge reflects central chillers; both leakage assumptions are conservative screening values within the equipment-class envelopes reported by IPCC and UNEP RTOC [49]. Table 28 combines the indirect and direct terms for the two school service cases.

Table 28 – Morocco: education cooling energy and emissions by school service case (current low penetration)

Component	Recirculating split case	Comfort-compliant case
School electricity	7.3 GWh/yr	16.2 GWh/yr
University electricity	17.0 GWh/yr	17.0 GWh/yr
Indirect emissions – electricity	20.1 kt CO_2eq/yr	27.5 kt CO_2eq/yr
Direct emissions – schools	4.2 kt CO_2eq/yr	9.3 kt CO_2eq/yr
Direct emissions – universities	1.5 kt CO_2eq/yr	1.5 kt CO_2eq/yr
Total education-cooling emissions	25.8 kt CO_2eq/yr	38.4 kt CO_2eq/yr

At current low penetration, estimated education-cooling emissions are about 25.8 kt CO_2eq per year for recirculating classroom splits and 38.4 kt CO_2eq per year for comfort-compliant outdoor-air treatment. Direct emissions are about 5.7 and 10.8 kt CO_2eq per year respectively. Halving the assumed annual leakage rates would reduce these direct terms to about 2.8 and 5.4 kt CO_2eq per year, showing that refrigerant management remains material but does not overturn the ranking of the two service cases.

Intervention logic

The estate divides into two segments that call for different responses. The first comprises rural and small schools in the hot interior and south, often with constrained provincial budgets and a high share of multi-level classes. Here the priority is passive: reflective or insulated roofing to cut the dominant solar-transmission load, cross-ventilation and ceiling fans, and external shading of glazing [20][59], with evaporative cooling in the hot-dry interior and pre-Saharan zones, which delivers comfort at a fraction of the energy of vapour-compression systems [20]. These measures are aligned with the RTCM envelope provisions for new and rehabilitated tertiary buildings [18], remain effective during the warmest school weeks, and rest their investment case on learning outcomes and resilience rather than on energy savings.

The second segment, urban and institutional schools and universities with reliable grid access, is the near-term market for efficient mechanical cooling: inverter splits and, in larger buildings, VRF and mini-chillers, procured under low-GWP refrigerants (R-32) [11][16] and with award criteria that weight life-cycle cost and seasonal efficiency rather than lowest purchase price. On-site photovoltaics are a natural complement in this segment, since Morocco's abundant solar resource and the daytime coincidence of generation with the cooling peak make rooftop PV well matched to school and campus loads [60]. Sequencing matters: passive measures first, since they shrink the plant every subsequent investment must serve; efficient equipment second; on-site generation third.

Quick summary

The key barriers and enablers for sustainable cooling investment in the education sector are summarised in Table 29.

Table 29 – Morocco: education sector cooling quick summary

Dimension	Barriers	Enablers
Technology	Low mechanical-cooling penetration, modelled at 9.56% of classrooms in the central scenario; no official equipment inventory exists. Lowest-price procurement can favour on/off splits, while the measured 2022 new-unit market average was 2.84 W/W [16]	Inverter splits and VRF; R-32 transition under the national MEPS and Kigali trajectory [16][45]; evaporative cooling in the dry interior and south [59]
Economics & procurement	Constrained provincial budgets; awards on purchase price ignore life-cycle cost (qualitative assessment, not a published statistic)	Life-cycle and efficiency criteria; aggregated purchasing; development and climate finance [16]
Building stock	Largely uninsulated, pre-RTCM stock [18]; large classes raise internal heat loads [54][55]	RTCM envelope requirements for new/rehabilitated tertiary buildings [18]; school-construction pipeline [51]; cool roofs and passive measures [56][59]
Infrastructure & resilience	Earlier ministry reporting identified 25,605 multi-level classes; the 2024–2025 estate used 182,791 rooms [51]. Grid quality and maintenance capacity can be thinner at remote sites	Near-universal electrification (about 100%; 99.9% rural) [8]; abundant solar; rooftop PV matched to the cooling peak [60]
Energy & emissions	Latent demand large (this study); coal-heavy grid at 0.83 kg CO_2eq/kWh [12][16]	Current low-penetration cases: ≈ 24.3 GWh and 25.8 kt CO_2eq/yr for recirculating splits; ≈ 33.2 GWh and 38.4 kt CO_2eq/yr for comfort-compliant outdoor-air treatment. Peak heat falls largely in the summer break [51].
Data	No Morocco-specific classroom-heat or cooling-penetration data	Strong enrolment and infrastructure statistics; Massar MIS; PISA-based class-size evidence [51][54]

Food Cold Chain

Morocco's food cold chain is best understood as two systems operating at different levels of formality. Export-oriented horticulture and fisheries use pack-houses, refrigerated transport, freezing plants and port logistics to serve European and other international markets [61][62][63][67][69]. Alongside them, domestic distribution remains more fragmented and is served by a mixture of traditional wholesale/retail channels and expanding modern grocery formats [68][71]. The quantitative model covers selected horticulture and fisheries segments rather than the complete national food-refrigeration system: retail refrigeration, much domestic refrigerated transport, dairy, meat and food-service loads are not comprehensively represented. Within this defined perimeter, the greenhouse-gas footprint includes refrigeration electricity, refrigerant leakage and emissions embodied in modelled food losses. Spoilage is retained because it is central to the investment case, but it is reported as a scenario rather than as an observed national inventory.

Structure and context

Agriculture and fisheries are important to the Moroccan economy and export base [1][21][61][63]. The horticultural chain is documented through official foreign-trade statistics and product-specific reporting; for example, the USDA 2024–2025 citrus outlook projected approximately 597,000 tonnes of citrus exports across mandarins/tangerines, oranges and lemons/limes [62]. The fisheries administration reports national marine production on the order of 1.4 million tonnes in 2024 and a large processing/export industry [63][66]. These value chains are framed by the Generation Green 2020–2030 strategy and the associated World Bank programme, both of which emphasise value-chain modernisation and stronger post-harvest performance [64][65].

Cold-chain capacity is concentrated in export production zones, fisheries-processing hubs and the principal port/logistics corridors. Official fisheries reporting documents a diversified onshore processing sector and substantial frozen-product activity [63][66]. Tanger Med provides Ro-Ro services for temperature-sensitive exports and a Port Community System that coordinates digital trade and border processes [67][69]. Food-safety and cold-chain modernisation projects also document continuing investment needs, while domestic distribution and retail remain structurally more fragmented than the export chain [68][71]. Key indicators are summarised in Table 30.

Table 30 – Morocco: food cold chain key indicators

Indicator	Value	Source
Citrus exports (2024–2025 projection)	approx. 0.597 Mt: 0.500 Mt mandarins/tangerines, 0.090 Mt oranges and 0.007 Mt lemons/limes	[62]
Marine fisheries production (2024)	approximately 1.4 Mt	[63]
Official agricultural trade statistics	2024 product- and destination-level series available from the Office des Changes	[61]
Policy framework	Generation Green 2020–2030 and the Green Generation Program-for-Results	[64][65]
Export logistics	Tanger Med Ro-Ro services and Port Community System	[67][69]
Domestic retail structure	Modern formats are expanding, while traditional trade remains important	[71]
Cold-chain modernisation context	Food-safety and logistics projects document continuing investment needs	[68]

A two-speed cold chain

The export chain is comparatively formalised and increasingly digital. Refrigerated road transport links production and processing zones with Tanger Med, whose Ro-Ro services connect Moroccan exports with European markets [67]. The Tanger Med Port Community System coordinates digital exchange among port, customs and control actors and can reduce administrative friction at transfer points [69]. The fisheries chain relies on freezing, frozen storage and export logistics documented in official sector reporting [63][66]. The principal nodes and their vulnerabilities are set out in Table 31.

Table 31 – Morocco: export cold-chain nodes and bottlenecks

Node / link	Function	Vulnerability
Production-zone pack-houses (Souss-Massa, Gharb)	Pre-cooling, grading and cold storage for export horticulture [61][62][64][65]	Uneven cold-storage capacity; energy cost; peak-season congestion
Agadir & Dakhla freezing hubs	Freezing, processing and frozen storage of fish products [63][66]	Energy-intensive; ageing plant; refrigerant servicing
Refrigerated road haulage to Tanger Med	Refrigerated road transport from production and processing zones to export gateways [67]	Reefer-unit efficiency and maintenance; diesel reliance
Tanger Med ro-ro / refrigerated terminal	Ro-Ro transfer, border processes and digital port-community coordination [67][69]	Dwell time at inspection; cold-storage buffer capacity
Domestic distribution (wholesale & retail)	Wholesale, distribution-centre, supermarket and last-mile refrigeration [68][71]	Fragmented, under-refrigerated; high spoilage [68][70]

Market trajectory and drivers

Demand for cold-chain capacity is rising through export-oriented value-chain modernisation under Generation Green [64][65], the expansion of formal food retail and urban distribution [71], and the need to comply with product-specific sanitary, official-control and temperature-monitoring requirements in destination markets [72]. USTDA-supported work on food safety illustrates the continuing need for modern storage, handling and traceability infrastructure, but no single authoritative national market-size estimate is used in this report [68].

The main drivers and the corresponding cold-chain response are summarised in Table 32.

Table 32 – Morocco: food cold chain demand drivers

Driver	Cold-chain implication
Export growth (Generation Green)	More pre-cooling, frozen storage and reefer capacity at production zones and ports [64][65]
EU sanitary & traceability rules	Product-specific chilled and frozen temperature control, traceability and official controls; exact temperature ranges depend on the commodity and process [72]
Modern retail & urbanisation	Distribution centres, supermarket cold rooms and last-mile refrigeration as formal retail expands [71]
Fisheries value addition	Freezing, processing and cold storage documented in official fisheries reporting [63][66]
Climate & efficiency agenda	Pressure to cut refrigeration energy and shift to low-GWP refrigerants and solar [11]

Energy footprint

Final energy is estimated bottom-up across four selected segments. Stationary cold storage and fish freezing are electricity loads. Road transport refrigeration is represented as diesel energy used by the trailer refrigeration unit, not as grid electricity. The model adopts 1.8 litres of diesel per operating hour as a transparent operating assumption informed by transport-refrigeration literature and manufacturer efficiency documentation [73][74], together with a 20-tonne payload and modelled refrigeration-unit operation of 32 hours for chilled horticulture and 44 hours for frozen seafood. Using 9.8 kWh per litre as the diesel lower-heating-value conversion gives about 28.2 and 38.8 kWh per tonne, rounded to 29 and 40 kWh/t. These are scenario coefficients, not nationally measured fleet averages.

$$Energy = \Sigma_i \, (T_i \times e_i)$$

For stationary storage, energy is estimated from average stored inventory rather than directly from annual throughput. Annual throughput is converted to average inventory as Q × d/365. The model then applies a central volumetric benchmark of 49.5 kWh/m^3·yr, within the 44.3–61.9 kWh/m^3·yr range reported for refrigerated food cold stores [75], and an explicit effective stored-product density assumption of 0.30 t/m^3. This is equivalent to 165 kWh per tonne of average inventory per year. The coefficient is therefore derived by this assessment rather than reported directly by Evans et al.; studies using tonne-based denominators show strong variation between facilities and operating practices [76]. Project appraisal should replace density, occupancy and dwell assumptions with measured storage volume and operator data. Published fish-refrigeration case studies likewise demonstrate substantial plant-specific variation [77]. The model therefore adopts 130 kWh/t for the freezer load plus 10 kWh/t for product handling, pumps, fans and short-term frozen holding as explicit engineering assumptions, giving 140 kWh/t. FAO food-loss publications are not used as energy-intensity sources. Segment flows, assumptions and citations are set out in Table 33.

Applied to the selected horticulture and fisheries flows, the model gives about 273.3 GWh per year of final-energy equivalent: 179.6 GWh of stationary electricity and 93.7 GWh-equivalent of diesel used by transport refrigeration units. Industrial fish freezing and processing is the largest represented load at 140 GWh. The result is not a complete national cold-chain energy inventory because retail refrigeration, much domestic refrigerated transport, dairy, meat and food-service loads are outside the perimeter.

The resulting segment-level final-energy calculations are reported in Table 33.

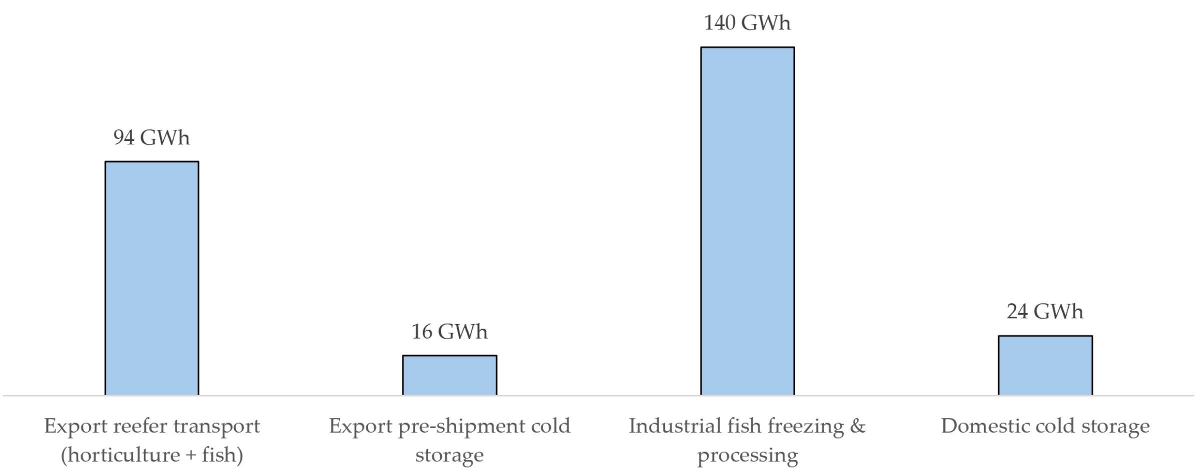
Table 33 – Morocco: final-energy demand in selected cold-chain segments

Segment	Basis	Final energy [GWh/yr]
Export reefer transport – horticulture	2.1 Mt modelled export-oriented horticulture flow × 29 kWh/t; the flow is an assessment assumption informed by official trade and citrus-export context [61][62], while the transport coefficient is derived from [73][74]	60.9 diesel-equivalent
Export reefer transport – seafood	0.82 Mt modelled seafood export flow × 40 kWh/t; the flow is an assessment assumption bounded by official fisheries statistics [63], while the transport coefficient is derived from [73][74]	32.8 diesel-equivalent

Segment	Basis	Final energy [GWh/yr]
Export pre-shipment cold storage	49.5 kWh/m3·yr [75]; 0.30 t/m3 effective density (assessment assumption), equivalent to 165 kWh/t of average inventory·yr; dwell 5 d horticulture / 30 d frozen fish	15.9 electricity
Industrial fish freezing & processing	1.0 Mt modelled processing flow × (130 kWh/t freezer load + 10 kWh/t auxiliaries); explicit engineering assumptions informed by plant-specific variation in [77]	140.0 electricity
Domestic cold storage	3.5 Mt throughput; 49.5 kWh/m3·yr [75] and 0.30 t/m3 effective density (assessment assumption), equivalent to 165 kWh/t of average inventory·yr; dwell 15 d	23.7 electricity
Selected modelled segments	179.6 GWh electricity + 93.7 GWh diesel-equivalent	273.3

The resulting segment-level final-energy demand is visualised in Figure 9, making clear which parts of the cold chain drive the largest refrigeration load.

Figure 9 – Morocco: selected cold-chain segment final-energy equivalents.



Emissions estimation

The greenhouse-gas footprint combines stationary electricity, diesel combustion by transport refrigeration units, direct refrigerant leakage and production-stage emissions embodied in spoiled food. Applying 0.83 kg CO_2eq/kWh to 179.6 GWh of stationary electricity gives 0.149 Mt CO_2eq/yr [16]. Converting the 93.7 GWh diesel-equivalent back to fuel volume and applying the 2025 government diesel factor gives about 0.026 Mt CO_2eq/yr [78]. Direct emissions use the same explicit formula as the education and healthcare models: capacity or equipment count × charge × leakage × GWP. The central result is 17.5 kt CO_2eq/yr, rounded to 0.018 Mt CO_2eq/yr; low and high leakage cases give about 0.012 and 0.023 Mt CO_2eq/yr [46][47][49].

The central assumptions and calculation of direct refrigerant emissions from the selected cold-chain equipment are detailed in Table 34.

Table 34 – Morocco: cold-chain direct-refrigerant-emission calculation (central assumptions)

Segment	Capacity / stock basis	Refrigerant assumption	Charge and leakage	Direct emissions
Industrial fish freezing	70 MWth from 140 GWh, COP 2.0, 4,000 h	70% NH_3; 30% HFC, GWP 3,000	0.40 kg/kW of HFC share; 15%/yr	3.8 kt CO_2eq/yr
Stationary cold storage	33 MWth from 39.6 GWh, COP 2.5, 3,000 h	HFC blend, GWP 2,500	0.40 kg/kW; 15%/yr	5.0 kt CO_2eq/yr
Transport refrigeration	≈ 2,920 units: 2.92 Mt ÷ (20 t × 50 loaded trips/yr)	HFC blend, GWP 2,500	6 kg/unit; 20%/yr	8.8 kt CO_2eq/yr
Total	Central assumptions	Ammonia treated as GWP 0	Leakage sensitivity: 0.012–0.023 Mt CO_2eq/yr	17.5 kt CO_2eq/yr

Spoilage is retained as an explicitly modelled scenario. The horticultural production base is constructed reproducibly from FAOSTAT 2022 production quantities for a defined basket of cold-chain-relevant crops [79]. It totals 11.963 Mt: 7.128 Mt of vegetables, roots and melons; 2.679 Mt of citrus; and 2.156 Mt of selected other fruits. Citrus is included exactly once, and no separate citrus quantity is added from the USDA export outlook [62]. The broader FAO food-loss report is retained only as international context and is not used for energy intensities or Moroccan production quantities [80]. Applying the explicit central assumption of a 20% horticultural loss rate gives 2.393 Mt lost and 1.196 Mt CO_2eq of embodied emissions at 0.5 kg CO_2eq/kg [81]. Fisheries add 0.256 Mt lost and 0.511 Mt CO_2eq at the explicit 18% loss assumption and an intensity of 2.0 kg CO_2eq/kg [63][82]. Central spoilage emissions are therefore about 1.707 Mt CO_2eq/yr. At horticultural loss assumptions of 15% and 25%, the complete modelled footprint is about 1.60 and 2.20 Mt CO_2eq/yr. These loss rates are scenario parameters, not nationally observed averages. The crop-group composition of the 2022 production base is set out in Table 35.

Table 35 – Morocco: composition of the 2022 cold-chain-relevant fruit-and-vegetable production base [79]

Group	Included FAOSTAT crops	Production [Mt]
Vegetables, roots and melons	Potatoes, tomatoes, onions, watermelons, melons, carrots/turnips, pumpkins/squash, peppers, green and string beans, cucumbers, peas, broad beans, cabbages, artichokes, green garlic, green maize, spinach, cauliflower/broccoli, asparagus, mushrooms, lettuce/chicory, eggplants and other vegetables	7.128
Citrus	Mandarins/clementines, oranges, lemons/limes, other citrus and pomelo/grapefruit	2.679
Selected other fruits	Apples, grapes, peaches/nectarines, plums, strawberries, avocados, apricots, quinces, pears, raspberries, blueberries and cherries	2.156

Group	Included FAOSTAT crops	Production [Mt]
Total cold-chain-relevant basket	Citrus is included once; olives, nuts, dried fruit and non-selected tropical fruit are excluded	11.963

The central spoilage assumptions and resulting embodied emissions are summarised in Table 36.

Table 36 – Morocco: central cold-chain spoilage scenario

Stream	Production base	Modelled loss rate	Loss tonnage	Emission intensity	Mt CO_2eq/yr
Fruit and vegetables	11.963 Mt, FAOSTAT 2022 basket [79]	20% assumed	2.393 Mt	0.5 kg CO_2eq/kg [81]	1.196
Fisheries products	1.42 Mt national catch [63]	18% assumed	0.256 Mt	2.0 kg CO_2eq/kg [82]	0.511
Citrus accounting check	Citrus is already included once within the 11.963 Mt FAOSTAT basket [79]; USDA export projections provide context only [62]	No separate loss rate applied	No additional tonnage	–	–
Central scenario total	Defined horticulture basket + national catch	Scenario assumptions	2.649 Mt	–	1.707

The complete central emissions balance for the modelled cold-chain perimeter is reported in Table 37.

Table 37 – Morocco: modelled food cold-chain emissions summary (central scenario)

Emission component	Mt CO_2eq/yr	Share
Stationary refrigeration electricity	0.149	≈ 8%
Transport-refrigeration diesel combustion	0.026	≈ 1%
Direct refrigerant leakage	0.018	≈ 1%
Spoilage – embodied in lost perishables	1.707	≈ 90%
Separate screening indicators	1.900	100%

Within the defined model perimeter, the climate cost embodied in spoiled food remains much larger than the operational footprint of the represented refrigeration systems. The two screening indicators sum arithmetically to about 1.90 Mt CO_2eq/yr, but they should not be presented as a national inventory total because the operational footprint and the food-loss scenario have different analytical boundaries; roughly 90% of the arithmetic sum is the spoilage scenario. This does not imply that all losses are preventable by cooling: project appraisal must demonstrate the share causally attributable to temperature management and compare avoided spoilage emissions with the additional energy and refrigerant impacts of the proposed system.

Intervention logic

Three priorities follow. First, target loss reduction where the evidence and causal link to cooling are strongest: pre-cooling and cold-storage capacity for horticulture in production zones, and improved handling and temperature control in domestic distribution. In the central scenario, each tonne saved avoids production-stage emissions of about 0.5 t CO_2eq for fruit and vegetables and about 2.0 t CO_2eq for fish [81][82], but project appraisal should quantify the share of loss actually attributable to inadequate temperature management.

Second, make the energy-dominant segment efficient. The fisheries-processing and freezing base is the single largest electricity load in the represented perimeter, so high-efficiency compressors, heat recovery and on-site photovoltaics can concentrate savings in a limited number of processing hubs [60][63][66].

Third, lock in low-GWP refrigerants: ammonia and CO_2 for industrial plant, and the HFC phase-down under the Kigali Amendment for commercial and transport refrigeration [11].

The export and domestic chains call for different emphases. The export chain is more formalised and benefits from established Ro-Ro logistics and digital port-community processes [67][69]; its agenda is efficiency, refrigerant transition and monitoring. The domestic chain remains more fragmented across wholesale, traditional retail and emerging modern formats [68][71], so progress depends on aggregating demand, de-risking investment in distribution-centre and retail refrigeration, and extending traceability and temperature-monitoring practices beyond the principal export gateways.

Quick summary

The key barriers and enablers for sustainable cooling investment in the food cold chain are summarised in Table 38.

Table 38 – Morocco: food cold chain cooling quick summary

Dimension	Barriers	Enablers
Technology	Ageing freezing plant; reefer-unit efficiency; legacy high-GWP refrigerants in commercial storage	Ammonia/CO_2 industrial systems; high-efficiency compressors and heat recovery; R-32/low-GWP transition
Economics & finance	Fragmented, under-capitalised domestic chain; energy cost of freezing	Generation Green value-chain investment, documented food-safety modernisation programmes and development/climate finance [64][65][68]
Infrastructure	Uneven pre-cooling and storage capacity in production zones; fragmented domestic distribution	Tanger Med Ro-Ro and Port Community System; documented cold-chain modernisation projects [67][68][69]
Energy & emissions	Coal-heavy grid; fish freezing energy-intensive	≈ 273 GWh/yr final-energy equivalent for selected horticulture and fisheries segments: 179.6 GWh electricity and 93.7 GWh diesel-equivalent; ≈ 0.193 Mt CO_2eq/yr operational emissions including refrigerants.
Food loss	The 20% horticulture and 18% fisheries loss rates are explicit scenario assumptions, not observed national averages	Pre-cooling and storage can cut avoidable losses and emissions together where inadequate temperature control is demonstrated as a causal factor

Dimension	Barriers	Enablers
Data	No Morocco-specific cold-chain energy/emissions quantification; loss rates partly estimated	Strong export, fisheries and port statistics; documented citrus loss; Foodex/ONSSA digital records

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