# *National Energy Efficiency Strategy for Sudan*

**(DEL4 – Tasks 5, 6 and 7)**

**PROJECT: "Preparation of the Lighting, Residential Air Conditioning, Refrigerators, Fans and Evaporative Coolers Energy Efficiency Strategy for Sudan"**

Deliverable 4

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| | |
|---|---|
| AC | Air Conditioner |
| AE | Annual Energy |
| AEC | Annual Energy Consumption |
| BAU | Business as Usual |
| CAGR | Compound Annual Growth Rate |
| CDM | Clean Development Mechanism |
| CEN | Comité Européen de Normalisation (European Committee for Standardization) |
| CER | Certified Emission Reduction |
| CIF | Climate Investment Funds |
| $CO_2$-eq | Carbon Dioxide Equivalent |
| CSPF | Cooling Seasonal Performance Factor |
| CTF | Clean Technology Fund |
| DAC | Development Assistance Committee |

| | |
|---|---|
| DC | Direct Current |
| DEL2 | Deliverable 2 of this assignment |
| DEL3 | Deliverable 3 of this assignment |
| DOC | Declaration of Conformity |
| EE | Energy Efficiency |
| EEI | Energy Efficiency Index |
| EER | Energy Efficiency Ratio |
| EES | Energy Efficiency Strategy |
| ER | Emission Reduction |
| ERA | Electricity Regulatory Authority |
| EU | European Union |
| GCF | Green Climate Fund |
| GEF | Global Environment Facility |
| GHG | Greenhouse Gas |
| GSP | Global Support Programme |
| GWh | Gigawatt Hour |
| GWP | Global Warming Potential |
| HCFC | Hydrochlorofluorocarbons |
| HFC | Hydrofluorocarbons |
| HFC-134a | Tetrafluorethan |
| HFO | Hydro-fluoro-olefin |
| HPMP | HCFC Phase-out Management Plan |
| HSPF | Heating Seasonal Performance Factor |
| IE | Implementing Entity |
| IEC | International Electrotechnical Commission |
| IKI | International Climate Initiative |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Organization for Standardization |
| ITMO | Internationally Transferred Emission Reductions |
| KA | Kigali Amendment |
| K-CEP | Kigali Cooling Efficiency Program |
| kW | Kilowatt |
| kWh | Kilo-watt Hour |
| LACEES | Lighting and Air Conditioning Energy Efficiency Strategy |
| LCC | Lifecycle Cost |
| MAC | Mobile Air Conditioner |
| MDB | Multilateral Development Bank |
| MEPS | Minimum Energy Performance Standards |
| MEV | Monitoring, Enforcement and Verification |
| MIT | Mitigation |
| MLF | Montreal Protocol's Multilateral Fund |
| MOE | Ministry of Environment |
| MEO | Ministry of Energy and Oil |
| MOP | Meeting of the Parties |
| MP | Montreal Protocol |
| MRV | Monitoring, Review, and Verification |
| $MTCO_2eq$ | Million Ton Carbon Dioxide Equivalent |
| NAMA | Nationally Appropriate Mitigation Action |

| | |
|---|---|
| NAP | National Adaptation Plan |
| NDC | National Determined Contribution |
| NEEAP | National Energy Efficiency Action Plan |
| NGO | Non-Governmental Organization |
| NOU | National Ozone Unit |
| ODP | Ozone Depletion Potential |
| ODS | Ozone Depleting Substances |
| PA | Paris Agreement |
| PU | Polyurethane |
| R134a | Tetra-fluoro-ethane |
| R22 | Chlorodifluoromethane |
| R290 | Propane |
| R404A | Blended cooling agent from R134a 4 %, R143a 52%, R125 44 % |
| R410A | Blended cooling agent from R32 50 %, R125 50 % |
| R600a | Isobutane |
| R717 | Ammonia |
| R744 | Carbon Dioxide |
| RAC | Refrigeration and Air-Conditioning |
| RE | Renewable Energy |
| SAE | Standard Annual Energy |
| SEER | Seasonal Energy Efficiency Ratio |
| SSMO | Sudanese Standards and Metrology Organization |
| UAC | Unitary Air Conditioner |
| UNDP | United Nations Development Program |
| UNEP | United Nations Environment Program |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNIDO | United Nations Industrial Development Organization |
| VCS | Verified Carbon Standard |
| WP | Work Program |
| WTP | Willingness to Pay |

# 1 EXECUTIVE SUMMARY

Climate change is rapidly becoming one of the most important policy issues worldwide and it's no different for Sudan. With increasing temperatures and higher electrification rate, the demand for air conditioning, refrigeration, and lighting will steadily increase. As a member party to the Paris Agreement, Sudan also has an obligation to reach climate targets, i.e., net GHG neutrality latest by the middle of this century. This goal can be reached through its increasing ambition and setting specific sector goals within Sudan's Nationally Determined Contributions, NDCs (ratcheting up mechanism).

The country saving assessment for Sudan released in October 2020 by United for Efficiency (U4E), a United Nations Environment Program initiative, estimated the annual electricity savings by 2030 from minimum ambition scenario of energy efficiency policies on lighting, cooling, industrial motors and distribution transformers at two terawatt hours (TWh).

According to the World Bank report of September 2020 (P175040), the Sudanese population is growing at 2.4 percent per year, increasing to 56 million by 2031 from 40 million in 2019. The number of households with access to electricity is 2.2 million while 4.5 million households still do not have access to electricity. This highlights the importance to implement highly efficient technologies, reducing the overall increase in energy demand as well as ensuring that available energy serves as many households as possible. This national goal is the key element of this "Energy Efficiency Strategy" (EES) report for Sudan and includes the following six main parts:

1. the **market study**, performed in the fourth quarter of 2020, aimed to better understand the stock of appliances' and their technical and performance characteristics,
2. a proposal for a **MEPS and Labels regulation** based on the survey results and the regional and international best practices,
3. a proposed **Monitoring, Enforcement and Verification (MEV) process**,
4. the **financing approach** to support the introduction of energy-efficient appliances through the enforcement of a MEPS and Labels system.
5. a proposal for the integration of the **EES into Sudan's NDC**, and
6. **strategy recommendations** for a timely migration towards energy efficient market in Sudan.

The first element of this report is the sectors' assessment which is based on a market analysis, collecting technical data from models on sale. The collected information was then clustered according to capacity and analysed for frequency distribution of energy efficiency levels. Key findings related to energy demand and resulting Green House Gas (GHG) emissions, in each sub-sector, are summarized in Table 1 below.

*Table 1: Electricity demand and connected emissions in the studied five subsectors.*

| Electricity demand (GWh) | | | | Emissions from Electricity use (Mt $CO_2$ eq) | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **2020** | **2030** | **2050** | **Year** | **2020** | **2030** | **2050** |
| **Split and window type ACs** | 3055 | 11920 | 35681 | | 932 | 3636 | 10883 |
| **Evaporative Coolers** | 594 | 2568 | 10309 | | 181 | 783 | 3144 |
| **Refrigerators** | 1205 | 3387 | 7708 | | 368 | 1033 | 2351 |
| **Fans** | 2829 | 7339 | 18414 | | 863 | 2238 | 5616 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Lighting** | 6495 | 11033 | 57057 | | 1981 | 3365 | 17402 |
| **Total** | 14179 | 36247 | 129169 | | 4325 | 11055 | 39397 |

This demand could be reduced if energy is used more efficiently. When compared to the economic cost of installing new power plants, energy efficiency (EE) is a low-cost alternative to meet the country's energy needs. In addition, the consumer saves on the electricity bill and $CO_2$ emissions are reduced.

One of the most useful tools to increase the level of energy efficiency of products on the market is through Minimum Energy Efficiency Standards (MEPS) and Energy Efficiency labels, which is the second element of this strategy report. MEPS indicate the minimum level of efficiency of the products that can be introduced in the market, eliminating the most inefficient devices. On the other hand, the labels inform the consumer of savings opportunities in energy consumption and the environmental benefits by choosing more efficient products, increasing sales of the most efficient products, and preparing the market for the application of more restrictive MEPS in the future. So far, Sudan lags behind other developed and developing countries on the development and introduction of mandatory MEPS and labels. The adoption of advanced energy efficiency standards along with the transition to low GWP refrigerants are required to realize GHG savings. With the current electricity prices in Sudan life-cycle-costs (LCC) will stay about the same; and with the expected higher electricity prices, that cost will even be lower for end-users and the economy.

In order to fulfil the goal of driving the country to a more energy efficient market, MEPS and labels must be designed and implemented correctly. They must be reviewed and updated frequently to account with the technology improvements over time.  Furthermore, these energy regulations have to be monitored, enforced and verified in the marketplace through an efficient MEV process constituting the third key element of the national EE strategy for Sudan.

As a fourth element of this report, there is a proposal for a Funding and Financing Mechanism to support the intended market transformation towards energy efficient and low GWP appliances targeted for the five in-scope sectors. The Funding and Financing Mechanism refers to a consistent set of measure to accelerate that transition and it covers the following key elements:

- An import levy on imported appliances and refrigerants linked to the energy efficiency and label classes of, initially, ACs and refrigerators, and the carbon content of refrigerants,
- An incentive mechanism based on carbon credits on the purchase of climate-friendly and efficient appliances linked to the return of old, inefficient cooling appliances sent for environmentally sound disposal,
- Financial mechanisms, like soft loans, and a baseline and credit program are proposed, whereby soft loans are used to support the private sector investment, while the baseline and credit program to cover the cost for a recycling and disposal facility,
- Available funding source from national and international programs. These are analysed regarding the available level of funding and their applicability in Sudan.

This report includes recommendation to integrate the EES into Sudan’s NDC, whereas climate friendly and energy efficient appliances, within the 5 in-scope sectors, can contribute to a significant reduction of Sudan’s current GHG emissions. Chapter 9 includes recommended actions for the integration of the EES into sectoral measures of the NDC covering the energy, building, transport, industry, waste and agricultural sectors.

# 2 INTRODUCTION AND BACKGROUND

## 2.1 General introduction

As a signatory to both, the Paris Agreement and the Montreal Protocol (including the Kigali Amendment) Sudan is looking to deliver on its international commitments as well as reaping the multiple benefits from rational energy efficiency and environmental policies such as enabling the already stretched electricity system to meet a greater proportion of demand in the country, reduction of noxious emissions (i.e., particulates), and reducing Investment needs on the electricity grid. As such, a transition to low-emission cooling and lighting in Sudan is an important aspect that should be integrated into Sudan's development strategies.

In this context the EES will identifies potential energy demand reduction, energy efficiency interventions, the transition from high to low GWP refrigerants, and proposes a timeline for the implementation of these actions in an integrated national energy efficiency plan. There is a focus on the appropriate framework to implement Minimum Energy Performance Standards (MEPS) and labelling system for the five subsectors (domestic refrigeration, air-conditioning, evaporative coolers, lighting, and domestic fans) as the current main contributors to carbon emissions and energy consumption.

The EES was developed by a consortium led by HEAT GmbH and included OTB Consult as partner company. The work was implemented for the Sudanese Electricity Regulatory Authority (ERA) (within the Ministry of Energy and Oil of Sudan), under the direct supervision of the Sudan's Energy Efficient Appliances and Lighting (SEEAL) Project Manager, and in coordination with the local UNDP team. The EES is funded by the Global Environment Facility (GEF).

## 2.2 EES objectives and elements

The EES aims at an effective action plan that tackles energy efficiency and related GHG emissions with coherent policies. To meet these objectives the development of the EES covered discrete elements of work as shown in Table 2 below. The first three elements produce the foundational basis with information on the current state of appliances in the market as well as the current state of EE policies in Sudan. The following three elements generate the necessary recommendations and tools to achieve the EES's objectives. The final element is capacity building and awareness necessary to empower local officials and institutions to implement the tools effectively.

*Table 2: Development steps of the EES*

| Elements | Development steps description |
|---|---|
| 1 | General overview and analysis of the refrigeration, air conditioning, evaporative coolers, lighting, and domestic fans sectors, including a market survey of related appliances. |
| 2 | Overview and projection of electricity consumption in the five subsectors and electricity demand in Sudan. |
| 3 | Assessment of the energy efficiency regulations and national policies related to the five subsectors. |
| 4 | Recommendations for the establishment of Minimum Energy Performance Standards (MEPS), a labelling programme and the development of test procedures. |
| 5 | Assessment and proposals of funding and financial mechanisms for market transformation. |
| 6 | Development of an energy efficiency strategy covering the five in-scope subsectors. |
| 7 | Capacity Building and Awareness. |

This EES report brings together all the information gathered during the stages of its development to formulate robust recommendations and guidance for the sustainable and low carbon development of cooling, refrigeration, and lighting in Sudan.

The objectives of the EES include:

- Provide information on the current state of the market and projections of the potential future paths of energy demand and GHG emissions for the five subsectors,
- Identification of key subsectors with the highest GHG emissions as well as the highest emission reduction and energy-saving potential,
- Provide recommendations and the background support for the development and implementation of mitigation measures, especially a MEPS and Labelling scheme,
- Provide recommendations to support Sudan's Monitoring, Reporting and Verification (MRV) activities,
- Support the development and achievement of Sudan's National Determined Contribution (NDC) targets based on the GHG projected emissions and mitigation measures defined and implemented in the five subsectors,
- Provide recommendations to support the preparation for the implementation of the Montreal Protocol (MP), especially the Kigali Amendment.

This EES report concentrates first on a summary of the current state of demand for appliances in Sudan as well as the status of energy efficiency and environmental policy in this sector. Then, the report proposes a series of interventions oriented towards achieving Sudan's Paris and Montreal related commitments. The reports will delve into the financial aspects of implementing the mentioned interventions, from revenue gathering through levies or penalty payments to providing direct subsidies to stimulate action. Finally, the report provides an action plan with suggested interventions and an optimum timeline for implementation.

## 2.3 Legal framework

Sudan has committed to several national and international regulations and agreements relevant to the in-scope sectors, which are explained below according to three policies:

- **Climate policies.** Sudan has signed the Paris Agreement on 22 April 2016 and ratified the Paris Agreement on climate change in August 2017. The Paris Agreement entered into force on 04.11.2016, ratified by the critical number of countries reaching the threshold for its entry into force. Sudan, via its Ministry of Environment, has submitted in October/2015 its first Nationally Determined Contribution (NDC).

  The Montreal Protocol was also amended in 2016 with the signing of the Kigali Amendment. With reaching the critical mass of ratifying countries the Kigali Amendment entered into force on 01.01.2019. Sudan has to date (July 2021) not yet ratified the Kigali Amendment but is in the process of preparing its ratification. With the implementation of the Kigali Amendment, Sudan needs to phase-down the use and consumption of HFCs along the phase out of HCFCs. Figure 1 illustrates the relevant phase down schedule for Sudan, belonging to the A5 Group 1 countries. Noting that Sudan, being a country with high ambient temperature conditions where suitable alternatives do not exist, has an exemption that allows for a delay in the HFC freeze date and initial control obligations by an initial duration of four years. The exemption applies to multi-split air conditioners (commercial and residential), split ducted air conditioners (residential and commercial), and ducted commercial packaged (self-contained) air conditioners.

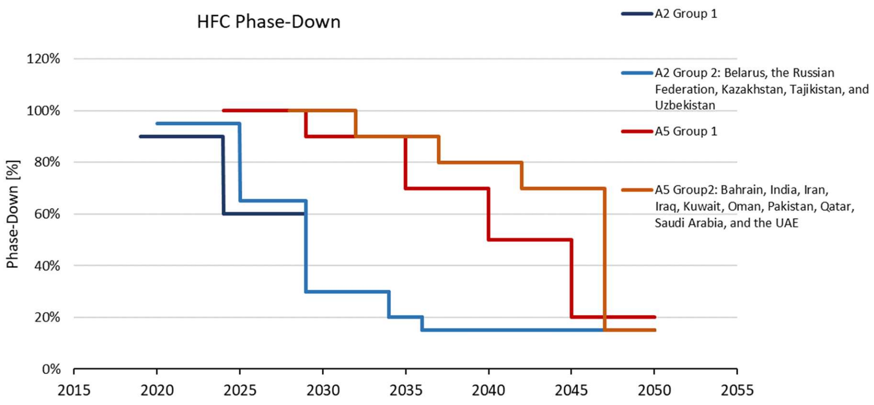



*Figure 1 Kigali Amendment HFC phase-down schedule.*

- **Energy policies.** Sudan has a lack of national policies regarding the energy efficiency in the energy sector, especially the RAC sector. There is a draft of Electricity Sector Strategy 2020-2035, which includes an indication to policies required for Quality control for electrical equipment imports in terms of energy efficiency.
- **Refrigerant related policies.** The XIX$^{th}$ Meeting of the Parties (MOP) to the Montreal Protocol in September 2007, through its Decision XIX/6, adopted an accelerated phase-out schedule for HCFCs. As a member of the Montreal Protocol, Sudan is implementing the HCFC Phase-out Management Plan (HPMP).

### 2.3.1 HCFC Phase out Management Plan (HPMP) stage I

The Government of Sudan reported a consumption of 42.07 ODP tons of HCFC in 2016 (see details in the market survey report of deliverable 2), which was 20.2% below the baseline and slightly below the maximum allowable consumption of 42.13 tons under its Agreement with the Executive Committee for that year.

All HCFC-22 consumption occurs in the refrigeration and air-conditioning (RAC) servicing sector. The major uses are for servicing split air-conditioning units and commercial refrigerators. HCFC-141b is used to produce polyurethane (PU) foam and insulation foam for refrigeration equipment.

#### 2.3.1.1 *Progress on the implementation of the HPMP stage I*

**1. Legal framework**

The National Ozone Unit (NOU) is established within the Ministry of Industry and is supervised by the Higher Council for Environment and Natural Resources (HCENR) and supported by the National Committee (NC) for the Implementation of the Montreal Protocol.

The licensing and quota system for HCFC import control is implemented in collaboration between the NOU and the Sudanese customs authority. The efficiency of the import control has been further improved by developing a shared electronic database on quotas and actual imports. Import documents must be submitted to customs and the NOU.

The manufacturing sector phase-out is being implemented at the four PU-foaming companies in Sudan. The umbrella project covered four locally owned enterprises using HCFC-141b as a blowing agent in the manufacture of domestic refrigerators and freezers (two companies) and insulated panels (two companies). The conversions at Modern Refrigeration Factory (domestic refrigerators and freezers) and Amin Panels Co. (insulated composite panels) have been completed and the old equipment has been destroyed. The conversion at Coldair company (domestic refrigerators and freezers) was finalized in 2017 and at Akadabi Steel company (insulated panels and slabstocks) was completed in 2019. The four companies selected pentane as a replacement for HCFC-141b. The completion of the conversion of these four enterprises resulted in a phase-out of 107.9 Mt (11.87 ODP tons) of HCFC-141b, representing over 23% of the total HCFC consumption in 2013.

### 2.3.2 HCFC phase-out management plan (stage II)

On behalf of the Sudanese government, UNIDO as the designated implementing agency has submitted a request for funding for the third and final tranche of stage II of the HCFC phase-out management plan (HPMP), at the amount of US $36,716, plus agency support costs of US $2,570. 2 The submission includes a progress report on the implementation of the second tranche, the verification report on HCFC consumption for 2019 and the tranche implementation plan for 2020 to 2021.

#### 2.3.2.1 *Progress report on the implementation of the second tranche of the HPMP Stage II*

**1. Legal framework**

The Decree for Management and Organization of Ozone Depleting Substances Regulation (2001) was amended in 2013 to include the licensing and quota system for HCFCs. The National Ozone Unit (NOU) works closely with the Sudan Customs Administration to enforce the licensing and quota system to control the HCFC imports. Currently the ODS regulation is being revised to include control measures for HFCs and the zero quota for HCFC-141b and HCFC-141b contained in pre-blended polyols. To ensure safety of refrigeration technicians, the Government has stipulated that the introduction of flammable refrigerants must meet the existing occupational health and safety standards.

The Government of the Sudan has initiated the Kigali Amendment ratification process, and the ODS regulation will be amended to include HFCs in the licensing and quota system. Due to the social and political unrest in the country, the Government has gone through institutional changes which potentially delayed the process of ratification. The newly appointed Secretary General has confirmed that the Kigali Amendment will be given priority. The NOU expects the ratification document to be approved in March 2021.

**2. Completion of stage II**

The Government of the Sudan has established a licencing and quota system to control the import of HCFCs and no quotas for HCFC-141b has been issued since 1 January 2020. The HCFC consumption in 2019 is 42% below the Montreal Protocol control target and 1.6% below the target in the Agreement with the Executive Committee. The conversion of foam manufacturing at four enterprises had been completed and the remaining two, despite some delays due to the country's situation and the COVID-19 situation, are on track for completion. Training in good servicing practices and the safe handling of flammable refrigerants have been provided to technicians, and equipment and tools have also been provided to strengthen the training institute and to support refrigerant recovery, recycling and reuse. Low-GWP alternatives are being promoted in the servicing sector to maximize climate benefit. The direct involvement of universities and refrigeration associations in implementation ensures the long-term sustainability of training for technicians in the servicing sector. The overall disbursement has reached 98%. Stage III will be submitted to the 87th meeting.

UNIDO has confirmed that stage II for the Sudan will be completed on 31 December 2021 as established in paragraph 14 of the Agreement.

### 2.4 Energy efficiency regulations in Sudan

The introduction of mandatory regulations with Minimum Energy Performance Standards (MEPS) and labels has proven internationally its effectiveness. These are a universally applicable instruments to drive the energy efficiency of household appliances, particularly, room ACs and domestic refrigerators.

In Sudan, the Electricity Regulatory Authority (ERA) is sole entity regarding issuance and execution of electrical energy efficiency. ERA had drafted a law for electricity which now under ratification process. This draft includes the only energy efficiency regulation in Sudan.

## 2.5 Key stakeholders

Table 3 provides an overview of the involved stakeholders for carrying out the appliances' assessment.

*Table 3: Overview of involved stakeholders for the RAC assessment.*

| Stakeholder | Roles and responsibility |
|---|---|
| **SSMO** | Sudan's regulatory body issuing and adopting standards and potentially labels. |
| **ERA** | Electricity Regulatory Authority, in charge of the issuance and execution of electrical energy efficiency in Sudan. |
| **Sudanese Customs Authority** | The authority in charge for controlling the imports of appliances. Providing data on imports and exports of equipment and refrigerants. |
| **UNDP** | GEF Fund manager, funding the EE Strategy of Sudan project |
| **Manufacturers and assemblers** | Local manufacturers and assemblers of ACs, refrigerators, fans, lighting and evaporative coolers; they will be directly affected by MEPS enforcement. |
| **Higher Council for Environment and Natural Resources (HCNER)** | 1. Lay out of general policies in collaboration with competent authorities in the area of:<br>o Sustainable natural resources, conservation, management, and rationale use.<br>o Protection of the environment.<br>2. Coordinate with the State's councils in the assessment of natural resources and determine their current and future utilization. |

| | |
|---|---|
| | 3. Lay out long-term federal programs for natural resources conservation and protection of the environment and coordinate their implementation with competent authorities.<br>4. Regular review of national legislation related to environment and natural resources to ensure compliance with international standards.<br>5. Coordinate efforts of Sudan to join international environmental agreements and their implementation with relevant institutions.<br>6. Encourage scientific research in the area of environment and natural resources.<br>7. Raise funding at both national and international levels.<br>8. Work with education, media, etc, on capacity building, public awareness.<br><br>The HCENR coordinated and facilitated Sudan efforts to join the following:<br>i. UNCBD<br>ii. Bio-safety Protocol<br>iii. Nagoya Protocol (ratification underway)<br>iv. UNFCCC<br>v. Kyoto Protocol<br>vi. Paris Agreement<br>vii. Ramsar Convention on Wetlands.<br>viii. Vienna Convention for the protection of Ozone Layer.<br>ix. Montreal Protocol for the Ozone Depletion Substances.<br>x. Basel Convention on the Control of Trans boundary Movements and Hazardous Wastes and their Disposal.<br>xi. Stockholm Convention on Persistent Organic Pollutants.<br>HCNER is the host of Sudan's UNFCCC climate focal point and overseeing the majority of climate change and environmental projects in Sudan. HCNER is also the National Focal Point for the Montreal Protocol and activities carried out under the Montreal Protocol. |
| **Equipment Providers** | Including local retailers, wholesalers, importers, and selling points offering lighting, refrigeration, and air conditioning equipment |
| **End users** | Households and other users buying and using the equipment. MEPS will have a direct impact on their energy consumption and maybe the cost of equipment. |

The following sections explain the adopted approach for the sectors' in-depth assessment (i.e., appliances' inventory) across the five in-scope subsectors including unitary air conditioning, domestic refrigeration, lighting, domestic fans, and evaporative coolers.

# 3 SECTORS' SURVEY ASSESSMENT

The ***sectors' survey assessment*** analysis included two main activities:

[1] Sectors' inventory assessment done through interviews and questionnaires conducted with leading producers, suppliers, and service providers in the RAC and lighting sectors, combined with trade and production information at the national level.

[2] Equipment assessment done through a national survey covering retail shops and sales point, where field visits are conducted to collect market data and specifications.

## 3.1 Sectors' inventory survey

For the sectors' GHG inventory assessment a bottom-up approach is applied to determine the current, historic, and projected future stock of appliances, the related energy use and GHG emissions. These emissions are calculated for each subsector and appliance type based on critical technical parameters determining direct and indirect emissions. The energy consumption is calculated using the same approach related to the relevant technical parameters for energy use.

The inventory covers the following elements:

- The calculated emissions' mitigation potential of all the 5 subsectors based on the appliances in use and their respective refrigerant and energy use according to IPCC 2006, Tier 2 methodology approach,
- For each of the subsectors and their respective appliance types, an inventory of historic and future unit sales and stock data is established,
- For each appliance type, the historic, current and future energy and refrigerant use and their respective emissions are estimated,
- RAC appliances in use in Sudan are compared with international best practice technologies for their potential to mitigate GHG emissions on a unit basis. The approach considers the gradual replacement of the stock through the sale of new appliances and the growth of the market through additional sales,
- Future trends of RAC subsectors are analysed under Business as Usual (BAU) and mitigation scenarios. Both BAU and mitigation scenarios assume the development of appliances in use in line with the overall economic growth. The scenarios differ with regard to the technical parameters specific to conventional appliances and alternative low-GWP appliances.

### 3.1.1 Data collection process

The data for this inventory was collected from primary and secondary sources. The following activities were carried out to obtain information for completing the RAC inventory assessment:

- National kick-off workshop in Khartoum on October 27, 2020. It took place at the MOE with relevant stakeholders (see Table 3), with main outcomes included in the inception report.
- For primary data, a comprehensive market assessment performed at local shops, sales points, and designated showrooms, including a total of entries as follows:
    - Domestic Refrigerators: 301 entries, from 26 different brands.
    - Unitary AC: 170 entries, from 20 brands.
    - Evaporative Coolers: 127 entries, from 24 brands.

- Fans: 364 entries, from 37 brands.

The sample size is oriented along Cochran's formula for a 95% confidence interval. As can be seen in Table 4, sample sizes do not increase with higher populations to be studied and our sample sizes result in error margins of at least 2%.

*Table 4: Recommended sample size based on Cochran's formula.*

| | | Population to be studied (units on sale) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Error margin** | **Confidence interval** | 100 | 500 | 1000 | 2500 | 5000 | 7500 | 10000 |
| **5%** | 95% | 27 | 35 | 36 | 37 | 37 | 37 | 37 |
| **2.50%** | 95% | 43 | 66 | 71 | 74 | 75 | 75 | 75 |
| **1.67%** | 95% | 63 | 127 | 146 | 160 | 165 | 167 | 168 |
| **1.25%** | 95% | 75 | 189 | 233 | 271 | 286 | 292 | 295 |

- In addition, supplier-specific surveys were conducted among distributors and manufacturers. Thirty-four questionnaires were completed through face-to-face interviews, covering the 5 subsectors, covering more than 70% of the overall market for each. The market shares have been computed during the market survey based on data collected, local expert's experience, and results of the interviews. The surveys conducted are split as shown in Table 5 below.

*Table 5: Supplier survey coverage by sub-sector*

| Sub-sector | Surveyed Companies | | | Cumulative Market Share |
|---|---|---|---|---|
| | Manufacturers | Importers | Total | |
| **Domestic Refrigerators** | 2 | 5 | 7 | 80% |
| **Unitary AC** | 3 | 3 | 6 | 75% |
| **Evaporative Coolers** | 9 | 1 | 10 | 85% |
| **Fans** | 2 | 1 | 3 | 70% |
| **Lighting** | 2 | 6 | 8 | 75% |

- Secondary data is collected through compilation of statistical data, reviewing previous surveys and survey data, custom data through the Sudanese custom authority for imported equipment and refrigerants, and official trade records, complemented with IPCC default values and expert opinions.

Current and historical data are based, where available, on factual data from the sources listed above. Future projections are based on historic development for population[1] and economic growth[2].

### 3.1.2 Sector inventory survey methodology

The assessment is based on the IPCC Tier 2 methodology covering both the refrigerant, i.e., direct emissions and energy related emissions, i.e., indirect emissions, for the cooling appliances in use. The same methodology is applied for estimating the energy use in Section 2. Based on this methodology, the future BAU emission, the energy use until 2050 and the mitigation options are estimated.
The proposed Tier 2 methodology allows for the preparation of GHG mitigation actions (such as NAMAs) in relevant RAC subsectors and the integration of the RAC sector into the NDC development and the reporting of mitigation actions under the National Communications (NC) and Biennial Update Reports (BURs) as part of Sudan's commitments to the UNFCCC.

[1] UN (2020). United Nations World Population Prospects: 2018 Revision. Urban population (% of total population) - Sudan. ID: SP.POP.TOTL
[2] World Bank (2020). World Bank national accounts data, and OECD National Accounts data files. ID: NY.GDP.MKTP.CD

- Estimating the direct, refrigerant related, emissions during all stages of the appliance's life includes refrigerants that are filled into newly manufactured products, available in operating systems (average annual stocks), and those remaining in products at decommissioning.

#### 3.1.3 Subsectors surveyed

The analysed subsectors and appliance types are listed in Table 6.

*Table 6: Surveyed subsectors and appliances type.*

| Subsector | Appliance type |
|---|---|
| **Unitary air conditioning (UAC)** | Window-type air conditioners<br>Split residential air conditioners<br>Split commercial air conditioners |
| **Lighting** | Incandescent lamps<br>Fluorescent tubes<br>CFL<br>LED (Bulbs and tubes)<br>Street lighting |
| **Domestic fans** | Stand fan<br>Ceiling fan |
| **Domestic refrigeration** | Refrigerator<br>Combi refrigerator/freezer |
| **Evaporative coolers** | Evaporative coolers (a.k.a. desert coolers) |

### 3.2 Lighting sector

Electricity tariffs in Sudan was one of the lowest, if not the lowest, in the world at USD 0.006/kWh at end of 2020[3]. Such tariffs impede the deployment of energy efficiency measures as there is no economic incentive to adopt new technologies, even a step-change technology such as LED's payback period is not attractive. A sharp increase in electricity tariffs in early 2021 is beginning to reverse the situation and LED is becoming a more attractive technology to adopt to save energy while doing substantial savings.

According to the Project Document template of "Leapfrogging Sudan's markets to more efficient lighting and air conditioners" (2018), a typical household in Sudan usually contains a total of 400 Watt of lighting units, 50% incandescent, 35% CFL, and 15% Linear Fluorescent. However, the share between technologies is based on data collected in 2015 and the average power per household has been updated to take into account the penetration of LED lighting as early as 2014 for the first sales, leading to an average consumption per household of 360 Watt. The complete shift to LED technology would decrease the power needed for lighting to 150 Watt.

The saving potentials were estimated for three sectors (see Table 7): domestic lighting, professional sector (government buildings, commercial sector, and industrial sector) and street lighting. These are assessment findings for 2020 and projections resulting from the calculation for 2030, 2040 and 2050. The savings are expressed in terms of energy consumption per year but also power saved. The power saved by transforming the market to LED is an important input for energy policy makers. Indeed, to provide enough electricity for

[3] Sudan Energy Transition and Access Project (P175040), September 2020, World Bank.

the demand, Sudan must import electricity or build new power plant. The cost for building and maintaining a natural gas power plant with a capacity of 1 MW is 1 million USD per year[4].

For both residential and street lighting subsectors, the consumption is decreasing between 2020 and 2032 due to the conversion towards efficient LED lighting. Consumption is then increasing in a moderate way following the increase in the number of electrified households and increasing demand for street lighting. The improvements in the LED's efficiency are moderating the increase in energy consumption. For residential sector, the consumption is kept stable at 1.1 TWh from 2036 till 2050 due to an assumed slower growth rate of number of households with access to electricity compared to the 2020 to 2035 period, 3% instead of 10%.

For the professional sector (mainly offices and commercial sector), lighting consumption also decreases strongly until all light sources are converted to LED, around 2032, it stabilizes in 2020 at around half of its initial value until 2050, despite the growth of this sector.

*Table 7: Consumption and power saved for residential, professional, and street lighting.*

| Sector / Year | | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| **Residential** | Consumption (GWh/yr) | 792 | 771 | 1,054 | 1,126 |
| | Power saved (MW) | *** | 447 | 1,219 | 1,929 |
| **Street lighting** | Consumption (GWh/yr) | 3534 | 3,015 | 3 154 | 5 297 |
| | Power saved (MW) | *** | 684 | 1 516 | 2 433 |
| **Professional** | Consumption (GWh/yr) | 1,586 | 963 | 824 | 831 |
| | Power saved (MW) | *** | 255 | 389 | 536 |

Professional sector can be split between commercial lighting (34%), industrial lighting (40%) and governmental lighting (26%) as shown in Table 8.

*Table 8: Energy consumption of the professional sector by category.*

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **Commercial (TWh)** | 545 | 331 | 283 | 286 |
| **Industrial (TWh)** | 633 | 384 | 329 | 332 |
| **Governmental** | 407 | 247 | 212 | 213 |

Overall energy consumption and savings, between 2020 and 2050, are summarized in Table 9 below.

*Table 9: Overall consumption and power saved for lighting in Sudan.*

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **Consumption (TWh)** | 5.91 | 4.75 | 5.03 | 7.25 |
| **Power saved (GW)** | *** | 1.3 | 3.12 | 4.90 |

Sudan's commitment to leapfrog to efficient LED lighting will support the country's efforts to increase development while the electricity consumption for lighting remains lower than current levels until 2040.

For a typical household, the investment for changing all lighting to LED lighting is around $28 and has a payback of about 2 years. It is of note that short payback period is due to the sharp increase in the electricity cost in January 2021 (from $0.006 per kWh to $0.03 per kWh).

[4] United for Efficiency estimation

That sharp increase in the electricity price is also pushing strongly towards efficient street LED lighting where the payback period is in the range of few months. As an example, for street lighting, changing Metal Halide to LED generates greater savings with a payback of less than one year.

### 3.2.1 Market survey

In the following sections we will detail the outcomes of the lighting's market survey including supply base and market share, lighting models, pricing, Life Cycle Cost (LCC), etc.

A market survey of local retailers was conducted in November and December 2020 involving a questionnaire with questions about sales in the last years 3 years, market share, prices of products, sectoral distribution, and some important products features.

#### 3.2.1.1 *Market share*

There are three companies producing bulbs in Sudan meeting about 20 % of the market demand combined. Exports are about 3% of the local production and the informal market is estimated to be around 7 % of total sales. Products on the informal market are mainly coming from China and are of fair quality.

The surveyed companies represent 86 % of the Light Emitting Diode (LED) bulb market in Sudan, 67 % of the Compact Fluorescent Lamps (CFL) market, 53 % of the incandescent lamps market, and nearly all the market for LED tubes and High Intensity Discharge (HID) lamps. TOLA represents 35% of the overall lighting market in Sudan with a majority of sales currently focused on CFLs and TFL (Figure 2).

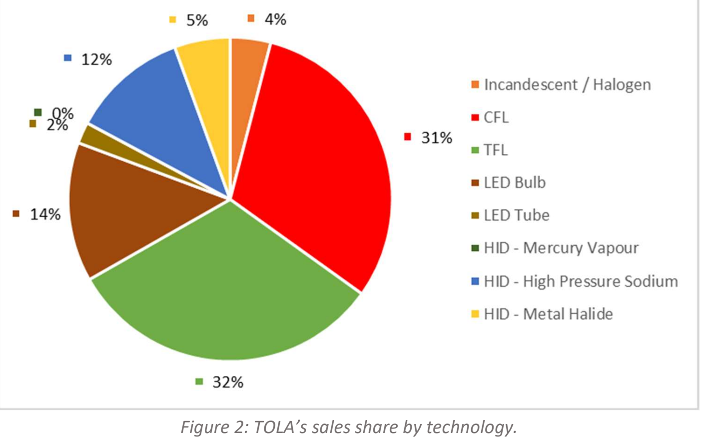



*Figure 2: TOLA's sales share by technology.*

Sales of lighting sources increased by around 10 % per year between 2010 and 2019, but in 2020, there is an expected decrease of 9% believed to be caused by the current difficult economic conditions.

Figure 3 shows that incandescent lamps sales start decreasing in 2013 and are largely phased-out by 2020. The number of CFL sold, on the other hand, increase continuously until 2017, then slowly decreases as they are increasingly replaced by LED bulbs which first appeared in 2013 increasing rapidly (+ 67 % of sales compare to 2014). However, the increase of LED bulbs' sales is slowing down and expected to be 16 % in 2020 compared to 2019.

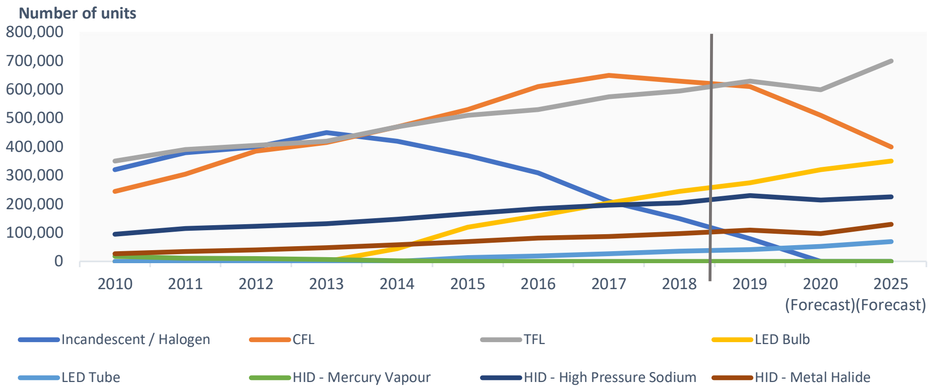



*Figure 3: TOLA sales 2010-2025 by technology.*

Tubular Fluorescent lamps (TFL) or fluorescent tubes market share is increasing each year with an average of plus 7 % in sales. Sales of LED tubes is still increasing since 2015.

HID lamps are a generic name used for High pressure Sodium, Mercury vapour and Metal halide. Those lamps are mainly used for street lighting and sales are increasing with quite stable 10 % yearly rate between 2011 and 2020. Sales of mercury vapour lamps stopped in 2015. In 2019, more than 2/3 of the HID lamps sold were High pressure Sodium, about 1/3 Metal Halides and no LED luminaires.

#### 3.2.1.2 *Product characteristics*

Luminaire products are described through few main characteristics, namely prices, efficiency, lifetime, colour temperature, colour rendering index and power. Those parameters are briefly explained below.

1. *Efficiency*

The amount of light is expressed in terms of luminous flux (unit: lumen or lm). *The efficiency of the light source is then the amount of lumen produced per Watt consumed (unit: lm/W).*

2. *Lifetime*

Expressed in hours and is the time at which point half of the lamps (the median) are expected to have failed or become useless in providing the intended service e.g., having dropped to 70% of its initial luminous flux.

3. *Correlated Colour Temperature (CCT)*

CCT is the temperature of the Planckian radiator when it emits colour most similar to the light emitted from the light source. The unit is Kelvin (K). Lamps with a high CCT, i.e., 5,000K produce a cool blueish-white light, whereas those with a low CCT e.g., 2,700K produce light that is warm yellowish-white.

4. *Colour Rendering Index (CRI)*

CRI is a measure of the ability of a light source to accurately reveal the colours of various objects in comparison with an ideal or natural light source. Its value ranges from 0 (no colour) to 100 (natural colour).

5. *Power*

The average wattage per lamp.

### 3.2.2 Key findings

Data collection suffers some gaps, but the quality of the collected data is sufficient to build a good view of the lighting sector in Sudan. Few minor corrections had to be made and assumptions to be taken.

Sales of Compact Fluorescent Lamps are decreasing in favour of LED bulb but are still dominant. Sales of incandescent lamps are dropping down.

Sales of fluorescent tubes are still increasing while sales of LED tube are still at a low level (2 % of TOLA's overall sales). The two types of the fluorescent tubes are 18 Watt and 36-Watt, typical normalized power for the fluorescent tubes. Those fluorescent tubes are called T8 tubes can be easily retrofitted by LED tubes.

Average Prices and features of the different lamps used in households (Incandescent lamp, CFL, Linear fluorescent lamps and LED bulb) in Sudan are shown in Table 10 below.

*Table 10: light sources technologies comparison for residential sector in Sudan.*

| | Incandescent lamp | CFL | Linear fluorescent | LED bulb | LED tube |
|---|---|---|---|---|---|
| **Price (USD)** | $ 0.38 | $ 1 | $ 0.7 | $ 1.7 | $ 4 |
| **Efficiency (lm/W)** | 12 lm/W | 50 lm/W | 70 lm/W | 90 lm/W | 90 lm/W |
| **Lifetime (hours)L70B50** | 1,000 h | 5,000 h | 5,000 h | 15,000 h | 20,000 h |
| **Colour Temperature (Kelvin)** | 4,000 K | 6,500 K | 6,500 K | 2,700 K to 6,500 K | 3,000 K to 6,500 K |
| **Colour Rendering Index** | 100 | 80 | 70 | 80 | 80 |
| **Average wattage (Watt)** | 60 W | 15 W | 18 W/36 W | 15 W | 9 W/18 W |

Table 11 summarizes the key parameters related to the street lighting sector.

*Table 11: light sources technologies comparison for street lighting in Sudan.*

| | HID – Mercury Vapour | HID – Metal Halide | HID – High Pressure Sodium |
|---|---|---|---|
| **Price (USD)** | $ 2.70 | $ 10.5 | $ 8 |
| **Efficiency (lm/W)** | 55 lm/W | 100 lm/W | 120 lm/W |
| **Lifetime (hours) L70B70** | 15 000 h | 25 000 h | 30 000 h |
| **Colour Temperature (Kelvin)** | 3 500 K | 4 700 K | 2 100 K |
| **Colour Rendering Index** | 65 | 69 | 25 |
| **Average wattage (Watt)** | 125 W/250 W | 400 W/250 W | 400 W/250 W |

To be noted, lifetime is given for L70B70 contrary to L70B50 previously used. Data are coming for typical products from Philips' website[5].

### 3.2.3 Life cycle assessment for lighting products

To assess the benefit of replacing one technology by another, one should consider the complete life cycle cost of both technologies. The total cost of ownership of the product includes:

- Purchase price,
- Operating cost,

[5] https://www.lighting.philips.com

- Maintenance and service, and
- Appropriate disposal.

**Purchasing**

Purchasing the light source is the upfront cost of the product, including the different taxes that may apply. Prices vary from $0.38 for an incandescent lamp to $4 for a LED tube.

**Operating**

Operating cost is the electricity consumption cost of the light source in KWh: power of the light source multiplied by the time of use. For a given amount of light, the power required for a light source depends on its efficiency. A LED lamp will consume 7.5 times less electricity than an incandescent lamp for the same amount of light (LED efficiency is 7.5 times higher). The time of use depends on the application. Table 12 shows the operating hours for different applications/sectors in Sudan, based on experiences and norms.

*Table 12: hours of operation per year.*

| Application | Operating hour per year | Assumptions[6] |
|---|---|---|
| **Residential sector** | 1,000 hours | All year, 2h45min per day |
| **Office buildings** | 2,349 hours | 5 weekdays a week; 8 am to 5 pm |
| **Hôtel, restaurant** | 5,475 hours | All year; 7 am to 10 pm |
| **Industry** | 6,570 hours | All year, 5 am to 11 pm |

*Note: for the residential sector, major international standards (e.g., EN, ISO, IEC, CIE…) use an operation time of 1,000 hours per year.*

**Maintenance**

Maintaining the "service" means that the product is producing the service that was planned until it is replaced. The "service" for a light source is the amount of light produced expressed in luminous flux (unit: lumen). The capacity of a light source to effectively produce light will decrease along the lifetime (as defined in paragraph 2) of the product. To produce light for 20 000 hours, 20 incandescent lamps lasting 1 000 hours each are needed whereas just one LED tube lasting 20 000 hours is needed. To compare the technology, the cost of the extra 19 incandescent lamps is included in the maintenance cost.

**Disposal**

Appropriate disposal fees are not in place in Sudan. Hence, no information could be collected on the recycling cost of lamps.

The Minamata Convention on Mercury is a global treaty to protect human health and the environment from the adverse effects of mercury[7]. Sudan did sign the convention on the 24th of September 2014, and it was ratified on April 6, 2021.

LED light sources and LED control gear are electronic components, and their waste are considered also as Waste of Electrical and Electronic Equipment (WEEE). It implies that they should be collected and disposed in a proper way as specified in the Basel Convention on the Control of Transboundary Movements of

[6] based on experience and standard EN 15193-1:2017 "Energy performance of buildings - Energy requirements for lighting - Part 1: Specifications, Module M9"
[7] https://www.mercuryconvention.org/

Hazardous Wastes and their Disposal[8]. Sudan did ratify the convention that came into force in the country on the 9th of April 2006.

### 3.2.3.1 *Residential sector*

#### *3.2.3.1.1 Life Cycle Cost of incandescent lamp vs LED lamp*

Typical incandescent lamps in Sudan have a power of 60 Watt. They can be replaced by LED of 8 Watts. The typical household annual use is 1,000 hours of operation. Purchase price of a LED is 4.5 times higher than an incandescent lamp. However, LED lamp total cost of ownership is below the incandescent lamp with a Payback time of 10 months.

After 10 years, the total cost using traditional incandescent lamps is $22.18 against $4.10 for a LED lamp representing a saving of more than $18 as shown in Figure 4.

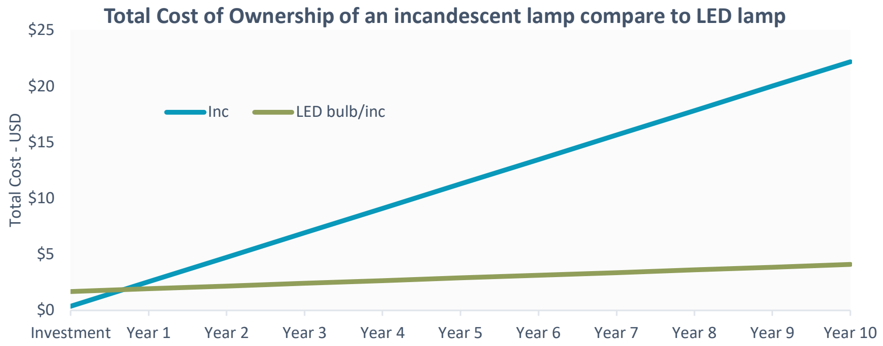



*Figure 4: Total cost of an incandescent lamp compared to an equivalent LED lamp in Sudan.*

#### *3.2.3.1.2 Typical household*

In a typical household, there are 400 Watt of electrical power dedicated for lighting, with a share by technology of 50% incandescent, 35% CFL, and 15% Linear Fluorescent. That implies an installed power of 200 Watt of incandescent sources, 140 Watt of CFL and 60 Watt of fluorescent tubes.

The market assessment showed the average power used by technology. We can determine the average number of light sources by technology per household leading to 3.33 incandescent sources, 7.78 CFL and 2.22 linear fluorescent sources. Figure 5 compares total cost of ownership of light for a household equipped with traditional technologies to one equipped with the equivalent LED products. After 2 years, the total cost of LED lighting is less than the total cost of traditional lighting. In 10 years, a household can save up to $74 by using LED lighting.

[8] http://www.basel.int/

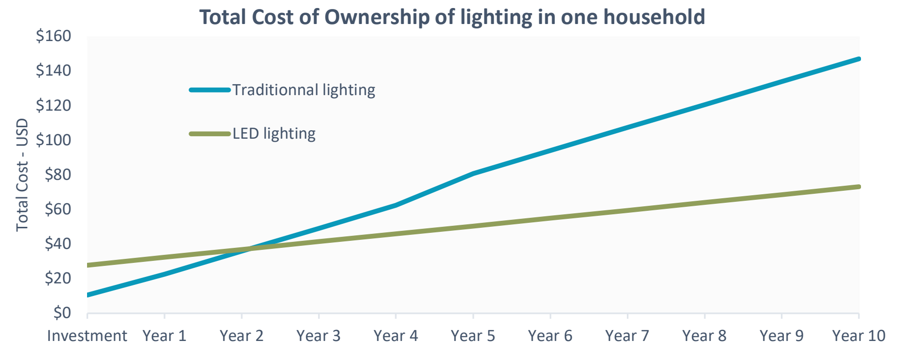



*Figure 5: Total's cost of light for a typical household in Sudan.*

### 3.2.3.2 *Professional sector*

The professional sector includes office buildings, hotel, restaurants, and industry.

#### *3.2.3.2.1 Life Cycle Cost of fluorescent tube vs LED tube*

One of the market assessment key findings is that fluorescent tubes in use are the normalized T8 tubes (18 Watt), operating with a ferromagnetic control gear between the tube itself and the mains. The power dissipated in the control gear is typically 15 % of the fluorescent tube power. For example, the total power for operating a 36-Watt fluorescent tubes on the mains is 41 Watt (5 Watts being dissipated in the control gear). Table 13 gives a view on the fluorescent tubes (T8) currently sold on the Sudanese market[9].

*Table 13: T8 fluorescent tubes sold in Sudan.*

| Fluorescent tubes | Lamp power | Total power | Flux | Downward flux | CCT | Length | Mercury content |
|---|---|---|---|---|---|---|---|
| T8 (G13 cap) | 18 W | 21 W | 1 200 lm | 1 020 lm | 4 100 K | 2 feet | 8 mg |
| T8 (G13 cap) | 18 W | 21 W | 1 050 lm | 893 lm | 6 200 K | 2 feet | 8 mg |
| T8 (G13 cap) | 36 W | 41 W | 2 850 lm | 2 423 lm | 4 100 K | 4 feet | 8 mg |
| T8 (G13 cap) | 36 W | 41 W | 2 500 lm | 2 125 lm | 6 200 K | 4 feet | 8 mg |

According to the market assessment, the LED market share is still small. LED tubes with equivalent light output downward were found on the publicly available Philips' website[10]. Those LED tubes emit light only downward with a beam angle of 160°. Their characteristics are summarized in Table 14 below.

*Table 14: T8 LED tubes equivalent for Sudan.*

| LED tubes | Lamp power | Total power | Flux | Downward flux | CCT | Length | Mercury content |
|---|---|---|---|---|---|---|---|
| T8 (G13 cap) | 10 W | 10 W | 1 050 lm | 1 050 lm | 4 000 K | 2 feet | No |
| T8 (G13 cap) | 10 W | 10 W | 1 050 lm | 1 050 lm | 6 500 K | 2 feet | No |
| T8 (G13 cap) | 16 W | 16 W | 2 500 lm | 2 500 lm | 4 000 K | 4 feet | No |
| T8 (G13 cap) | 14 W | 14 W | 2 100 lm | 2 100 lm | 6 500 K | 4 feet | No |

[9] https://www.tolaelectrical.com/en/product-category/philips-lighting/tld/
[10] https://www.lighting.philips.com/main/prof/led-lamps-and-tubes/led-tubes/master-ledtube-em-mains-t8#page=&layout=

The TCO of a 36-Watt T8 fluorescent tube with a colour temperature of 6,200 K is compared, in Figure 6 below, to its LED equivalent in office building application.

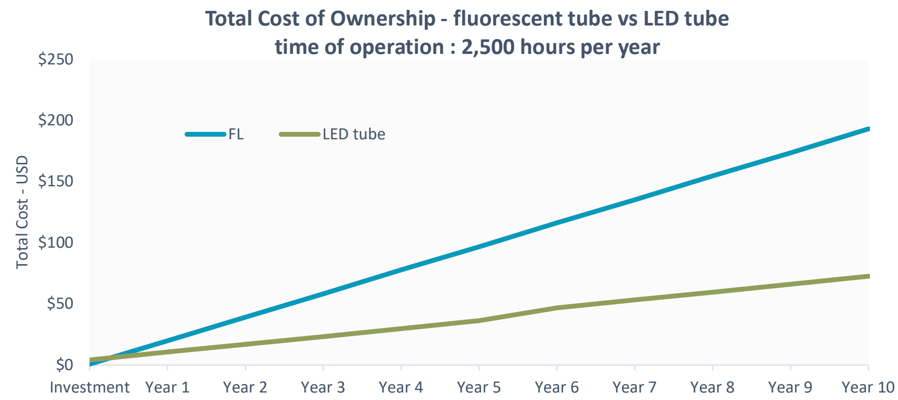



*Figure 6: Total Cost of Ownership - Fluorescent tube vs LED tube for office lighting in Sudan.*

After 10 years, savings exceeds $120 due to a better efficiency and lifetime of the LED tube. Over the 10 years, fluorescent tube has to be changed 5 times against once for the LED tube. Payback period is less than one year of operation (Figure 7), taking into consideration the electricity price of 0,1844 $/kWh for commercial sector.

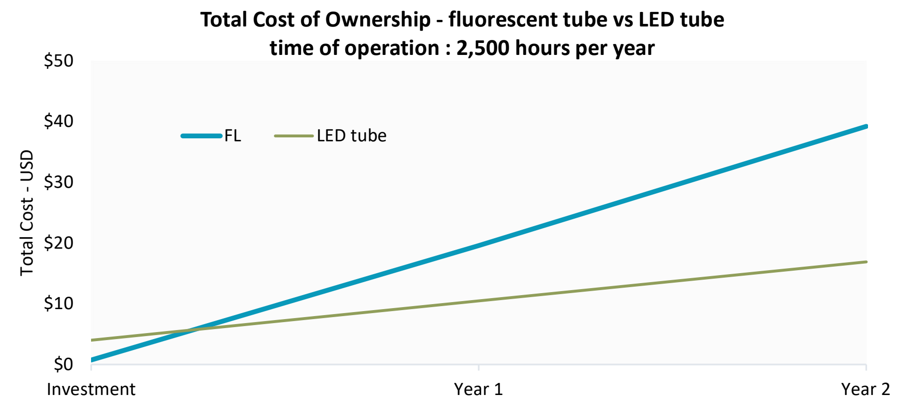



*Figure 7: Payback of a LED tube replacing fluorescent tube for office building lighting.*

In commercial buildings, and after 10 years of operation, savings exceeds $240 (see Figure 8) due to a higher efficiency and longer lifetime of the LED lighting. Payback period is less than two months of operation.

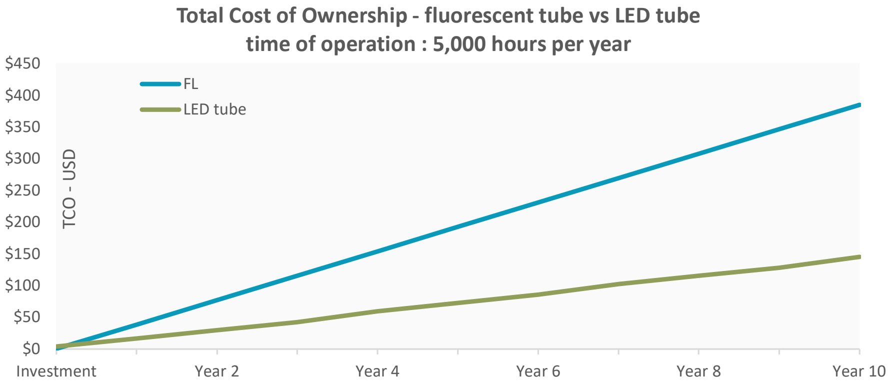



*Figure 8: Total Cost of Ownership (TCO) - Fluorescent tube vs LED tube for commercial buildings in Sudan.*

The difference with the office building applications is due to the difference in the annual operation time: 2,500 hours for office building versus 5,000 hours for a commercial building.

### 3.2.3.3 *Street lighting*

Times for sunrise and sunset in Sudan will not differ much all over the year due to the fair proximity to the equator, with up to approximately 13:10 hours for the longest days in June. In December, a night in Khartoum last almost for 13 hours[11]. For one year, the night-time is 4,380 hours, which is the operation time of street lighting per year.

#### *3.2.3.3.1 Life Cycle Cost of Metal Halide lamp vs LED in Sudan*

Based on the market assessment and typical luminaires used for street lighting, useful life of the different technologies are 3.5 years for High pressure mercury lamps, 5.5 years for metal halides lamps and 7 years for high pressure sodium lamps. LED luminaires lifetime is typically 50,000 hours for L70B70 or 11.5 years.

From an economical point of view, replacing a traditional discharge lamp by a LED luminaire is interesting. The investment cost for a LED luminaire is ten times higher ($100) than for the Metal Halide Lamp alone ($10.5). Replacing the lamp inside an existing luminaire is obviously cheaper than replacing the whole luminaire. Nevertheless, after 11 years, the economic benefit due to the lower consumption of the LED luminaire is $1,283 as shown on Figure 9, where the electricity price is at $0,1844 per kWh for the governmental sector.

[11] https://www.worlddata.info/africa/sudan/sunset.php

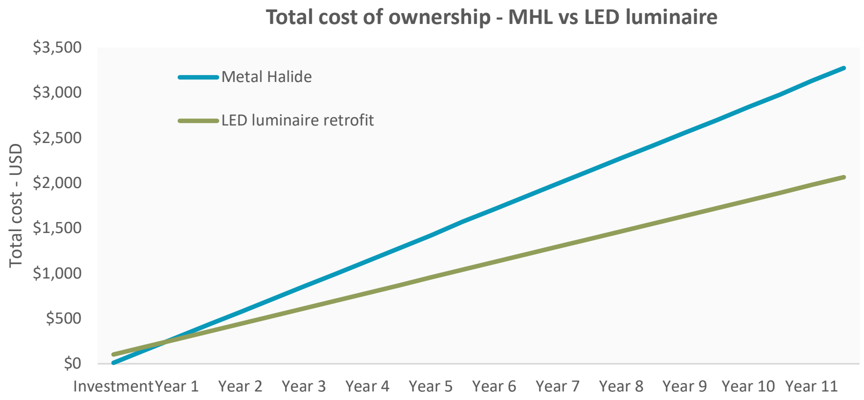



*Figure 9: Total cost of ownership - MHL vs LED luminaire in Sudan.*

Figure 10 shows the return on investment, in less than one year, of the LED luminaire replacing the Metal Halide luminaire for the street lighting in Sudan.


*Figure 10: Payback of LED luminaire replacing MH luminaire.*

Due to lack of data, the cost of replacement of the Metal Halide lamp is not considered in the payback calculations. That service cost includes workers mobilization and material cost.

### 3.2.4 Overview and projection of electricity consumption in the lighting sector

#### 3.2.4.1 *Residential sector*

As mentioned earlier and according to the Project Document template of "Leapfrogging Sudan's markets to more efficient lighting and air conditioners" (2018), the lighting power needed for a typical household is 400 Watt with a share by technology of 50% incandescent, 35% CFL, and 15% Linear Fluorescent. That implies an installed power of 200 Watt of incandescent sources, 140 Watt of CFL and 60 Watt of fluorescent tubes. The share between technologies is based on data collected in 2015 (project document for leapfrogging EE – 2018). Market assessment shows a penetration of LED as early as 2014 for the first sales. Some incandescent lamps are assumed to have been replaced by LED lamp since 2015 and the power share is assumed to be 47% for incandescent lamps and 3% for LED lamps. To be noted, the share of power due to LED is small due to the higher efficacy of LED lamps compared to incandescent lamps. As a consequence, the overall power needed for lighting in households is assumed to be 360 Watt.

According to the World Bank[12], the number of households with access to electricity is 2.2 million whereas the number of households without access to electricity is 4.5 million. Considering an average annual time for operation of 1,000 hours, the consumption for residential sector is 792 GWh per year.

###### *3.2.4.1.1 Business-as-Usual (BAU) scenario*

Market assessment shows a natural tendency for incandescent lamps phase out. We consider as BAU a number of incandescent lamp decay of 10 % per year beginning in 2021. Complete phase out of incandescent lamps in households is achieved by 2030. As the need for light is considered to be the same, the incandescent lamps are replaced by LED bulbs producing the same amount of light with less power (higher efficiency).

The growing number of households with access to electricity is preferred to the population growth as a key parameter for the calculation of electricity demand. Indeed, when a household has access to electricity, first electrical appliance bought is electric light sources. The number of households with access to electricity is assumed to grow at a rate of 10 % per year to reach 6.9 million in 2032 (all households existing today plus 200 000 new households will have access to electricity: 2.2+4.5+0.2=6.9 million. This growth rate is assumed to decrease to 3% from 2036 to 2050 to reach 14.3 million households with access to electricity by 2050.

###### *3.2.4.1.2 Mitigation scenario - Shift to LED scenario*

**Incandescent lamps**: in this scenario, we consider a shift from incandescent lamps to LED with the same rate as for the BAU.

**Compact Fluorescent lamps**: CFL replacement by LED will be at the same rate (decay of 10 % per year), beginning two years later, in 2023. Complete phase out of CFL from households is achieved in 2032.

**Fluorescent tubes**: fluorescent tubes are replaced by more efficient LED tubes beginning in 2024 with a rate of 10 %. Complete phase out of fluorescent tubes is achieved in 2033.

**Efficacy**: efficacy of LED bulbs and LED tubes is continuously improving with time. It is assumed to increase by 5 lm/W every year for LED bulbs until 2035 then 2 lm/W per year from 20360 to 2050. LED tubes efficacy is assumed (see footnote 13) to increase by 6 lm/W every year until 2035 then 3 lm/W per year from 2036 to 2050. This rate is lower than the rate observed for developed countries from 2010 to 2016 (7.2 lm/W per year for LED bulbs)[13]. Indeed, LED efficiency tend to improve slower in developing countries with no strong regulation in place than in countries where ambitious regulations are in place for more than 10 years like in Europe.

**Demand**: the hypothesis on the number of households with access to electricity is the same as for the BAU scenario.

The analysis is performed until 2050. That means, LED bulbs that are replacing traditional lighting in 2021 have to be replaced in 2036, after 15,000 hours of operation. LED bulbs in 2021 had an efficacy of 90 lm/W whereas LED bulbs in 2036 have an efficacy of 150 lm/W. Hence, to produce the same amount of light, less power is needed.

[12] Sudan Energy Transition and Access Project (P175040), World Bank, September 2020

[13] "Lamp Efficiency: Performance Requirement", CLASP, M. Scholand 2019

As shown in Figure 11, the energy consumption for lighting is decreasing until 2030 due to the shift of existing light sources to LED. From 2030 to 2032, only few remaining fluorescent tubes have to be replaced, compensating the increasing number of households with access to electricity so that the overall domestic lighting consumption is stable. From 2032 to 2035, the increase in LED efficacy does not fully compensate the increasing number of households with access to electricity and the overall consumption of domestic lighting is increasing. From 2036 onward, the growth rate of the number of households with access to electricity is slowing down to 3 % per year and the increase in LED efficacy keep the consumption quite stable around 1.1 TWh per year.

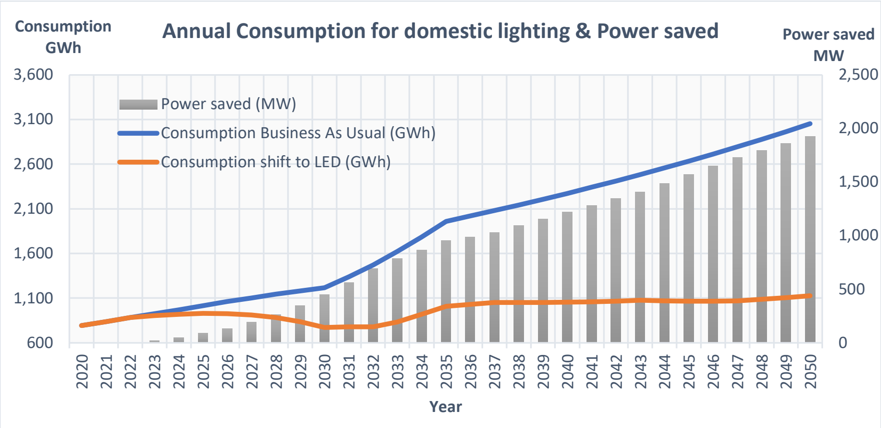



*Figure 11: Energy consumption and power saved until 2050 for residential lighting in Sudan.*

The power saved by transforming the market to LED is an important input for energy efficiency policy makers. Indeed, to provide enough electricity for the demand, Sudan must import electricity or build new power plant, as previously mentioned. Consumption and savings figures, for 2020, 2030, 2040, and 2050, are shown in Table 15.

*Table 15: Consumption and power saved for domestic lighting in 2020, 2030, 2040 and 2050.*

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **Consumption per year** | 792 GWh | 771 GWh | 1 054 GWh | 1 126 GWh |
| **Power saved** | *** | 447 MW | 1 219 MW | 1 929 MW |

### 3.2.4.2 *Street lighting*

There is limited data on street lighting. TOLA is the only company that sells suitable luminaires for this sector. However, they estimate their market share to be 70 % of High-Pressure Sodium lamps and 65 % of Metal Halide lamps. The growth of sales of high intensity discharge lamps (High pressure Sodium, Mercury vapour and Metal halide) used for street lighting was stable, around 10 % from 2011 until 2020. Sales of mercury vapour lamps stopped in 2015.

The consumption for street lighting was estimated based on the number of lamps sold by TOLA as seen in the market assessment multiply by their average power time the number of yearly operation hours, reaching an average of 3534 GWh in 2020.

*Note: to estimate the power installed based on the sales of discharge lamps, the consumption of the control gear must be taken into account in the calculation. As the market data did not show a clear share between applications, we assumed that 90% of HID lamps sold are used for street lighting and 10% for the professional sector.*

###### 3.2.4.2.1 Business-as-Usual (BAU) scenario

The electricity price is too low for a natural shift to LED luminaires. The demand growth is estimated at 5 % between 2020 and 2025 (in conformity with TOLA's forecast) and remain at a steady 5 % growth per year driven by an increased electrification of the rural regions.

###### 3.2.4.2.2 Mitigation scenario - Shift to LED scenario

For that scenario, we consider a replacement of discharge lamps, Metal Halides (MH) and High-Pressure Sodium (HPS), by LED luminaires at the same rate of 10 % per year. Replacement of MH have higher energy impact than replacement of HPS. Incentives to replace MH are assumed to be in place before incentives for HPS' replacement.

**Metal Halides lamps**: gradual replacement by LED begins in 2022 for MH and is completed by 2031.

**High Pressure Sodium**: gradual replacement begins in 2025 for HPS and is completed by 2034.

The assumption on the street lighting growth is the same as for the BAU scenario.

Efficacy of LED luminaires for outdoor lighting is improving with an assumed rate of 6 lm/W per year until 2035 the 3 lm/W per year from 20360 to 2050. This rate is lower than the rate observed for developed countries from 2012 to 2018 (8.6 lm/W per year for LED bulbs)[14]. This is a lower year-on-year efficacy improvement compared to developed countries, as it was mentioned earlier.

Street lighting consumption is kept at the same level due to the shift to LED lighting and efficacy improvement of LED luminaires. Shift from MH lamps to LED is achieved in 2031 while it takes 3 more years for HPS (Figure 12). When all street luminaires are LED, in 2034, we observe a little increase in consumption due to still increasing rural electrification.

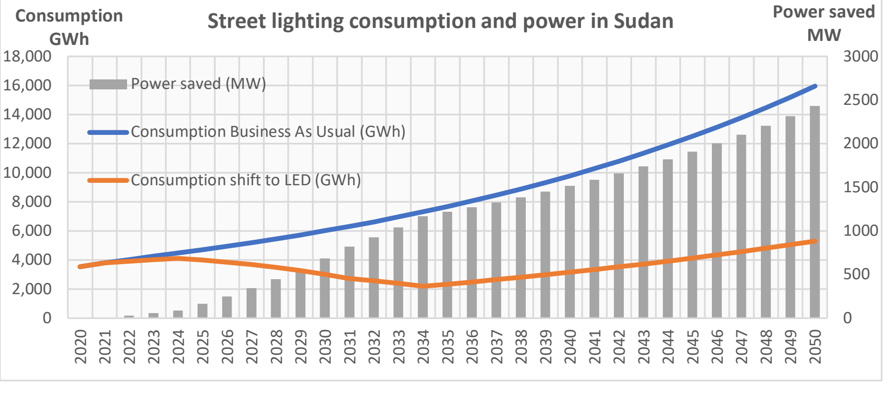



*Figure 12: Energy consumption and power saved until 2050 for street lighting in Sudan.*

[14] "Lamp Efficiency: a Performance Requirement", CLASP, M.Scholand 2019

Similarly, as in the residential sector, there is a "low hanging fruit" opportunity for power saving by transforming the market to LED as shown in Table 16.

*Table 16: Consumption and power saved for street lighting in 2020, 2030, 2040 and 2050.*

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **Consumption per year** | 3 534 GWh | 3 015 GWh | 3 154 GWh | 5 297 GWh |
| **Power saved** | *** | 684 MW | 1 516 MW | 2433 MW |

### 3.2.4.3 *Professional sector*

In terms of lighting needs for the professional sector in 2020, we used the United for Efficiency (UNEP/U4E) country assessment data[15]. The model starts from the regional stock estimates for the individual lamp types in 2018 from 3 separate sources validated against market data for countries where that is available. This stock is then converted to light service in 2018 (teralumen-hours) based on estimates of wattage and operating hours.

The need for lighting in the professional sector in 2020 is then estimated to be 113.83 Teralumen-Hours of Lighting Consumption Annually (Tlm.h/yr). Main light sources used in this sector are traditionally fluorescent lamps, fluorescent tubes, High Pressure Sodium (HPS) lamps and Metal Halides lamps (MH). As a first approach we consider 40 % of the light coming from CFL, 40 % from fluorescent tubes, 10 % from HPS lamps, and 10 % from MH lamps.

The annual lighting consumption is converted in energy consumption considering the efficacy of the light sources, leading to an annual consumption in 2020 of 1,586 GWh.

#### *3.2.4.3.1 Business As Usual (BAU) scenario*

As seen in the life cycle assessment part and in Table 12 "hours of operation per year", the lighting operation hours in the professional sector vary from 2,500 for office building to 5,000 hours in the commercial sector and even 6,500 hours in the industrial sector.

Main light sources used in the professional lighting are traditionally fluorescent lamps, fluorescent tubes, High Pressure Sodium (HPS) lamps and Metal Halides lamps (MH). As a first approach we consider 40 % of the light coming from CFL, 40 % from fluorescent tubes, 10 % from HPS lamps, and 10 % from MH lamps.

#### *3.2.4.3.2 Mitigation scenario - Shift to LED scenario*

Fluorescent tubes are replaced gradually by LED tubes (retrofit completed in 2032) whereas CFL are replaced by LED bulb (retrofit completed 2030). LED bulbs and LED tubes are improving their efficacy with the same rate as for domestic application.

High Pressure Sodium lamps and Metal Halides lamps are gradually replaced by LED luminaires at the same rate as for street lighting. The efficacy of LED luminaires is the same as for street lighting.

As for LED bulbs and LED tubes, LED luminaires have a lifetime of 11 years and are replaced with LED luminaires with an improve efficacy.

Recent projections from the international energy agency (IEA)[16] are predicting an increase of 50% in light demand service in 2040. Following the IEA prospective, that amount will be 170.74 Tlmh per year by 2040.

[15] https://united4efficiency.org/country-assessments/sudan/
[16] IEA (2020), World Energy Outlook 2020, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2020

Market transformation to LED lighting has a strong impact on the professional sector's energy consumption. When the phase out of traditional sources is achieved in 2032, the consumption will be stabilized as shown on Figure 13 below. Indeed, the increasing demand is compensated by the increase in the LED lighting efficiency.

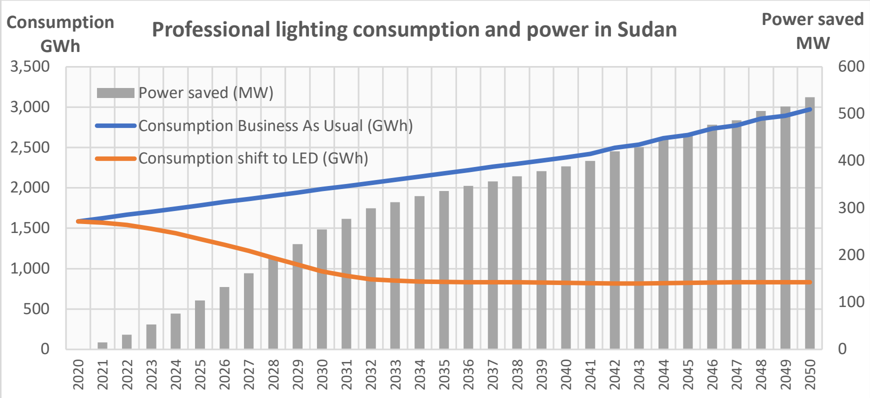



*Figure 13: Energy consumption and power saved until 2050 for professional lighting in Sudan.*

The power saved with LED (Table 17) can avoid the construction of a new power plant with a capacity of 392 MW by 2040, saving around USD 392 million.

*Table 17: Consumption and power saved for professional lighting in 2020, 2030, 2040 and 2050.*

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **Consumption per year** | 1 586 GWh | 963 GWh | 894 GWh | 831 GWh |
| **Power saved** | *** | 255 MW | 389 MW | 536 MW |

To be noted, according to the project document, the share of consumption between governmental, commercial, and industrial sector is:

- 34 % of the consumption in the commercial sector,
- 40 % in the industrial sector, and
- 26 % in the governmental buildings sector.

### 3.2.5 Conclusion – Lighting Sector

The projected BAU electricity demand for the lighting sector is shown in Figure 14: Projected electricity demand for lighting applications in Sudan. below. The largest part is consumed by the street lighting applications.

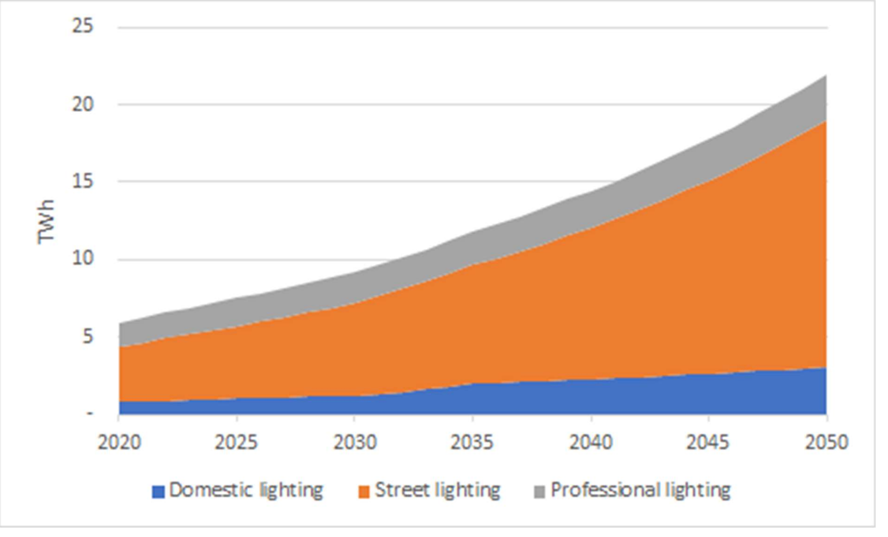



*Figure 14: Projected electricity demand for lighting applications in Sudan.*

In the residential sector, the market assessment showed a slow trend toward LED lighting, while traditional lighting is still sold in the professional and public lighting sectors. This situation could be explained by a low electricity tariff that embedded the shift to LED due to a long payback period. The recent sharp increase in electricity tariff will reverses this trend and shifting to LED will lead to more savings for consumers and professionals and potentially reduce the need for additional new power plants to supply the growing demand of artificial light.

## 3.3 Residential Fans Sector in Sudan

According to the World Bank, energy is a key priority of the new Government in its journey towards global economic integration, access to development aid, and resilient COVID-19 recovery[17].

The Sudanese population is growing at a pace of 2.4 percent a year, it is expected to increase to 56 million from its current level of 40 million by 2031. The number of households with access to electricity is today 2.2 million whereas 4.5 million households are non-electrified. It is even more important to leapfrog as soon as possible to efficient technologies to mitigate the fast-growing need of electricity in the country.

Using air conditioners and electric fans to stay cool accounts for nearly 20% of the total electricity used in buildings around the world today.[18] Alternative technologies to air conditioning – such as high-efficiency fans, evaporative coolers (in dry climates) and dehumidifiers (in humid climates) – could help to improve access to thermal comfort in the evening, when people return home, while using far less electricity than an air conditioner. These measures could fit well with current solar PV module deployment in many countries.[19]

The market assessment done in November and December 2020 gave us a good idea of products on the market and their features. This report deals with ceiling fans and stand fans only. Their performance is

[17] Sudan Energy Transition and Access Project (P175040), September 2020
[18] The Future of Cooling, IEA 2018
[19] https://www.iea.org/commentaries/helping-a-warming-world-to-keep-cool

compared to performance in importers country like China, India and Pakistan which have labelling and minimum energy performance standards in place.

Adopting efficient technology for fans is an important source of savings and additional savings could be obtained by shifting from stand fans to ceiling fans when it is possible and suitable.

The energy saving potentials (Table 18), and related electrical power saved, by transforming the market to a more energy efficient product, is an important input for energy policy makers. Indeed, to provide enough electricity for the demand, Sudan must import electricity or build new power plant. The ratio for building and maintaining a gas power plant with a capacity of 1 MW is 1 million USD per year.

*Table 18: Potential energy saving from switching the market to energy efficient fans.*

| | | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Electricity consumption (TWh)** | Business as usual | 2.83 TWh | 7.34 TWh | 49.37 TWh |
| | Efficient technology | 2.83 TWh | 5.34 TWh | 12.84 TWh |
| | + shift to ceiling fans | 2.83 TWh | 4.89 TWh | 11.71 TWh |
| **Power needed (MW)** | Business as usual | 775 MW | 2011 MW | 13526 MW |
| **Power saved (MW)** | Efficient technology | 0 | 548 MW | 1,527 MW |
| **Power saved (MW)** | + shift to ceiling fans | 0 | 672 MW | 1,836 MW |

To be noted, an important share of products made in Sudan are existing in the market today. Minimum energy performance and labelling could be made in cooperation with manufacturers in order not to impede the economy.

### 3.3.1 Market assessment

Fans are used to increase people comfort by lowering the temperature. Actually, the temperature does not decrease. The feeling of comfort is coming from the air movement around the body that increases convection and evaporation. Comfort fans is an alternative to air conditioning, but it is not efficient enough above 35°C.

In this report, standalone fans and ceiling fans are treated separately. Indeed, their applications and functioning are quite different. Standalone fans take the air from back side and throw it to the front. They are directive. Ceiling fans take the air from outside of the blades, concentrate it on the centre and throw it from the centre with a "large aperture", creating vertical air flow and distributing the air temperature. Standalone fans are used for a small area but are moveable while ceiling fans are used in large area.

A market assessment was conducted in November and December 2020. Data collection was performed at three levels:

- National Level: collected from customs, statistics bureau, and governmental entities.
- Wholesale Level: collected through interviews or surveys (annex 1.3) with wholesalers, large distributors, and local manufacturers.
- Retail Level: collected through field surveys covering markets and end suppliers.

The survey was done through extensive field visits in 4 major cities (Khartoum, Port Sudan, Wad Madani, and Al Obeid) conducted by the local project team, collecting information on products capacity, energy performance, brand, type, labelling status, country of origin, use, and unit price. Data was collected from retail shop surveys, with more than 88 shops and sales points selling fan across Sudan were visited as part of the survey, collecting 364 input logs.

**National level**

Harmonized System (HS) Codes is used by customs authorities around the world to identify products when assessing duties and taxes and for gathering statistics. Table 19 summarizes the imported volumes, and their USD values, according to the Sudanese customs.

The two codes for stand fans and ceiling fans are:

HS code-841451: Table, floor, wall, window, ceiling, or roof fans, with a self-contained electric motor of an output ≤125 W

HS code-841459: Fans (Excluding Table, floor, wall, window, ceiling, or roof fans, with a self-contained electric motor of an output ≤125 W).

*Table 19: Stand fans - import volume and values of fans.*

| | Volume (Tons) | | | | | Value (1,000 USD) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hs code & label | 2015 | 2016 | 2017 | 2018 | 2019 | 2015 | 2016 | 2017 | 2018 | 2019 |
| 841451 | 7.187 | 5.104 | 1.617 | 3.622 | N/A | 14.628 | 15.357 | 15.241 | 9.483 | 14.892 |
| 841459 | 617 | 361 | 114 | 440 | N/A | 1.738 | 1.182 | 2.057 | 1.170 | 3.151 |

**Wholesale Level**

Surveys were involving companies and wholesalers who together cumulatively make at least 80 % of the local market share. Collected data covered information on the item's brand, model number, radius, power rating, speed levels, air flow, price, country of origin, and expected lifetime. Key results are shown in the following two sections.

### 3.3.1.1 *Stand fan*

Data collection covered 161 model of stand fans with a radius ranging from 203 mm (8 inches) up to 660 mm (26 inches). Most stand fans (43.5%) have a radius of 610 mm (24 inches), followed by 17.2% at 457 mm (18 inches), with an average radius at 508 mm (20 inches) as shown in Figure 15 below.

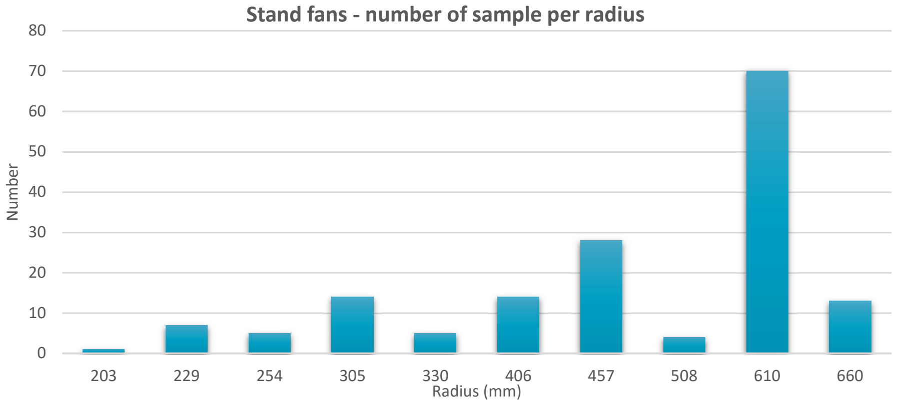



*Figure 15: Stand fans - Number of samples per radius.*

Figure 16 shows the power range from 30 Watt up to 200 Watt. The most common power for stand fans is 180 Watt (46.6%) with 90 % having a power higher than 110 Watt. The average power is 148 Watt.

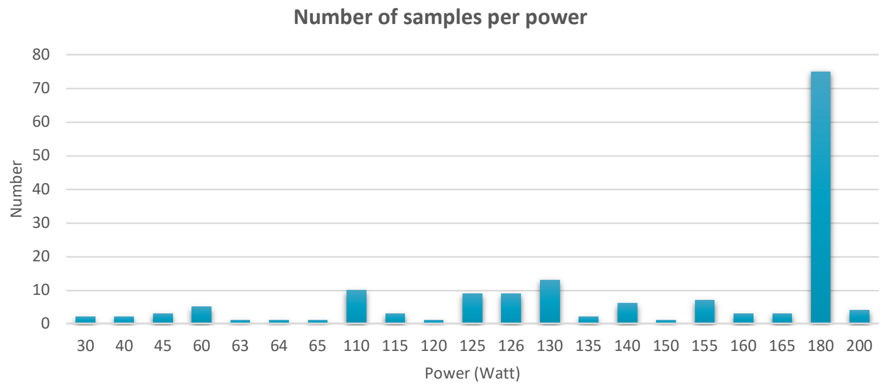



*Figure 16: Stand fans - distribution of references with power.*

Stand fans are imported mainly from China, Egypt, and Pakistan. Sales from products made in the country are representing 28 % of the total sales as shown in Figure 17.

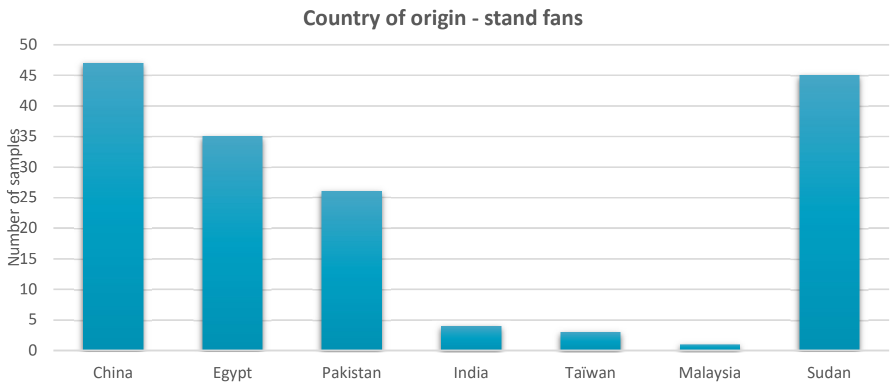



*Figure 17: Stand fans - distribution of imported product per country.*

Figure 18 shows the average unit price is 66.4 USD. The standard deviation is a measure of the dispersion of sample prices around that average value. A low standard deviation means a low dispersion, i.e., that values are close to the mean. For our data set, the standard deviation is 14.8 USD. More than three quarter (76 %) of our samples are within the first standard deviation.

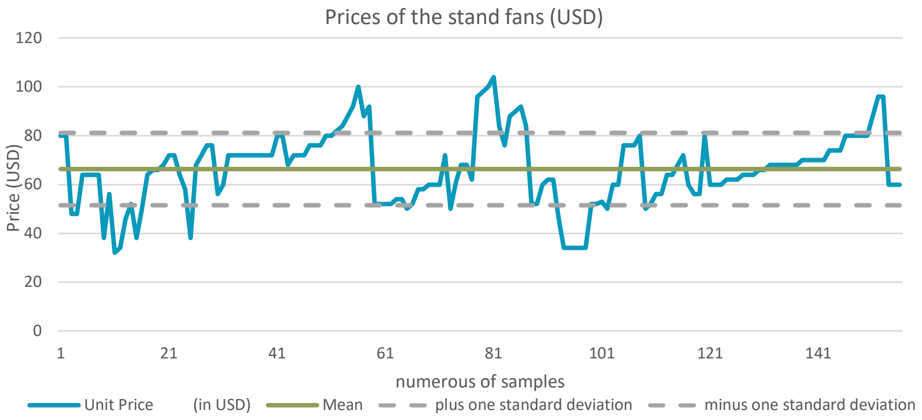



*Figure 18: Stand fans – Prices.*

#### 3.3.1.2 *Ceiling fans*

Data collection covered 161 model of ceiling fans with a radius ranging from 508mm (20 inches) to 1524 mm (60 inches) and an input power between 65 and 120 Watt.

**Radius of ceiling fans:** Table 20 below shows the distribution by radius where vast majority (187 fans) has a radius of 1422 mm.

*Table 20: Ceiling fans - radius dispersion.*

| Radius | 508 mm (20 inches) | 1422 mm (56 inches) | 1448 mm (57 inches) | 1524 mm (60 inches) |
|---|---|---|---|---|
| Number/(Percent) | 2 (1%) | 187 (93.5%) | 6 (3%) | 5 (2.5%) |

**Power:** Table 21 shows the distribution by input power where most of the ceiling fans have a power 75 and 80 watt with an average at 78 Watt.

*Table 21: Ceiling fans - power distribution.*

| Power | 65 Watt | 70 Watt | 75 Watt | 80 Watt | 85 Watt | 120 Watt |
|---|---|---|---|---|---|---|
| Number/(Percent) | 1 (0.5%) | 10 (5%) | 81 (40.5%) | 103 (51.5%) | 2 (1%) | 3 (1.5%) |

**Country of origin for ceiling fans:** Figure 19 shows that ceiling fans sold are coming mainly from India (41.5%) while 25,5% are made in Pakistan.

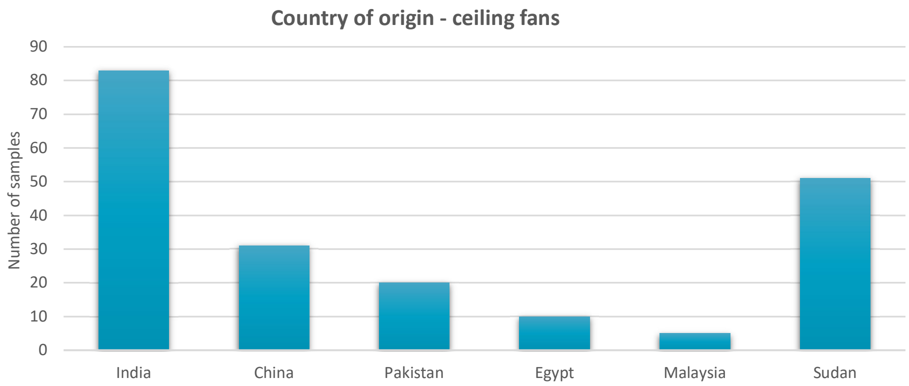



*Figure 19: Ceiling fans - distribution of products per country.*

Prices are higher for larger fans as shown in Table 22, with an average price of $35.45.

*Table 22: Ceiling fans - prices range.*

| Radius | 508 mm (20 inches) | 1422 mm (56 inches) | 1448 mm (57 inches) | 1524 mm (60 inches) |
|---|---|---|---|---|
| **Price range** | $30 to $32 | $24 to $58.8 | $28 to $30 | $52 to $70 |

### 3.3.2 Key findings

The dominant radius for stand fans in the household sector is 610 mm (24 inches). In the analysed samples, prices are not proportional neither to the radius of the fan nor to its power.

The service value measures the efficiency of the fan in [$m^3$/min/W]. This is the volume of air moved per minute divided by the input power of the fan. The efficiency of stand fans increases with the radius (until a certain point). The service factor is increasing almost linearly with the radius of the fan as shown in Figure 20 for the stand fans and in Figure 21 for the ceiling fans.

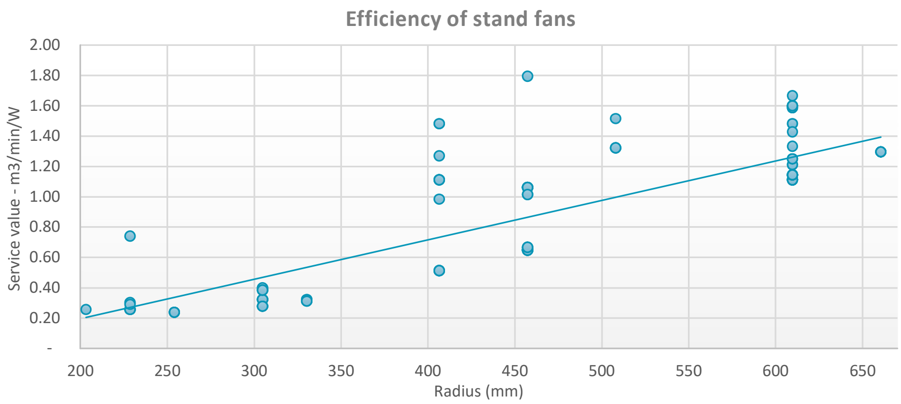



*Figure 20: Stand fans – Service Value.*

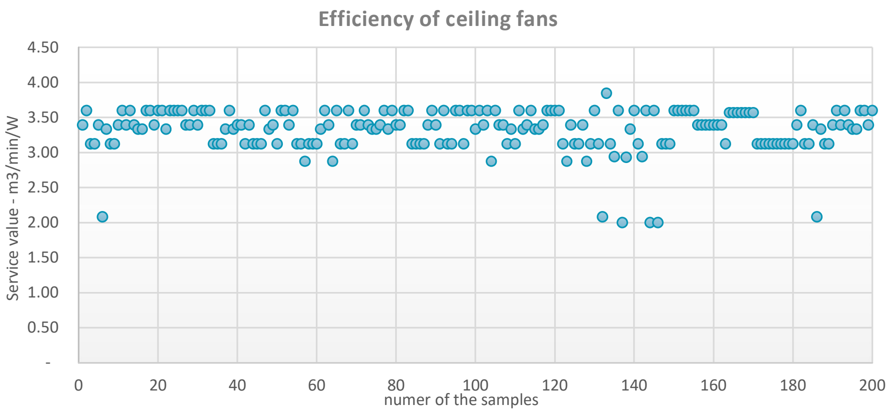



*Figure 21: Ceiling fans – Service Value.*

As explained previously, ceiling fans and stand fans have different functionalities and diameters and cannot be easily compared. However, the efficiency of ceiling fans, to create an airflow for a given input power, is about three times higher compared to stand fans. To be noted, our sample shows that efficiency does not depend on the radius.

More than 25% of all comfort fans (stand fans and ceiling fans) are manufactured in Sudan. Manufacturers should be involved in the establishment of MEPS so that the national industry is not penalized.

### 3.3.3 Life Cycle Assessment

According to the market assessment, in average, a household has 2.7 units installed when it is connected to the grid[20]. Time of use is 10 hours per day or 3,650 hours per year.

According to the World Bank[21], the number of households with access to electricity is 2.2 million whereas the number of households without access to electricity is 4.5 million.

**Stand fans**

Stand fans have an average power of 148 Watt and a radius of 508 mm (20 inches). The average consumption is then 540.2 kWh per year. Considering the residential electricity tariff of \$0.030/kWh, the electricity running cost is \$16.21 per year. To obtain the Total Cost of Ownership (TCO) over typical lifetime (8 years), the average price of a 508 mm stand fans (49.5 USD) should be added. TCO over 8 years is then USD179.18 (8*16.21+49.5).

According to the graph in Figure 20 (stand fans service value versus radius), the service factor is 1 for the 508 mm (20 inches) radius. The service value is equal to the air flow divided by the power. Since the average power is 148 Watt, the air flow is equal to 148 $m^3$/min.

**Ceiling fans**

Ceiling fans have an average power of 78 Watt and a radius of 1422 mm (56 inches). The average consumption is then 284.7 kWh per year. Considering the residential electricity tariff of \$0.03 USD/KWh, the electricity running cost per fan is at \$8.54 per year.

[20] World Bank (2019). From Subsidy to Sustainability: Diagnostic Review of Sudan's Electricity Sector: Final Report.
[21] Sudan Energy Transition and Access Project (P175040), World Bank, September 2020.

The Total Cost of Ownership (TCO) over 8 years' typical lifetime, is the sum of the running cost (8 * $8.54) and the purchase price of a 1422 mm (56 inches) ceiling fans (35.02 USD), totalling 103.34 USD.

According to the graph in Figure 21 of the service value versus the radius, the service factor of ceiling fans sold in Sudan is 3.5 and the air flow for the 78-Watt ceiling fans is then 273 $m^3$/min.

### 3.3.4 Overview and Projection of Electricity Consumption in the Fan Sector in Sudan

As previously mentioned, and according to the World Bank, the number of households non-electrified (4.5 million) is the double of the number of households with access to electricity (2.2 million) for a total of 6.7 million of households.

The number of households with access to electricity is assumed to grow at a rate of 10 % per year until 2035, reaching 6.9 million in 2032 (all households existing today plus 200 000 new households will have access to electricity: 2.2+4.5+0.2=6.9 million). From 2036 to 2050, the growth rate of electrified households is assumed to slow down to 3 % per year.

#### 3.3.4.1 *Business as Usual (BAU) scenario*

As previously noted, the market assessment showed an average of 2.7 units installed per household connected to the grid[22]. Main characteristics of the installed fans are summarized in Table 23 below.

*Table 23: Ceiling and Stand fans features - Business as Usual.*

| Type | Power [W] | Diam. [inch] | Diam. [mm] | Price [USD] | Service value [$m^3$/min/W] |
|---|---|---|---|---|---|
| **Stand fan** | 148 | 20 | 508 | $ 49,50 | 1 |
| **Ceiling fan** | 78 | 56 | 1422 | $ 35,02 | 3,5 |

Ceiling fans are not as easy to install and as the stand fans. We assume a share of 90% for ceiling fans and 10% for stand fans.

Figure 22 and Table 24 shows the consumption (TWh) of fans in Sudan and the supply power (MW) needed in the Business As Usual scenario. This scenario is based on the assumptions of a yearly growth rate of 10 % in the number of electrified households. That growth rate takes into account the growth of the overall population (2.4 % per year according to the World Bank) and the increase of the electrification rate (32% in 2018[23]).

[22] World Bank (2019). From Subsidy to Sustainability: Diagnostic Review of Sudan's Electricity Sector: Final Report.
[23] Sudan National Data, OTB Consult, December 2020

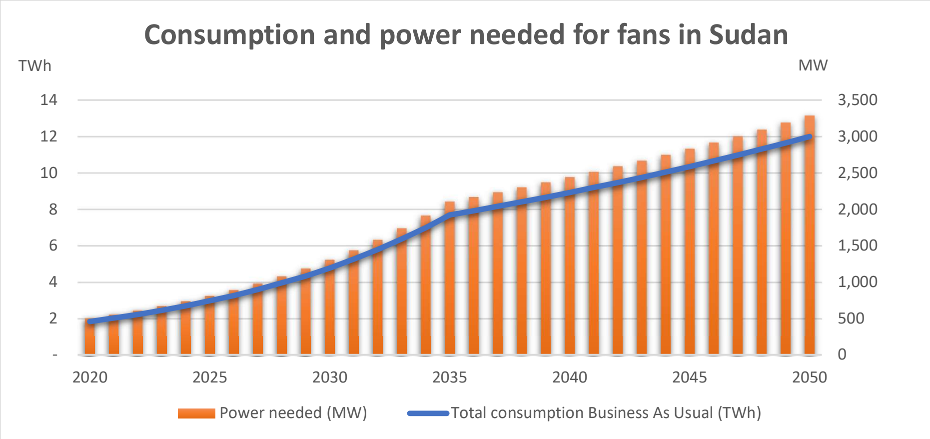



Figure 22: Consumption and power needed for fans in Sudan.

*Table 24: Electricity consumption and power needed for fans in Sudan - Business as usual.*

| | 2020 | 2030 | 2050 |
|---|---|---|---|
| **Electricity consumption (TWh)** | 1.84 TWh | 4.78 TWh | 11.99 TWh |
| **Power needed (MW)** | 505 MW | 1,310 MW | 3,286 MW |

### 3.3.4.2 *Mitigation scenario - Adoption of international standards*

There are no standards for comfort fans performance today in Sudan. However, some standards are existing in the country of origin of the imported products sold in Sudan. The minimum energy performance standards and labelling scheme are reported for the main importers in Sudan, i.e., Pakistan, China, and India. No established standard could be found in Egypt.

**Pakistan**

The National Energy Efficiency & Conservation Authority (*NEECA*) in Pakistan issued a voluntary scheme of energy label for electric fans[24] as shown in Table 25 below. Minimum Energy Performance Standard (MEPS) is the first level (Level 1).

*Table 25: Pakistan energy label for fans.*

| | | Service value [m$^3$/min/W] | | |
|---|---|---|---|---|
| | Sweep (mm) (= diameter) | Level 1 1 star | Level 2 2 stars | Level 3 3 stars |
| **Stand fan** | 200 | 0.54 | 0.6 | 0.71 |
| | 230 | 0.64 | 0.7 | 0.84 |
| | 250 | 0.74 | 0.79 | 0.91 |
| | 300 | 0.8 | 0.86 | 0.98 |
| | 350 | 0.9 | 0.95 | 1.08 |
| | 400 | 1 | 1.06 | 1.25 |
| | 450 | 1.1 | 1.19 | 1.42 |

[24] https://neeca.gov.pk/Detail/OGQ5MDVmMjQtZjA5Yy00ZWZmLWJiNGUtOTYxN2Y3YmEwNWMw

| | | | | |
|---|---|---|---|---|
| | 500 | 1.13 | 1.25 | 1.45 |
| | 600 | 1.3 | 1.43 | 1.65 |
| | | Service value [m^3/min/W] | | |
| | Sweep (mm) | Level 1<br>1 star | Level 2<br>2 stars | Level 3<br>3 stars |
| Ceiling fan | 900 | 2.75 | 2.87 | 2.95 |
| | 1050 | 2.79 | 2.93 | 3.1 |
| | 1200 | 2.93 | 3.08 | 3.22 |
| | 1400 | 3.15 | 3.32 | 3.45 |
| | 1500 | 3.33 | 3.52 | 3.68 |
| | 1800 | 3.47 | 3.67 | 3.81 |

**<u>China</u>**

On August 26, 2020, China's Standardization Administration released a proposed revision (a draft for opinion gathering) of the national standard. A summary of the draft is given in Table 26 below.

*Table 26: China energy label for standing fans.*

| Type | Size (mm) | Energy performance ($m^3$/min.w) | | |
|---|---|---|---|---|
| | | Energy efficiency grade | | |
| | | Grade 1 | Grade 2 | Grade 3 |
| Table fan, Box fan, Wall fan, Floor fan, and Living fan | 200 | 1.00 | 0.70 | 0.45 |
| | 200 - 230 | 1.10 | 0.84 | 0.55 |
| | 230 – 250 | 1.30 | 0.95 | 0.65 |
| | 250 – 300 | 1.50 | 1.05 | 0.78 |
| | 300 – 350 | 1.65 | 1.15 | 0.93 |
| | 350 – 400 | 1.85 | 1.35 | 1.03 |
| | 400 – 450 | 2.15 | 1.50 | 1.15 |
| | 450 – 500 | 2.40 | 1.55 | 1.20 |
| | 500 - 600 | 2.65 | 1.70 | 1.37 |

**<u>India</u>**

A standard is existing in India, IS 374: 2019 "Electric Ceiling Type Fans — Specification (Fourth Revision)". It specifies minimum service values and minimum air delivery values for ceiling fans which is summarized in Table 27.

*Table 27: Indian Standard- Ceiling fans minimum service values and air delivery.*

| Fan Size (mm) | Minimum Air Delivery ($m^3$/min) | Minimum Service value ($m^3$/min/W) |
|---|---|---|
| 900 | 130 | 3.1 |
| 1050 | 150 | 3.1 |
| 1200 | 210 | 4.0 |
| 1400 | 245 | 4.1 |
| 1500 | 270 | 4.3 |

The Bureau of Energy Efficiency (BEE) of India presented the market penetration of star labelled ceiling fans as per existing voluntary energy consumption standard (5 stars rating). BEE proposed to include other sweep sizes. Two separate star rating plans are proposed, one for sweep size < 1,200 mm and another for sweep size ≥ 1,200 mm as shown in Table 28.

*Table 28: BEE in India- proposal for labelling of ceiling fans.*

| | Sweep (=diameter) size < 1200 mm | Sweep (=diameter) size ≥ 1200 mm |
|---|---|---|
| Star rating | Service value (SV) | Service value (SV) |
| 1 star | 3.1 ≤ SV < 3.6 | 4.0 ≤ SV < 4.5 |
| 2 stars | 3.6 ≤ SV < 4.1 | 4.5 ≤ SV < 5.0 |
| 3 stars | 4.1 ≤ SV < 4.6 | 5.0 ≤ SV < 5.5 |
| 4 stars | 4.6 ≤ SV < 5.1 | 5.5 ≤ SV < 6.0 |
| 5 stars | ≥ 5.1 | ≥ 6.0 |

The scenario with the adoption of international standards is calculated considering a progressive shift of the installed fans to a higher energy performance product.

For stand fans of 508mm (20 inches) diameter, three stars service value for Pakistan is 1.45 $m^3$/min/W and 1.70 $m^3$/min/W for grade 2 in China. It is reasonable to expect a service value of 1.5 $m^3$/min/W in Sudan.

For ceiling fans of 1,400 mm diameter three stars service value for Pakistan is 3.45, lower than existing fans on the market. Indian standard is more ambitious with a minimum service value of 4.1 $m^3$/min/W (Table 27). The label proposal in Table 28 is at 6 $m^3$/min/W for 5 stars rating.

For the same airflow in $m^3$/min but higher service value, the power of the fans is lowered to 99 Watt for the stand fan and 67 Watt for the ceiling fan as shown in Table 29.

*Table 29: high performance fans service value.*

| | Existing fan | | | High performance fan | |
|---|---|---|---|---|---|
| Type | Power [W] | Diameter [mm] | Service value [$m^3$/min/W] | Proposed Service value [$m^3$/min/W] | Power for the same air flow [W] |
| Stand fan | 148 | 508 | 1 | 1.5 | 99 |
| Ceiling fan | 78 | 1,422 | 3.5 | 4.1 | 67 |

### 3.3.4.3 *Impact of the mitigation scenario*

Shifting to a more efficient technologies is assumed to occur at a rate of 10% per year beginning in 2022. The complete shift is achieved in 2031. Related savings are shown in Figure 23 (note that the consumption is in TWh but the power saved is in MW. These savings can avoid the construction of new power plant capacity) and Table 30 below.

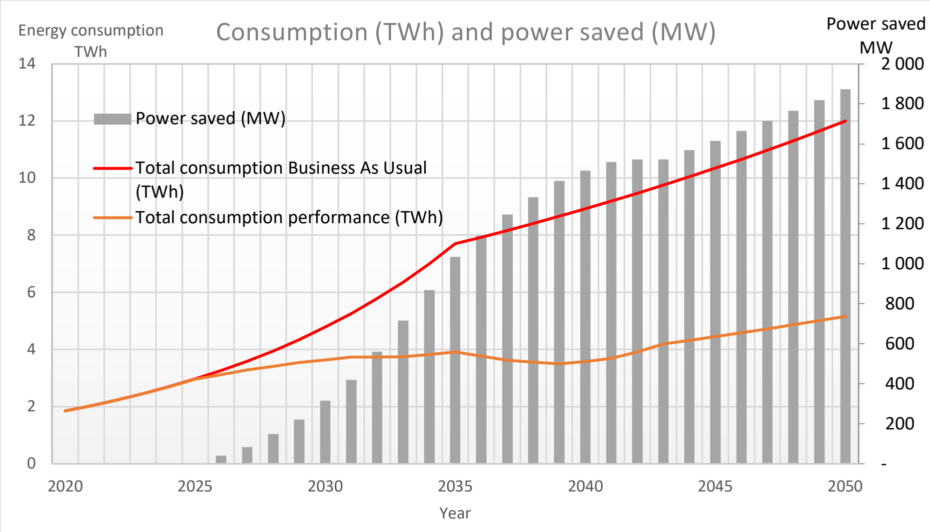



*Figure 23: Energy demand for BAU vs. Mit scenario and related energy savings.*

*Table 30: Electricity consumption and power saved for fans in Sudan - Efficiency scenario.*

| | 2020 | 2030 | 2050 |
|---|---|---|---|
| **Electricity consumption (TWh)** | 2.83 TWh | 5.34 TWh | 12.84 TWh |
| **Power saved (MW)** | 0 | 548 MW | 1 527 MW |

### 3.3.5 Conclusion

Figure 24 shows the projected electricity demand 2020-2050 for the fans sector in Sudan under the BAU scenario.

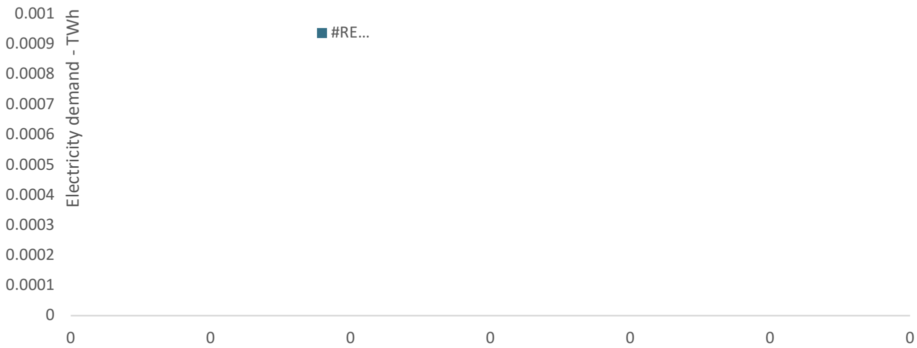



*Figure 24: Projected electricity demand of fans in Sudan.*

The market assessment of the fans sold in Sudan showed that the performance of existing units could be determined and compared with either the neighbouring countries or the countries of origin. That comparison is based on existing minimum energy performance scheme and/or labelling scheme in those countries. The mitigation scenario is considering the shift to more efficient fans (ceiling and stand fans).

## 3.4 Residential Refrigerators

### 3.4.1 Market assessment

The market assessment was based on customs data and a survey of local manufacturers and sellers. The assessment was used to estimate future sales, stocks, energy demand, and GHG emissions which in turn were used for to develop the MEPS and labels recommendations for refrigerators in Sudan. The data collected from both sources present similar patterns and the figures are comparable indicating a reasonably robust dataset.

The data provided by local manufacturers and importers indicates that their sales volume accounts for around 90% of the market. The majority of the market is for sizes under 500 litres (Table 31), with an average size of 331 litre combined (fridge plus freezer). In terms of energy efficiency, around 65% of the models did not have labels, 20% showed a label with grade "A", and the remaining 15% was spread among model showing "C", "B", "A+" and "A++". It is of note that looking at the stated annual energy consumption for "A++", it is not believed that they would meeting the current requirements for the EU, so they may be outdated.

The top brad brands of refrigerating appliances in Sudan are LG, Digi, Samsung, Ideal, Startech. Liebherr, Coldair, Toshiba, Sharp and Hafab with the majority imported from China, Egypt, and India.

*Table 31: Frequency of refrigerator types and average volumes of studied refrigerators (Source: HEAT Analysis).*

| Type | Frequency | Average Volume (l) |
|---|---|---|
| Bottom-Freezer | 2 | 246 |
| French Door | 2 | 613 |
| Full-Freezer | 16 | 208 |
| Full-Refrigerator | 6 | 317 |
| Mini Freezer | 1 | 170 |
| Mini Fridge | 24 | 168 |
| Side-by-Side | 18 | 594 |
| Top-Freezer | 230 | 334 |
| Chest Freezer | 2 | 444 |
| **Total** | **301** | **331** |

Using the method detailed in U4E the model regulation[25], we calculated the reference annual energy consumption (AEC) and compared them to the provided AEC to determine the R-value, which is the measure of energy efficiency proposed by the model regulation. It is of note that for Sudan's climate, the estimation should use a base temperature of 32°C, but it was believed that the values provided on the studied fridges used the more common base of 24°C. As such, 24°C was used as base temperature to determine the R values (a performance ratio against a reference model performance). Using this method, and accounting for an approximate difference of 28% between the two base temperatures, an average AEC 467 kWh/year was estimated for the models in the Sudan market.

[25] https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficient-and-climate-friendly-refrigerating-appliances/

The U4E Model Regulation recommends a minimum R-value of 1 and grade efficiencies according to Table 32. However, the majority of refrigerator currently in the market have an estimated R-value between 0.5 and 1, meaning that they use up to twice as much energy than the reference model annual energy consumption.

*Table 32: Labelling requirements for refrigerating appliances (Source: U4E Model regulation for refrigerators).*

| Grade | Refrigerators | Refrigerators-Freezers | Freezers |
|---|---|---|---|
| **High Efficiency** | R>= 1.50 | R>= 1.50 | R>= 1.50 |
| **Intermediate** | 1.25 ≤ R < 1.50 | 1.25 ≤ R < 1.50 | 1.25 ≤ R < 1.50 |
| **Low Efficiency** | 1.00 ≤ R < 1.25 | 1.00 ≤ R < 1.25 | 1.00 ≤ R < 1.25 |

In terms of the main refrigerants in the market, 70% of the studied refrigerators use the natural refrigerant R600a (isobutane), while the remaining 30% use the hydrofluorocarbon R134a, which as GWP of 1430 and it use will be phased down under the Kigali Amendment.

### 3.4.2 Key findings

The majority of refrigerators being sold in Sudan do not carry an energy efficiency label and are considered inefficient appliances by the classification of the U4E model regulation. Thus, it is very difficult for consumers to make informed decisions and have a wide selection of highly efficient appliances to choose from.

### 3.4.3 Life Cycle Assessment

The life cycle cost (LCC) of a fridge includes the purchasing price plus the annual electricity consumption costs. As the price of grid electricity in Sudan is one of the lowest in the world, with 0.03 USD/KWh, the running cost for appliances is very low as well. Table 33 below shows the average LCC cost for the most common fridges type in Sudan.

*Table 33: Average Life cycle Cost [USD] of common fridge types (Source: HEAT Analysis).*

| | < 300 l | 300-500 l | > 500 l |
|---|---|---|---|
| **Top-Freezer** | 426 | 766 | 997 |
| **Mini Fridge** | 348 | 784 | No models |
| **Side-by-Side** | No models | 674 | 2014 |

The low electricity cost means that the LCC of appliances is dominated by the initial price for the fridge. However, a slight trend of the LCC decreasing as the appliances become more energy efficient can still be observed with the trend being more pronounced in the smaller refrigerators, under 300 litres (Figure 25).

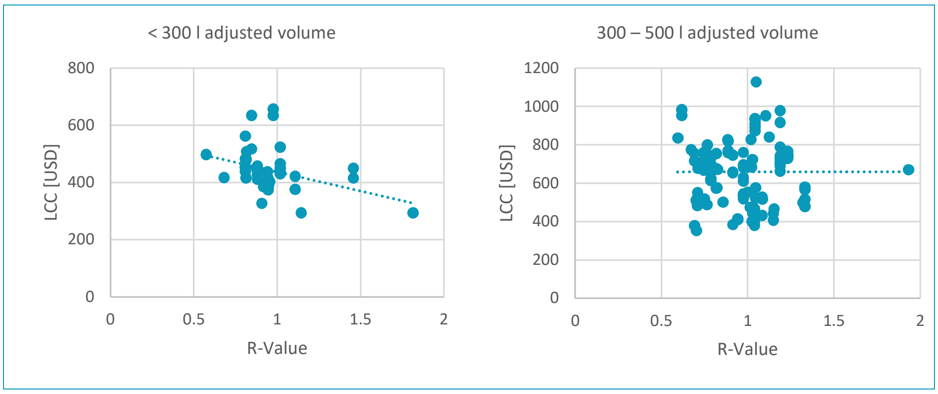



*Figure 25: LLC for refrigerators in Sudan for adjusted volumes <300 l (left) and 300-500 l (right) (Source: HEAT analysis) (Source: HEAT Analysis).*

### 3.4.4 Overview and projection on Electricity Consumption of refrigerators in Sudan

For the projection of refrigerator ownership, we considered two key driving factors: the planned progress of household electrification and increasing owner ship rates among electrified households.

#### 3.4.4.1 *Business as Usual*

Refrigerators are one of the first appliances bought once a household is connected to the electricity grid. With the ambitious government plan to provide all household with access to electricity within the next decade, the number of refrigerators in use are expected to rise sharply.

The key assumptions for the development of the market projections centre on population growth, the achievement of the government objectives on electrification, the development of the economy and addressing poverty.

Based on the assumptions above, Sudan's population reaches 89 million in 2050 up from 43 million in 2019, more than double. At the same time, the resulting number of households with access to electricity increases from 2.2 million in 2020 to over 14.3 million in 2050, a 6.5-fold increase.

#### 3.4.4.2 *Development of sales and stock figures*

Sales during the 2010 – 2020 period fluctuated around 140 000 units per year, with a dip below 130 000 unit in 2018 and 2019 and an optimistic view for 2020. The stock numbers remained somewhat stable in recent years. For the 2020 – 2050 period, the stocks increase as the continued electrification is expected to result in increased ownership levels from 20% in 2020 to close to 100% in 2050. In absolute terms, the stock increases by 12 million, over an order of magnitude more than the 1.5 million units in 2020 (Figure 26).

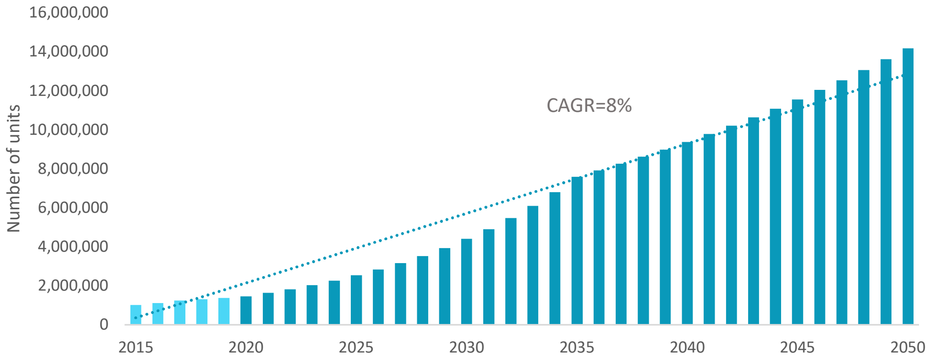



*Figure 26: Residential refrigerator stock development between 2020 and 2050 (Source: HEAT Analysis)*

In terms of sales, they also increase rapidly at a CAGR of 5.4% per year for the 2020-2050 period, rising from around 230,000 units in 2020 to around 1.1 million units per year by 2050, a more than 4-fold increase. The peak observed in 2034, is a result of the assumed rapid increase of ownership due to a projected high number of households gaining access to the electricity grid in these years. Once all households are electrified, further increases in sales are then due to the assumed economic growth.

### 3.4.4.3 *Business-as-usual energy demand*

The combination of increased ownership and only slight improvements of the energy efficiency of refrigerators in the BAU scenario results in a considerable increase of electricity demand for domestic refrigeration in Sudan.

In the BAU scenario, electricity demand increases from 930 GWh (1.5 million units in use multiplied with 640 kWh of average energy consumption per refrigerator) in 2020 to around 7,600 GWh (projected 14 million units multiplied with 540 kWh of projected average electricity consumption per refrigerator) in 2050 as shown in Figure 27.

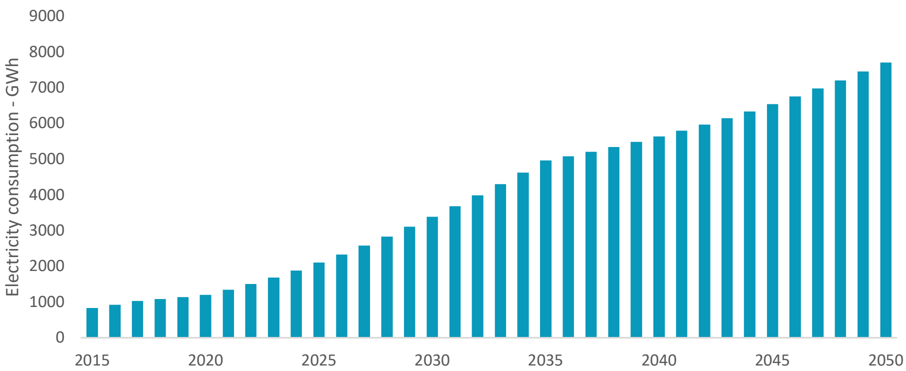



*Figure 27: Electricity consumption from domestic refrigerators in Sudan 2020-2050 (Source: HEAT Analysis)*

### 3.4.4.4 *Business as usual emissions*

As refrigerant emissions are typically low for refrigerators and the shift low GWP refrigerant R600a is well under way, the GHG emissions of fridges are largely caused by their electricity consumption. Assuming a constant grid emission factor, GHG emissions rise from 0.3 in 2020 to 2.4 Mt $CO_2$eq in 2050 (Figure 28).

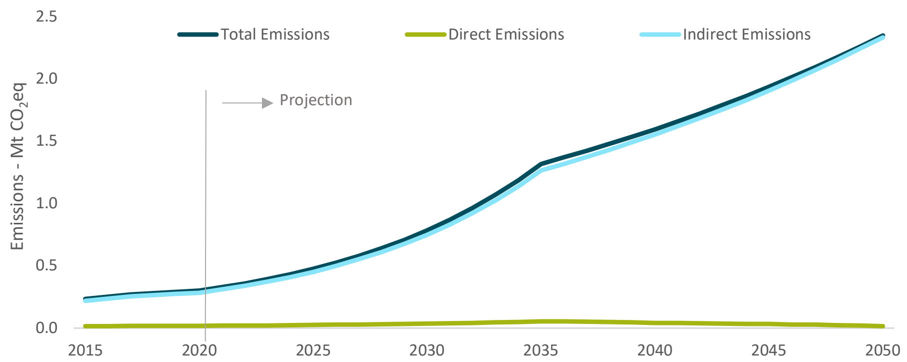



*Figure 28: Projected emissions from refrigerators in the BAU scenario (Source: HEAT Analysis).*

### 3.4.4.5 *Emissions mitigation potential*

Figure 29 illustrates the potential GHG reductions possible from a strong application of energy efficiency regulation and an immediate adoption of near-zero GWP refrigerants. Thus, the increase of energy demand is reduced by about 50%.

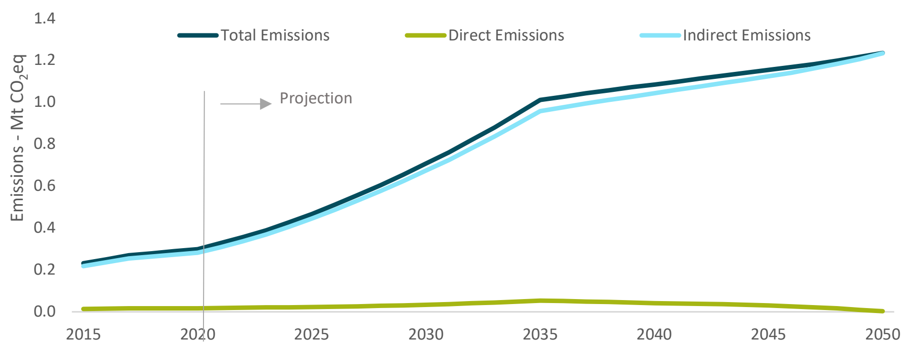



*Figure 29: Potential emissions reductions from refrigerators (Source: HEAT Analysis).*

### 3.4.5 Conclusion

The operation of refrigerators constitutes a base load to any electricity grid. With the ambitious plans for full electrification of households in 2030, more refrigerators will be used in Sudan. To keep the strain on the electricity grid low, a shift to highly efficient refrigerators is strongly recommended.

## 3.5 Residential air conditioners

### 3.5.1 Market assessment

Sudan's very hot climate, with a mean summer temperature of 30 degrees and with 228 days of the year reaching temperatures above 35ºC, make air conditioning more of a necessity than a luxury and there is high demand for them for a low-income country.

**Sales of AC units**

Sales of residential AC units have showed a decreasing trend in recent years, but after the low of 2018, sales have increased by 7% and 9% indicating of market recovery and future development. This pattern of growth in expect to continue and possibly accelerate in the future as the country looks to improve economic development and extend the reach to of the electrical grid to a greater proportion of the population.

The great majority of units are imported from a number of international brands from Japan, China, Korea, and more. For the five years of available data, imports made around three-quarters of all sales. Local manufacturing is represented by domestic brands Coldair and TCL-Nesma which concentrate largely in low-cost units without inverters, and international brand LG to make up around a quarter of domestic sales.

**Stock**

Based on very limited data availability, the initial stock is estimated at around 300,000 AC units operational in 2014. Based on growth assumptions from population, AC sales, and retiring of old units this stock has grown to around 495,000 units by 2020.

Considering that these estimates account for only one third of total households (around two-thirds of households have no access to electricity) and that only a quarter of the HH that have electricity have an AC, it is expected that this number will grow significantly over time.

#### 3.5.1.1 *Market trends*

The Sudan residential AC market is currently dominated by small to medium size relatively inefficient units. with 83% of the units available having capacities of 5kW or less, while larger units make only 17% of all available units (Table 34). There is no data to indicate the progression of the size over time, but it is expected that as cooling demand and affordability for cooling increases, the size of appliances may increase.

*Table 34: Cooling capacity of residential AC units in the Sudan market (source: HEAT analysis).*

| Size | Proportion of the market |
|---|---|
| Under 3 kW | 52% |
| 3 to 5kW | 31% |
| 5 to 7 kW | 14% |
| Over 7 kW | 2% |

Efficiency levels across the market are relatively low with an average EER for all units in the market of 2.7, too low for existing MEPS in many countries. In Brazil for example, the MEPS have just been updated with a minimum SEER of 3.14, increasing to 3.5 by 2025; while they are 3.2 in China, and 3.3 in India for split ACs.

Similarly, the lack of efficiency regulations means that 67% of the market relies on non-inverter models, which usually have a lower cost, but are less efficient.

In terms of the refrigerant in use in the Sudan AC market, around 46% of the market still relies on R-22, an HCFC with a global warming potential (GWP) of 1760. The remainder of the market uses R-410a, an HFC with a GWP of 2088. Around the world, HCFCs (R-22) is being actively phased out as part of the Montreal Protocol implementation actions. Similarly, HFCs are in the process of being phased down in many countries, the EU has issued a regulation that bans AC units using refrigerants with a GWP greater than 750, and this is under review with many calls to reduce this threshold to 150.

### 3.5.2 Life cycle assessment

However, despite the low operational costs due to low electricity prices, there is a clear downward cost trend as the energy efficiency of the units increase (Figure 30). This is the result of low purchase and installation costs along with the very high individual unit consumption.

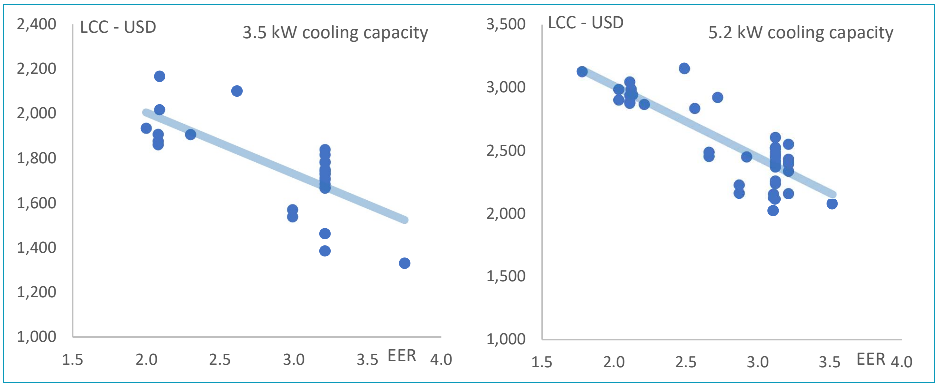



*Figure 30: LLC for split AC units in Sudan for cooling capacities 3.5 (left) and 5.2 (right) (Source: HEAT analysis).*

This pattern is repeated over other AC sizes and window AC units with increased energy efficiency consistently resulting in a lower LCC. In the 3.5 kW category, the lowest LLC was 38% lower than the largest representing potentially significant savings. However, due to the low electricity tariffs, the absolute difference in the example above is around USD 800 which spread over 10 years is USD 80 per year which is unlikely to be a strong incentive for the market to demand higher EER units.

### 3.5.3 Overview and projection of electricity demand of air conditioners in Sudan

The development of the residential AC market in Sudan are expected is expected to gather pace in the future as the country develops economically, increasing the purchasing power of households and supporting the development of the electricity grid that currently services only a third of households.

#### 3.5.3.1 *Business-as-usual*

The business-as-usual projections of the Sudan residential AC market are based on assumptions of how the country will develop. The key assumptions for the development of the market projections centre on population growth, the achievement of the government objectives on electrification, the development of the economy and addressing poverty.

The population projections and economic projections are in line with growth statistics from the past and conform to previous patterns. On the other hand, it is assumed that the government target to reach 100% electrification by 2030 will be achieved. This target will require a high level of investment and commitment that may not be feasible considering the many competing priorities looking to develop.

Based on the assumptions above, Sudan’s population reaches 89 million in 2050 up from 43 million in 2019, more than double. At the same time, the resulting number of households with access to electricity increases from 2.2 million in 2020 to over 14.3 million in 2050, a 6.5-fold increase.

#### 3.5.3.2 *Development of sales and stock figures*

Sales during the 2014-2020 period fluctuated significantly with a generally increasing trend from 2018 resulting in a similarly increasing stock of split ACs in Sudan. For the 2020-2050 period, the stocks are projected to continue to increase at the high CAGR of 10% as the continued electrification and AC affordability resulting in increased ownership levels of AC from 7% of all households in 2020 to 40% in 2050. In absolute terms, it is a growth of over 8 million units, nearly 17 times more than the 0.5 million units in 2020 (Figure 31).

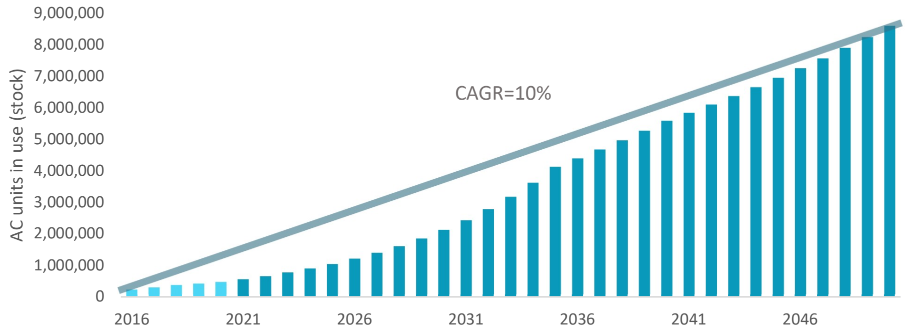



*Figure 31: Residential AC stock development between 2020 and 2050 (Source: HEAT Analysis).*

In terms of sales, they also increase rapidly at a CAGR of 7.1% per year for the 2020-2050 period, rising from around 160,000 units in 2020 to close to one million units per year by 2050 almost a 6-fold growth. It is of note that differences between these figures and the published sales figures for these products is believed to be the proportion of sales that go to small and medium commercial buyers.

#### 3.5.3.3 *Business-as-usual energy demand*

The combination of increased ownership and Sudan's very hot climate results in large increases of electricity consumption which in turn will increase the need for electricity grid improvements, not only to extend its reach to more population, but to operate at much higher capacities needed to supply the increase demand from cooling and other uses. In the BAU scenario, electricity demand increases from 3,200 GWh in 2020 to around 42,800 GWh in 2050 (Figure 32) an over 11-fold increase.

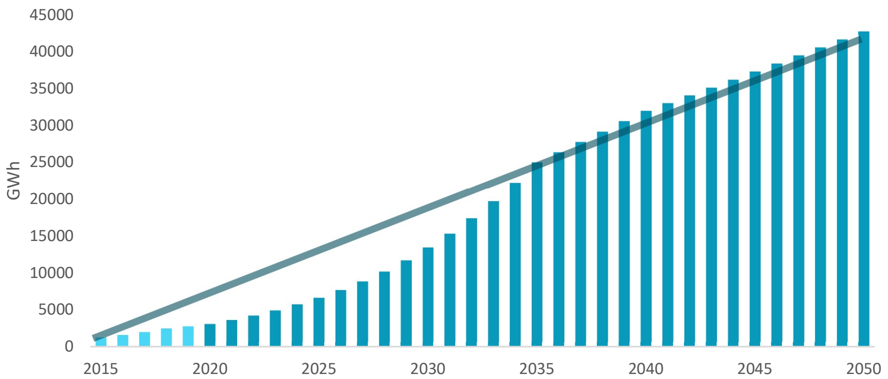



*Figure 32: Electricity consumption from split AC units in Sudan 2020-2050 (Source: HEAT Analysis).*

The energy demand increase is larger than the entire production of energy in the country in 2020 and supporting the development of the grid will be essential to ensure that this market develops strongly providing with social and economic benefits to the country.

#### 3.5.3.4 *Business-as-usual emissions*

The BAU scenario assumes the international default refrigerant charges for residential AC units and a slow transition in the market towards refrigerants with lower GWP, in this case R-32 and R-290 with GWP values of 675 and 3, respectively. The assumptions made concerning emissions from the electricity grid are that they remain at the current level of 305 grams of $CO_2$eq per kWh throughout the 2020-2050 period.

Based on these assumptions, total emissions from the residential demand and use of AC units increases at CAGR of 8.1% per year to a total of 14.1 million tons of $CO_2$eq ($MtCO_2$eq), a more than ten-fold increase from the 1.2 $MtCO_2$eq in 2020 (Figure 33).

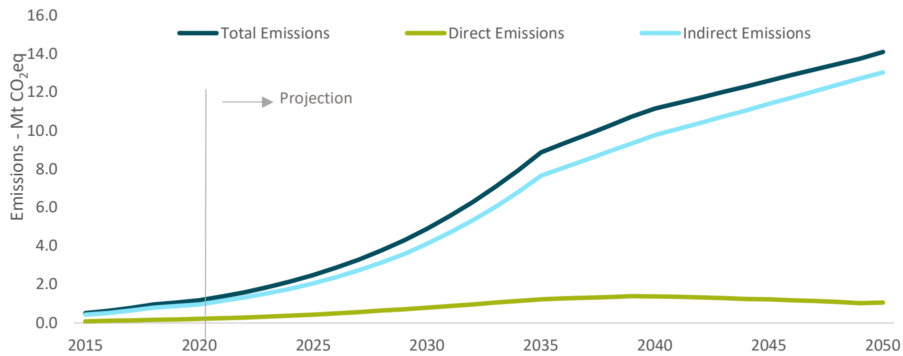



*Figure 33: GHG emissions from AC units in Sudan in the 2020-2050 period in $MtCO_2eq$ (Source: HEAT Analysis).*

The increase is due to large increases in both, direct emissions from refrigerant leakage and indirect emissions from the energy consumed by the AC units. Emissions from these sources grow at an CAGR of 5.5% and 8.5% respectively indicating a close relationship with the growing number of units in the market.

#### 3.5.3.5 *Emissions mitigation potential*

In order to address this dramatic emissions increase, it is essential to accelerate the process of migration to low GWP refrigerants, the lower the better. At the same time, Sudan needs to transition away from fossil generated electricity to arrest the large increases projected in this report. A greater and faster penetration of the near-zero GWP refrigerants such as R-290 would result in significant decrease of direct emissions.

Figure 34 illustrates the potential GHG reductions possible from an immediate adoption of near-zero GWP refrigerants and strong application of energy efficiency. This adoption sees direct emissions reducing to a very low level and indirect emissions become a much more dominant component. Similarly, indirect emissions are reducing by 39% and options for further reductions through the adoption of renewable energy.

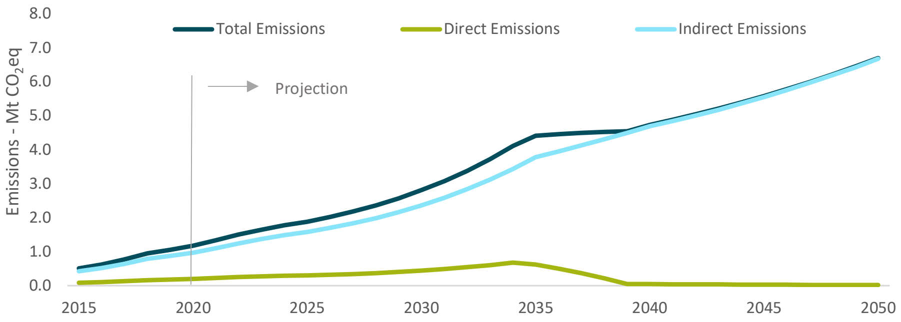



*Figure 34: Potential emissions reductions from ACs (Source: HEAT Analysis).*

### 3.5.4 Conclusions

Considering the prevalent climate in Sudan, and the project warming patterns, ACs are seen less as a luxury and more and more as a necessity. This results in large sales and stock increases during the 2020-2050 period culminating in a stock of around 8.5 million operating units which require more energy than the existing electricity supply of 2020. GHG emissions increase at an equivalent pace.

These very large increases need to be mitigated to enable the country to support this growth and reduce the impact on the environment and the economy. This is specially the case, since electricity is heavily subsidized and increases in demand will be expensive for the country.

## 3.6 Evaporative AIR coolers (EACs)

Evaporative air coolers are well suited for the prevalent weather in the central and southern regions of Sudan, where the weather is hot, largely dry, but with sufficient water supply areas. Under these conditions, EACs can provide a good level of cooling with a much-reduced electricity demand compared to ACs. However, it is essential that the placing and installation of the system to achieve optimum performance.

### 3.6.1 Market assessment

EACs are popular in Sudan with sales level similar to those of ACs ranging between 134,000 in 2015 and 180,000 in 2020 with a high of 208,000 in 2018. These levels of sales indicate that the EACs are well known in Sudan and one of the preferred options for cooling.

In terms of size, the majority of the systems sold have a medium cooling capacity comparable to medium AC units, between 5,000 and 10,000 cubic feet per minute. Given the way they operate, it is difficult to compare the cooling capacity of EACs against ACs, as the performance is highly dependent on prevailing weather conditions. It is of note that most of these units are manufactured in Sudan with little regulations to ensure quality and consistency across the different brands.

### 3.6.2 Life cycle assessment

The life-cycle cost for the EACs is a complicated proposition given that the variation in performance is more due to prevailing environmental conditions than the energy efficiency of the device, as they are very simple devices. To evaluate the LCC, it was estimated that EACs are in operation for 4,000 hours per year, using the rated watts capacities.

Without energy efficiency differentiation and their close watts ratings, the LCCs results are compared against total cooling capacity, and they show a linear relationship between capacity and LCC with the key source of difference being the purchase price (Figure 35). The LCC of EACs ranges between around USD 300 and 1,200 depending on size assuming the current electricity tariff of 3 US cents per kWh over 10 years. Figure 35 illustrates the LCC over 10 years with two different tariffs.

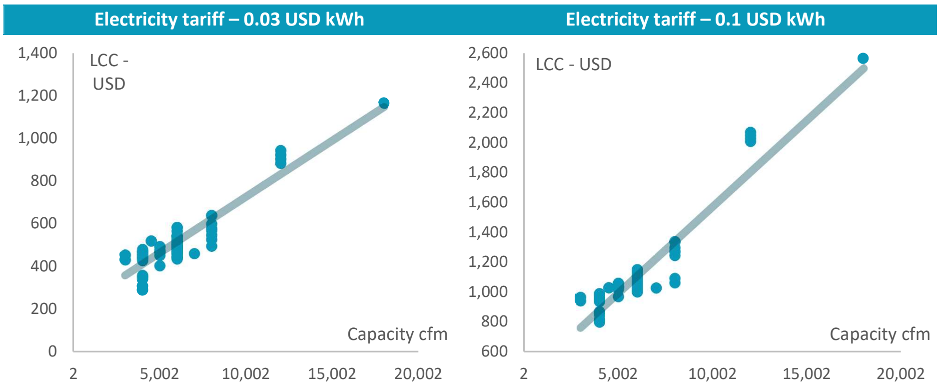



*Figure 35: LCC Evaporative coolers (Source: HEAT Analysis).*

These costs are very attractive to consumers as they can get cooling for a much lower cost than ACs. However, it is worth mentioning that EAC are unlikely to produce the same level of service. While they are technically capable, they are more dependent on daily conditions, require more maintenance, and their basic operation does produce humid air, which is not always welcome.

### 3.6.3 Overview and projection of electricity demand of EACs in Sudan

#### 3.6.3.1 *Business-as-usual*

With the assumption on initial ownership levels of around 11.4% (World Bank, 2019) and following the electrification expansion and the economic development expectations used for other appliances (e.g., ACs and refrigerators), the market for EACs is projected to develop at a fast pace growing from around 0.5 million units in 2020 to over 8.5 million units in 2050, a CAGR of 10% for the 30-year period (Figure 36).

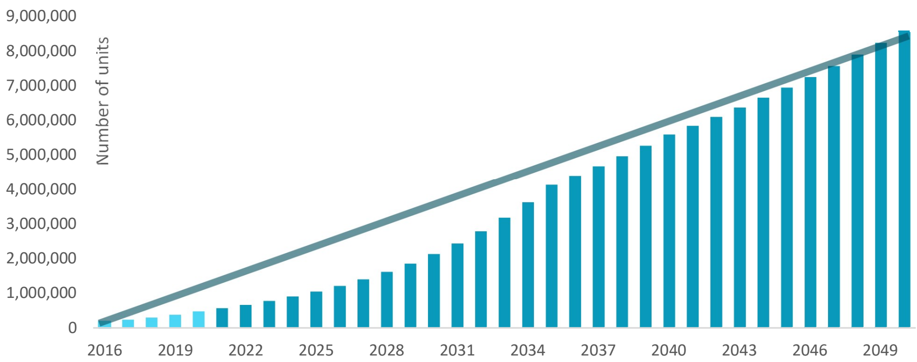



*Figure 36: Evaporative coolers stock projections 2020-2050 (Source: HEAT analysis)*

In terms of sales, they also increase rapidly at a CAGR of 7.1% per year for the 2020-2050 period, rising from around 180,000 units in 2020 to close to one million units per year by 2050, almost a 6-fold growth.

###### 3.6.3.1.1 *Business-as-usual energy demand*

As with the ACs, the combination of increased ownership and Sudan's very hot climate results in large increases of electricity consumption. In the BAU scenario, electricity demand increases from 594 GWh in 2020 to around 10,300 GWh in 2050 (Figure 37) an over 17-fold increase.

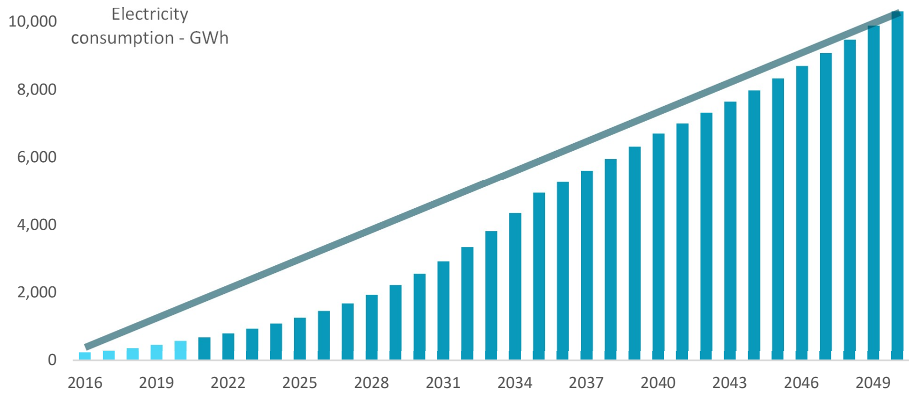



*Figure 37: Electricity consumption from EC units in Sudan 2020-2050 (Source: HEAT Analysis).*

While this level of electricity demand, increases are smaller than that projected for ACs, they still represent more than 50% of all electricity generated in Sudan today.

#### 3.6.3.2 *Business-as-usual emissions*

The increase in energy demand from the growth in EACs operating in the market, results in a commensurate increase in emissions from 0.18 $MtCO_2$-eq in 2020 to 3.14 $MtCO_2$-eq in 2050 as shown in Figure 38 below.

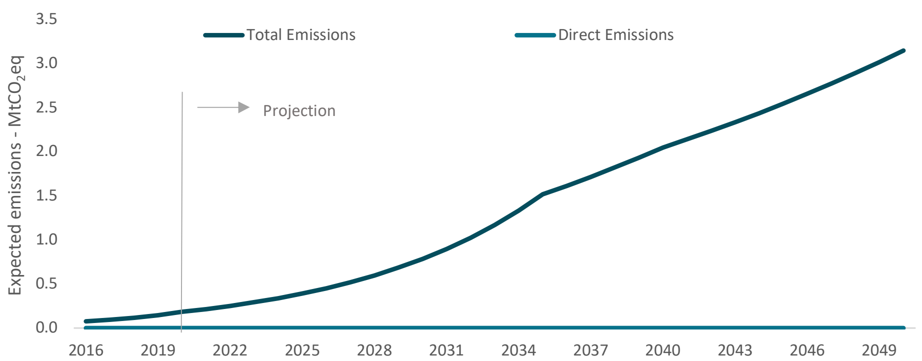



*Figure 38: Expected emissions increase between 2020 and 2050.*

A key difference in the emissions increase between EACs compared to ACs, is that they do not use refrigerants for their operation, so there are no direct emissions.

#### 3.6.3.3 *Emissions mitigation potential*

The key avenues for the mitigation of emissions from the increase in demand from this appliance would centre on three key possible responses: the improvement in appliance efficiency, an increase in the share of renewable energy in the electricity mix and reducing demand for cooling from improved building design.

Considering that there is not data on the efficiency of EACs in Sudan and that performance is dependent on variables external to the technology, it is not possible to estimate the potential emissions reduction potential. However, some key recommendations include:

- Ensure that manufacturers use efficient motors and pumps as well as designing systems to minimize the losses in the appliance.
- Provide training for buyers and installers to ensure optimum location and installation.
- Provide education to users, to ensure optimal use.

### 3.6.4 Conclusions

As with ACs, the use of evaporative air coolers expands massively reaching around 40% of households by the end of the period 2020-2050 causing commensurate increases in electricity demand and emissions. Unlike ACs, they do not need to use refrigerants, removing one source of emissions, and they can produce satisfactory cooling for households at a much-reduced cost, demand for electricity, and associated emissions compared to ACs.

However, EAC do have several drawbacks that may reduce the value of EACs for many consumers including:

- EACs are not suitable for use in all regions of the country.
- The service they provide can fluctuate over the year depending on conditions.
- They require more maintenance.
- Generate humidity inside households, which is not always desirable.

# 4 OVERVIEW AND PROJECTION OF ELECTRICITY DEMAND IN SUDAN

The cumulated electricity demand in the BAU scenario of the five studied sectors (Figure 39) amounts to 12.6 TWh in 2020. For the development under a business-as-usual scenario, the trend generally follows the projected ownership rates or installed capacity for street lighting. The highest shares are attributed to lighting and residential split air conditioners. Highest growth rates are exhibited by residential split ACs and evaporative coolers, at around 10% CAGR, the two applications bringing thermal comfort to living spaces.

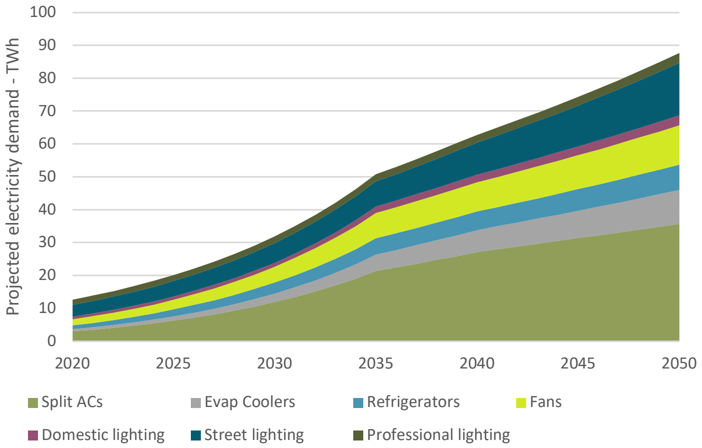



*Figure 39: Projected electricity demand in Sudan from the five studied sectors in the BAU scenario.*

Total Sudanese electricity demand for 2018 is reported as 17.3 TWh and for 2019 at 18.5 TWh. That shows that the studied sectors make up a considerable share of the total demand. The projected growth rates show the urgent need for ambitious energy efficiency policies to curb the steep growth rates and thus reduce the need for more generation capacity.

The calculated energy consumption translates to 3.8 Mt $CO_2$eq emissions at the current grid emission factor of 0.305 kg $CO_2$/kWh. At a constant grid emission factor, these emissions are projected to rise to 26.7 Mt $CO_2$eq in 2050 (Figure 41).

The mitigation scenarios developed for four of the five studied sectors can lead to an accumulated mitigation of 8 Gt $CO_2$eq until 2030 from the cumulated reduced energy consumption (27 TWh). The highest saving potential lies in the split and window type ACs, followed by the lighting sector. By implementing the proposed mitigation actions, the emission growth up to 2050 can be significantly lowered, with around half of the BAU emissions in 2050 (Figure 39). Further detailed numbers are provided in Table 35.

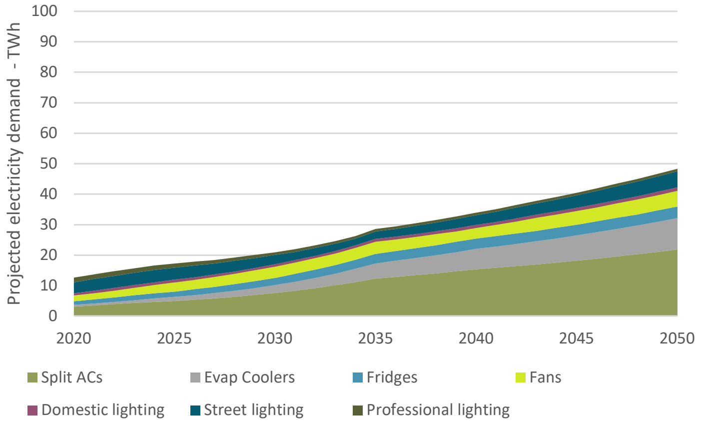



*Figure 40: Projected electricity demand in Sudan from the five studied sectors in the mitigation scenario.*

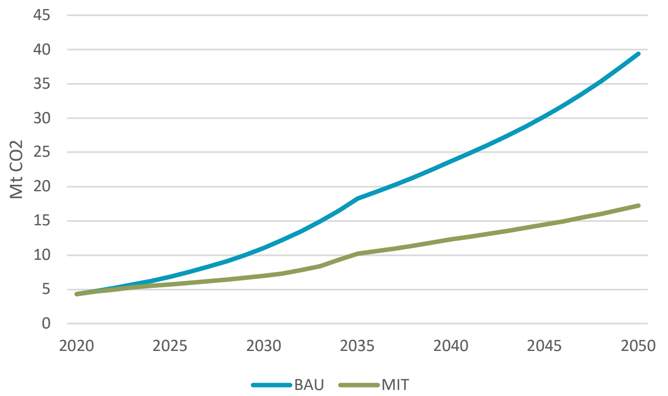



*Figure 41: Projected emissions from energy consumption of the five studied applications in Sudan for BAU and mitigation (MIT) scenario.*

*Table 35: Energy demand and resulting emissions for BAU and mitigation scenario for the five studied applications in Sudan and related savings*

| Business as usual Scenario | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Electricity demand (GWh) | | | | Emissions from Electricity use (Mt $CO_2$ eq) | | | |
| **Year** | **2020** | **2030** | **2040** | **2050** | **2020** | **2030** | **2040** | **2050** |
| **Split and window type ACs** | 3,055 | 11,920 | 27,102 | 35,681 | 932 | 3,636 | 8,266 | 10,883 |
| **Evaporative Coolers** | 594 | 2,568 | 6,712 | 10,309 | 181 | 783 | 2,047 | 3,144 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Refrigerators** | 1,205 | 3,387 | 5,638 | 7,708 | 368 | 1,033 | 1,720 | 2,351 |
| **Fans** | 1,843 | 4,780 | 8,924 | 11,994 | 562 | 1,458 | 2,722 | 3,658 |
| **Lighting** | 5,912 | 9,213 | 9,675 | 21,982 | 1,803 | 2,810 | 2,951 | 6,704 |
| **Total** | 12,609 | 31,868 | 58,051 | 87,674 | 3,846 | 9,720 | 17,706 | 26,740 |
| **Mitigation Scenario** | | | | | | | | |
| | **Electricity demand (GWh)** | | | | **Emissions from Electricity use (Mt $CO_2$ eq)** | | | |
| **Year** | **2020** | **2030** | **2040** | **2050** | **2020** | **2030** | **2040** | **2050** |
| **Split and window type ACs** | 3,055 | 7,614 | 15,328 | 21,856 | 932 | 2,322 | 4,675 | 6,666 |
| **Evaporative Coolers** | 594 | 2,568 | 6,712 | 10,309 | 181 | 783 | 2,047 | 3,144 |
| **Refrigerators** | 1,205 | 2,398 | 3,347 | 3,773 | 368 | 731 | 1,021 | 1,151 |
| **Fans** | 1,843 | 3,629 | 3,573 | 5,160 | 562 | 1,107 | 1,090 | 1,574 |
| **Lighting** | 5,912 | 4,717 | 4,453 | 7,279 | 1,803 | 1,439 | 1,358 | 2,220 |
| **Total** | 12,609 | 20,926 | 33,412 | 48,376 | 3,846 | 6,382 | 10,191 | 14,755 |
| **Savings** | | | | | | | | |
| | **Electricity demand (GWh)** | | | | **Emissions from Electricity use (Mt $CO_2$ eq)** | | | |
| **Year** | **2020** | **2030** | **2040** | **2050** | **2020** | **2030** | **2040** | **2050** |
| **Split and window type ACs** | 0 | 4,307 | 11,774 | 13,826 | 0 | 1,313 | 3,591 | 4,217 |
| **Evaporative Coolers** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Refrigerators** | 0 | 989 | 2,292 | 3,935 | 0 | 302 | 699 | 1,200 |
| **Fans** | 0 | 1,151 | 5,351 | 6,834 | 0 | 351 | 1,632 | 2,084 |
| **Lighting** | 0 | 4,496 | 5,222 | 14,703 | 0 | 1,371 | 1,593 | 4,484 |
| **Total** | 0 | 10,942 | 24,639 | 39,297 | 0 | 3,337 | 7,515 | 11,986 |
| **Cumulated Savings** | | | | | | | | |
| | **Electricity demand (GWh)** | | | | **Emissions from Electricity use (Mt $CO_2$ eq)** | | | |
| **Year** | **until** | **2030** | **2040** | **2050** | **until** | **2030** | **2040** | **2050** |
| **Split and window type ACs** | | 17,693 | 106,037 | 237,807 | | 5,396 | 32,341 | 72,531 |
| **Evaporative Coolers** | | 0 | 0 | 0 | | 0 | 0 | 0 |
| **Refrigerators** | | 4,136 | 21,934 | 53,288 | | 1,262 | 6,690 | 16,253 |
| **Fans** | | 2,959 | 40,185 | 100,654 | | 903 | 12,256 | 30,700 |
| **Lighting** | | 2,009 | 11,359 | 216,025 | | 613 | 3,464 | 65,888 |
| **Total** | | 26,798 | 179,515 | 607,774 | | 8,173 | 54,752 | 185,371 |

# 5 MINIMUM ENERGY PERFORMANCE STANDARD IN SUDAN FOR THE FIVE IN-SCOPE SECTORS

The growing demand for electricity has several implications, mainly:

- More frequent electricity shortages as production does not meet demand,
- New investments in electric power production plants,
- Increase in $CO_2$ emissions, contributing to global warming.

This demand could be reduced if energy is used more efficiently. One of the most useful tools to increase the level of energy efficiency of products on the market is through Minimum Energy Efficiency Standards (MEPS) and Energy Efficiency labels.

MEPS indicate the minimum level of efficiency of the products that can be introduced in the market, eliminating the most inefficient devices. On the other hand, the labels inform the consumer of savings opportunities in energy consumption and the environmental benefits by choosing more efficient products, increasing sales of the most efficient products, and preparing the market for the application of more restrictive MEPS in the future. Furthermore, in countries where electricity is totally, or partially, subside by the government, the energy efficiency improvement in consumer products will also produce governmental savings, which can be return to society with rebate programs to help consumers to buy more efficient appliances.

In order to fulfill the goal of driving the country to a more energy efficient market, MEPS and labels must be designed and implemented correctly. Furthermore, they must be reviewed and updated frequently to account with the technology improvements over time.

In Sudan, MEPS and Energy Efficiency labels are not yet in place but the country has started the legal framework to develop them. The Electricity Regulatory Authority (ERA) is the sole entity regarding issuance and execution of electrical energy efficiency. ERA had drafted a law for electricity which is now in the ratification process. This draft includes the only energy efficiency regulation in Sudan. This law will give ERA the authority to develop secondary regulation for MEPS and labels that will apply to the specific product groups (in cooperation with the Ministry of Finance and the Sudanese Standards and Metrology Organization (SSMO), who will act as a supervisory body).

## 5.1 Refrigerator

Typically, the energy efficiency of refrigerators is calculated by comparing the energy consumption measured in the laboratory under certain requirements, with the theoretical standard energy consumption based on the characteristics of the refrigerator being measured (volume, target temperatures, defrost type, etc.). Therefore, the country must define precisely which test standard should be used for the country, and how to calculate the standard energy consumption.

It is recommended to use the latest international test standard IEC 62552-1-2-3:2015+AMD1:2020 and the U4E (United for Efficiency) Model Regulation[26] metrics for the calculation of the standard energy consumption.

### 5.1.1 U4E metrics for the domestic refrigerators

Equation 1 shows the energy efficiency index calculation represented by R, which is defined as the standard energy consumption (AEC_Max) divided by the energy consumption in the laboratory (AEC) at the corresponding ambient reference temperature. An R=2 means that the energy consumption of the tested refrigerator is half of the standard energy consumption.

$$\mathbf{R} = (\boldsymbol{AEC\_Max})/\boldsymbol{AEC} \qquad \textbf{Equation 1}$$

The model regulation is based on the best international practices, and they have been developed by dozens of experts with the support from the industry. Furthermore, the regulations of other countries such as Rwanda, are expected to be based also on the U4E metrics. Further, we will provide a life cycle cost analysis, putting the higher upfront cost in perspective to the benefit of reduced electricity consumption during use.

The scope of the U4E Model Regulation includes all refrigerating appliances of the vapor compression type, with a rated volume at or above 10 Liters (l) and at or below 1,500 l, powered by electric mains and offered for sale or installed in any application.

It is recommended for Sudan to use an ambient reference temperature of 32ºC, even if it is a bit higher than the average indoor temperature, this difference will compensate the load processing energy consumption, which is not considered during laboratory tests. Other countries, such as US, Colombia, or Mexico, also use 32℃ as reference ambient temperature.

Table 36 shows the U4E equations to calculate $AEC_{Max}$ at the reference ambient temperature of 32℃. Three different equations are used depending on the type of refrigerator: Refrigerator, Refrigerator-Freezer, and Freezers. A more detailed information about the refrigerator classification in the U4E Model Regulation can be found in the Supporting[27] material of the regulation.

AV refers to the adjusted volume, which depend on the temperature of the different compartment ($T_C$) that form the refrigerator. AV can be calculated by Equation 2 as follows:

$$\textbf{Adjusted Volume (AV)} = \sum_{i=1}^{n} 〚(\boldsymbol{V_i} \times \boldsymbol{F_i} \times〛 \frac{\mathbf{32} - \boldsymbol{T_{Ci}}}{\mathbf{32} - \mathbf{4}}) \qquad \textbf{Equation 2}$$

Where the $V_i$ is the volume in liters of the $i_{th}$ compartment, $F_i$ is the compensation factor for automatic defrost in frozen compartments (which is equal to 1.1, or 1.0 for the other cases). And $T_{Ci}$ is the target

[26] U4E Model Regulation Guidelines for Energy-Efficient and Climate-Friendly Refrigerating Appliances. Download at Model Regulation Guidelines for Energy-Efficient and Climate-Friendly Refrigerating Appliances - United for Efficiency (united4efficiency.org)

[27] The Supporting material can be found in Model Regulation Guidelines for Energy-Efficient and Climate-Friendly Refrigerating Appliances - United for Efficiency (united4efficiency.org)

temperature of the $i_{th}$ compartment, which should be defined according to the test standard IEC 62552-1-2-3:2015+AMD1:2020.

*Table 36: $AEC_{Max}$ U4E equations for the three refrigerator categories at an ambient temperature of 32 ℃ (Source: U4E Model Regulation for Refrigerators)*

| Reference Temperature | Product Category | $AEC_{Max}$ (kWh/year) |
|---|---|---|
| **32°C** | Refrigerators | 0.220×AV+137 |
| | Refrigerator-Freezers | 0.288×AV+210 |
| | Freezers | 0.268×AV+247 |

Table 37 show the target temperatures depending on the compartment type.

*Table 37: Types of compartment and target temperatures according to IEC 62552-1-2-3:2015+AMD1:2020*

| Type of compartment | Target temperature (℃) |
|---|---|
| **Pantry** | +17℃ |
| **Wine storage** | +12℃ |
| **Cellar** | +12℃ |
| **Fresh food** | +4℃ |
| **Chill** | +2℃ |
| **0-star & ice-making** | 0℃ |
| **1-star** | -6℃ |
| **2-star** | -12℃ |
| **3-star** | -18℃ |
| **Freezer (4-star)** | -18℃ |

Figure 42 shows the U4E $AEC_{Max}$ at the reference ambient temperature of 32℃ as a function of the adjusted volume for the three different types of refrigerators (refrigerator, freezer only, and combination of fresh food and freezer). Hence the R-value for the shown (theoretical) appliances would be 1. One should notice that the U4E equations can also be used, if the definition of MEPS levels differs from the U4E model regulation. In this case, MEPS could be defined at a different R-value.

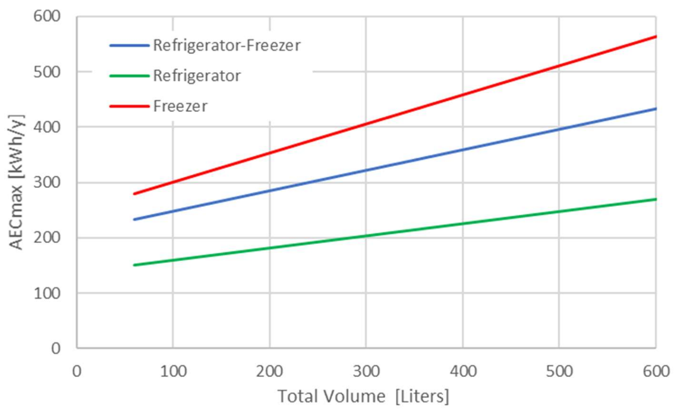



*Figure 42: Maximum Annual Energy Consumption ($AEC_{Max}$) defined in the U4E Model Regulation for the three different types of refrigerators.*

### 5.1.2 Test standard for the Annual Energy Consumption (AEC)

It is recommended to use the latest international test standard IEC 62552-1-2-3:2015+AMD1:2020, which is divided in three parts: 1) General requirements, 2) Performance requirements, and 3) Energy consumption and volume.

The new test standard leaves some open parameters that need to be specified locally by each country or region. Therefore, even if the international standard is adopted directly (no local adaptation), the country should specify those parameters to avoid ambiguities on the application of the standard. These parameters are discussed in the following subsections. The local specifications can be included in the MEPS and label regulation, or in the specific test protocol of the country. More information can be found in the DEL 3 report. Here a summarized is presented:

- Define the ambient reference temperature: Since this is 32ºC, only the test at 32ºC will be required
- It is recommended to exclude the load processing energy from the AEC in Sudan
- It is recommended to exclude the load processing energy from the AEC in Sudan
- For the auxiliary energy consumption of the ambient controlled anti-condensation heaters, Sudan shall elaborate a probability table of indoor temperatures and relative humidity. If difficult to elaborate for Sudan, it is recommended to copy it from other economies, for example from Australia, as it was done by China

The EN 62552-1-2-3:2020 is used in Europe as an equivalent to the IEC standard. The EN is based on the new IEC 62552-1-2-3:2015+AMD1:2020 with small local adaptations. The new EN entered into force in April 2021 with the new energy efficiency regulations.

### 5.1.3 MEPS and EE label levels

The U4E model regulation provides clear recommendations for MEPS and indicative categorization of refrigerators depending in the R-value (Table 38). This categorization is not a recommendation for label ranges, but to provide guidance on the efficiency levels of refrigerator models. Those recommendations are the basis for the proposed MEPS and labels for Sudan, taking into account the market research that was undertaken as part of this project.

*Table 38: Classification for refrigerating appliances (Source: U4E Model regulation for refrigerators).*

| Grade | Refrigerators | Refrigerators-Freezers | Freezers |
|---|---|---|---|
| **High Efficiency** | R>= 1.50 | R>= 1.50 | R>= 1.50 |
| **Intermediate** | 1.25 ≤ R < 1.50 | 1.25 ≤ R < 1.50 | 1.25 ≤ R < 1.50 |
| **Low Efficiency** | 1.00 ≤ R < 1.25 | 1.00 ≤ R < 1.25 | 1.00 ≤ R < 1.25 |

The frequency chart shows that 95% of the market are below the R=1, which is the recommended MEPS from U4E. Based on the frequency chart, we propose to set the MEPS to cut out the lowest 40% to 50% of the market, which corresponds to an R=0.63. This high percentage is justified with the very low efficiency prevailing in the Sudanese market. We further propose to allow for about two years between announcement of the regulation and the implementation to enable the market to prepare accordingly. As the energy efficiency level is low in Sudan, a strengthening of MEPS is proposed for 2027, where the U4E-recommended level of R=1 should be introduced.

From Figure 43, about 43% of refrigerators being sold in Sudan would be banned after the first implementation of the proposed MEPS in 2024. Based on the current market analysis, another 51% would be targeted with the strengthened MEPS in 2027. With the implementation of the MEPS and label scheme, a product data base should be introduced. The product database should contain technical parameters of all refrigerators put on the Sudanese market and related sales numbers. Such a database enables the authorities to monitor the progress of policy implementation and provides a sound data base for future MEPS strengthening.

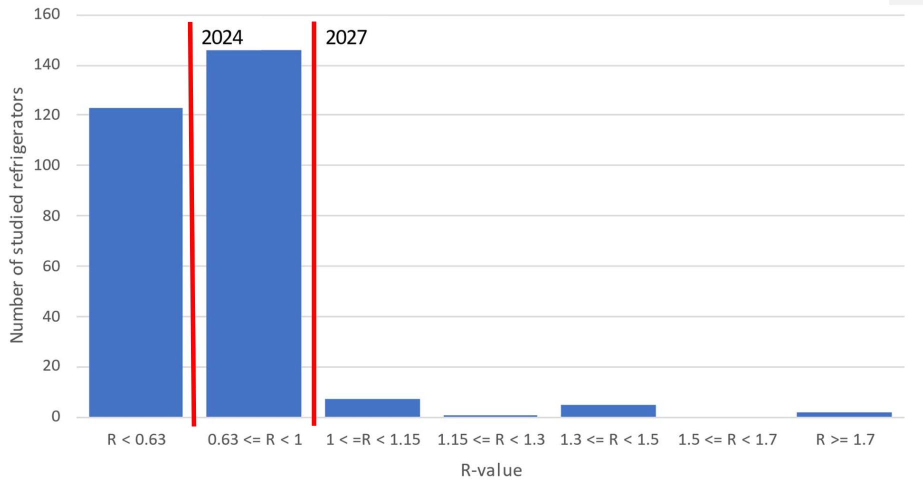



*Figure 43: Frequency distribution of energy efficiency of studied refrigerators (based on 32°C ambient temperature), the red lines and the years indicate the proposed MEPS.*

Due to the low electricity price in Sudan, the impact on the life cycle cost (LCC) is not very pronounced, but still visible, when plotting the LCC against the calculated R-values (Figure 44). In any case, no significant increase of LCC is to be expected with the implementation of the MEPS. Further, most studied models fall into the “low efficiency” category, providing a guiding effect to the market, especially, when top-runner models with efficiencies better than R = 1.5 would be promoted by granting tax rebates.

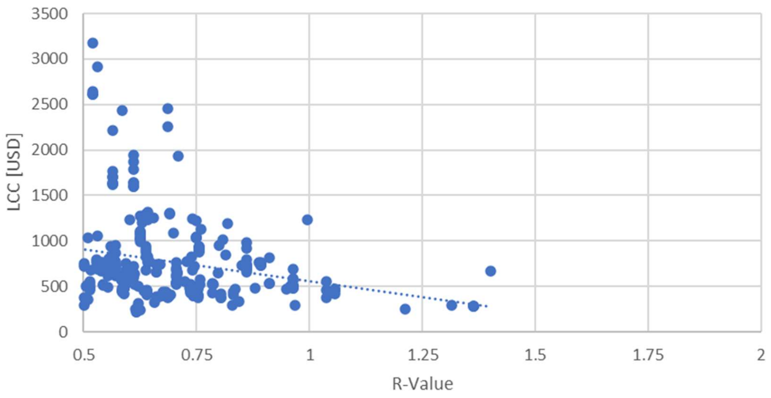



*Figure 44: Life cycle cost (LCC) against R-value (based on 32°C ambient temperature) for all 284 studied refrigerators models.*

The proposed label scheme contains seven categories and is shown in Table 39. With each strengthening of the MEPS one category is cut at the bottom. It is expected that the top two categories are almost empty at the moment of implementation and are meant to stimulate the market to provide more models that fall in this highly efficient category.

*Table 39: Proposed label scheme for refrigerators and freezers*

| Category | R-value | Date, when proposed MEPS cut out this category |
|---|---|---|
| **7** | R >= 1.7 | |
| **6** | 1.5 <= R < 1.7 | |
| **5** | 1. 3<= R < 1.5 | |
| **4** | 1.15 <= R < 1.3 | |
| **3** | 1.00 <= R < 1.15 | |
| **2** | 0.63 <= R < 1.00 | 2027 |
| **1 (MEPS)** | R < 0.63 | 2024 |

The proposed time schedule for implementation is designed to allow for adequate transition periods for the market to adjust to the MEPS and labels, but also ambitious enough to align with recommended MEPS levels within the next 5 years (Table 40).

Table 40: Proposed time schedule for refrigerator and freezer MEPS and label implementation

| Year | Action |
|---|---|
| 2021 | Discussion and design of MEPS and label regulation |
| 2022 | Finalization of Regulation<br>Awareness raising for upcoming label scheme and MEPS<br>Definition of responsibilities for product data base |
| 2023 | Market transition period.<br>Labelling mandatory starting July 2023<br>Pilot run of project database. |
| 2024 | First MEPS level enters into force, cutting out all models with R < 0.63<br>Product data base enters full operation |
| 2027 | Second MEPS level enters into force, cutting out all models with R < 1.00 |

Figure 45 compares the proposed MEPS for Sudan with other countries. The Sudan MEPS for 2024 are less stringent than the European MEPS (also the ones from 2014), while they are a bit more stringent than the Colombian and Chilean MEPS depending on the volume. The Chilean MEPS are from 2015, and they are being updated to more stringent ones. For 2027, it is proposed to implement the U4E MEPS recommendation, in line with the European Union for 2024. In this way, in 2027 the Sudan MEPS would be aligned with international best practices, but with more time to adapt.

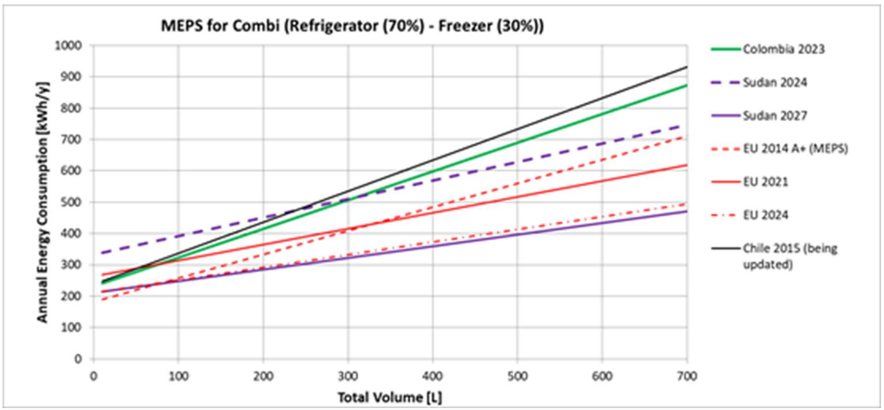



Figure 45: International MEPS comparison: Maximum energy consumption as a function of volume for the combi appliance (Refrigerator-Freezer).

Figure 46 compares the maximum energy consumption allowed by the proposed high efficiency level in the Sudan label and other countries. In this case, the highest efficiency level is less stringent than A and B classes in the new European label (2021), as they are considered too stringent to incentivize the Sudan market but is still more stringent than the old European A+++, which was adopt from 2011 to 2021.

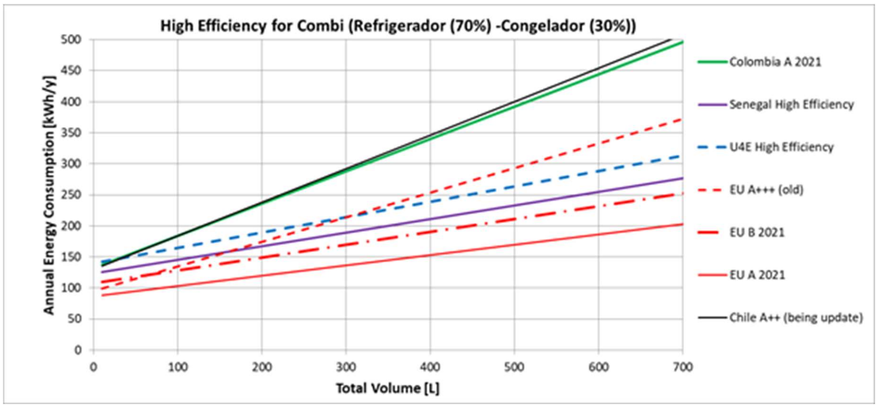



*Figure 46: International high energy efficiency class comparison: Maximum energy consumption as a function of volume for the combi appliance (Refrigerator-Freezer).*

The proposed implementation of MEPS is projected to result in considerable reduction of electricity consumption and thus emission reductions. The developments are illustrated in Figure 47 and Figure 48. Although no further MEPS strengthening after 2027 is included in the MEPS scenario, the reduction is still very pronounced in 2050. In 2030, 620 GWh (0.19 Mt $CO_2$eq) are reduced and in 2050, the reduction amounts to 3.0 TWh (0.91 Mt $CO_2$eq).

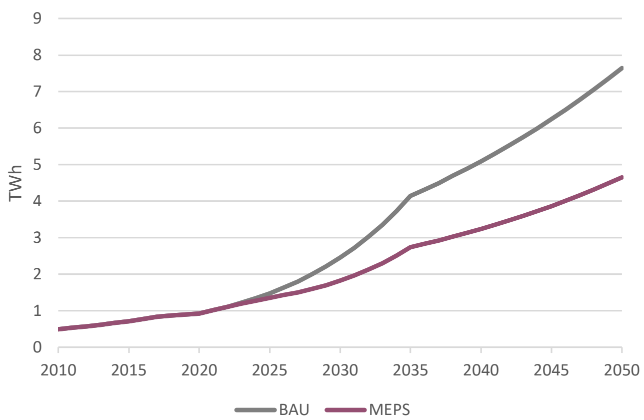



*Figure 47: Energy consumption of domestic refrigerators in BAU and MEPS scenario. (Source: HEAT Analysis)*

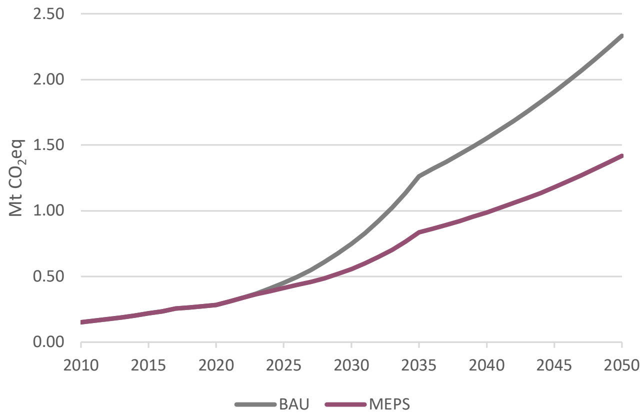



*Figure 48: Emissions from electricity use of refrigerators in BAU and MEPS scenario (Source: HEAT analysis)*

### 5.1.4 Refrigerant and foam blowing agent requirements.

Natural refrigerants are widely used in domestic refrigerators nowadays. Therefore, the following (Table 41) Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) over 100-year requirements can be applied for the refrigerant and foam blowing agent in domestic refrigeration:

*Table 41: Refrigerants' GWP and ODP requirement.*

| Product Class | GWP | ODP |
|---|---|---|
| **All types** | Below 10 | 0 |

These limits can be applied in the specific legislation for refrigerants, or directly in the MEPS and label standards to enter into force in the next revision. Nevertheless, if there are local manufacturers that still does not comply with these requirements, enough time should be given for the manufacturing line conversion. Supporting them on this transition will accelerate the process.

## 5.2 Air Conditioners

We recommend using the Seasonal Energy Efficiency Ratio (SEER), which considers variations in the ambient conditions, and is able to account with the benefits of variable speed compressors. The test standard ISO 16358-1:2013/Amd 1:2019, published in 2019 a method to calculate SEER (or Cooling Season Performance Factor (CSPF) as it is called in this standard) in hot weathers, which will provide a more realistic metric to measure the energy efficiency of air conditioners in extreme conditions.

### 5.2.1 Scope

The market survey showed that most of the AC's in Sudan are actually below 7 kW, hence, the 16 KW limit used in the U4E model regulation is a good capacity limit that will regulate most of the residential and light commercial AC's in the country.

The U4E Model Regulation includes in the scope all electrical single-phase non-ducted single-split, self-contained air-cooled air conditioners (also reversible units), and portable air conditioners, which represent most of the air conditioners below the 16 kW. Nevertheless, even though ducted and multi-split air conditioners might be a minority in the residential and light commercial application, we recommend to include them in the regulation to avoid loopholes, or to avoid developing a specific product regulation in the future.

### 5.2.2 Test standards and conditions

We recommend using the international test standard[28] ISO 16358-1:2013/Amd 1:2019 to calculate the Seasonal Energy Efficiency Ratio SEER (or the Cooling Seasonal Performance Factor "CSPF" as it is called in the ISO standard). This standard includes the methodology and the test conditions to calculate SEER, but it makes reference to other standards that includes the test procedures for testing the unit in the laboratory, which might depend on the type of air conditioner.

In this sense, the main test standard that should be considered are:

- ISO 16358:2013 (including ISO 16358-1:2013/AMD1:2019 for hot weathers): *Air-cooled air conditioners and air-to-air heat pumps — Testing and calculating methods for seasonal performance factors – Part 1 to 3.*
- ISO 5151:2017 *Non-ducted air conditioners and heat pumps — Testing and rating for performance.*
- ISO 13253:2017 *Ducted air-conditioners and air-to-air heat pumps — Testing and rating for performance.*
- ISO 15042:2017/AMD 1:2020 *Multiple split-system air conditioners and air-to-air heat pumps — Testing and rating for performance.*
- ISO 18326:2018, *Non-ducted portable air-cooled air conditioners and air-to-air heat pumps having a single exhaust duct – Testing and rating for performance.*

The ISO 16358-1:2013 includes a temperature frequency distribution, i.e., the number of hours that an air conditioner will work at a certain temperature, to calculate the SEER. Nevertheless, most countries use their own temperature distribution, which still can be used with ISO 16358-1:2013 to calculate SEER. Due to the high ambient temperatures reached in Sudan, it is recommended to use the high ambient temperature climatic zone 0B suggested in the U4E Model Regulation (see Table 42). See Deliverable 3 report for more information on the temperature climatic table. Another option would be to define a specific temperature bin hours distribution based on different climatic regions and considering the population of these regions.

We deem this climate group (0B) very fitting for the northern/desert area of Sudan. Although temperature do not reach those high values in the southern part of Sudan, we recommend only one climate group for MEPS and labelling that is oriented at the hottest temperature patterns. We also undertook some preliminary desk research, if split ACs usually sold in Sudan are recommended for use

[28] This standard contains three parts, one to calculate the efficiency for cooling (CSPF), another for heating (HSPF), and a third one for cooling and heating together (APF).

at or above 46°C to ensure that they can be tested for the 0B climate group. We found that most international split ACs are recommended for use until 46°C or higher, so testing at 46°C should not pose a problem.

There are 3 test points required for a variable speed air conditioner using the 0B climate zone, two at full capacity at an ambient temperature of 35℃ and 46℃, and another one at half capacity at 35℃.

Table 42: Temperature bin hours distribution for climate 0B (Group 2) for ACs in cooling mode.

| Outdoor temperature | 0B (Group 2) Extremely hot-dry |
|---|---|
| ℃ | Bin hours |
| **21** | 18 |
| **22** | 40 |
| **23** | 74 |
| **24** | 130 |
| **25** | 198 |
| **26** | 241 |
| **27** | 290 |
| **28** | 329 |
| **29** | 364 |
| **30** | 381 |
| **31** | 388 |
| **32** | 393 |
| **33** | 372 |
| **34** | 307 |
| **35** | 255 |
| **36** | 213 |
| **37** | 185 |
| **38** | 155 |
| **39** | 131 |
| **40** | 106 |
| **41** | 88 |
| **42** | 71 |
| **43** | 55 |
| **44** | 41 |
| **45** | 27 |
| **46** | 19 |
| **47** | 11 |
| **48** | 6 |
| **49** | 3 |
| **50** | 1 |
| **Total** | 4892 |

### 5.2.3 MEPS and EE label levels for Sudan

Hardly any of the split AC models studied during the market research carried labels indicating the seasonal energy efficiency rating. More common was an energy efficiency rating at standard rating conditions. Standard rating conditions are not explicitly stated and are assumed to be T1 (35°C outside, dry bulb temperature), as these are the most common conditions. However, for countries with very hot climate conditions, as Sudan, those rating conditions have limited meaning, as the working conditions can differ substantially from the rating (testing) conditions. To account for this issue, an additional test point was introduced at 46°C outside, dry bulb temperature in ISO 16358-1:2013/Amd 1:2019. We recommend making use of this addition.

The U4E Model Regulation gives recommendation for MEPS in the 0B climate zone, which depends also on the capacity of the system. As the U4E recommended MEPS is very high for the Sudanese market, we suggest taking those MEPS as a guidance for Sudan's regulation and allow adequate time periods for market transition. Suggested intermediate steps and a time frame will be proposed in the following section, based on the market research undertaken in Deliverable 2 of this project. For our analysis, we approximated the energy efficiency values of the models that are on the market in Sudan for the seasonal efficiency corresponding to climate group 0B.

As the Sudanese market mostly consists of models below 9.5 kW, we propose to have only one category for MEPS and labels up to 16 kW. The proposed MEPS levels are low enough to be achieved by any size. Once the market shows more differentiation and the MEPS levels are getting more ambitious, more categories could be introduced. However, several countries with high temperature conditions (e.g., Saudi Arabia and Qatar) also have only one capacity category for split ACs.

Figure 49 shows the suggested MEPS, starting with cutting out all models with an CSPF below 2.5 in 2024 and progressing to a MEPS level of 3.1 in 2026. As a 3rd level, a MEPS of 3.7 in 2028 is proposed. This 3rd level is very close to the MEPS recommended by the U4E model regulation. The market transition should be monitored using a product database containing all models approved to be put on the market in Sudan with technical parameters and import numbers. Based on this collected data, the future MEPS levels should be evaluated before they are implemented.

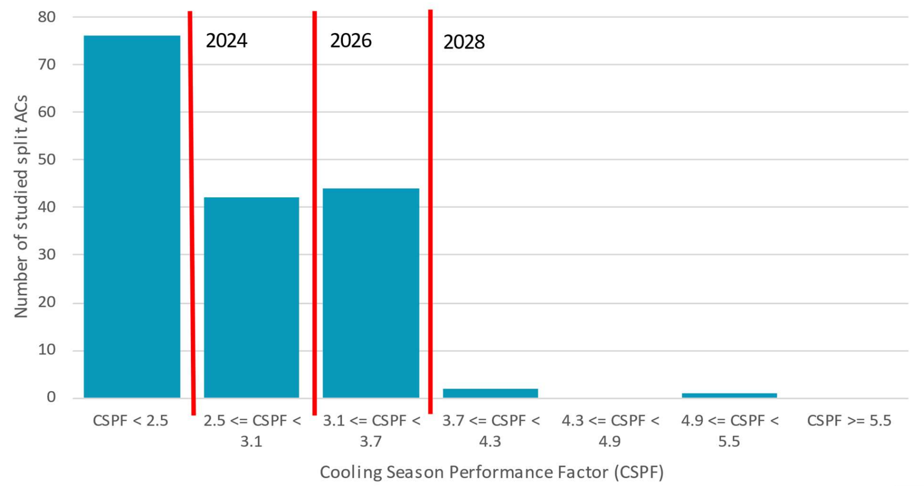



*Figure 49: Frequency distribution of energy efficiency of studied ACs (based on estimated CSPF for climate group 0B), the red lines and the years indicate the proposed MEPS.*

Due to the low electricity price in Sudan, the impact on the life cycle cost (LCC) is not very pronounced, but still visible, when plotting the LCC against the calculated CSPF values (Figure 50). In any case, no significant increase of LCC is to be expected with the implementation of the MEPS. Further, most studied models fall into the "low efficiency" category below a CSPF of 4, providing a guiding effect to the market, especially, when top-runner models with CSPFs higher than 5.6 would be promoted by granting tax rebates.

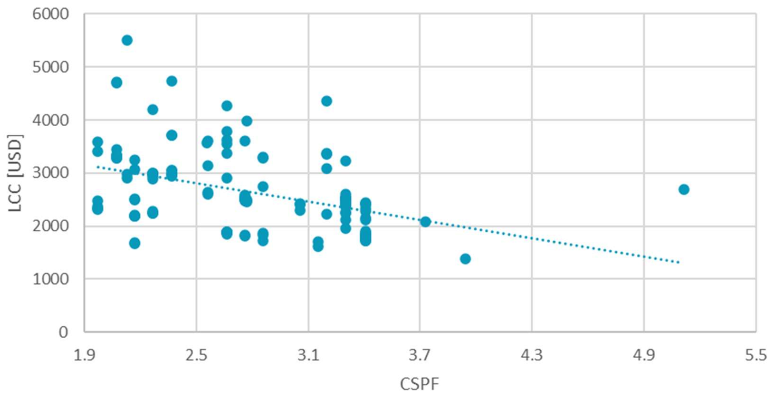



*Figure 50: Life cycle cost (LCC) against CSPF (estimated based on climate group 0B) for all 167 studied split AC models.*

The proposed label scheme contains seven categories and is shown in Table 43. With each strengthening of the MEPS one category is cut at the bottom. The top two categories are almost empty with the current market structure and are meant to stimulate the market to provide more models that fall in these highly efficient categories.

*Table 43: Proposed label scheme for split ACs (capacities up to 16 kW).*

| Category | CSPF-value (calculated for climate group 0B) | Date, when proposed MEPS cut out this category |
|---|---|---|
| 7 | CSPF >= 5.5 | |
| 6 | 4.9 <= CSPF < 5.5 | |
| 5 | 4.3 <= CSPF < 4.9 | |
| 4 | 3.7 <= CSPF < 4.3 | |
| 3 | 3.1 <= CSPF < 3.7 | 2028 |
| 2 | 2.5 <= CSPF < 3.1 | 2026 |
| 1 | CSPF < 2.5 | 2024 |

The proposed time schedule for implementation is designed to allow for adequate transition periods for the market to adjust to the MEPS and labels, but also ambitious enough to align with recommended MEPS levels within the next 5 years (Table 44).

Table 44: Proposed time schedule for ACs MEPS and label implementation.

| Year | Action |
|---|---|
| **2021** | Discussion and design of MEPS and label regulation |
| **2022** | Finalization of Regulation<br>Awareness raising for upcoming label scheme and MEPS<br>Definition of responsibilities for product data base |
| **2023** | Market transition period.<br>Labelling mandatory starting July 2023<br>Pilot run of project database. |
| **2024** | First MEPS level enters into force, cutting out all models with CSPF < 2.5<br>Product data base enters full operation |
| **2026** | Second MEPS level enters into force, cutting out all models with CSPF < 3.1 |
| **2028** | Third MEPS level enters into force, cutting out all models with CSPF < 3.7 |

Figure 51 compares the proposed MEPS for Sudan with the recommended MEPS in the U4E Model Regulations for a 0B climate and the European MEPS in 2014 and the proposed ones for 2023 (final regulation still not published). The European MEPS has been adjusted in order to be comparable with a 0B climate. Note that MEPS in Sudan will be in line with the U4E recommended MEPS for capacities up to 4.5 kW, which is more stringent than the MEPS implemented in Europe in 2014, but less stringent than the new MEPS in Europe.

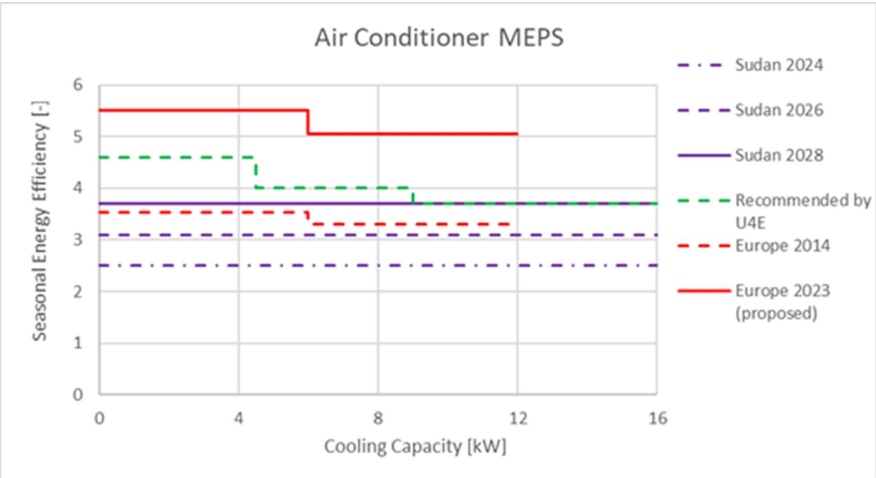



*Figure 51: comparison of some international MEPS.*

The proposed implementation of MEPS is projected to result in considerable reduction of electricity consumption, and thus emission reductions. The developments are illustrated in Figure 52 and Figure 53. Although no further MEPS strengthening is included after 2028 in the MEPS scenario, the reduction is still very pronounced in 2050. In 2030, 3.8 TWh (1.17 Mt $CO_2$eq) are reduced and in 2050, the reduction amounts to 11.6 TWh (3.5 Mt $CO_2$eq).

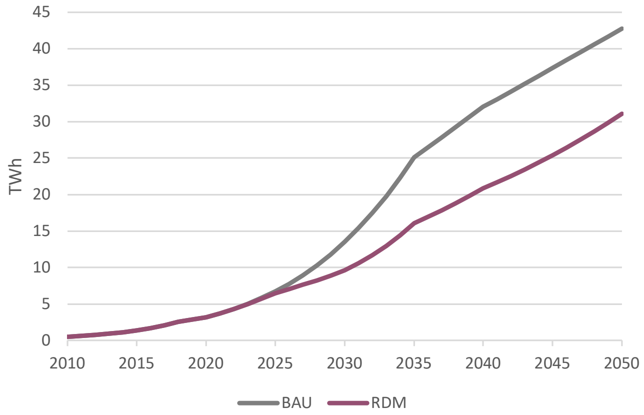



*Figure 52: Projected energy consumption of split ACs in BAU and MEPS scenario. (Source: HEAT Analysis)*

**Comentado [A1]:** Add a table

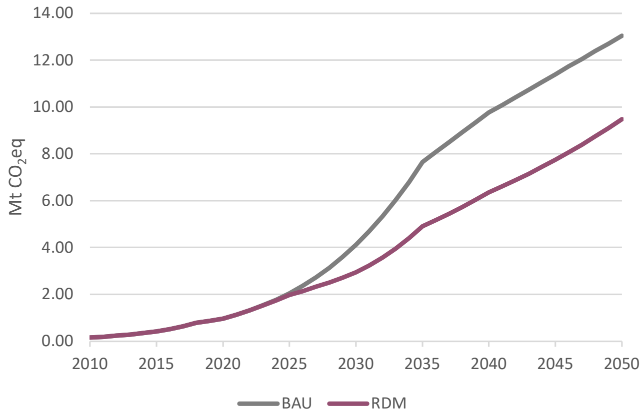



*Figure 53: Projected emission from electricity use of spit ACs in BAU and MEPS scenario (Source: HEAT analysis).*

**Comentado [A2]:** Add a table

### 5.2.4 Refrigerant requirements

The air conditioning industry is transitioning to low-GWP refrigerants. While the portable air conditioners commonly use Natural refrigerants (e.g., in Europe), split air conditioners with natural refrigerants are still rare in the market (although a grow is expected in the coming years). Therefore, it cannot be used the same requirements as in the domestic refrigerators. As for the U4E Model Regulation for air conditioners, a feasible Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) over 100-year requirements that can be applied for the refrigerant in air conditioners are shown in Table 45 below.

*Table 45: Refrigerants GWP and ODP requirements for ACs.*

| Product Class | GWP | ODP |
|---|---|---|
| **Self-contained system** | Below 150 | 0 |
| **Split system** | Below 750 | 0 |

These limits can be applied in the specific legislation for refrigerants, or directly in the MEPS and label standards to enter into force in the next revision. Nevertheless, if there are local/regional manufacturers that still does not comply with these requirements, enough time should be given for the manufacturing line conversion. Supporting them on this transition will accelerate the process.

Furthermore, since the 750 GWP limit is expected to be a transitory requirement (at least for capacities below 7 kW) until more experience is gained with natural refrigerants, if support is given to the local manufacturers to change their production lines, it is recommended to prepare the factory to work with natural refrigerants.

## 5.3 Evaporative AIR Coolers (EAC)

International experience with MEPS for EACs is limited to a few regions that have the heat and humidity climate conditions needed for optimum operation, such as Australia, Arizona, California, and Iran. To date, there are no MEPS for EACs anywhere in the World although Iran has implemented labels and the feasibility of MEPS implementation has been researched in Australia and the US.

### 5.3.1 Scope

Evaporative coolers are a simple technology based on pushing air through a wet surface to cause evaporation that cools and humidifies the air. EACs usually consist of a fan to push the air, wetting surfaces or pads, and a pump to push water into the wetting pads.

There are two key types of evaporative coolers:

1. Direct – The air is simply run through a wet pad for cooling and then directly circulated into the space that is meant to be cooled.
2. Indirect – After the air is cooled through the wet pad, the resulting cooling is transferred to a secondary air stream through a heat exchanger resulting in cooling air without the humidity.

There are no regulations worldwide that mandate energy performance for EACs, although two jurisdictions have provisions for energy efficiency labels: Iran and California. Also, there are standards to assess the quality of EACs performance in several areas:

- Australian/New Zealand – the AS/NZS 2913-2000 Standard for Evaporative Air-Conditioning Equipment specified testing procedure for air flow, evaporation efficiency, sound power measurements, and electrical consumption. The standard does not, however, corelate these measurements to determine the energy efficiency of units.
- United States – the ANSI/ASHRAE 133-2008: Method for testing Direct Evaporative Air Coolers standard establishes a uniform test method for rating the saturation effectiveness, airflow rate and total power of packaged and component direct evaporative air coolers.

While there is very little information about the market of EACs in Sudan, the collected data is indicative of direct systems with capacities of around 9,000 $m^3$ per hour or less, suitable for residential purposes.

### 5.3.2 Test Standards and conditions for EACs

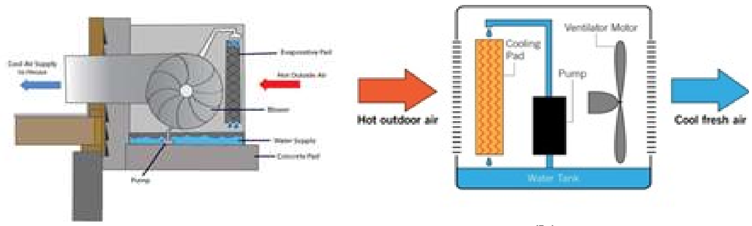
Because direct evaporative coolers convert sensible heat into latent heat, their performance is best measured by the net amount of sensible heat converted per hour. That is logically done by measuring the gross Btu/h or kJ/h of sensible heat converted by the wetting material and subtracting the Btu/h or kJ/h of sensible heat regained from fans, motors, pumps and other sources, including solar heat.

This standard establishes a uniform method of laboratory testing for rating packaged and component Evaporative Air Coolers (EAC). The scope of this standard covers a method of testing for rating the saturation effectiveness, airflow rate, and total power consumption of packaged and component direct evaporative air coolers.

### 5.3.3 Direct evaporative air cooler

A self-contained unit including a fan and fan motor whose primary functions are:

- The conversion of sensible heat of unsaturated air passing through the cabinet to latent heat by the process of evaporating water directly exposed to this air, and
- the movement of this air through the unit. Examples of a direct evaporative air coolers are shown in Figure 54. Figure 54(a) the EAC has three sides holding the cooling pads and the fourth side is dedicated to deliver the cooled air inside the space. The fan in this configuration is a centrifugal type driven by an electric motor and a belt. Whereas, Figure 54(b) is similar to Figure 54(a), but sometimes it has only one side for the cooling pads and the cooled air is delivered, here, by a direct-drive axial flow fan.




(a) (b)

*Figure 54: Evaporative Air Coolers: (a) Centrifugal Fan (b) Axial Flow Fan.*

### 5.3.4 Test method

The cooling efficiency test (or evaporation efficiency) is calculated from the following equation:

$$\eta = (t_{di} - t)_{do}/(t_{di} - t_{wi}) \qquad \textbf{Equation 4}$$

Where:

$t_{di}$ is the air dry-bulb temperature at the inlet,

$t_{do}$ is the air dry-bulb temperature at the outlet,

$t_{wi}$ is the air wet-bulb temperature at the inlet.

Power consumption test: Measure the power consumption of the EAC to determine EAC efficiency. The test shall be measured when the EAC is operated at free delivery conditions.

### 5.3.5 Test Standards

A test standard procedure is developed and recommended to be used for testing the performance of an EAC. This is based on ASHRAE 133-2015 "*Method of Test for Rating direct Evaporative Coolers" and the Iranian National Standard No. 4911 "Water cooler – test method*"[29]. The Energy Efficiency Ratio (EER) will be used for testing the performance and rating of the EAC.

The testing facility shall be equipped to create the Sudan's outdoor ambient design conditions. However, the cooling capacity, of an EAC under testing, can also be tested and determined according to nominal conditions similar to what are prescribed by the California Code and the Australia standards. The California Energy Commission and Australia rating temperatures are shown in Table 46 below.

*Table 46: Comparison of Rating Temperatures (°C) for evaporative Air Coolers.*

| | Evaporative, Australian Standards | Evaporative, California Code |
|---|---|---|
| **Outdoor dry bulb temperature** | 38 | 32.8 |
| **Outdoor wet bulb temperature** | 21 | 20.6 |
| **Indoor dry bulb temperature** | 27.4 | 26.7 |

The conditions of the Australian evaporative standards, shown in Table 46 above, are the recommended conditions. This includes the methodology and the test conditions to calculate the EER.

$$\boldsymbol{EER = q_s/P_{in} = \rho.C_{p}.Q\ (T_r - T_{in})/P_{in}} \qquad \textbf{\textit{Equation 5}}$$

Where:

*EER*: The energy efficiency ratio (Wh/Wh)

$q_s$: is the cooling capacity (kW)

$\rho$: density of standard air (1.20 kg/m$^3$ for standard air)

$c_p$: specific heat of moist air at constant pressure (1.024 kJ/kg °C, based on a humidity ratio of 10 g/kg)

$Q$: air volume flow rate corrected to standard temperature and pressure flow rate (m$^3$/s)

$T_{in}$: dry bulb temperature of air delivered by the EAC (°C)

$T_r$: exhaust air temperature from the conditioned space (assumed to be 27 °C)

[29] The ASHRAE is a testing procedure method. It is a uniform method of laboratory testing for rating direct EAC and the Iranian standard goes further to compute EER and suggest MEPS and Labels.

$P_{in}$: input power (kW)

Therefore, if the air delivered by the EAC is at a temperature equal or greater than the air being exhausted from the space, then the EAC is ineffective. Consequently, cooling is only achieved when *S* has a positive value.

### 5.3.6 MEPS and Labels

From the limited experience with EACs, the key efficiency measure proposed is the EER (Energy Efficiency Ratio - a direct relationship between the estimated cooling output and the energy input) used in Iran and Australia, and ECER (Evaporative Cooler Efficiency Ratio) which is similar to the EER but with different metrics. The **EER measure is recommended** for use in Sudan to ensure that it aligns with other forms of cooling. The existing labelling levels in Iran provide for seven possible ratings with a similar approach and color scheme to the European Union's energy efficiency labels.

The performance levels for a label process need to be assessed for each country to consider the current state of the market, the ability to improve, and account for local climate conditions. This is specially the case for EACs as the local temperature and humidity difference between indoor and outdoor air is essential for the optimum performance of the appliance. Assessing the EER requires to assess the cooling capacity of the device against their energy consumption based on the following equation:

$$\boldsymbol{EER = q\_s/P\_t} \qquad \textbf{Equation 6}$$

Where:

$q\_s$ is the cooling capacity in kW.

$P\_t$ is the power consumption of the appliance in kW.

All the information needed to complete the calculation is provided by direct measurements or are physical constants except for the cooling capacity which is estimated as follows:

$$\boldsymbol{q\_s = Q.\rho.C\_p.(t\_di - t\_do)} \qquad \textbf{Equation 7}$$

Where:

$Q$ is the air flow in cubic meters.

$\rho$ is the air density in kg per square meter.

$C\_p$ is specific heat of air in kilojoules per degree kelvin per kilogram.

$t\_do$ is the dry-bulb temperature of output air in degree Celsius.

$t\_di$ is the dry-bulb temperature of input air in degree Celsius.

Determining the MEPS and labels classes requires an assessment of the existing units in the market with a view to ensure that the worst performers are banned, and the best performers are placed in the second or third category to allow room for the market to deliver greater energy efficiency. At the same time, it will be necessary to meet with EAC manufacturers in Sudan to determine their ability to meet the requirements and to manufacture more efficient units in the future.

Table 47 below illustrate the categories breakdown of the EAC energy efficiency categories design for Iran, with equal intervals between categories. We recommend adopting a similar MEPS and labelling levels for Sudan.

*Table 47: Recommended MEPS (row G) and labelling levels for Sudan.*

| EER | Category |
|---|---|
| >65 | A |
| Between 58.5 and 65 | B |
| Between 52 and 58.5 | C |
| Between 45.5 and 52 | D |
| Between 39 and 45.5 | E |
| Between 32.5 and 39 | F |
| Between 26 and 32.5 | G |

Sudan should begin with an assessment of the EER for all units in the market and develop a breakdown of the EERs. Based on the proposed Sudanese design for the energy label, it is proposed that a 5-tier scheme should be developed to match the labels with the following guidelines:

- Tiers to have equal intervals between them.
- The top category or two should remain empty to allow market development in this area.
- MEPS are designed to ban the worst performers EACs.

## 5.4 Lighting sector

The function of an artificial light source is to produce artificial visible light. Different technologies exist to produce light. Today artificial sources are using electricity as the input energy. The main technologies that are still existing on the market in Sudan are incandescent lamps, discharge lamps and LED lamps or modules. We will briefly describe the physics of those three technologies, then we present the main characteristics of products now on the Sudanese market (according to the market assessment discussed in deliverable 2) and what could be expected.

### 5.4.1 Incandescent technology

Incandescent lamps were invented during the 19$^{th}$ century. The principle is to heat a material using the current flowing through to the point when it produces light. Incandescent lamps were popularized by Thomas Edison thanks to the General Electric Company founded in 1890.

Today, incandescent lamps use tungsten as the heated material and are filled with inert gas to prevent oxidation. Figure 55 shows the lamp's structure.

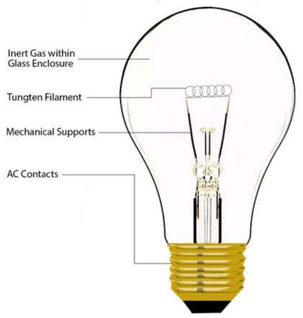



*Figure 55: structure of a filament lamp*

The emission of light by the tungsten filament, as shown in Figure 56, is similar to the emission of a black body. A black body is a body that is emitting a well determinate spectrum of light depending on the temperature at which it is heated.

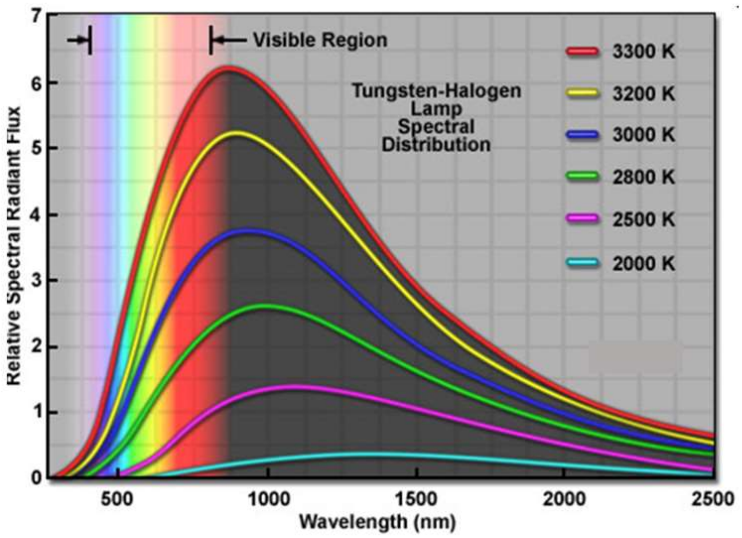



Figure 56: Emission spectrum of a tungsten filament

Human eye is sensible to radiations with wavelength between 380 and 780 nm. About 5 % of all the radiation emitted by the tungsten filament when heated is visible to human being. All the power dissipated to emit light that is not visible is lost.

### 5.4.2 Discharge technology

Discharge lamps are in fact plasma lamps. Plasma is an ionized gas in which electrons, atoms, ions, and photons are moving freely. Plasma is emitting light coming from the deexcitation of ions. As the example illustrated in Figure 57, when mercury atoms are exited due to the collision with an electron, its inner electron is transitioning from the lowest state ($E_1$) of energy to the upper state ($E_2$). To come back to its stable state, when the electron is at the lowest state of energy, energy is released as the emission of a photon.

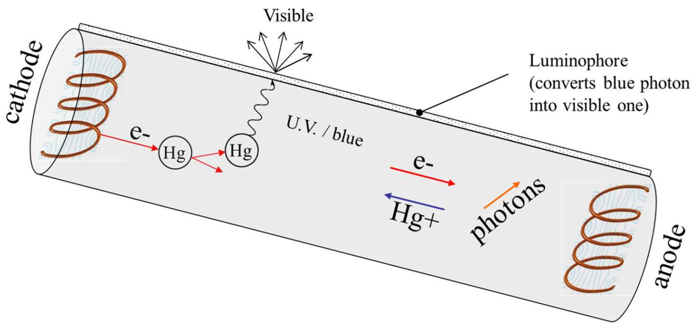
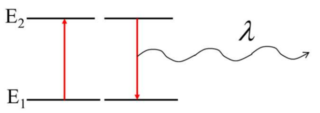



*Figure 57: principle of a fluorescent tube*

*Wavelength of the photon (λ) is determined by the difference in energy of the two energy levels (Figure 58). Indeed, h and c are the constants defined before. That wavelength is in the blue/UV region of the visible spectrum.*




$$E_2 - E_1 = hc / \lambda$$
$$\lambda = \frac{hc}{\Delta E}$$

*Figure 58: photon emission*

The ability of a plasma discharge lamps to convert electric power into radiative power is about 30 %.

### 5.4.3 LED technology

A LED is a Light Emitting Diode. Diodes are a well know and extensively used semiconductor. Figure 59 explains the phenomenon. When two materials, one with an excess of electrons (negatively charged, n-type) and the other with a deficit of electrons (positively charged, p-type) are stuck together, the positive and negative charges combine at the interface of the material, creating a non-charged zone ($W_D$). When this zone is large enough, combinations cannot occur anymore due to the high amount of energy to pass through that zone (a). Current is not passing through the diode.

When a certain voltage is applied to the diode, the energy barrier is lowered, and combination can occur again. When combination between charges occur, the energy is released as a photon in the blue region for LED (λ = hv). This photon is converted into visible light thanks to a luminophore (b).

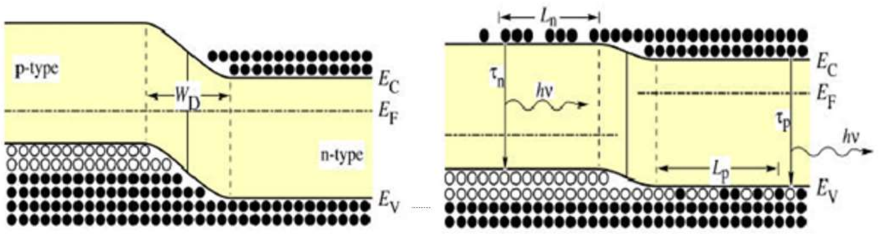


*Figure 59: Light Emitting Diode principle (a) current is not passing (b) current is passing and diode emits light.*

A LED chip is converting about 45 % of the electrical power into radiant flux.

### 5.4.4 Products under scope

It is important for the manufacturers and the authority to clearly define the products that should follow the standards. The electric sources that will be regulated by the proposed MEPS are detailed in the following sections.

According to the market assessment, products on the market are shown in Table 48 for the residential sector and in Table 49 for street lighting sector.

**For the residential sector:**

*Table 48: key characteristics of light sources for the domestic sector in Sudan.*

| | Incandescent lamp | CFL | Linear fluorescent | LED bulb | LED tube |
|---|---|---|---|---|---|
| **Price (USD)** | $ 0.38 | $ 1 | $ 0.7 | $ 1.7 | $ 4 |
| **Efficacy (lm/W)** | 12 lm/W | 50 lm/W | 70 lm/W | 90 lm/W | 90 lm/W |
| **Lifetime (hours)L70B50** | 1,000 h | 5,000 h | 5,000 h | 15,000 h | 20,000 h |
| **Color Temperature (Kelvin)** | 4,000 K | 6,500 K | 6,500 K | 2,700 K to 6,500 K | 3,000 K to 6 500 K |
| **Color Rendering Index** | 100 | 80 | 70 | 80 | 80 |
| **Average wattage (Watt)** | 60 W | 15 W | 18 W/36 W | 15 W | 9 W/18 W |

**For the street lighting sector:**

*Table 49: key characteristics of light sources for the street lighting sector in Sudan.*

| | HID – Mercury Vapor | HID – Metal Halide | HID – High Pressure Sodium |
|---|---|---|---|
| **Price (USD)** | $ 2.70 | $ 10.5 | $ 8 |
| **Efficacy (lm/W)** | 55 lm/W | 100 lm/W | 120 lm/W |
| **Lifetime (hours) L70B70** | 15 000 h | 25 000 h | 30 000 h |
| **Color Temperature (Kelvin)** | 3 500 K | 4 700 K | 2 100 K |
| **Color Rendering Index** | 65 | 69 | 25 |
| **Average wattage (Watt)** | 125 W/250 W | 400 W/250 W | 400 W/250 W |

The market assessment for lamps shows that incandescent lamps are more than 4 times less efficient than Compact Fluorescent lamps, and more than 7 times less efficient than LED lamps. In the following sections, incandescent lamps will not be considered as we will recommend a ban.

### 5.4.5 For domestic and tertiary sector

The list of regulated products below, is based on the U4E model regulation guidelines:

- "Energy Efficiency and Functional Performance Requirements for General Service Lamps", February 2021
- "Energy Efficiency and Functional Performance Requirements for Linear Lighting", February 2021

#### 5.4.5.1 *General Service Lamps (non-directional bulbs used in households), incandescent lamps, Compact Fluorescent Lamps or LED lamps*

Those general service lamps have:

1. one or more input voltages of alternating current between 50 and 300 V and frequency of 50 Hz or 60 Hz, and
2. a lamp base which can be connected to one of the following general service lamp sockets:
    - screw base types: E10, E11, E12, E14, E17, E26 or E27, or
    - bayonet base types: B15d or B22d, or
    - pin base types: GU10 or GZ10 base, or
    - alternative base types which can be connected to the above lamp base sockets by using commercially available passive adaptors.

#### 5.4.5.2 *Linear lamps like fluorescent tubes or LED tubes*

1. Linear fluorescent luminaire systems and their LED replacements,
2. Double capped linear fluorescent lamps (LFL) in three categories in line with commonly available types, T12, T8 and T5,
3. Double capped linear LED lamps of all sizes.

#### 5.4.5.3 *For street lighting and tertiary sector*

The list of products below is based on the European Commission regulation n° 2019/2020 laying down eco-design requirements for light sources and separate control gears of 1 October 2019.

1. **High Intensity Discharge (HID)** means an electric gas-discharge in which the light produced by the arc is stabilized by wall temperature and the arc chamber has a bulb wall loading in excess of 3 watts per square centimeter. It operates at pressure of few bars compared to low pressure discharges like fluorescent tubes. HID light sources are limited to mercury vapor, metal halide, high-pressure sodium types.
2. LED luminaires

### 5.4.6 Test standards and conditions

Regulations offer a highly cost-effective policy option for removing inefficient lighting technologies from a market and, when applied in conjunction with supporting policies, they encourage manufacturers to improve product efficiency. Regulations[30]:

- Provide a high degree of certainty for delivering energy savings,
- Minimize impact on governmental fiscal influence, such as subsidies,
- Encourage manufacturers to invest in R&D and create new, more efficient lamps,
- Can be adjusted periodically as lamps improve or new lamps become available,
- Can be designed to maximize consumer benefits with very low per unit transaction costs,
- MEPS must be ambitious while being realistic and applicable.

MEPS should include energy performance criteria to save energy but also quality performance criteria to ensure that the most efficient products will last longer and be accepted by consumers like the luminous efficacy of a light source but also other criteria like lifetime or quality of light.

Minimum criteria that are suggested for Sudan based on the market assessment learnings are summarized in the Table 50.

*Table 50: selected MEPS criteria for Sudan.*

| Energy efficiency | Durability |
|---|---|
| **1. Minimum efficiency level**<br>**2. Maximum Standby Power** | 3. Minimum Luminous Flux Maintenance<br>4. Maximum Early Failure Rate (maximum) |
| **Quality of light** | **Electrical parameters** |
| **5. Color Rendering Index (CRI)**<br>**6. Correlated Color Temperature (CCT)** | 7. Minimum Fundamental Power Factor also called displacement power factor |

### 5.4.7 Relevant parameters

1. **Minimum efficacy level or luminous efficacy**

Measure the ability of an electrical light source ability to convert electrical power (unit: Watt) into visible light in terms of visible flux (unit: lumen). Efficacy level is the ratio between the input power and the output light of a lamp or luminaire in lumen par Watt (lm/W). For the same amount of light needed, selecting the more efficient light source means less electrical power needed.

2. **Maximum standby power**

Relevant if the luminaire has a standby power (i.e., embedded detector or connected device). For an example, a luminaire with presence detector can save lot of energy due to its functionality but the sensor is still consuming energy when light is not needed to be able to detect movements.

3. **Lifetime**

[30] Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING / U4E POLICY GUIDE SERIES; https://united4efficiency.org

The capacity of a light source to convert electrical energy into luminous flux is decreasing with time of use. Lifetime of a light source is the time when a given percentage of the sources (factor B) have dropped to a given luminous flux. The luminous flux maintenance factor is given for a certain time and is the percentage of flux remaining compared to the initial flux. The luminous flux maintenance factor is quoted L. For example, a lifetime $L_{70}B_{50}$ equal to 50,000 hours means that at 50,000 hours, half of the source (50 %) have their flux equal to 70 % of their initial flux, the other 50 % having higher flux.

4. **Early failure rate**

Early failure rate is a percentage of the light source that fails long before their claimed lifetime. That rate is typically given for time of operation of 3,000 hours for LED in the new European regulation[31] (called survival factor)

5. **Color Rendering index (CRI)**

CRI is a measure of the ability of a light source to accurately reveal the colors of various objects in comparison with an ideal or natural light source. Its value ranges from 0 (no color) to 100 (corresponding to natural color).

6. **Correlated Color Temperature (CCT)**

CCT is a measure of the aspect of the white hues of the light emitted by the light source. It is measured in Kelvin. Lamps with a high CCT, i.e., 5, 000 Kelvin produce blueish-white light, whereas those with a CCT of 2,700 Kelvin produce light that is more yellowish white.

7. **Fundamental Power Factor**

It quantifies the displacement (phase-shift) between the fundamental current and voltage waveforms by calculating the cosines of the phase-shift angle. Power factor is the ratio of the active power flowing to the load over the apparent power of the circuit. Apparent power should be as close as possible to the active power to minimize negative effects on the network.

### 5.4.8 Norms and surveillance testing

The Table 51 below is listing the phenomena to be checked, the corresponding measurement standards, and the surveillance testing procedure for government.

*Table 51: List of phenomena to check and corresponding surveillance testing.*

| Phenomena | Measurement standards | Surveillance testing (for government) |
|---|---|---|
| **1.Luminous efficacy** | Measured luminous flux/measured power | From a sample of 11 units, 10 are selected randomly. The calculated luminous efficacy of each of the 10 units shall not be less than the required level with only one out of 10 allowed under the baseline by up to 5%. If one lamp fails catastrophically it is replaced with the reserve, if another fails then the product is non-compliant. |
| **Luminous flux (lm)** | CIE S 025 "Test Method for LED Lamps, LED Luminaires and LED Modules" | Sample of 10 units. The arithmetical mean of the measured luminous flux of the 10 units shall not be less than 90% of the rated luminous flux. |

[31] COMMISSION REGULATION (EU) 2019/2020 LAYING DOWN ECO-DESIGN REQUIREMENTS FOR LIGHT SOURCES AND SEPARATE CONTROL GEARS.

| | | |
|---|---|---|
| | CIE 84 “The measurement of luminous flux” | |
| **Power (Watt)** | IEC 62612 “Self-ballasted LED lamps for general lighting services with supply voltages > 50 V - Performance requirements”<br>IEC 600969 “Self-ballasted compact fluorescent lamps for general lighting services - Performance requirements”<br>IEC 60081 “Double-capped fluorescent lamps - Performance specifications” | Sample of 10 units. The arithmetical mean of the measured power of the 10 units shall not exceed 110% of the rated power, and the measured power of each individual lamp of the sample shall not exceed 115% of the rated power. |
| **2. Standby power** | IEC 63103 “Lighting equipment - Non-active mode power measurement” | Sample of 10 units. The arithmetical mean of the measured standby power of the 10 units shall not exceed the required level by more than 100 mW. |
| **3. Lifetime Claim** | L70F50 definition of IEC 62612<br>IEC 60969 for CFL<br>IEC 60081 for fluorescent tubes | Suppliers must provide evidence (of a scientific or experimental nature) to the government regulator that substantiates the lifetime claim. Lifetime claim shall not exceed the value demonstrated by the evidence. |
| **4. Early failure rate (for LED light sources only)** | see test below | Sample of 10 units. After 1200 cycles of 150 minutes ON and 30 minutes OFF, at least nine lamps shall still be operational and the arithmetical mean of the luminous flux of the remaining units shall be at least 90% of initial luminous flux (lumen maintenance). |
| **5. Color Rendering index** | CIE S 025 “Test Method for LED Lamps, LED Luminaires and LED Modules”<br>CIE 13.3 “Method of measuring and specifying color rendering properties of light sources” | Sample of 10 units. The arithmetical mean of the measured CRI (Ra) of the 10 units shall not be less than the required CRI (Ra) level minus 3. |
| **6. Correlated Color Temperature** | CIE S 025 “Test Method for LED Lamps, LED Luminaires and LED Modules”<br>CIE 15 “Colorimetry” | Sample of 10 units. The arithmetical mean of the measured CCT shall conform to the industry standard tolerances contained in the standards used for testing. |
| **7. Fundamental power factor** | IEC 62612 “Self-ballasted LED lamps for general lighting services with supply voltages > 50 V - Performance requirements”<br>IEC 600969 “Self-ballasted compact fluorescent lamps for general lighting services - Performance requirements” | Sample of 10 units. The arithmetical mean of the measured displacement factor of the 10 units shall not be less than the required level minus 0.05. |

**Combined test for early failure and lumen maintenance for LED linear products and LED GSL[32]**

The combined test for LED GSL products or LED linear products shall be conducted using a sample of 10 units. If more than one lamp fails before the end of the test, then both tests have failed, and the tests can be stopped. If not, then the test continues until 3000 test hours is reached and at that point the arithmetical mean of the measured luminous flux of the remaining products shall be at least 90% of the arithmetical mean of their initial luminous flux. (i.e., lumen maintenance). The testing shall be conducted:

a. in a room with an ambient temperature in the range of 15°C to 40°C where vibration and shock are minimized and the lamps under test are not subject to supplemental ventilation or cooling (e.g., blowing air from a fan or air conditioner directly onto the area where the testing racks and lamps are located),
b. with the LED products operated in free air in a horizontal position,
c. at the LED product's rated voltage and frequency if a single value is declared. If the rated voltage is a range, the LED product shall be tested at the mean voltage of that range. For dual-voltage LED products, for example those intended for operation at 110 V to 130 V and 220 V to 240 V, ageing and testing shall be conducted at the mean voltage of each voltage range. The test voltage supply shall have a tolerance within 2%. The total harmonic content of the supply voltage shall not exceed 3%. The harmonic content is defined as the root mean square (RMS) summation of the individual harmonic components using the fundamental as 100%. IEC 61000-3-2, Annex A, provides guidance on the supply voltage source,
d. with the LED products operating for 1200 cycles. A cycle is defined as a repeatedly switching cycle of 150 minutes ON followed by 30 minutes OFF. The hours of operation recorded (i.e., 3000 hours) shall only include the periods of the cycle when the lamp was switched ON.

Note 1: Luminous flux of each LED product under test should be measured at time t=0 (initial luminous flux prior to any cycling) and at the completion of 1200 cycles (150 minutes on, 30 minutes off).

Note 2: Linear LED products which can be connected directly to the electrical supply and to a magnetic control gear shall be tested as being connected to the electrical supply.

Note 3: Linear LED products that can only operate on control gear shall be tested using an inductive reference ballast in series.

**Test for LED luminaires (lifetime claimed superior to 25,000 hours)**

The method for measurement is the **standard IES LM-84-14** "Measuring Luminous Flux and Colour maintenance of LED lamps, light engines, and luminaires" until at least the 6,000 hours level is reached. The norm **IES TM-28-14** "Projecting long term luminous flux maintenance of LED lamps and luminaires" to extrapolate the measurements until claimed lifetime.

### 5.4.9 MEPS and Energy Efficiency labels

Minimum Energy Performance Standards are adapted to Sudan, based on international experience and what can be found on the Sudanese market.

[32] U4E model regulations for LED GSL lamps and LED linear products.

#### 5.4.9.1 *Rational for energy efficacy levels*

The minimum requirement applies to products that are sold on the Sudanese market, and a shift to highly efficient LED technology is proposed for this kind of products. The implication of the minimum efficacy level on the different technologies allowed to be placed on the market is as follow:

- For Bulbs, LED only technology will be sold by 2024,
- Linear lamps, LED only technology will be sold by 2025,
- Street lighting luminaires, LED only technology will be sold by 2026,

For domestic lighting, a ban of incandescent lamps, the less efficient technology, is proposed as soon as 2022. Compact Fluorescent Lamps (CFL) are still existing on the market, but the market share is declining, a ban is proposed 2 years later, in 2024.

For linear lamps, T8 fluorescent lamps are allowed to be sold until 2024 and T5 until 2025.

For street lighting luminaires, mercury vapor, the less efficient technology, is banned as soon as the MEPS are enforced in 2022.

Minimum energy levels for bulbs and linear lamps for years from 2025 onward are based on the U4E model regulations published in February 2021.

#### 5.4.9.2 *MEPS levels and label*

The requirements for Sudan are taking into account the existing technologies on the market and the oncoming efficacy levels for LED as indicated in Table 52.

*Table 52: Minimum energy efficacy levels.*

| Minimum efficacy levels (lm/W) | Bulb efficacy (lm/W) | Linear lamps efficacy (lm/W) | Street lighting luminaire efficacy (lm/W) |
|---|---|---|---|
| years 2024-2025 | ≥ 50 | ≥ 70 | ≥ 90 |
| years 2026-2027 | ≥ 70 | ≥ 90 | ≥ 110 |
| years 2028-2029 | ≥ 110 | ≥ 130 | ≥ 140 |
| years 2030-2031 | ≥ 125 | ≥ 145 | ≥ 160 |
| years 2032 | ≥ 140 | ≥ 160 | ≥ 180 |

To be noted: the three kinds of light sources can be easily physically recognized, and the relevant MEPS category can be identified without confusion. Indeed, the effect of the MEPS on the different technologies that can be sold on the market is explained in Table 53.

*Table 53: effect of MEPS on technologies allowed/sold in Sudan.*

| Technologies allowed on the market | Bulb | Linear lamps | Street lighting luminaire |
|---|---|---|---|
| years 2024-2025 | CFL, LED | T8, T5, LED | MH, HPS, LED |
| years 2026-2027 | LED | T5, LED | HPS, LED |
| years 2028-2029 | LED | LED | LED |
| years 2030-2031 | LED | LED | LED |
| years 2032 | LED | LED | LED |

The label proposed is based on seven tiers label proposed for other appliances. The label is different for the three kinds of products to consider as shown in Table 54.

Tier 7 is the MEPS for the first two years. Tier 6 will be the MEPS for 2026 and 2027. Tier 5 the MEPS in 2028 and 2029.The MEPS for 2030/2031 will be tier 4. And tier 3 the MEPS level in 2032.

*Table 54: label tiers for lighting.*

| Levels | bulb | linear | street |
|---|---|---|---|
| Tier 1 | ≥ 160 lm/W | ≥ 180 lm/W | ≥ 200 lm/W |
| Tier 2 | ≥ 150 lm/W | ≥ 170 lm/W | ≥ 190 lm/W |
| Tier 3 | ≥ 140 lm/W | ≥ 160 lm/W | ≥ 180 lm/W |
| Tier 4 | ≥ 125 lm/W | ≥ 145 lm/W | ≥ 160 lm/W |
| Tier 5 | ≥ 110 lm/W | ≥ 130 lm/W | ≥ 140 lm/W |
| Tier 6 | ≥ 70 lm/W | ≥ 90 lm/W | ≥ 110 lm/W |
| Tier 7 (MEPS) | ≥ 50 lm/W | ≥ 70 lm/W | ≥ 90 lm/W |

#### 5.4.9.3 *Other quality levels*

1. **Minimum rated lifetime:** Lifetime proposed here is minimum rated lifetime measured at 70 % of remaining flux for at least 50 % of the devices. We propose to fix those values for LED only. Other technologies will be phased out from the market quite rapidly.

- LED bulbs: 20,000 hours
- LED tubes: 25,000 hours
- LED luminaire for street lighting: 50,000 hours

To be noted, for LED bulbs ad LED tubes, lifetime required is not exceeding 26,000 hours and simplified test as the one describes in the chapter 3.2 can be conducted whereas LED luminaires for street lighting require a complete test following standard IES LM-84-14 and IES TM-28-14.

2. **Standby power:** level of standby for connected devices and/or with internal sensor should not exceed 0.5 Watt.

3. **Early failure rate**: after 3,000 hours of operation as per the test method described in chapter 3.2, luminous flux maintenance factor should be higher than 90 %.

4. **Color Rendering Index**: the color rendering index for indoor lighting should be higher than 80. For outdoor lighting, a color index of 60 or higher is sufficient.

5. **Correlated color temperature (CCT)**: the correlated color temperature should be based on existing product on the market but also prevent any potential harmful aspects for indoor lighting. For outdoor lighting, limitation is driven by light pollution mitigation. Indeed, blue component of the spectra has strong influence on light pollution and should be limited. The more the correlated temperature is high, the more the blue part of the spectrum is important.

6. **Fundamental power factor**: the fundamental power factor is depending on the input power of the light source or luminaire as described in Table 55.

*Table 55: fundamental power factor limits.*

| Rated input power | Fundamental power factor |
|---|---|
| P ≤ 5 Watt | No limit |
| 5 Watt < P ≤ 10 Watt | ≥ 0.5 |
| 10 Watt < P ≤ 25 Watt | ≥ 0.7 |
| P > 25 Watt | ≥ 0.9 |

### 5.4.10 Expected energy savings with the MEPS' enforcement.

The energy savings are calculated taking into account an effective application of the MEPS in 2024.

#### 5.4.10.1 *Domestic sector*

According to the market assessment, sales of incandescent lamps are already declining, and the enforcement of MEPS will accelerate their phase out. Due to their lifetime, of about one-year, incandescent lamps should disappear three years after their ban in 2024.

Sales of CFL is already slowly declining and will be banned from the market in 2026.They are expected to be phased out by 2032.

Sales of fluorescent tubes is not declining and the phase out will begin progressively in 2026 to be completed by 2035.

That results in a reduced annual energy consumption, therefore a higher power savings, compared to a Business As Usual (BAU) scenario as shown in Figure 60 below.

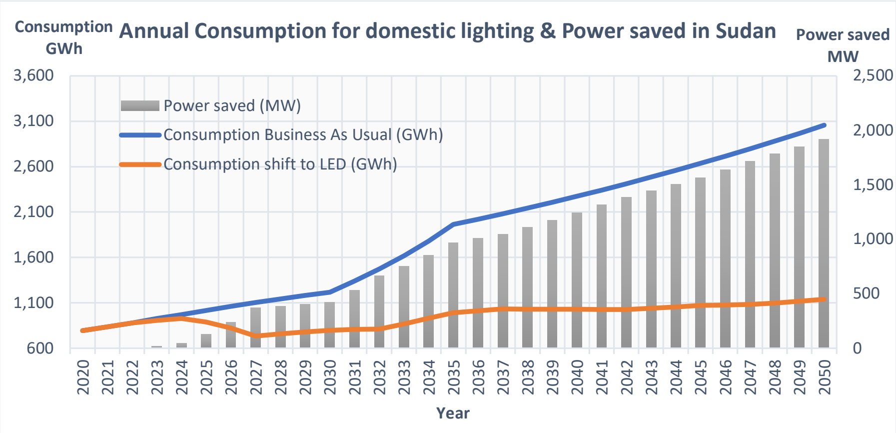



*Figure 60: Energy consumption and power savings due to the application of MEPS for residential lighting.*

### 5.4.10.2 *Tertiary sector*

CFL are widely used. Their ban in 2026 will lead to a complete phase out by 2029, earlier than in the household sector due to longer annual use time.

Fluorescent tubes' time of use per year is longer than for domestic applications and phase out from the sector is expected to occur in 2030.

High Pressure Sodium lamps and Metal Halides lamps are phased out respectively by 2031 and 2035, as for street lighting sector.

Note that for tertiary sector, with higher intensity of use and recent increase of electricity demand, the opportunities to shift to LED are higher than for domestic sector and a natural shift is taken into account before MEPS are applied.

That results in a reduced annual energy consumption and higher power savings compared to a Business As Usual (BAU) scenario as shown in Figure 61 below.

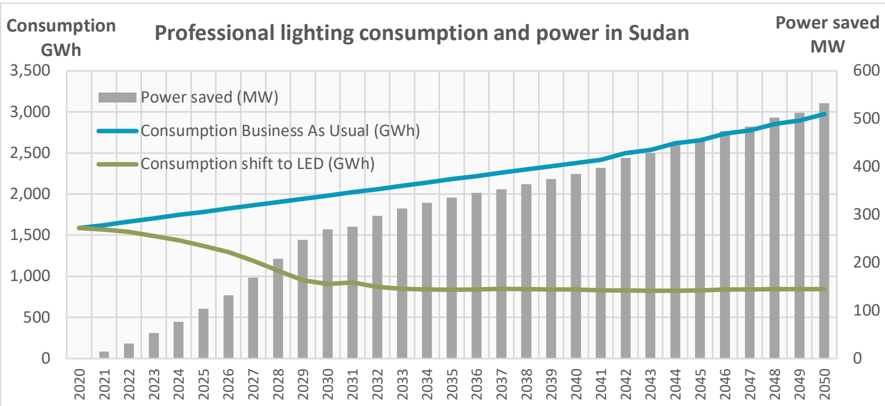



*Figure 61: Energy consumption and power savings due to the application of MEPS for lighting in tertiary sector.*

### 5.4.10.3 *Street lighting sector*

According to the market assessment, High pressure Sodium Lamps (HPS) and Metal Halides (MH) are still sold in Sudan at a constant rate for the last years.

MEPS will prevent MH lamps to be sold after 2026 and HPS lamps after 2028. Due to their lifetime (7 years for HPS and 6 years for MH lamps), MH lamps is expected to be phase out from all installations by 2031 whereas HPS will be phase out by 2035.

That results in a reduced annual energy consumption and power savings compared to a Business As Usual (BAU) scenario (Figure 62).

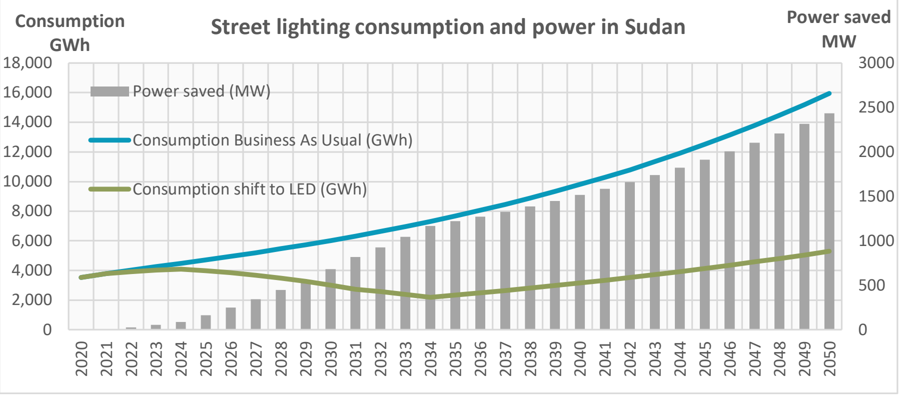



*Figure 62: Energy consumption and power savings due to the application of MEPS for the street lighting sector.*

### 5.4.11 **Overall effect of MEPS on the lighting sector**

The effect of MEPS on the electricity consumption for lighting is obtained by summing the effect on the domestic, street lighting, and professional sector as shown in Figure 63 below.

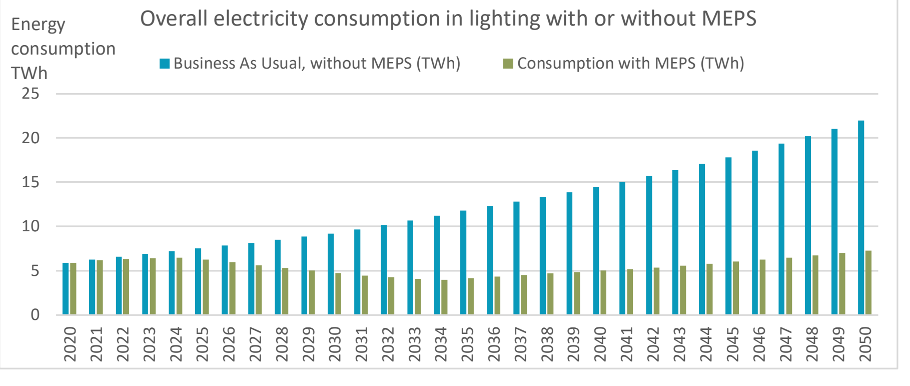



*Figure 63: Energy consumption for lighting with or without MEPS.*

### 5.4.12 Conclusion

The enforcement of lighting's MEPS in Sudan is key to mitigate the increase of electrical consumption in the lighting sector in the coming years. Higher electrification rate of the country will lead to a steep increase in the demand. The Minimum Energy Performance Standards that are suggested would ban the inefficient light sources progressively, beginning by incandescent lamps to the benefit of LED. Minimum Performances of LED are also set to follow the increase in efficacy and to ensure their quality. Minimum Energy Performance will lead to significant savings as shown in Table 56 below.

*Table 56: Electricity consumption due to lighting in Sudan with the application of MEPS.*

| | 2030 | 2040 | 2050 |
|---|---|---|---|
| **Consumption Business As Usual** | 9.2 TWh | 14.4 TWh | 22 TWh |
| **Consumption with MEPS** | 4.7 TWh | 5 TWh | 7.3 TWh |
| **Power saved** | 1374 MW | 3146 MW | 4882 MW |

## 5.5 Comfort fans sector

### 5.5.1 Definition and scope

The standard IEC 60879 “Comfort fans and regulators for household and similar purposes – Methods for measuring performance” gives the definition of comfort fan as: “fan primarily designed for creating air movement around or on part of a human body for personal cooling comfort, including fans that can perform additional functionalities such as lighting.” There are different types of comfort fans ranging from conventional fans, tower fans, bladeless fans, ceiling fans, table fans, pedestal fans, wall bracket fans, ceiling bracket fans and louvre fans.

The principle of fans is the same: the cooling sensation is obtained by the downdraft of air helping your sweat to evaporate quicker. A fan cools the body whereas an air conditioner cools the ambient air.

The market assessment in Sudan distinguishes between two technologies with different characteristics and efficiency, pedestal fan (more usually called stand fan) and ceiling fan. Those two technologies are described in the following 2 sections.

### 5.5.2 Stand fan

A stand fan blows the air with rotating blades actioned by an electrical motor, usually a single-phase AC induction motor for a single speed fan and a single-phase AC synchronous motor for a multi speed fan.

Standalone fans take the air from the back side and throw it to the front. They are directive. They blow the air and thus speeds up the evaporation process resulting in the cooling of human body. The drawing of Figure 64 shows two kinds of stand fans, a pedestal fan and a table fan.

Those fans can be used in offices, homes, or large rooms.

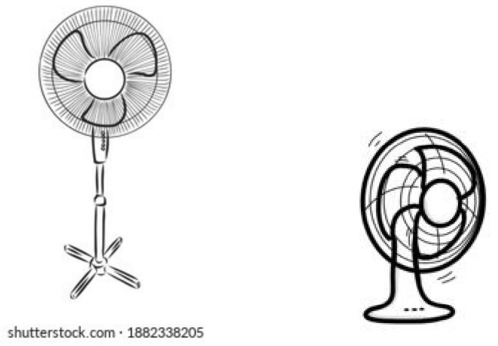



*Figure 64: stand fans - left pedestal fan and right table fan.*

### 5.5.3 Ceiling fans

Ceiling fans are suspended, fixed to the ceiling of a room. Ceiling fans take the air from the upper side of the blades, concentrate it on the center and throw it from the center with a “large aperture”, creating vertical air flow as shown in Figure 65, and distributes the air temperature. Modern ceiling fans are usually using a DC brushless motor, more efficient than AC motors but slightly more expensive.

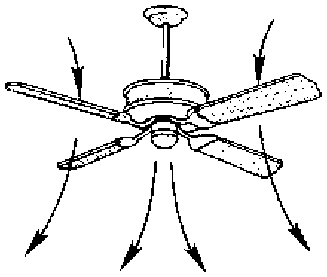


*Figure 65: ceiling fan air flow.*

Those fans can be used in commercial setting, for home style in the main room, for large area.

### 5.5.4 Products under scope

It is important for manufacturer and authority to clearly define the products that should follow the standards. Following the definitions from the standard IEC 60879, the fans that will be regulated by this standard are conventional fans:

- Pedestal fans
- Table fans
- Wall bracket fans
- Ceiling bracket fans

Their rated voltage being not more than 250 V for single-phase fans and 415V for 3-phase fans, and their rated power input being is less than 200 Watt.

### 5.5.5 Products in Sudan

The service value measures the efficiency of a fan in [$m^3$/min/W]. This is the volume of air moved per minute divided by the input power of the fan. The efficiency of stand fans increases with the radius. In fact, efficiency increases with increasing flow rate (until a certain point).

According to the market assessment the service factor of fans sold in Sudan are ranging from 0.2 $m^3$/min/W to 1.8 $m^3$/min/W for the stand fans and from 2 $m^3$/min/W to 3.85 $m^3$/min/W for the ceiling fans. The service values for the different type of fans on the market are shown below, function of the radius of the fan, Figure 66 for stand fans service values and Figure 67 for ceiling fans.

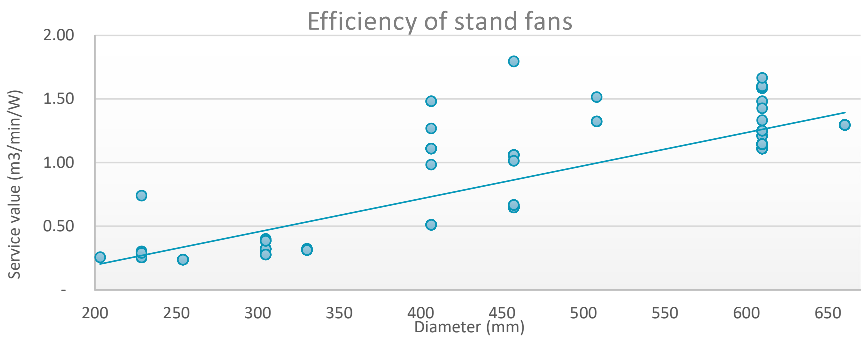



*Figure 66: Stand fans - service value.*

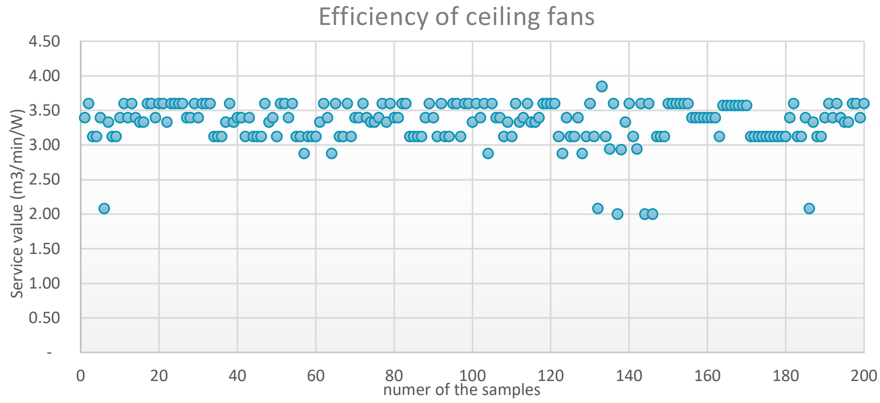



*Figure 67: Ceiling fans - service value.*

As explained previously, ceiling fans and stand fans have different functionalities and diameters and cannot be easily compared. However, the efficiency of ceiling fans, to create an airflow for a given input power, is about three times higher compared to stand fans. To be noted, our sample shows that efficiency does not depend on the radius.

The market assessment showed an average of 2.7 units installed per household connected to the grid. Main characteristics of the installed fans are summarized in Table 57 below.

*Table 57: Ceiling and Stand fans features.*

| | Power [W] | Diam [inch] | Diam or sweep size [mm] | Price [USD] | Service value [$m^3$/min/W] |
|---|---|---|---|---|---|
| **Stand fan** | 148 | 20 | 502 | 49.50 | 1 |
| **Ceiling fan** | 78 | 56 | 1 417 | 35.02 | 3.5 |

*Note: the term "sweep size" is mentioned here as it is mentioned in existing regulations in Pakistan, China, and India. This is equal to the diameter of the circle seen when the fan blades are in motion.*

### 5.5.6 Test standards and conditions

Regulations offer a highly cost-effective policy option for removing inefficient fan technologies from the market and, when applied in conjunction with supporting policies, they encourage manufacturers to improve product efficiency. However, establishing the right level of regulation is critically important, and governments typically conduct detailed cost-benefit analyses to ensure that the adopted regulatory measures provide a positive economic benefit.[33]

### 5.5.7 Minimum efficiency level

The efficiency of a fan measures its ability to create a certain air flow. This is defined as the ratio of the calculated maximum fan flow rate [$m^3$/min] to the measured fan power input [W]. The higher this value is, the more the fan is using the electricity effectively to generate the air flow. The efficiency of the fan depends on the efficiency of the electrical motor and the efficiency of the fan blades.

**Motors**

Brushless motors which are synchronous DC motors are usually more efficient than AC induction motors. Indeed, DC motors are made of permanent magnet whereas in AC motors use electricity to create the electromagnet, thus decreasing the efficiency of the motor. Brushless motors are more efficient than brush motors mainly because of the losses due to friction. However, brushless DC motors are more expensive than traditional AC induction motors.

**Blades**

The shape of the blades must be designed to provide maximum work for minimum power and the tilt angle should be chosen accordingly.

### 5.5.8 Norms and testing method

The relevant norm for testing performance of fans is the IEC 60879 "*Comfort fans and regulators for household and similar purposes – Methods for measuring performance*".

[33] Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING / U4E POLICY GUIDE SERIES; https://united4efficiency.org

As mentioned above, the key parameter to be measured is the service value as defined above is the ratio of the calculated maximum fan flow rate [m3/min] to the measured fan power input [W].

### 5.5.8.1 *Measurement of the flow rate*

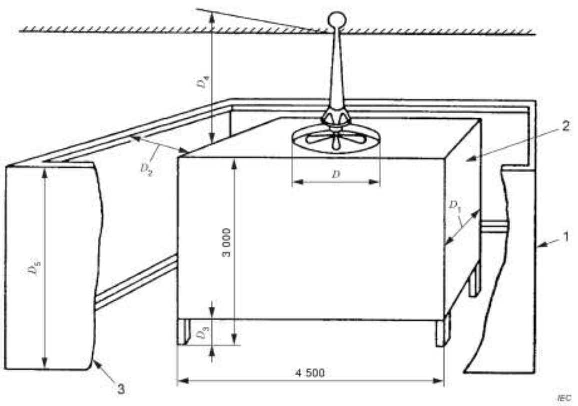
The air movement shall be measured by means of vane anemometers having an internal diameter not exceeding 100 mm. The air velocity shall be averaged over a period of 60 second using an update rate of not less than 2 Hz.

**Ceiling fans**

The test chamber shall have the following dimensions with a tolerance of ± 15 mm:

- Length of 4 500 mm,
- Width of 4 500 mm,
- Height of 3 000 mm.

The bottom of the test chamber is 450 mm from the ground, to leave a suitable space for air outlet. That test chamber should be placed in a larger room as shown in Figure 68.




**1: outer screen**
**2: test chamber**
**3: outer screen cut away**
**D1 = 4,500 mm**
**D2 = 1,000 mm to 1,250 mm**
**D3 = 450 mm**
**D4 = height of the ceiling, ≥ 1,000 mm**

**D5 = height of outer screen, ≥ 3,000 mm**

**D = 1.1 to 1.2 times the blade's sweep**

*Figure 68: Arrangement of test chamber and outer screen for ceiling fans.*

The fan must be placed in the center of the square room. Test plane is 1,500 mm ± 10 mm below the plane of the fan blades. The measurements shall be carried out with the fan running at full speed at the test voltage. Air velocity measurement must be performed along the four-axis formed with the four corners, from a point 40 mm from the center of the fan to each of the four corners with a reading every 80 mm as shown in Figure 69.

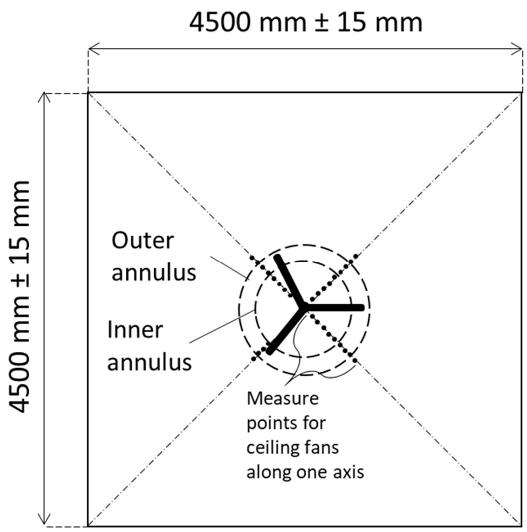



*Figure 69: measurements point for ceiling fans*

The average air velocity for one annulus (circle) is taken as the mean of the eight manometers, 2 per direction so that 4 detectors are inside the annulus and 4 just outside.

The mean radius of each annulus is equal to the mean of the inner and outer radii of the annulus.

For each annulus having an average air velocity equal to or greater than 9 m/min, the product of the area of the annulus and the average air velocity through that annulus, shall be taken as the air delivery through that annulus.

The sum of the air deliveries through all such annuli shall be taken as the measured flow rate of the fan.

**Stand fans**

The test chamber shall have different dimensions depending on the sweep size (equal to the diameter of the circle seen when the fan blades are in motion). For sweep size not larger than 400 mm, the length of the test chamber is 4,500 mm, width 4,500 mm and height 3,000 mm. For sweep size larger than 400 mm, the length should be 6,000 mm, width 4,500 mm and height 3,000 mm. Tolerance for the dimensions are ± 15 mm.

At least 4 vane anemometers shall be used. A greater number of anemometers may be used to reduce the time taken to map the airflow of the fan under test. Care should be taken to use an even number of anemometers. Anemometer vanes shall be moved both horizontally and vertically with respect to the fan blades' horizontal axis. The movement being at right angles to this axis and extendable in both directions. The axis of the anemometer vanes shall always be parallel to the fan blades' horizontal axis. An example of positioning of 4 anemometers in horizontal and vertical directions is given in Figure 70.

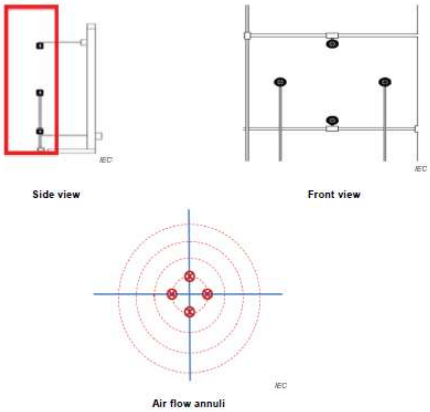



*Figure 70: Configuration of 4 anemometers for conventional fans.*

Air velocity measurements in each of the four directions shall commence at a point 20 mm from the axis of the fan blades and shall progress horizontally and vertically to the fan blade axis in increments of 40 mm. The measurements shall continue in the 40 mm increments until the average air velocity in each of the four directions falls below 24 m/min.

The average air velocity shall be the average of the measurements over a period of 60 sec using an update rate of not less than 2 Hz. The axis of the fan blades shall be horizontal during the test.

The average air velocity through each annulus is the mean of the 8 air velocities obtained at each anemometer position taken horizontally and vertically at each of the inner and outer radii of the annulus. The mean radius of each annulus is equal to the mean of the inner and outer radii of the annulus. Average air velocities below 24 m/min are discarded.

For each annulus having an average air velocity equal to or greater than 24 m/min, the product of the area of the annulus and the average air velocity through that annulus, shall be taken as the total air delivery through that annulus.

The sum of the air deliveries through all such annuli shall be taken as the measured fan flow rate of the fan.

### 5.5.9 MEPS and energy efficiency labels

#### 5.5.9.1 *Energy efficiency levels rationale*

The proposal for the minimum energy efficiency is based on the existing products on the Sudanese market, and the minimum requirement applies to these products that are sold in Sudan.

The market assessment showed that more than one quarter of all sold comfort fans (stand fans and ceiling fans) are manufactured in Sudan. Manufacturers should be involved in the establishment of Minimum Energy Performance Standards (MEPS) so that the national industry is not penalized.

Other countries of origin of the products are India, China, Pakistan, and Egypt. There are no standards for fan performance today in Sudan. However, some standards are existing in the country of origin of the imported products sold in Sudan. If a performance standard has to be adopted in Sudan, it should not impede the local manufacturers and reasonably avoiding any negative impact on their competitive advantage.

Minimum Energy Performance Standards of those countries were analyzed in section 3.3.4.2. Pakistan have Minimum Energy Performance standards for stand fans and ceiling fans whereas China has a standard for stand fans only and India for ceiling fans only.

Pakistan released a label scheme for ceiling fans and stand fans whereas India has one for ceiling fans.

#### 5.5.9.2 *MEPS levels and label*

The requirements for Sudan are taking into account the existing technologies on the Sudanese market and the oncoming efficiency levels for fans based on existing MEPS in Pakistan, China, and India. To facilitate the market surveillance, Tier 7 of the proposed label is the MEPS for fans sold in Sudan.

The 7 Tiers for fans are listed below in Table 58. Based on the existing products in Sudan, we suggest 2 categories for stand fans and two for ceiling fans.

*Table 58: Tiers value for fans.*

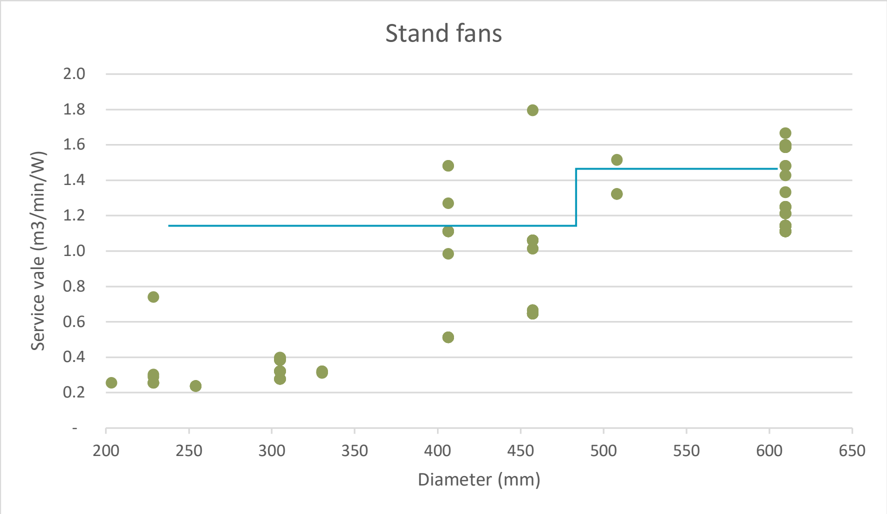
| Minimum Service Value (m3/min/W) | Stand fans | | Ceiling fans | |
|---|---|---|---|---|
| Sweep diameter | < 500 mm | ≥ 500 mm | < 1 200 mm | ≥ 1 200 mm |
| **Tier 1** | ≥ **2.5** | ≥ **3** | ≥ **5.1** | ≥ **6** |
| Tier 2 | ≥ 2.3 | ≥ 2.8 | ≥ 4.6 | ≥ 5.5 |
| **Tier 3** | ≥ **1.65** | ≥ **2.65** | ≥ **4.1** | ≥ **5** |
| Tier 4 | ≥ 1.15 | ≥ 1.7 | ≥ 3.6 | ≥ 4.5 |
| **Tier 5** | ≥ **1.08** | ≥ **1.65** | ≥ **3.1** | ≥ **3.45** |
| Tier 6 | ≥ 0.95 | ≥ 1.43 | ≥ 2.93 | ≥ 3.32 |
| **Tier 7** | ≥ **0.9** | ≥ **1.3** | ≥ **2.79** | ≥ **3.15** |

The Tier 7 will apply in 2024 and is the proposed MEPS for products sold on the Sudanese market. Other tiers will apply with the chronology as shown in Table 59 and are minimum energy performance standards for that year.

*Table 59: Chronology of the MEPS implementation.*

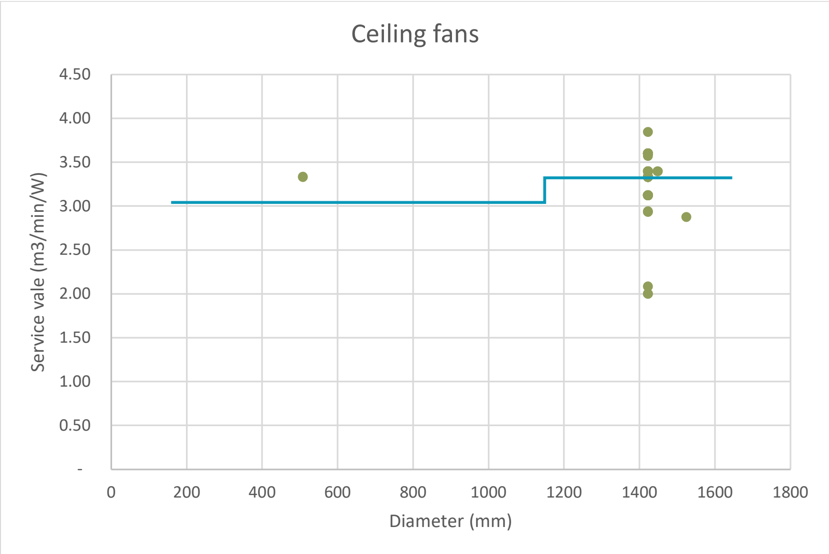
| Minimum Service Value (m3/min/W) | Stand fans | Ceiling fans |
|---|---|---|
| **Year 2024-2025** | **Tier 7** | **Tier 7** |
| Year 2026-2027 | Tier 6 | Tier 6 |
| **Year 2028-2029** | **Tier 5** | **Tier 5** |
| Year 2030-2031 | Tier 4 | Tier 4 |
| **Year 2032-2033** | **Tier 3** | **Tier 3** |
| Year 2034-2035 | Tier 2 | Tier 2 |
| **Year 2036-2037** | **Tier 1** | **Tier 1** |

The effect on products on the market in Sudan according to the market assessment is shown for the tier 7 to tier 5 for stand fans in Figure 71 and for ceiling fans in Figure 72.




Service value   MEPS Tier 7

*Figure 71: Tiers' level compared to the market assessment for stand fans.*




Service value   MEPS Tier 7

*Figure 72: Tiers' level compared to the market assessment for ceiling fans.*

MEPS enforcement will have a significant effect on stand fans with radius inferior to 400 mm as all fans of that size in Sudan are below the proposed Minimum Energy Performance level. As a consequence, they will be banned from entering the market as of 2024. To be noted, more efficient products that would comply with tier 7 of the proposed MEPS for Sudan in 2024 are already applied in Pakistan for stand fans with a diameter ≥ 350 mm. More than half (52 %) of the stand fans with diameter from 400 mm to 500 mm (16 and 18 inches) will still be allowed for selling in 2024. For stand fans with diameter higher than 500 mm, 40 % of existing fans have higher service values than the MEPS.

MEPS enforcement in 2024 will ban 1/3 of ceiling fans with diameter higher than 1200 mm that are sold on the Sudanese market today.

#### 5.5.9.3 *Expected energy savings with MEPS' enforcement*

Savings are calculated considering a fans lifetime of 8 years as learnt from the market assessment. The electrical consumption in the Business as Usual (BAU) scenario is compared to the consumption of the scenario when MEPS are applied. The power saved by applying MEPS is also shown in Figure 73.

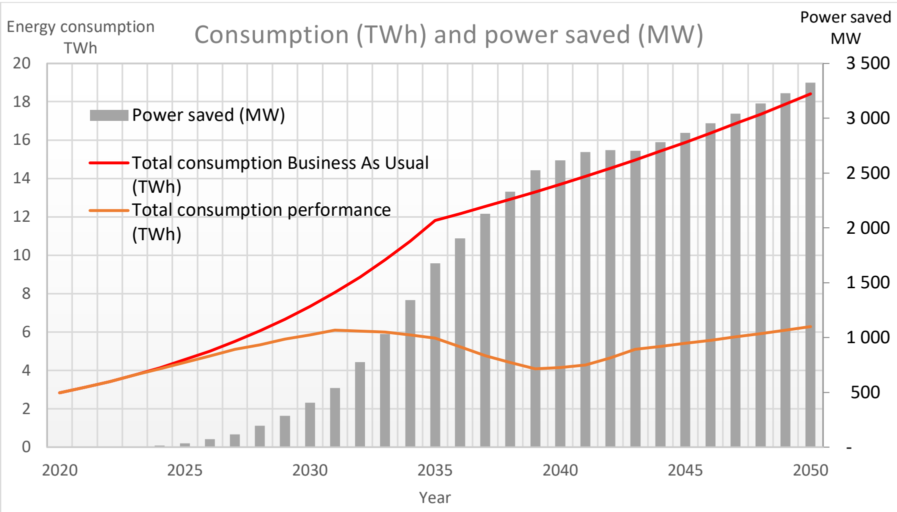



*Figure 73: energy consumption and power savings due to the application of MEPS for comfort fans.*

The consumption of comfort fans and the power saved, due to the enforcement of MEPS, are summarized in Table 60 for the current situation, in 2035 and 2050.

*Table 60: Consumption and power saved compared to BAU scenario for comfort fans in 2035 and 2050.*

| | 2020 | 2035 | 2050 |
|---|---|---|---|
| **Consumption per year (GWh)** | 2 829 | 5 692 | 6 280 |
| **power saved (MW)** | 0 | 1 679 | 3 324 |

#### 5.5.10 Conclusion

Minimum energy Performance and label is proposed for the next 15 years based on the MEPS and label from the main countries of origin of the products sold in Sudan. Compared to the Business-as-Usual scenario, Minimum Energy Performance Standards enforcement will compensate the growing fans' electrical demand caused by the growing number of households.

Indeed, MEPS enforcement for fans represents 52 % of energy saved by 2035 and 66 % by 2050 compared to the Business-as-Usual scenario.

# 6 MONITORING VERIFICATION AND ENFORCEMENT (MVE) – (DEL4-T6-Act6.1)

It is known that the implementation (and update) of Minimum Energy Performance Standards (MEPS) and energy efficiency labels of appliances are powerful tools to transform the markets to more energy efficient products. However, all efforts to implement such standards can be worthless if the different actors within the program does not fulfil their obligations. The set of mechanisms used to safeguard compliance with MEPS and labels are known as MVE "Monitoring, Verification and Enforcement".

In addition to ensuring increased energy efficiency, and therefore lower energy consumption, compliance with MEPS and labels provides fairer competition for brands, incentivizing research and development of more efficient products, and increasing credibility among consumers, encouraging the purchase of more energy efficient appliances. Therefore, it is of crucial importance to safeguard compliance with MEPS and labels programme through the application of effective MVE mechanisms.

Table 61 shows the main MVE activities at different stages: introducing the product into the market (conformity assessment), market surveillance, and enforcement of non-compliance products. The activities comprise among others: entry conditions, registration system, product performance database, market surveillance, verification testing, enforcement guidelines, penalties for non-compliance.

The following subsections analyses the current MVE activities in Sudan and recommends procedures to implement an effective MVE program.

*Table 61: MVE activities at different stages.*

| Conformity assessment | Market survillance | Enforcement |
|---|---|---|
| • Establish requirements for product certification<br>• Define test standards and requirements for products and laboratories<br>• Test and declare performance<br>• Product registration system | • Custom checks<br>• Review technical product documentation<br>• Monitor label compliance in fisical and online shops<br>• Verification tests ofcertified products | • Informe stakeholders about enforcement activities<br>• Penalties for non-compliance (informal, administrative ot civil actions)<br>• Deter non-compliance |

## 6.1 Conformity assessment

The Conformity assessment includes the requirements and procedures to ensure that imported and locally manufactured products adhere to relevant standards and regulations, which might include the energy efficiency label and MEPS regulations.

These requirements and procedures must be clearly stipulated to avoid confusion and hence non-conformity. It might include reference to the test standards, requirements for the laboratories, information about the product, requirements for the registration system, MEPS and label requirements, other performance requirements, reports from the supplier (such as the Conformity[34] Assessment Report), etc.

[34] The Conformity Assessment Report (CAR) is the legal instrument to show that the supplier is aware of the local standards and regulations and is responsible for the veracity of the declared performance.

In Sudan there are not yet MEPS and Energy Efficiency labels in place but has started the legal framework to develop them. The following sections present a summary of the conformity assessment for importing products into Sudan, and other international experiences.

## 6.2 Conformity assessment in Sudan

**The Electricity Regulatory Authority (ERA)** is an integral part of the Ministry of Energy and Oil (MEO) is the sole entity regarding issuance and execution of electrical energy efficiency regulations. ERA had drafted a law, to regulate all issues regarding electricity, which is now under ratification process. This draft includes the only energy efficiency regulation in Sudan. The law will give ERA the authority to develop secondary regulation for MEPS and labels, that will apply to the specific product groups, in cooperation with the Ministry of Finance and the Sudanese Standardization and Metrology Organization (SSMO), who will act as a supervisory body.

**The Sudanese Standardization and Metrology Organization (SSMO)** was established in 1993 as an independent organization under the Presidency to succeed the Department of Standards of the Ministry of Industry, which existed since 1969. A decision was made to combine with SSMO the Weights and Measures Department and the Quality Control Department of the Ministry of Trade and Industry to form the nucleus of the present SSMO[35].

SSMO was established to work as an authorized agency having the capacity of dealing with all issues related to standards and metrology, supervision, measurements, and calibration. SSMO has its headquarters in the capital Khartoum and has branches in the states of the country, in particular, those states where import entry points exist.

Furthermore, SSMO enjoys the membership of international organizations such as ISO (International Standardization Organization) and IEC (International electro-technical Commission) and is considered one of the main founders of ARSO (African Standardization Organization) and SMIIC (Standards & Metrology Institute for Islamic Country).

Even though there are still no MEPS and energy efficiency labels in place, the SSMO has experience for conformity assessment on safety for food, toys and electrical products among others.

**Process to import a good to the Sudanese market:**

In order to enter a product into the Sudanese market, the goods should comply with the relevant SSMO standards or other international standards adopted by the Government of Sudan.

According to the Exporter Guide to Sudan[36], In order to clear their goods in the Republic of Sudan, importers need to present at Sudanese Customs conformity certificates comprising Certificate of Inspection (COI) and other inspection certificates for respective products issued by the inspection companies (such as COTECNA and Baltic Controls). These companies are certified under Article 5 of the Constitutional Law of the SSMO as an international surveyor, to inspect, test and verify goods imported into Sudan.

The Conformity Assessment Process can be summarized as follow:

[35] SSMO site: http://www.ssmo.gov.sd/
[36] The Exporter Guide to Sudan can be download here:
https://www.sun-connect-news.org/fileadmin/DATEIEN/Bilder/Resources/Datasheet_for_Exporters_Sudan_EN.pdf

1. Documentation verification: the exporter will send to the inspection company all required documents such as request of certification, laboratory test reports, quality certificates, technical datasheet, etc. Based on these documents, the inspection company will verify the conformity and decide if complains, or more actions are needed.
2. Testing: All tests should be issued by an ISO 17025 accredited laboratory. If no valid test reports are presented by exporter, the inspection company can collect samples to be analyzed in an ISO 17025 accredited or otherwise qualified laboratory (as per the inspection company /SSMO's procedures). Costs are borne by the exporter.
3. Physical inspection in exporting country
4. Collect final documents and issuance of the Certificate of Inspection (COI) and Non-Conformity Report (NCR).

In some cases, the SSMO can withdraw samples for laboratory analysis procedures to ensure its compliance to standard specifications. The SSMO account with 21 laboratories certified under the ISO 17025 to ensure quality and safety. There are not yet laboratories for energy efficiency of refrigerators and air conditioners, but the SSMO was planning to establish a laboratory for testing the performance of all electrical appliances.

## 6.3 International experience for conformity assessment on MEPS and Labels

The main difference between conformity assessment in terms of procedures to obtain the product certification are related to the requirements for the test laboratory:

- Self-declaration (first party): The supplier declares to conform with all requirements. This leads to less delays and lower cost to certificate the product for the supplier but needs a robust market surveillance program to avoid cheating.
- In-house accredited assessment body (second party): Even though the body should demonstrate impartiality from supplier, this is not guaranteed.
- Independent laboratory (third-party): Only designed laboratories can make the test for certification. This might be more expensive for suppliers, but it increases conformity and reduces the need for market surveillance (still needs to be done).

The self-declaration process is widely used over the world, such as in the EU, Australia and Japan. Some countries allow several pathways for the conformity assessment. As seen in the previous section, in Sudan, the process for the current conformity requirements involves self-declaration from the suppliers, but with a certain independent control from the inspection companies and the checks carried out by the SSMO. Furthermore, testing laboratories should be accredited with ISO 17025.

The Nigerian conformity assessment process is a mix of the above-mentioned methods, and somehow similar to the Sudan procedure. The SON (main agency responsible for the enforcement of MEPS compliance in Nigeria) has established different processes depending on if it is locally manufactured or imported product. For local manufactured products, the MANCAP certification process applies, for which the production processes are inspected on site and products must by sampled from production and tested under Nigerian standards before the products can be approved for commercialization. For imported products, the SONCAP certification process applies, for which the test can be done at the manufacturer laboratory, but this needs to be certified with ISO 17025, and the process has to be supervised by one Independent Accredited Firms (SGS, Intertek, Cotecna, CCIC, BV and CSIC).

The independent laboratory might be the most trustable procedure if well implemented, but sometimes is not used due to lack of infrastructure (laboratories) and to simplify the certification process, reducing the cost for testing for manufacturers and importers. Some examples of third-party certification are Tunisia and Chile. In these cases, the supplier usually informs the authority about the intention to put a product in the market. Then, the sample is sent to an authorize laboratory, which might be public or private, and local or international, but should be always authorized[37] by the authorities and should be independent from the supplier. The authorized laboratory will check the values declared by the supplier, and if different, the ones measured by the independent laboratory will be used for the energy efficiency certification (if MEPS are complying).

## 6.4 Fees for certification

Apart from the import fees and fees for other product certification types, some countries also apply fees for the energy efficiency certification. The benefits obtain with the fees are then used as a financial source for the MVE procedures and the MEPS and label programme.

Table 62 shows the example of India. Each company shall register themselves on the Standard and Labelling (S&L) web portal, for which they should pay a refundable security deposit that can be recovered if they stop their business. Then, other fees are paid by model/family and by product.

If extra fees are used for energy efficiency certification, we recommend exempting models with the higher energy efficiency rating in the label to incentivize manufacturers and importers to introduce energy efficient products in the market.

*Table 62: Fees for the energy efficiency certification in India (Source: Indian[38] Guidelines for certification).*

| Type of fee | Fee in USD |
|---|---|
| **Refundable security deposit (company registration in the program)** | 1410 USD<br>(352 USD for small/medium enterprise) |
| **Registering fee per model/family of models** | 28 USD |
| **Renovation of registering fee (once every 3 years)** | 7 USD |
| **Labelling fee per unit (for refrigerator)** | 0.14 USD |

## 6.5 Conclusion

Even though the third-party certification procedure is the most trustable in terms of conformity before a product is placed in the market, Sudan does not have the infrastructure to follow the independent test procedures in this moment, unless it uses international independent laboratories. Therefore, Sudan might adapt the current conformity assessment process to include energy certification for MEPS and energy efficiency labels, for which the laboratories must be accredited with ISO 17025 and test must conform with Sudanese standards. As in the other type of certifications, and following the

[37] If international laboratories are accepted, they should usually be accredited by an accreditation body member of the International Laboratory Accreditation Cooperation (ILAC) and International Accreditation Forum (IAF)
[38] The complete Indian guidelines can be download here Guidelines for Permittee - dummy (beestarlabel.com)

example of Nigeria, the process of certification for energy efficiency shall be oversight by the inspection companies, customs and the SSMO in Sudan.

Nevertheless, an authorized local/regional laboratory for energy efficiency is still needed to carry out verification test. The laboratory can also be used for certification purposes, and if the capacity is big enough, the third-party certification might be considered.

The following sections include information about other MVE activities that needs consideration to guarantee product compliance, such as product registration, product information, verification test, and sanctions.

### 6.6 Registration system and product information

A product registration system (product database) aims to gather information about the products being introduced in the market by manufacturers and importers. In some countries it is mandatory to register the product in order to place it on the market. For instance, the new appliance database[39] in the EU. This kind of product registration databases are a good practice, the main advantages are:

- Use the information for surveillance, for instance by checking technical information of the product, and by identifying products, brands and laboratories that have failed to obtain certification in the past.
- The information can be used to understand the market in terms of energy efficiency distribution (models and sales), product stock, market evolution, etc. This information can be used to design more effective MEPS and energy efficiency labels, or to set the requirements for sustainable public procurement.
- Increase the rate of compliance.
- Monitor the effect of MEPS and labels.
- Information could be used by consumers, for example by creating applications[40] to inform about the most efficient products in the market.

In some countries, the required information is similar to the information required for the energy efficiency label, which might include (in the case of a domestic refrigerator):

- Model name and number.
- Type of unit and main characteristics.
- Country where the product was manufactured.
- Size (e.g., volume of compartments for fridges and capacity in kW for air conditioners)
- Rated performance grade in the label.

[39] The product registration is mandatory in the EU from 2021, https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/product-database_en

[40] One example is TopTen, which exist in several countries. The aim of this site is to inform consumers about the most efficient products in the market, https://www.topten.eu/

- Rated energy efficiency (e.g., Efficiency Index for refrigerators or Cooling Seasonal Performance Factor (CSPF) for air conditioners).
- Yearly electricity consumption in kWh according to applicable standards.
- Reference ambient temperature(s) used for performance testing.
- Refrigerant and foam-blowing designation in accordance with ISO 817 including the Ozone Depletion Potential (ODP) and GWP.

**While this information might be useful for consumers and basic surveillance checks, it is recommended to require all technical information necessary to check energy efficiency calculations for surveillance.** Reviewing technical information is considered a cost/effective method for surveillance.

The database could even automatically calculate some parameters and compare with the declared parameters by the manufacturer, if inconsistencies are found, the problem can be solved before introducing the product in the market, for example:

- If compensation factors are used to calculate energy efficiency, but the corresponding characteristics is not declared (for instance automatic defrost in refrigerators).
- Total volume of refrigerator does not match the sum of the volumes declared for the compartments separately.
- The energy efficiency equation does not correspond to the declared type of product.

All technical data does not need to be accessible by all public, the required information for surveillance might be accessible only by the authorities, while a more reduced data (for instance the one that is in the label) can be accessible to consumers. The new EU registration system have two entries, information publicly available for consumers, and more detailed confidential data available only by the authorities. To see an example of the information required by the EU for domestic refrigerators, see Annex V (product information available for consumers) and Annex VI (technical information available for authorities) of the new EU labelling regulation EU 2019/2016[41].

Furthermore, United for Efficiency (U4E) has developed a guidance note on product registration systems outlining best practices, which include[42]:

1. What is a Product Registration System and Why Use One?
2. Planning to Build a Product Registration System? – Foundational Considerations
3. Planning to Build a Product Registration System?
4. Detailed Consideration Implementing a Product Registration.

## 6.7 Verification test

Product registration systems with technical information revisions for surveillance are a very useful complement to verification testing, but not a replacement. Even in third-party conformity assessment procedures, verification testing is needed at some degree to check compliance. These tests are used

[41] Regulation EU 2019/2016 can be download here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R2016
[42] All the U4E notes on the Product Registration System are available at: https://united4efficiency.org/product-registration-systems/

to verify that a product that has already obtain the certification meets the performance declared by the supplier.

Usually, one unit or more are withdrawn from the market and tested to check compliance with the declared energy efficiency. Other parameters, such as the capacity, volume, freezing capacity, light power factor, lighting colour temperature etc. depending on the type of appliances can also be verified. The procedure to verify compliance vary from country to country and from type of appliances, in some countries, three units of the same model are tested, and the average results should be within the specified tolerance, while in other countries a minimum number of the selected units should be within tolerance (e.g., two out of three). For lighting products, compliance tests should be performed on 10 samples.

Figure 74 shows an example of verification test procedure that could be used in Sudan, which is based on best international practices. In this case, one unit of the selected product is tested in the first step, if the unit pass the test, the supplier is informed about the compliance and test is finalized, if the unit does not pass the test, the supplier is informed about the non-compliance, and a corrective measure is negotiated depending on the degree of non-compliance, e.g., to re-label the unit. If the supplier accepts to apply the corrective measures and sanctions, the process of test verification finish here (after enforcing compliance), if the supplier does not accept, two (2) more units of the same model will be tested, for which the supplier should pay the costs. If both units pass the test, the model is considered compliant, if one, or both does not pass the test, the model is considered not compliant, and the corrective actions and sanctions should be applied.

Verification test are expensive, therefore, in many countries, the selection of models to be tested is not totally random. For instance, in Australia the authorities take their decisions considering the following risk of non-compliance criteria (units can also be selected randomly):

- Evidence based on information received from various sources: competitors, consumer groups, individuals, etc.
- History of non-compliance.
- History of laboratory failures.
- Laboratories participating in the program for the first time.
- Market share. Products with high market shares have more impact.

Then the SSMO (or the agency in charge of MVE) might use this risk criteria to select the model for verification test. Furthermore, it is recommended to give the opportunity to third parties to initiate the verification process, known in the Indian legislation as “Challenge test”. This type of verification test occurs when a third party (competitor, consumer association, etc.) open a written complaint of non-compliance of a product. The plaintiff must submit an affidavit stating that, if their claim is proven false, they will cover all related costs (samples, testing, transportation, etc.). Otherwise, it will be the supplier of the product who will cover the costs. The verification test will follow the same steps shown in Figure 74.

The verification process should be clear and written in the energy efficiency regulations or any other legal document, so there is no doubt about the validity of the procedure and suppliers will know beforehand which procedure will be applied to their products if they are selected for a verification test.

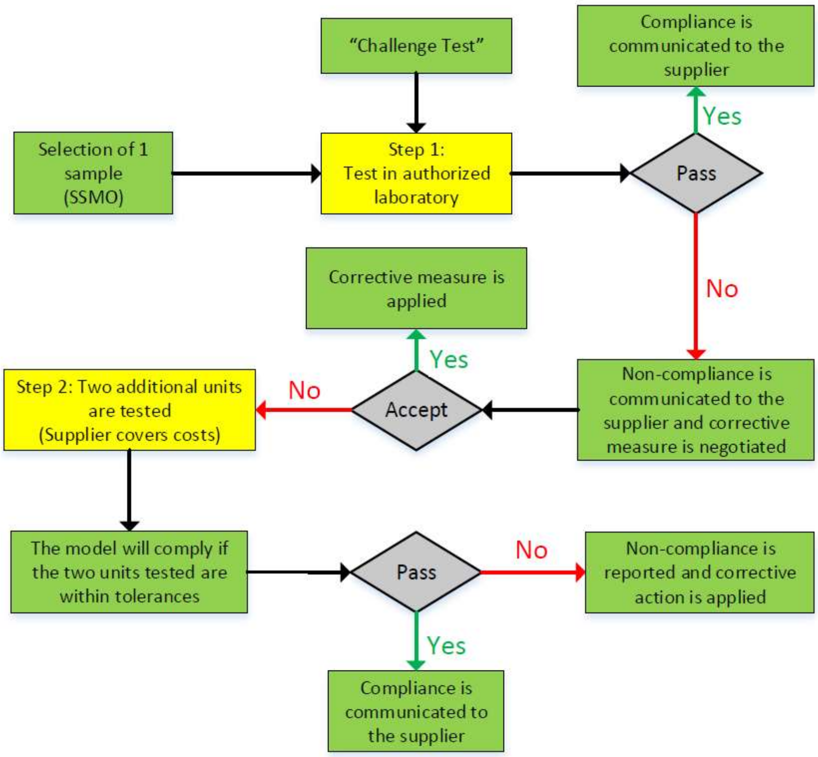



*Figure 74: Verification test procedure.*

Within different units of the same model, it is impossible to obtain the same results due to production tolerances and test uncertainties. Therefore, test tolerances should be defined for the parameters that will be checked during the verification test. If test measurements during the verification test are within the declared value +- the tolerances, then the unit passes the verification test.

Table 63 shows an example of test tolerances concerning the energy consumption of freezing capacity and volume of domestic refrigerators. These tolerances are based on the EU regulations, which are similar to the ones applied in other countries.

For Air Conditioners, the verification tolerances used in the European Union (EU Regulation[43] 626/2011) are only for the energy efficiency. The measured value shall not be more than 8 % lower than the declared value. It is anticipated that in the new regulation, which is expected for 2023, the tolerances will be more stringent for air conditioners above 2 kW.

[43] The EU Regulation 626/2011 can be download here: EUR-Lex - 32011R0626 - EN - EUR-Lex (europa.eu)

*Table 63: Verification tolerances for refrigerators (Source: EU Regulation[44] 2019/2019).*

| Parameters | Verification tolerances |
|---|---|
| **Total volume and compartment volumes** | The measured value shall not be more than 3% or 1 liter (whichever is greater) lower than the declared value. |
| **Freezing capacity** | The measured value shall not be more than 10 % lower than the declared value. |
| **Annual energy consumption** | The measured value shall not be more than 10 % higher than the declared value. |
| **Energy consumption of auxiliaries ($E_{aux}$)** | The measured value shall not be more than 10 % higher than the declared value. |

For lighting, verification tolerances for fundamental power factor, correlated color temperature, color rendering index and luminous flux are given as an example in Table 64 below.

*Table 64: Examples of recommended verification tolerances for lighting products*

| Parameters | Verification tolerances |
|---|---|
| Fundamental power factor | Sample of 10 units. The arithmetical mean of the measured displacement factor of the 10 units shall not be less than the required level minus 0.05. |
| Correlated Color Temperature | Sample of 10 units. The arithmetical mean of the measured CCT shall conform to the industry standard tolerances contained in the standards used for testing. |
| Color Rendering index | Sample of 10 units. The arithmetical mean of the measured CRI (Ra) of the 10 units shall not be less than the required CRI (Ra) level minus 3. |
| Luminous flux (lm) | Sample of 10 units. The arithmetical mean of the measured luminous flux of the 10 units shall not be less than 90% of the rated luminous flux. |

## 6.8 Labelling market surveillance

The sections showed different procedures to ensure compliance with the energy efficiency regulations, such as the conformity assessment, custom checks, the revision of technical data, the registration system, and the verification test. All these mechanisms will increase also the compliance rate with the energy efficiency label.

Apart from being sure that the information of the label is true, this information should be visible for the consumer at the moment of purchasing. In this sense, retailers should also fulfil their obligations on showing the efficiency label as it is required in the efficiency regulation, both at physical and online

[44] The EU Regulation 2019/2019 can be download here: EUR-Lex - 32019R2019 - EN - EUR-Lex (europa.eu)

shops. To monitor compliance on this issue, the authority can use inspectors that visit physical and online shops to check compliance.

The non-compliance might be for several reasons: lack of label, wrong label, obscured label, damaged label, etc. Figure 75 shows an example of non-compliance labels found during an inspection campaign in Australia.


*Figure 75: Examples of labels that do not comply with Australian regulations due to defective or low visibility (Source: [www.energyrating.gov.au/](www.energyrating.gov.au/)).*

## 6.9 Information procedures

It is important that each actor knows and understands their obligations and the possible consequences if they are not fulfilled to avoid non-compliance due to lack of knowledge and cheating. Hence a transparent information and communication system is needed.

Stakeholders should not only be informed about the certification procedures, programme requirements, or their obligations, but also about market surveillance and their consequences.

An example of good practice is the Australian MEPS and label programme. All important information for consumers, retailers, and suppliers (manufacturers and importers) can be found on their website[45] for product labelling. The website contains information about energy efficiency, free courses for retailers, access to the product database, and requirements and obligations for retailers, manufacturers, and importers. Furthermore, the results of the market surveillance campaign[46] are also published on the website: number of verification tests with fail products, market labelling surveillance including the type of problem found, etc.

On the website there are also compliance guidelines[47] where possible consequences due to non-compliance are explained to the stakeholders. Figure 76 shows the relationships between the type of infraction and the action taken by the supervisory body. The concept of risk is used, the action not only depends on the infraction, but also on the risk it represents and the intentions of the offender. The

[45] Australian website for product labelling: Home | Energy Rating
[46] The results of the Australian market surveillance campaigns can be download here: Market Surveillance | Energy Rating
[47] The compliance guidelines can be download here: Compliance Policy | Energy Rating

type of correction measure will depend on the infraction, for instance, it can be a re-scaling of the label, or a product withdrawn from the market if the MEPS are not met.

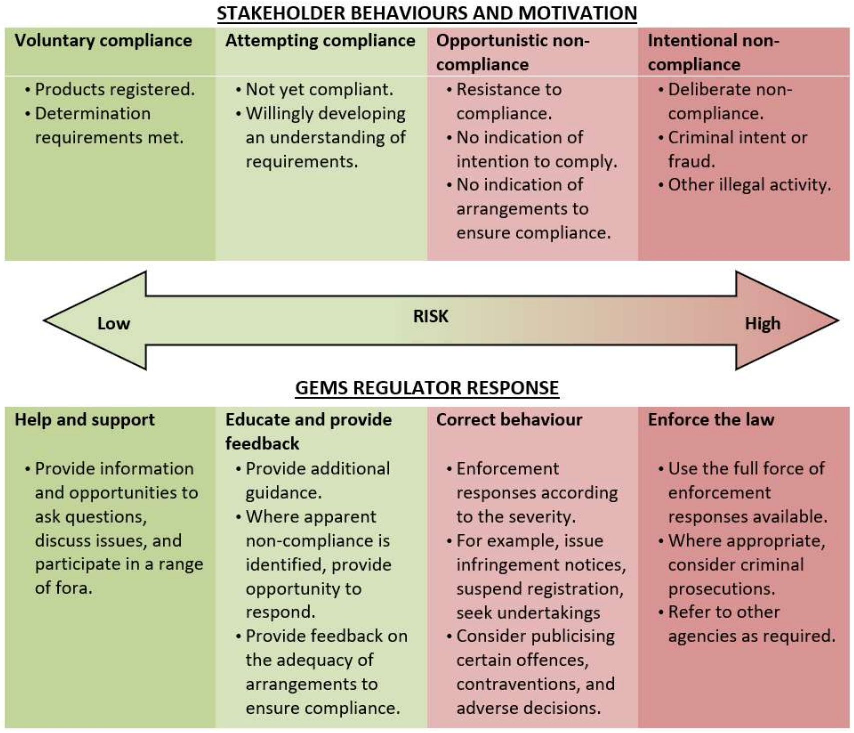



*Figure 76: Australian approach to risk for infraction sanction (Source: GEMS Compliance Policy).*

## 7 NATIONAL END-OF-LIFE APPLIANCE MANAGEMENT PLAN

### 7.1 Elements of End-of-life Management

At the end of their lifetime, electrical appliances become electronic waste (e-waste). E-waste needs to be handled through a proper end-of-life appliance management plan (EOL-MP). Figure 77 illustrates the key elements of the EOL-MP.


*Figure 77: End-of-Life Management Plan.*

For the EOL-MP we are recommending for the EES in Sudan adopting the principles of the EOL-MP as applied in the European Union under the Directive on Waste of electrical and electronic equipment (WEEE Directive, 2012/19/EU). The European EOL-MP regulations represents international best practice and are also recommended good practice in the United for Efficiency (U4E) guides such as Climate Friendly and Energy Efficient Refrigerators and Air Conditioners (2017). The WEEE Directive is embedded in the 2008 Waste Framework Directive (2008/98/EC) which sets the overarching legislative framework for waste collection and handling. It defines the main concepts such as the ‘polluter pays principle’, i.e., that the manufacturers and distributors who are bringing WEEE equipment on the market have the key responsibility for the EOL management of the appliances and are ultimately responsible for bearing the costs for the EOL management. In many developing countries the ‘polluter pay principle’ has not or not yet full been implemented. Consequently, responsibilities are insufficiently defined and payments for the EOL of equipment are not provided and a proper EOL-MP is not established and implemented.

The most important elements of the WEEE directive are included in the following key articles:

- Disposal and transport of collected WEEE (Article 6)
- Collection rates and minimum collection rates (Article 7)
- Proper treatment (Article 8)
- Recovery targets (Article 8, Annex V)

All the product categories addressed in the Nation Cooling Plan of Sudan are products in the framework of the WEEE. We recommend that with the EES of Sudan, the EOL-MP will be established following the same principles as in the EU, particularly the responsibility by manufacturers and distributors to set up the EOL-MP and to bear the related costs.

Following the same principal as in Europe (Table 65) we suggest that the target recycling quota for the industry are raised over time. For the introduction of the WEEE in Sudan, the starting recovery and recycling quota level can start low with an increasing ambition level over time.

*Table 65: EU WEEE Recycling and recovery targets for manufacturers and distributors.*

| Targets 2012-08/2015 | Targets 09/2015-08/2018 | After 09/2018 |
|---|---|---|
| Recovery 80%<br>Recycling 75% | Recovery 85%<br>Recycling 80% | Recovery 85%<br>Recycling 80% |

The handling of WEEE products in Europe follows the European standard EN 50625 which provides a detailed set of guidance and requirements for the collection, logistics and treatment for all WEEE appliances. The treatment and disassembly of old appliances needs to take place in authorized facilities. The WEEE defines minimum requirements for the treatment, disassembly, and recovery.

## 7.2 EOL-MP for appliances with chlorinated/fluorinated refrigerants

Within the WEEE there are special requirements for appliances containing fluorinated or chlorinated refrigerants, which includes room air conditioners and refrigerators. There are different rules for the following to separate groups of cooling appliance:

- **Plug-n-play units (such as refrigerators):** End-users have the obligation to transport these units to authorized city collection centres. Alternatively, end-users can request distributors to collect the units form their homes against a fixed and regulated handling fee.
- **Installed units (as room air conditioners):** Installed units need to be installed and dis-assembled through authorized, certified, and registered service technicians. These service technicians are required to deliver the appliances at the end of their life to authorised city or rural collection centres. The services technicians have the obligation to collect the old ozone depleting or F-gas containing refrigerants at the site of disassembly of appliances. F-gas and ODS refrigerant recovery from the old appliances must be done with the appropriate equipment, by certified technicians and the old refrigerant gas must be recovered in marked containers. Qualified, authorized and certified ODS and F-Gas refrigerant handling centres will either recycle or destroy the refrigerants. To encourage the collection of F-gases we recommend providing the end-users the right to make recovery of F-gases from installations always free of charge. Service companies and distributors not following their obligation for the collection of old appliances or refrigerants have lower costs and thereby unfair competitive advantages. For allowing a fair level playing field. The collection of F-gas can also be incentivized. In this scheme contractors and distributors are compensated upon delivery of recovered F-gases. This can be funded via a levy or fee on virgin HFC refrigerants placed on the market by importers of bulk refrigerants. A levy on HFC has a dual added value: this increases the incentive to keep leakages low and to recover all gases at EoL.

## 7.3 Requirements on hazardous substances

In addition to special treatment requirements for the refrigerants contained in WEEE-waste, ideally other environmentally hazardous substances in WEEE should be controlled. The European Union is doing so through a parallel directive controlling the use of hazardous substances in WEEE, which is the RoHS Directive. It's also recommended for Sudan to ratify the Minamata convention (which was signed by Sudan on 24 September 2014) concerning the use and disposal of equipment using mercury.

## 7.4 Implementation considerations for introducing an EOL-MP

For the implementation of an EOL-MP system similar to the WEEE scheme in the EU, Sudan needs to implement training and capacity building for the local administrations so that they can introduce, enforce and control an EOL-MP correctly and consistently. Table 66 lists the main responsibilities of the relevant stakeholders for the introduction of an EOL-MP with the key elements of a WEEE system.

*Table 66: Responsibilities of key stakeholders under the WEE scheme.*

| Actors | Responsibilities |
|---|---|
| Importers, manufacturers, and distributors placing products on the market | • ***Report annual quantities of EEE placed on the market and WEEE collected,***<br>• ***The collection of old appliances and the establishment of collection points***,<br>• ***The environmentally friendly recycling of old appliance,***<br>• ***Environmental sound treatment of refrigerants,***<br>• ***Bearing the costs for collection and waste treatment.*** |
| Retailers | • **Retailers are obliged taking back old appliances from customers** |
| Waste management/ recycling companies | • **Waste management/recycling** companies are obliged to carry out the environmentally sound treatment of old appliances according to established national and/ or international standards (for a good practice example for applied international standards on e-waste handling are the Technical Guidelines on Environmentally Sound E-Waste Management for Collectors, Collection Centres, Transporters, Treatment Facilities and Final Disposal in Ghana (2018) established by the Environmental Protection Agency in Ghana[48]<br>• Waste management and recycling companies need to be registered and acquire permits and authorisations for handling WEEE waste. Scrap-dealers with only a permit to store, sort and/or dismantle scrap waste are not allowed to accept WEEE. |
| Cities and municipalities | • **Provide municipal collection service for manufacturer (paid by manufacturers)** |
| End-users | • **Using the official municipal waste collection system** |

Figure 78 below illustrates good practices for the dismantling of old appliances.

[48] See here https://elink.io/sem/yrp79qee5hg3i02i

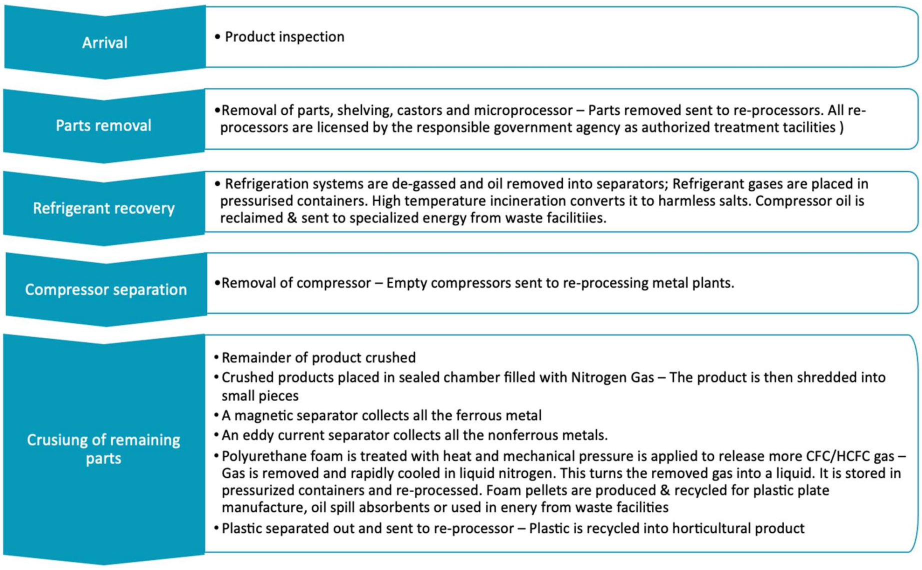



*Figure 78: EEE dismantling steps.*

## 7.5 Take back schemes

Take-back schemes provide debt payments for new appliance against evidence for handing back old appliances. In some countries take-back schemes receive government incentives in order to establish processes where old in-efficient appliances are replaced with new, highly energy efficient appliance. The replacement of old appliances with new, highly energy efficient appliances promote the transition to energy saving practices, and, at the same time, allow the return of old appliances to environmental sound recycling process, the recovery and destruction of toxic substances, including F-gas containing refrigerants and ODS. Exchange programmes can be particularly effective if the energy efficiencies of old appliances differ significantly from very energy efficient new appliances. In such cases, replacement programmes can be an effective decarbonisation strategy towards lower carbon emissions.

## 7.6 Conclusion

The increasing number of cooling appliance placed on the market requires the establishment of an end-of-life management plan, in order to limit and eventually eliminate accumulated toxic and environmental hazardous substances contained in the appliances and also to recover valuable raw materials. It is established good international practice that importers, manufacturers, and distributors who place the appliances on the market are taking the key responsibility for taking back old appliances and the financing of the end-of-life management. Importers, manufacturers, and distributors must provide evidence annually on the numbers placed on the market and the share of recovered and recycled appliances. The government of Sudan needs to provide the required framework for the industry for the end-of-life management. This includes permits and authorisations to waste handling companies. The recycling of EEE needs to follow international sound practices avoiding environmental pollution and the release of climate and ozone damaging substances contained in refrigerants.

# 8 ENABLING FUNDING AND FINANCING MECANISM FOR MARKET TRANSFORMATION – (DEL4-T5)

This chapter discusses the financing options to implement the EES for Sudan. It will explore financing tools to incentivize actions as well as raising the needed funds. The proposed funding mechanism under the EES takes consideration of the current situation of Sudan's limited available financial resources. The suggested funding sources therefore build on levies on imported, high GWP refrigerants and energy inefficient appliances as national co-funding in combination with international climate finance. In turn, the raised funds will finance incentives for highly energy efficiency appliances in top label classes in line with the label system proposed in Chapter 5 of this EES report. The intended impact of the incentive system will be the accelerated market introduction of climate friendly and energy efficient appliances, the installation of the relevant labs, the costs of certification tests, the costs for the registration process and the market surveillance system including an effective fining system for non-compliance.

As per the terms of reference, the funding requirements and financing mechanisms recommendations is requested as follows: **Assessment and development of funding and financial mechanisms for market transformation**. In this description, this analysis includes the following elements:

1. Developing financial mechanism(s) to help incentivize the market introduction and deployment of high-performance product.
2. Assessment of financing mechanism previously implemented by the government of Sudan is studied, and modifications are proposed to develop a similar mechanism for energy efficient products.
3. Developing actions for comprehensive market transformation program and how it can be funded.
4. Assessing opportunities to integrate energy efficiency into the HCFC phase-out, HFC phase-down and incandescent lamps phase-out planning, identify mechanisms, inform prioritization of sectors and interventions, and develop strategies and roadmaps.

This report will also explore funding and financing mechanisms for the intended market transformation towards low GWP domestic ACs and refrigerators. The Funding and Financing Mechanism refers to a consistent set of measures to generate sustainable funding to support the National Cooling Plan and its objectives.

In line with the project requirements, the proposed funding and financing mechanism includes the following elements:

- Funding options including a tax on HFCs and import duties on inefficient appliances.
- Costs assessment for the actions to develop and implement the LACEES with flexibility for updates of the plan and development of new activities. These activities include a continuous MEPS improvement, and possible extension to other appliances and energy efficiency initiatives.
- Support a phase-down of fluorinated gases use.
- Available funding source from international programs. These are analyzed regarding the available level of funding and their applicability in Sudan (section 8.2).

Conclusions are drawn from the analysis provided in sections 8.1 and 8.2. These conclusions lead to recommendations and action steps.

## 8.1 Financial and funding mechanisms for market transformation

Several approaches are available and have been extensively implemented around the world achieving significant penetration of low emission cooling and refrigeration equipment including but not limited to:

- Laws and regulations that prohibit sales or installation of high-emission cooling and refrigeration appliances as well as lighting and fans appliances such as the MEPS and labels.
- Economic incentives can accelerate the transition to climate friendly and energy efficient appliance and promote the replacement of old and inefficient appliances.
- Taxes and penalties on poor performing appliances and high GWP refrigerants. For lighting, those taxes could target incandescent lamps first.
- Influencing consumer behavior through the provision of information in the true life-cycle costs of appliances, environmental responsibility, efficient application of appliances.

In the following sections, supporting incentives, financing measures and their funding are explored, and a financing mechanism is proposed for Sudan. The aim will be to provide sustainable and secure funding for the actions directly required in this project and to enable future actions in the LACEES.

### 8.1.1 Target group

A market transformation requires an assessment of where an intervention will deliver the greatest momentum, or where it is most needed to initiate the transformation. The proposed initial component of the LACEES focuses on MEPS implementation and is supported with an incentive program for low-income households to adopt energy efficient light sources, refrigerators and ACs, and an information and awareness campaign to support effective decision making by households. The actions in this analysis look to change the behavior of actors in different ways (incentives, regulations, etc.) to achieve results:

- **Residential consumers of appliances** – An incentive program for consumers of light sources, ACs and dom ref to enable low-income households to access highly efficient appliances.
- **All market actors** – an information program that enables consumers to make informed choices and the industry to understand the technology options and how to support adoption.
- **Sellers of residential appliances** – While not recipients of funds, sellers of the appliances are essential for the implementation of a swap out program, as they are the transaction point at which the residential inceptive will be applied. As influencer of purchasing decisions, sellers can also play a role in the adoption of efficient technologies.
- **Manufacturers and assemblers of appliances** – While implementation of efficient cooling is essential, it is also important to ensure that the local economy and local industry thrive. For this, efficiency and low GWP refrigerant programs need to ensure that the changes will not negatively impact local manufacturers. Through receiving technical support for the design of new efficient units, or grants for updating and retooling production lines, or support with testing and verification.
- **Importers of appliances and fluorinated gasses** – Importers are a key point in the implementation of taxes or ban on undesirable products.
- **Local authorities** – Responsible for the street lighting network and its maintenance,
- **Building operators** – Responsible for building lighting and its maintenance, they should also be informed on possible energy and financial savings with the adoption of quality LED luminaires.

### 8.1.2 Uninformed decision making

When buying any home appliance/product for domestic use, the appliance's upfront cost, look and functionality are the prime considerations for the customer. However, additional information on the life-cycle costs (LCC) of appliances are rarely available and customers have low awareness of "hidden" costs, such as electricity consumption, rather focusing on comparing upfront costs (Renew, 2016). The provision of additional information on energy efficiency, LCC and other associated benefits of low emissions, has proven to be a successful tool to increase the market share of efficient appliances (CLASP, 2020).

Peter K. Smith et al. (2010) conclude that "*rather than finding ways to make customers pay more for environmentally sound products, the marketing challenge for eco-innovation should be reconceptualized as one of lowering customers' perceived initial cost and increasing awareness of LCC*". Most existing studies report a positive effect of LCC information on the purchase likelihood of eco-innovations. Disclosing LCC information provides an important base for long-term thinking on the individual, corporate, and policy levels.

The LACEES will seek to provide the needed regulatory environment with the implementation of MEPS and labels and support information and awareness creating activities. The Energy Efficiency Strategy in this project will build on this work with the provision of an incentive for low-income households to access highly efficient refrigerators and a cooling plan that addresses long-term development needs.

#### 8.1.2.1 *Design of the Funding and Financing Mechanism*

For this project, the financial mechanism will look to support an incentive program for 300,000 appliances (dom ref and ACs) over 2 years (approximately 50% of the 2020 sales of these appliances) for low-income households, the enforcement and administration activities related to the fluorinated gas phase-down, and the development and implementation of a MEPS and labelling program with regular updates. However, it is recommended that an integrated financial and funding mechanism should be developed to support an integrated energy efficiency program in Sudan.

In Deliverable 1, the market assessment illustrated that more efficient RAC appliances tend to have higher purchase prices (upfront cost) but lower life-cycle cost. The lower operating costs of energy efficient appliances are explained by their substantially lower electrical consumption and lower maintenance requirements. Now, the low cost of electricity in Sudan, causes for this differentiation to be less apparent than other markets. It is recommended that Sudan phase-out electricity subsidies.

Currently, Sudan does not have an operating MEPS program, resulting in a large proportion of appliances in Sudan are of low energy efficiency and would not pass MEPS in other countries. This suggests that appliances in Sudan cause a significant waste of energy resulting in high costs for government due to the subsidies.

To stimulate action, a two-step system simultaneously rewarding good behavior and penalizing bad practices is recommended (i.e., incentive and tax system). This would take the form of taxes or levies on fluorinated gases and inefficient appliances to raise funds for incentives on efficient appliances, low GWP refrigerants, and running the program.

1. **Taxation system[49],** which increases the price of inefficient appliances and high GWP refrigerants.

   ***Tax on the import of inefficient appliances:*** the life cycle cost of inefficient appliances will be increased through a tax collected at purchase or the import of inefficient appliances. This would lead to higher price of inefficient appliances which are normally cheaper due to the use of cheaper

[49] In the context of this study custom duties or tax are to be understood as inter-exchangeable terms for "surcharges" on relatively inefficient appliances with high GWP refrigerants.

inefficient components. Increasing the value proposition of efficient appliances and lowering the cost of entry barrier. The level of the tax will be defined by the energy efficiency label of each device. More details are in section 2.6.

***Tax on the import of the GHG potential of refrigerant:*** an import tax based on the GWP weighting of HFC refrigerants is proposed to trigger the transition to low GWP refrigerants. The import levy will be imposed on HFCs but not on HCFCs, as the phase out is already comprehensively addressed as part of the HCFC phase out management plan. Initially an entry carbon tax of 30 USD / t $CO_2$-eq is proposed. The levy can be increased over time. The HFC import levy will be introduced on bulk imported refrigerants and it is proposed not to differentiate the levy according to different appliance types as the refrigerants are usually used across different appliances. The main refrigerant types affected will be the imports of HFC-134a and HFC-410A. The HFC-134a is the main HFC refrigerant used in refrigerators and mobile air conditioning, while HFC-410A is the main HFC refrigerant used in ACs replacing HCFC-22 which is being phased out. It is of note that natural refrigerant R-600a (isobutane) is increasingly important in domestic refrigeration as its use is expanding globally.

2. **Incentive upon purchase of efficient appliances with the exchange of inefficient old appliances.**

   The introduction of an incentive on the purchase price or direct cash subsidy for the purchase of energy efficient appliances in exchange of handing back an inefficient appliance for disposal, the Swap-out program. The incentive program is envisaged to support up to 300,000 appliances over two years with a discount provided only for the purchase of units in the top two EE classes with low GWP refrigerants and only be paid once the old device is handed back to the retailer or service provider for proper disposal. The retailer or service provider will hand over the old units to a recycling and disposal service to scrap the devices and dispose or recycle the refrigerants. Cost for disposal of the systems and the cost for the recycling and disposal facility are considered in chapter 2.6.

3. **Penalties for non-compliance with MEPS and Labelling requirements by importers and sellers**

   Another potential source of revenue for the Energy Efficiency Strategy implementation is from penalties assigned for breaches of regulatory requirements. This may include, but is not limited to, penalties for non-compliance with the MEPS and labels scheme, recycling fees for refrigerants outside the incentive program, and non-compliance with recycling requirements.

### 8.1.3 Implementation and management

An overall transition program should result in energy efficient appliances using low and ultra-low GWP refrigerants. For Sudan, this could be achieved with the following components:

- The effective enforcement of the existing MEPS and labels policy with periodic reviews and updating component for the transition to super-efficient appliances,
- An acceleration program for the phase down of HFC-refrigeration gases through taxes on imported refrigerants based on their GWP.
- The administrative component of the set-up of the program and its administration.
- An incentive program for the deployment of super-efficient appliances (refrigerators and ACs) and recycling program for leap-frogging form very energy-inefficient old refrigerators to super-efficient refrigerators. Older, inefficient appliances have been operating for many years (sometimes imported second hand) have energy efficiencies is far behind what modern and ultra-efficient appliances can achieve.

The following section 8.1.4 will explain in further detail the implementation program and its costs. Section 8.1.5 will provide a fund-raising program for financing the costs.

The list of stakeholders engaged in these financial activities are listed in Table 67 below.

*Table 67: Stakeholder's list.*

| Stakeholder | General roles and responsibilities | Task in the financial system |
|---|---|---|
| **Regulator** | | Develops energy efficiency standards and analyze test results to derive energy labels. |
| **National Ministry** | | Proposed issuing authority for MEPS and label certificates to manufacturers and importers.<br>Testing center for RAC appliances<br>Assumption that they will need to test 50 devices per year for the market surveillance.<br>Carry out the market surveillance with shops and refrigerant distributors for illegal imports of appliances and refrigerants.<br>Establish and manage a central online database for market surveillance and the Monitoring, the Review and Verification of measures. |
| **Customs** | | Administer import taxes for cooling equipment and refrigerants based on their energy efficiency and the GWP of refrigerants. |
| **K-CEP?** | | International fund targeting the transition to low carbon RAC appliances. |
| **Other Government Entities? Energy, Environment, Ozone Unit, Revenue?** | | |
| **Industry organizations relevant to cooling? Including Engineering, service providers, Architects.** | | Installers are responsible for appropriate and safe installation, environmentally-sound deinstallation, and proper and energy efficient installation and maintenance of the new appliances.<br>Knowledge of replacement program - marketing and advertisement |
| **Consumer organizations that provide information and support complaints?** | | |
| **Electricity Utilities** | | Support in the implementation of the program. |
| **Manufacturers, Assemblers and Distributors** | Local manufacturers and assemblers of RAC equipment; they will be directly affected by MEPS enforcement | Manufacturers, assemblers and distributors, are bringing the appliances on the market and will be responsible for the registration of the energy efficiency classification of the appliances, which they bring into the market. |

| | | |
|---|---|---|
| | | They will be also responsible for the take back of old appliances and bringing them to environmentally sound recycling centers. |
| **End Users** | Households and other users buying and using RAC equipment. MEPS will have a direct impact on their energy consumption and maybe the cost of equipment | Purchase device, cover investment and operating cost, decommissions old device in case of refrigerators and ACs |
| **Recycling and disposal facility** | | Recycling old appliances and recovery and destruction of HFCs.<br>The recycling and disposal facility receive equipment from retailers or assemblers or services companies. |

### 8.1.4 Costs of a transition program

The costs for the proposed program are analyzed for domestic refrigerators and domestic room ACs within a context of wider energy efficiency actions. Each of the actions below has been broken down to the components to generate cost estimates, but there are potential areas where similar actions from separate components can be done together to reduce costs. The key cost elements include:

1. LACEES Program development and implementation (icl. MEPS). Cost items include:
    a. Program assessment review and update – personnel, consultation, workshops, and training.
    b. Market Surveillance – personnel and training
    c. Testing and verification – premises, equipment, personnel, training, and expert support.
    d. Enforcement – personnel and training.
    e. Promotion and marketing of program – media time, media publications, and the design of the campaign.
2. Fluorinated Refrigerants phase down. Cost items include:
    a. Program design and implementation – personnel, training, and expert support.
    b. Tax/ban administration – personnel and training.
    c. Enforcement – personnel and training.
    d. Reclaim/recycle/destruction of high GWP refrigerants – equipment, personnel, and training.
3. Financing Mechanism development and administration. Cost items include:
    a. Set-up and administration– personnel and training.
    b. Computer systems, databases, etc. – equipment and personnel.
    a. Enforcement – personnel
    b. Promotion and marketing – media time, media publications, and the design of the campaign
4. Incentive for efficient appliances (proposed)
    a. Team is established, responsibilities set, and operating – Personnel, office administration.
    b. Team is trained – training.
    c. Incentive is administered – cost of subsidy.
    d. Promotion and marketing of program - media time, media publications, and the design of the campaign.

#### 8.1.4.1 *Cost assumptions and required funds*

The required funds are estimated through a bottom-up cost analysis. The incentive levels are calculated for each group of appliances, using the assumption that full exchange of all equipment takes place after their average lifetime is reached.

*1. Personnel cost (Table 68)*

- Program manager – Experienced personnel in charge of managing the program.
- Policy – Policy analyst to support with the program development, MEPS policy updates, action plan updates, among other activities.
- Administrators – Personnel to support the general activities of the program.
- MVE Officers – Experience inspection, market surveillance, and verification personnel to assess compliance.
- Testing – Skilled technicians to carry out product testing when needed.
- Marketing and communications – Skilled professionals to develop marketing campaigns and craft messages to facilitate learning and uptake of EE technologies.
- Recycling and refrigerants disposal - Certified technicians to carry out this hazardous task.

*Table 68 - Cost for employment as basis for the cost assumption.*

| Cost Assumptions (USD) | USD/year |
|---|---|
| Annual Salary - Program Manager | 20,000 |
| Annual salary – Policy analyst | 10,000 |
| Annual salary – M&E officer | 10,000 |
| Annual Salary - Associate Admin Officer | 10,000 |
| Annual Salary – Communications and marketing officer | 10,000 |
| Annual office, materials, transport costs for CE, IE | 10,000 |

*2. Equipment cost*

The assumptions relating to equipment involves the implementation of a testing facility for the energy efficiency of refrigerator (RF) and AC units in accordance with the enforcement of a MEPS program and the implementation of a refrigerant and recovery protocol involving several centers across the country. The specifics of the equipment requirements are not discussed in this report, but overall figures are in Table 69.

*Table 69 - Costs of testing center and recycling facility.*

| Facility | Cost and general inclusion |
|---|---|
| **Energy efficiency testing center** | 1,952,000 USD Involves the equipment, lab set up, personnel training, ancillary admin and operations equipment and facilities like offices, computers, etc., based on the quotes from deliverable 3 report. |
| **Refrigerant gas recovery and disposal (destruction) network.** | 3,782,000 USD Refrigerant recovery and reclamation: provision of equipment to establish five reclamation centers; provision of 1000 servicing tools to develop servicing network; carrying out |

| | |
|---|---|
| | 20 training workshops for small servicing workshops; conducting awareness campaign on refrigerant quality (UNEP, 2018). |

An assumption of 10% of the set-up costs is made to cover the annual operations and maintenance of the lab, offices, and staff.

### 3. *Services cost*

Training and expert advice are the key services assumed along with possible IT services required for database implementation and maintenance. The successful execution of a large-scale technology replacement program requires strong technical and policy skills. The requirements assumed are as follows:

1. Activity 1: LACEES Program development and implementation (icl. MEPS)
    a. Training on MEPS Policies, appliance technologies, program implementation, refrigerant disposal policies, and disposal.
2. Activity 2: Fluorinated gasses phase-down
    a. Program design, training on tax policy and tax mechanisms, enforcement options, and the related gas recycling and destruction.
3. Activity 3: Setting up the financial mechanisms that enables gathering revenue from taxing refrigerants and inefficient appliances.
    a. Support program design and training of financial mechanism developments.
4. Activity 4: Implementation of an incentive program for major appliances.
    a. Development of incentive mechanism and training on MEPS, efficiency appliance technologies.

### 4. *Incentive cost*

For the successful deployment of highly efficient appliances, an economic incentive can support consumers overcome the price barrier discussed above. For this study, an incentive on refrigerators and Air conditioners is proposed as they are the major consumers of household energy in the Sudan as well as the most expensive. Considering the average purchase prices of USD 661 and 523 for ACs and refrigerators respectively, an incentive of USD 200 and USD 150 respectively for units in the top efficiency category provided to low-income households. We propose that 200,000 refrigerators and 100,000 ACs per years for two years to introduce the new technologies. This is something that could be repeated each time the MEPS are updated with ambitious new top categories.

### 5. *Overall cost*

When all the activities of the project are added up, the total cost for the program implementation at large scale are summarized in Table 70, where it is clear that the largest cost is the incentive program, for equipment replacement, accounting for 69% of the total implementation cost. The remaining costs are related to staff and administration which are relatively minor compared to subsidies.

It is also important to note that if all activities are implemented as part of a concurrent program, a number of management and administration activities could be merged to generate synergies and reduce costs, although they are small compared to the incentive costs.

*Table 70 - Total cost of program implementation.*

| Total cost of activities | Cost for 9 years |
|---|---|

| | | |
|---|---|---|
| **Activity 1** | LACEES Program development and implementation | 14,283,600 |
| **Activity 2** | Fluorinated gas phase-down | 4,385,600 |
| **Activity 3** | Financing mechanism set up | 400,000 |
| **Activity 4** | Two-year incentive program | 42,237,333 |
| | TOTAL | **61,306,533** |

### 8.1.5 Measures to cover the cost

#### 8.1.5.1 *Levy system*

It is proposed that a levy system in form of custom duties for imported appliances based on their energy efficiency and on HFC refrigerants will be established to re-finance the incentive system. As this system will drive the market towards low GWP refrigerants and more efficient appliances, it can be expected that there will be only a transitory impact on higher appliance prices. The medium to longer term effects will not have a lasting effect on increasing the upfront prices for appliances. The market for appliances is international and very competitive, more energy efficient appliances do not have significant higher upfront costs. The longer effect for the economy and end users will be deflationary with lower life cycle costs, i.e., savings, for the end users and the economy. If HFC refrigerants are replaced by natural refrigerants, equally, the costs of refrigerants will decrease as these refrigerants are not patented, have lower purchasing costs and are less environmental damaging and have superior thermodynamic properties.

*1. Import tax*

The proposed import tax is beneficial to local producers of cooling appliances, as these will not be impacted by the tax. The tax shall be staggered to penalize inefficient cooling appliances and making efficient appliances more attractive. The taxation level is suggested to be set at 5% of the cost of devices with the top energy efficiency rating increasing to 75% in case the device only meets the lowest energy rating for refrigerators or room ACs. The suggested tax levels for each efficiency level are based on the price differentials between each given efficiency level and the most efficient in such a way that the purchase price of appliances at all efficiency levels are similar. This will highlight the value of the reduced energy costs from energy efficiency.

Energy-efficient devices with low GWP refrigerants will therefore only face a low-price increase. High emission cooling appliances will though be burdened twice, at the import as well as through the HFC tax, which will be introduced on the top of the import tax. In addition, the proposed levy will reinforce the introduction of the proposed new MEPS and labelling system for refrigerators and ACs. The tax will impose a strong market push to energy-efficient appliances. Given the high share of electricity consumption of RAC appliances, the proposed tax and incentive system will have a significant impact in lowering the electricity consumption supporting the achievement of the government’s objectives.

The following tables outline the levels of import tax suggested. The suggested taxation levels are based on the equipment’s price. Inefficient devices should not be available at a significantly cheaper price than highly efficient equipment. The customer will benefit from the lower LCC of highly efficient equipment, which should be used as the selling argument.

The risk exists that the proposed tax level will impact the market so strongly that only top labelled products will be imported impacting the possible revenue from the tax to run program. The revenue estimate from the tax on refrigerators is based on sales of 230,000 in 2021 increasing to 613,000 in 2030 with an import rate of 100%. The revenue estimates also assume a worst case (for revenue) that all units imported are in the top energy efficiency scale units to minimize risk of insufficient funds estimation. This resulted in revenues of nearly 11.6 million USD in 2021 and increasing to over 34 million by 2030 as sales appliances increase fast due to increased electrification, economic development, and population growth (Table 71).

*Table 71 - Revenue from domestic refrigeration appliances tax in 2021 (Source: HEAT analysis).*

| Energy classes | Mean unit price [USD] | Import-tax (theoretical) | Import-tax (practical) | Tax revenue per device | Price per unit (USD) | Revenue from refrigerator taxes |
|---|---|---|---|---|---|---|
| G | 460 | 41.30% | 50.00% | 230 | 690 | Assumption: 100% class A devices imported |
| F | 500 | 30.00% | 35.00% | 175 | 675 | |
| E | 530 | 22.64% | 25.00% | 133 | 663 | |
| D | 560 | 16.07% | 15.00% | 84 | 644 | |
| C | 590 | 10.17% | 10.00% | 59 | 649 | |
| B | 620 | 4.84% | 10.00% | 62 | 682 | |
| A | 650 | 0.00% | 5.00% | 33 | 683 | 7,475,000 |

For AC units, the revenue estimates assume 121,000 units sales in the starting year increasing to 430,000 a year with 100% of importation rates. These numbers are conservative and can be updated when market data becomes more accurate. The amount of AC sales is also expected to rise dramatically in decades to come, providing a source of revenue to support energy efficiency and refrigerant actions in the long term. The total tax revenue based on all units being in top efficiency class is 4.2 million USD as shown in Table 72.

*Table 72 - Revenue from AC appliances tax mechanism (Source: HEAT analysis).*

| Energy classes | Mean unit price [USD] | Import-tax (theoretical) | Import-tax (practical) | Tax revenue per device | Price per unit (USD) | Revenue from refrigerator taxes |
|---|---|---|---|---|---|---|
| G | 300 | 66.67% | 75.00% | 225 | 525 | Assumption: 100% class A devices imported |
| F | 330 | 51.52% | 50.00% | 165 | 495 | |
| E | 360 | 38.89% | 30.00% | 108 | 468 | |
| D | 390 | 28.21% | 20.00% | 78 | 468 | |
| C | 420 | 19.05% | 20.00% | 84 | 504 | |
| B | 450 | 11.11% | 15.00% | 68 | 518 | |
| A | 500 | 0.00% | 5.00% | 25 | 525 | 4,200,000 |

It is unlikely that the market will shift to low GWP refrigerants and top efficiency appliances in the short-term allowing for revenues to be gathered for multiyear efforts. However, the combination of the two levies ensures the availability of finds as well as targeting the sources from GHG emissions (energy and refrigerant) from the sector.

### *2. HFC tax*

An HFC tax, which is proposed for imported HFCs on a mass quantity (kg) basis and proportional to its GWP matching the goals of the Kigali Amendment, as Sudan is committed to phase down the import of high GWP HFCs.

The proposed HFC tax is recommended to range between 30 and 70 USD per $tCO_2$-eq. For the most common refrigerants, the tax per kg would be in the ranges shown in Table 73 below.

*Table 73 - Proposed tax options for HFC and HCFC tax per kg at different levels of carbon prices.*

| Refrigerant | GWP | HFC tax: 30 USD/ t $CO_2$-e: Tax [USD/kg] | HFC tax: 70 USD/ t $CO_2$-e: Tax [USD/kg] |
|---|---|---|---|
| HCFC-22 | 1,810 | 54.30 | 126.70 |
| HFC-134a | 1,300 | 39.00 | 91.00 |
| HFC-404A | 3,922 | 117.66 | 274.54 |

| | | | |
|---|---|---|---|
| **HFC-407A** | 2,107 | 63.21 | 147.49 |
| **HFC-410A** | 2,088 | 62.64 | 146.16 |

In total, the collected tax for the HFC-134a, HFC-404A, HFC-407A, and HFC-410A (which are the main refrigerants used in cooling and refrigeration) would range between 20 and 45 million USD per year (Table 74), based on the import numbers from 2019, which is the only year in which disaggregated import data is available. This revenue would help to cover the cost of an incentive system and a RAC program at large. The HFC tax will be paid for HFCs which are imported in bulk to fill the appliances that are manufactured in country, and to refill AC appliances during the regular operations and maintenance of the appliances over their lifetime.

*Table 74 - Estimated yearly tax revenue from HFC-134a, HFC-404A, HFC-407A, and HFC-410A (Source: HEAT Analysis).*

| Refrigerant | Average 2019 [t] | Tax @ 30 USD/t $CO_2$-eq | Tax @ 70 USD/t $CO_2$-eq |
|---|---|---|---|
| **HFC-134a** | 410.84 | 16,022,760 | 37,386,440 |
| **HFC-404A** | 17.76 | 2,089,642 | 2,089,642 |
| **HFC-407A** | 4.24 | 268,010 | 268,010 |
| **HFC-410A** | 33.12 | 2,074,637 | 4,840,819 |
| **Total** | | 20,455,049 | 44,584,911 |

As the HFC measures progress and make an impact on the Sudan market, the revenue would fall over time as low GWP refrigerants become more common (R-290 and R600a). The lower revenue may not be sufficient to support extensive activities. However, as the transition takes hold, extensive activities may not be needed and a transition plan to place attention on energy efficiency and safety will be required.

#### *3. Total revenue from the dual tax*

The overall tax revenue for nine years (until 2030) is over 380 million USD from a conservative perspective (Table 75), meaning using a low 30 USD tax per carbon and assuming the base year market size numbers. Over time, the revenue would be expected to increase on the appliance tax component and decrease on the HFC tax component, balancing out and ensuring sustainability.

*Table 75 - Total revenue estimated over 9 years (until 2030) (Source: HEAT Analysis).*

| | | Revenue for 9 years |
|---|---|---|
| **Revenue 1** | Import taxes for inefficient room ACs | 197,256,389 |
| **Revenue 2** | A tax on HFC imports is legally established and operating | 184,095,439 |
| | **Total Revenue** | **381,351,828** |

### 8.1.5.2 *Baseline carbon credit programs*

The baseline and carbon credit programs refer to the issuing of project-based carbon credits if project measures lead to reducing carbon emissions below a defined baseline. The carbon credits ban be them sold to international buyers that will use them to offset their own emissions. Such projects are also referred to as offset projects and the tradable emission reductions. In principle, the revenue created by these measures are a subsidy for emissions reduction activities and the subsidy is measured by the amount of emission reductions achieved and the market price of corresponding certificates.

A baseline and credit program can be applicable for any situation where the emissions reduction measure is **not** imposed by law. For the cooling appliances discussed in this report, the emission reductions accrued through the switch to low GWP refrigerants and energy efficient appliances could be targeted.  Some of the key international carbon credit schemes are discussed below.

### *1. International baseline and carbon credit schemes*

In the following, the potential of international carbon markets, i.e., the issuing of carbon credits, to finance the measures under the EES in Sudan will be discussed. There are three principal options to consider:

1. Mandatory reductions objectives of industrialized countries under the Kyoto Protocol coordinated by the United Nations Framework Convention on Climate Change (UNFCCC),
2. Voluntary projects, where a variety of registries lay down the rules for participation and private clients purchase emission reduction certificates to reduce their own emissions and
3. Trading of emission reduction units between governments under the Paris Agreement.

Item 1 is the historically most important international systems, the Clean Development Mechanism (CDM) and Joint Implementation (JI), both of which are anchored in the Kyoto Protocol and are supervised by the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). CDM and JI certificates were credited against the reduction obligations of the Parties to the Kyoto Protocol. In Europe, installations subject to emission trading obligations can continue to use CDM certificates instead of European emission rights with restrictions until the end of 2020.

Figure 79 shows the development of project-based greenhouse gas reduction certificates under the UNFCCC and illustrates both the decline in the importance of project-based Kyoto certificates in recent years and the resulting price erosion.

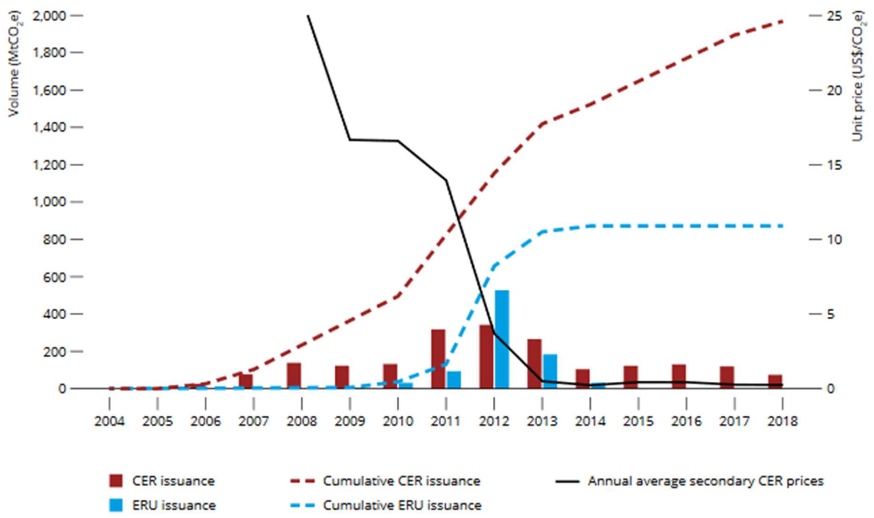



*Figure 79: Issued project-based certificates and their prices under the Kyoto Protocol (CER & ERU) (World Bank, 2019)*

Due to the recent developments and the Paris Agreement, these mechanisms lost relevance. Nevertheless, they are a good showcase for the functioning principle of baseline and crediting systems.

Item 2. Refers to the voluntary carbon market. There are various non-governmental standards for the certification of project-based emission reductions, including mainly Verra[50] (formerly Verified Carbon Standard, VCS) and the Gold Standard. Most of these certificate flow into the market for voluntary $CO_2$ offsetting, but some are also recognized with restrictions in national or sub-national emissions trading systems (e.g., California).

Pricing in this market varies considerably. The World Bank Group's *State and Trends of Carbon Pricing 2019* reports a range of 0.1 USD/t$CO_2$eq to just over USD 70/t$CO_2$eq for credits transacted in the first half of 2018, with approximately half of those transactions taking place at under USD 1/t$CO_2$eq (World Bank, 2019). Many observers expect these prices to increase after 2020, given a noticeable increase in voluntary demand and the potential supply restrictions associated with host countries NDCs. The voluntary market has been comparatively stable, albeit at a much lower level.

Item 3. refers to article 6 of the Paris Climate Agreement, which provides two new market mechanisms for the international transfer of emission reductions. The precise rules of which are still being negotiated. It is becoming apparent, however, that these mechanisms will function at least in part according to the baseline and credit principle and could thus effectively replace the CDM and JI mechanisms of the Kyoto Protocol, with the difference that the transfer of emission reductions will take place directly between governments, which shall eb able to purchase emission reductions achieved in other countries.
However, the future of the CDM post-2020 is uncertain and its role within Art. 6 mechanisms is subject to much debate by negotiating parties. Whether CERs in vintages post-2020 will at all be issued under the Paris Agreement regime and what their price levels would be compared to Internationally Transferred Emission Reductions (ITMOs, Offset Credits under Articles 6.2 and 6.4 of the Paris Agreement) cannot be judged at present.

### *2. Offsetting options for the Energy Efficiency Program of Sudan*

Based on the description above, the only feasible option to use carbon credits substantially under an energy efficiency strategy in Sudan's EES are the carbon credits under Article 6.2 of the Paris Agreement, e.g., within the framework of bilateral agreements between a country like Switzerland and Sudan as host country. For example, Switzerland's newly revised $CO_2$-act is expected to enter into force in 2021 and is currently debated in parliament. The debated version of this new law obliges private companies that import fossil fuels into Switzerland, to compensate for up to 90% of fuel-related $CO_2$ emissions. This shall be done by financing carbon offset projects that meet strict requirements. Within this offsetting scheme it may be possible to develop a replacement program that is financed by the Swiss Foundation for Climate Protection and Carbon Offset KliK to incentivize the usage of low emission appliances in Sudan.

[50] https://verra.org/project/vcs-program/

## 8.2 FUNDING OPTIONS FOR THE ENERGY EFFICIENCY STRATEGY

In its 2021 update of the Nationally Determined Contributions (NDCs), Sudan estimated a BAU increase in the electricity sector of over 10 $MtCO_2$-eq and proposed increased renewable electricity (solar and wind) deployment and energy efficiency and key actions to mitigate this.

This chapter explores the key relevant international climate financing facilities that can possibly support the implementation of the LACEES strategy in Sudan and the integration of these actions into the NDCs and other national policy initiatives.

### 8.2.1 The Kigali Cooling Efficiency Program (K-CEP)

To enable energy efficient and environment friendly cooling in developing countries, K-CEP has been founded. The funds of K-CEP are supposed to help nations to transform their RAC sectors towards more efficient cooling equipment and to shift the production and use of HFCs to newer, climate-safe refrigerants.

K-CEP aims for increased access of efficient and clean cooling and strives to increase the climate and development benefits of the Montreal Protocol, i.e. a refrigerant transition and a simultaneous improvement in the energy efficiency of cooling (K-CEP, 2019).

**Level of funding available**

The financial means of K-CEP are provided by 17 foundations and philanthropists that have pledged USD 51 million and K-CEP plans to use them during the K-CEP Phase I period (essentially 2017 – 2020). On its website K-CEP announced that its seeking fund raising for its second phase, K-CEP Phase II. Phase II funds will equally be targeted on sustainable cooling on a broader scope, going beyond energy efficiency (see K-CEP Year 3 Report[51]).

**Eligibility, focus and application**

All 127 countries listed as A5 Group 1 countries in the Kigali Amendment to the Montreal Protocol are eligible. K-CEP will prioritize support on the basis of emissions reduction potential, cooling market status (e.g., major producers, exporters), policy frameworks, political economy, geographical distribution, and existing initiatives (K-CEP, 2019).

K-CEP will focus on specific cooling solutions. Priority will be given to those solutions with the greatest emissions reduction potential. Air-conditioning will be a major focus, but refrigeration and district cooling will also be considered. The program will seek to identify the most accessible, sustainable cooling solutions, which are expected to include building and urban design solutions and off-grid technologies such as DC fans and fridges.

**Current activities in Sudan**

K-CEP has no current projects directly aimed at Sudan, but with the Phase II K-CEP funding, it is possible to apply for this funding and to support the implementation of an energy efficiency strategy

[51] See here https://www.k-cep.org/year-three-report/

under the final recommendations of this work along and along the zero-carbon cooling guidelines which K-CEP sets out in its Net-Zero Action plan (K-CEP Net Zero Action Table, 2021)

- ***Transition to Passive Cooling*** for new and existing buildings, including the setup of new financing mechanisms and the financial support through multi-lateral, regional and national developing bank.
- ***Transition to Superefficient Appliances*** with multi-lateral, regional and national developing banks and investors increasingly committing themselves in their financing taxonomy dedicating an increasing share of funds to superefficient appliances.
- ***Transition to Ultra-low GWP Refrigerants*** financing taxonomy dedicating an increasing share of funds to ultra-low GWP refrigerants. Similarly, an increasing share of national and international funds (MLF and others) will shift towards the promotion and the financing of ultra-low GWP refrigerants.

### 8.2.2 The Montreal Protocol's Multi-Lateral Fund (MLF)

The MLF is a global fund financing the country implementation programs under the Montreal Protocol. The institutional structure of the MLF was established at the 1990 Meeting of the Parties to the Montreal Protocol in London.

The MLF operates under the authority of the Parties to the Montreal Protocol. The MLF has an Executive Committee comprising seven developed and seven developing countries, which oversee MLF operations. The Fund Secretariat assists the Executive Committee and carries out day-to-day operations. In delivering financial and technical assistance, the MLF works together with the following implementing agencies: UNDP, UNEP, UNIDO, the World Bank and a number of bilateral agencies. The Fund Treasurer is responsible for receiving and administering pledged contributions (cash, promissory notes or bilateral assistance) from industrialized countries (, and disbursing funds to the Fund Secretariat and the implementing agencies, based on the decisions of the Executive Committee (Multilateral Fund, 2019).

The MLF finances activities that are carried out by four implementing agencies: The United Nations Environment Program (UNEP), the United Nations Development Program (UNDP), the United Nations Industrial Development Organization (UNIDO), the World Bank and bilateral agencies. These four UN agencies and the bilateral agencies have contractual agreements with the Executive Committee and are present as observers at Executive Committee meetings and at the Meetings of the Parties.

Any Party that is a developing country and whose annual calculated level of consumption of the controlled substances in Annex A of the Montreal Protocol is less than 0.3 kilogram per capita is referred to as an Article 5 country to the Montreal Protocol. Article 5 countries may receive assistance under the Multilateral Fund. Currently over 120 countries hold Article 5 status. Being a A5 Group 1 country, Sudan is eligible for MLF funding.

**Level of funding available**

The MLF has channeled several billion dollars to developing countries to facilitate compliance with the Montreal Protocol. The Executive Committee approved a total of USD 33.6 million for projects for immediate implementation of the HFC phase-down (Climate Finance Advisors, 2019; Multilateral Fund, 2019). UNEP, UNDP, and UNIDO are multilateral implementing organizations supporting Sudan for implementing its working program under the Montreal Protocol. UNIDO specially has supported the HCFC phase-down management projects (HPMP) with MLF funded projects for several years and is now supporting initiatives on HCF alternatives (Document: UNEP/OzL.Pro/ExCom/85/17, UNIDO Work Program for 2020). Sudan has ratified the Kigali HFC Phase-Out management plan on 20.12.2018 and has begun the preparation steps for the implementation of the Kigali Amendment the submission of a project in 2020 that looks to raise awareness amongst stakeholders about the objectives of the Kigali Amendment, capacity building among HFC stakeholders and policy makers for adoption of HFC refrigerants regulations and to update ODS legislation.

The level of funding available to developing countries depends on the funding requirements from developing countries (A5 countries) and the funding provided by the industrialized non-A5 countries. The funding requirements are calculated with the assistance of the Technology Assessment Panel (TEAP) of the Montreal Protocol. The TEAP calculates the funding needs mainly on the basis of incremental costs of alternative substances with lower GHG potential regarding the HFC Phase Down targeted under the Kigali Amendment. Currently, the parties to the Montreal Protocol negotiate the replenishment for the Triennium 2021 to 2023. A substantial part of the funding will target the phase-down of HFCs under the Montreal Protocol's Kigali Amendment. TEAP's Replenishment Task Force estimates that funding requirements range from USD376,697,000 to USD808,706,000[52].

**Eligibility, focus and application of MLF funds**

The planned activities for the Phase Down of HFCs, include the transition to low GWP refrigerants with simultaneously enhancing the energy efficiency of appliances and systems, including the following:

- ***Institutional and policy strengthening*** (including the enhancement of MEPS and labels, replacement programs, energy efficiency, and low GWP appliance buyers' clubs).
- ***Training*** (including the training for the improvement of the energy efficiency of the equipment during their lifetime).
- ***Production transition assistance*** (including technical support to convert production lines from HFC systems to low GWP systems).
- ***Compliance assistance***

### 8.2.3 Green Climate Fund (GCF)

The Green Climate Fund (GCF) was set up in 2010 by the countries who are parties to the United Nations Framework Convention on Climate Change (UNFCCC). When the Paris Agreement was reached in 2015, the Green Climate Fund was given an important role in serving the agreement and supporting the goal of keeping climate change well below 2 degrees Celsius by 2050 (Green Climate Fund, 2018).

**Level of available funding - Eligibility, focus and application**

[52] See here https://enb.iisd.org/ozone/ExMOP4-OEWG43/summary

The GCF has currently announced pledges of 10.3 billion USD, with confirmed amounts of 8.3 billion USD[53] and 8.4 billion USD of committed funds[54]. Additional and new resources for climate financing are a major topic during the COP26 negotiations and additional and new funding can be expected for the next years.

Funds available for Sudan from the GCF are available through the following three funding windows:

- ***GCF readiness facility.*** The readiness facility aims at strengthening the institutional capacities, governance mechanisms, and planning and programming frameworks towards a transformational long-term climate action agenda. As such the readiness facility can also be used for the further framing of the EES, their integration into NDCs and, e.g., strengthening the transparency framework for achieving the (sectoral) targets in the heating and cooling sector. The available funds under the readiness facility are 1 million USD per year and country. The GCF gives priority to African countries.
- ***GCF private sector facility.*** The GCF's private sector facility targets the financing of the private sector, primarily through private equity funds and project financing. In the cooling sector private equity fund can for example fund Energy Saving Companies (ESCOs) which in turn invest in energy efficiency projects, e.g., by providing innovative financing models such as cooling as a service financing for energy efficient appliances. About 20% of the committed funds of the GCF are through the private sector facility.
- ***GCF simplified and standard approval process.*** The simplified approval process is for grant applications below 10 million USD in areas with low environmental and social risks. In principle we can assume that the cooling sector has low risk profile. The simplified approval process is less time consuming and has a faster approval and more streamlined approval process than the standard approval process. Both processes are required to meeting the investment criteria of the GCF which are of equal importance (mitigation impact, paradigm shift potential, sustainable development potential, needs of the recipient, country ownership, efficiency, and effectiveness). The mitigation impact for implementing ultra-efficient appliances with ultra-low refrigerants is high. Energy efficient can have a timely impact in achieving 2030 climate targets. In principle the shift to low GWP refrigerants and super-efficient appliance will qualify the required paradigm shift. Sudan can demonstrate country ownership, e.g., through a commitment in enforcing stringent MEPS and labels, levying a tax on high GWP refrigerants, and moving to low GWP refrigerants ahead of the Kigali schedule.

The application process for the GFC readiness facility is through the National Designated Authority (NDA). The application process for the private sector facility, simplified and standard approval process is through an accredited entity with the approval of the NDA. In a webinar in 2020 the GCF outlined the importance of climate action and transformative projects in the cooling sector[55]. So far,

[53] See here https://www.greenclimate.fund/about/resource-mobilisation/irm

[54] See here https://www.greenclimate.fund/

[55] See here https://www.greenclimate.fund/event/gcf-and-unep-webinar-scaling-gcf-projects-energy-efficient-and-climate-friendly-cooling

no project in this area has been approved. GIZ has submitted a concept note for multi-country approach with Ghana, Costa-Rica, and Indonesia as proposed project countries[56].

As a country with a large population and potentially strong demand growth for cooling, Sudan could be a good case for a GCF proposal on cooling.

### 8.2.4 Global Environment Facility (GEF)

The Global Environment Facility (GEF) Trust Fund was established in 1992 at the Rio Earth Summit, to help tackle our planet's most pressing environmental problems. GEF funding to support projects is contributed by 39 GEF donor countries and is replenished every four years.

The World Bank serves as the GEF Trustee, administering the GEF Trust Fund. The Trustee disburses funds to GEF Agencies (World Bank, UNDP and UNEP) and prepares financial reports on investments and use of resources. Furthermore, it monitors application of budgetary and project funds. The Trustee creates periodic reports that contain an array of fund-specific financial information (GEF, 2019).

#### Level of funding available

The current funding of the GEF under its GEF-7 funding is already fully committed. GEF is currently negotiation its GEF-8 replenishing round where the negotiations will likely to be completed at the beginning of 2022.

Sudan has experience with the GEF, participating in three projects, one of which is still underway:

1. Promoting utility-scale power generation from wind energy (2014-2019) – Project received 3.5 million USD in funding to support investment in green energy with a focus to increase access in vulnerable communities.
2. Promoting the use of electric water pumps for irrigation in Sudan (2016-2021) – A 4.3 million USD project to support access to electric pumps to facilitate more efficient and sustainable food production.
3. Promoting the use of electric water pumps for irrigation in Sudan (2019-2023) – A 1.7 million USD project to support the development of policy tools to implement energy efficiency in Sudan.

#### Eligibility, focus and application

GEF funds are available to developing countries and countries with economies in transition to meet the objectives of the international environmental conventions and agreements such as the Vienna Convention for the Protection of the Ozone Layer (Montreal Protocol) or the United Nations Framework Convention on Climate Change (UNFCCC) (Paris Agreement).

The application process for project takes place through the UN implementing organizations (UNDP, UNEP, UNIDO, the World Bank, and the African Development Bank).

Regarding GEF-8, the GEF secretariat has prepared the paper, "Strategic Positioning and Programming Direction" (GEF, 04/2021), which addresses the following areas:

[56] See here https://www.greenclimate.fund/document/green-cooling-accelerating-transition-climate-friendly-and-energy-efficient-air

- ***Energy efficiency and green buildings.*** A new generation of energy efficiency policies and building codes which are in line with NDCs and LTS. The GEF will have a particular focus on social housing and public buildings.
- ***Energy efficiency and financing.*** The scaling up of energy efficiency and financing programs supporting the scaling up of energy efficiency policies through cooling as services contracts, aggregating demand for energy efficient appliances and systems.
- ***MRV and transparency.*** The GEF will support the capacity development of monitoring of policies and green building codes.
- ***Building and cities.*** The GEF will seek strengthening low carbon building, with energy efficient cooling, through nature-based solutions such as green facades and roofs.
- ***Energy efficiency of appliances.*** seek strengthening low carbon building, with energy efficient cooling, district cooling solutions, and super-efficient appliances.
- ***Digitalization and energy management systems.***
- ***Innovative cold chains.*** The focus will be on linkages to food security, water, health, and efficient cooling systems.

As noted above, the GEF-8 will continue address prominently energy efficient and climate friendly cooling solutions. As cooling represents a key component of the carbon footprint of building, the energy efficiency of buildings will be inherently related to the energy efficiency of appliances.

### 8.2.5 Other Funds

**Clean Technology Fund (CTF)**

The Clean Technology Fund (CTF), one of two multi-donor trust funds under the Climate Investment Funds (CIF) framework, promotes scaled-up financing for demonstration, deployment and transfer of low-carbon technologies with significant potential for long-term greenhouse gas emissions savings implementation in renewable energy, energy efficiency, and clean transport in emerging market middle-income and developing economies.

CTF funding is only accessible through Multilateral Development Banks (the World Bank Group, Inter-American Development Bank, African Development Bank, European Bank for Reconstruction and Development and the Asian Development Bank) acting as implementing partners[57].

Although the principal focus of the CTF meets the requirements for climate friendly and energy efficient cooling solutions, the current financing for Sudan under the CTF so far is very limited to only a small financing for 1.25 million USD on a credit line for energy efficiency and renewable energy.

The implementation and approval mechanism of the CTC through a panel of Multilateral Development Banks (MBDs) is relative complex.

[57] See here https://climatefundsupdate.org/the-funds/clean-technology-fund/

# 9 INCLUSION OF THE EES IN SUDAN's NDC AND ROADMAP

In Sudan, in line with many countries, particular in warmer climatic zones, the demand for cooling is a major driver for electricity consumption and GHG emissions. If these emissions are left unabated, they pose a massive threat to sustainable development and a stable climate. The electricity demand in Sudan for cooling and lighting combined with insufficient power supply is a key reason for continuous power outages during hot days.

The EES addresses the effort to ensure that Sudan's need for cooling and lighting is met with energy efficient and climate-friendly technologies. The EES provides a critical guidance to the sector on more sustainable, climate friendly technologies that are less energy intensive.

Under the Paris Agreement, countries are requested to submit updated Nationally Determined Contributions (NDCs) ahead of the 2025 round of NDC revisions. The EES of Sudan could be used to enhance the overall mitigation ambition of Sudan's NDCs, and to strengthen specific implementation strategies targeted under its NDC. With this Sudan can contribute to the substance of its NDC and contribute to the required global effort of raising ambitions for meeting the objectives of the Paris Agreement in meeting the global mitigation requirements and temperature targets. Every 5 years, the UNFCCC conducts a global stocktake to assess the collective progress towards achieving the purpose of the Paris agreement. The guiding principles for NDC revisions are progression and highest possible ambition.

It is recommended that the following key elements and principles are included into Sudan's NDC and are considered for the NDC targets for 2025, 2030 and 2050 as further outlined in the EES roadmap in section 9.3 below. Chapter 5 outlines that against the business-as-usual emissions, the introduction of the measures suggested in the EES will result in emission reduction of up to 12 Mt $CO_2$-eq.

## 9.1 Institutional setup

It is recommended that ERA leads the cross-sectoral and inter-ministerial coordination for integrating the EES into the NDC. As such ERA will have the mandate to adapt the EES systematically and to conduct the outreach to relevant counterpart ministries in order to coordinate the integration of the EES and its recommended actions and measures into the NDC.

## 9.2 Integration of F-gas phase down

The 2016 Kigali Amendment to the Montreal Protocol mandates an F-gas phase-down, which entails a freeze from 2024 and phase-down schedule from 2029. Therefore, the climate benefit from the F-gas transition will accrue reasonably close to the 2030 timeframe of NDC targets. However, Sudan did not include F-gas phasedown actions or Kigali Amendment commitments in its initial NDCs, and it is worthwhile for Sudan to include their plans for compliance in their NDC revision, consistent with recommendations on cooling and lighting efficiency measures as suggested in this EES. It is suggested in the EES, particular, in the outline of the funding and incentive system in Chapter 8, that the HFC-phase down of the Montreal Protocol's Kigali Amendment, is linked to the targeted energy efficiency improvement programme. Specifically, that the proposed levy on HFC is raised to accelerate the phase down of HFC and to provide the funding of the proposed MEPS and label programme.

## 9.3 Roadmap and sectoral integration into the EES

It is recommended that the EES targets, as outlined in Table 76, are referenced in Sudan's updated NDC. This includes sectoral targets relevant for cooling energy, building, industry, waste, transport and agricultural sectors. The classification of these sectors follows the categorisation of sectors according to the IPCC methodology for the national reporting of GHG emissions.

Key measures in the **energy sector** are the introduction of mandatory MEPS and labels as outlined earlier, initially for the 5 in-scope subsectors, later extended to all cooling, refrigeration and domestic electrical equipment. The introduction of energy efficiency labels for cooling/refrigeration and lighting appliances will allow end-users to identify higher-performing products and can be paired with procurement and incentive programs or inform the specifications of buyers' clubs. Such information is currently hardly available in Sudan. It is recommended, that along the introduction of MEPS and labels, a compliance and testing programme will be established. The programme will safeguard that energy inefficient appliances, that do not comply with national energy performance standards, from entering the market. These programs will require coordination between ERA and SSMO. The EES further recommends an import levy based on the energy efficiency label of imported appliances. For products being imported, this is a key factor to avoid sub-standard products entering the market. Environmental dumping of sub-standard appliances by manufacturing countries (which may have higher domestic standards) must be safeguarded against. Relevant regional trade alliances can be considered, i.e., in coordination with neighbouring countries such as Egypt, Kenya, etc.

In the **industrial/manufacturing** sector, the EES recommends the retooling of appliance manufacturing lines for local manufacturers and/or assemblers to comply with the refrigerant transition and to redesign cooling appliances, mainly refrigerators, to reach or exceed the recommended MEPS. Further, the EES recommends measures for the accelerated phase down of HFCs, ahead of the targets under the Kigali Amendment. The proposed levies on imported HFCs will be used to finance the transition to climate friendly and energy-efficient systems using low GWP refrigerants. According to the methodology established under the IPCC, F-gas emissions are categorized under industrial or manufacturing sector. Technicians in the RAC sector should be qualified and certified dealing safely with low GWP and flammable hydrocarbon refrigerants or, alternatively, low GWP but high-pressure $CO_2$ or dealing with toxic Ammonia refrigerant.

In the **agriculture and food sector**, measures include the deployment of energy efficient refrigeration systems using low GWP refrigerants. Efficient clean cold chains are important for reducing food loss and waste, as well as losses in other products which are temperature sensitive. Every stage of the food cold chain which is mechanically cooled should be efficient and use low-GWP refrigerants, from cold warehouses storage to refrigerated transport, to warehouses and supermarket cooling. Where possible, cold storage should be renewably powered. Alternative cooling technologies and reducing the need for cooling.

In the **building sector**, the typical building in Sudan uses about half of its energy consumption on cooling. Tighter and better insulated buildings will allow gradually to lower the cooling demand. Passive house standards, as an integral part of the EES, should become the mandatory standard for new buildings and, also, increasingly with increased renovation rates for the existing building stock. Measures such as cool roofs and pavements, and greening of urban spaces, can reduce urban temperatures by up to 4˚C. This reduces the number of cooling appliances needed, as well as reducing the amount of time they need to be running, saving indirect emissions from electricity use.

Mandatory, energy-efficient building codes and building retrofit plans are a key policy tool for minimizing cooling and lighting loads. Recommended buildings standards are included in the recommend roadmap in Table 76. Additional measures include the installation of smart thermostats reduce electricity demand and there are even battery storage technologies which can interact with the electric grid to shift load peaks from ACs.

Thermal energy storage is another way to shift load peaks, where cold is stored at low-demand times (e.g., at night) and used to offset AC needs during the heat of the day. These systems can be paired with renewables such as rooftop solar.

Table 76 summaries the above-described measures in the form of a national energy efficiency roadmap with sectoral milestones.

*Table 76: Recommended roadmap milestones for the EES implementation.*

| Feature | Status (2020) | 2024 | 2030 | 2050 |
|---|---|---|---|---|
| **Cross-sectoral financing** | No or limited dedicated incentive programs for cooling appliance | • Import levies based on energy consumption of appliances and their labels<br>• Import levies based on GWP content of refrigerants<br>• Carbon credit programme to finance take-back system | Continued | Continued |
| **Energy** | No mandatory MEPS and labels for appliances | • Mandatory MEPS and labels for cooling, refrigeration and lighting appliances according to the recommendations of the EES<br>• Compliance and spot testing of MEPS and labels<br>• Ban on import of second-hand appliances | • Mandatory MEPS and labels for commercial refrigeration and AC systems (alignment with U4E model standards)<br>• Updated MEPS and labels for domestic refrigerators and ACs | Increasingly ambitious MEPS and labels |
| **Buildings** | No-mandatory building standards | Target building standards (e.g., < 150 KWH/$m^2$); Improved tightness and insulation standards; Cool rooftops for >50% of new buildings | Target building standards (< 100 KWH/m2); Cool rooftops and/ or solar for all new buildings and 50% of old buildings; | Target building standards (< 50 KWH/m2); Cool rooftops/ rooftop solar for all buildings; |
| **Industry/ Manufacturing** | F-gases: No/limited restriction on F-gases; | • F-gases: Levies on F-gases based on EES;<br>• Ban for F-gas use on appliances with ready alternatives: refrigerators; < GWP 10 ACs; < 1000 commercial AC and refrigerator<br>• Manufacturing: incentive climate friendly and energy efficient design<br>• Mandatory certification and registration for all cooling/refrigeration technicians | • F-gases: Increased levies<br>• Ban for F-gas use on appliances with ready alternatives: refrigerators; < GWP 10 ACs; < 1000 commercial AC and refrigerator<br>• Mandatory certification and registration for all cooling technicians | • F-gases: Phase out of HFC; HFC limits < GWP 10<br>• Mandatory certification and registration for all cooling technicians |
| **Transport** | No/ limited cooling standards | >25% of new vehicles with AC or refrigeration systems with refrigerants < GWP10 | >55% of new vehicles with AC or refrigeration systems with refrigerants < GWP10 | >75% of new vehicles with AC or refrigeration systems with refrigerants < GWP10 |

| | | | | |
|---|---|---|---|---|
| **Waste** | No or limited recycling of cooling appliances & recovery of refrigerants | Establishment of a central recycling facility, establishment of a take back programme | Achieving > 80% recycling quota for all mass cooling appliances; environmental sound destruction of refrigerants and foam blowing agents | Achieving > 90% recycling quota for all mass cooling appliances and destruction of refrigerants and foam blowing agents |
| **Agriculture and food** | No cold chain standards | 25% of all cold stores with renewable power and integrated cooling appliances | 50% of all cold stores with renewable power and integrated cooling appliances | >75% of all cold stores with renewable power and integrated cooling appliances |

# 10 STRATEGY AND RECOMMENDATIONS

The EES is the overarching approach covering an integrated approach on regulatory, technical, environmental and operational matters. It's an important step in order for Sudan to contribute towards the targets of the Paris Agreement and the Kigali Amendment of the Montreal Protocol. The underlying rationale for Sudan's Energy Efficiency Strategy includes the following considerations:

- Increased Energy Efficiency has been an important side benefit of the Montreal Protocol through two previous transitions of refrigerants over 30 years. There are many opportunities to achieve improvements in EE during the transition to low GWP refrigerants,
- Demand for RAC equipment is increasing rapidly,
- EE aspects require additional training and further awareness,
- Some EE degradation over the lifetime of equipment is inevitable; improved design and improved servicing (installation and maintenance) limits degradation,
- The impact of proper installation, maintenance, and servicing on the efficiency of equipment and systems is considerable over the lifetime of these systems while additional cost is minimal,
- Appropriate maintenance and servicing practices can reduce up to 50% reduction in performance and maintain the rated performance over the lifetime,
- MEPS and labels can be a powerful and cost-effective instrument for pushing the market towards higher-efficiency products by removing inefficient equipment from commerce,
- MEPS can work together with labels and other incentive programs, such as rebates, to "pull" the market towards more efficient technologies,
- MEPS will push manufacturers to improve the efficiency of their products.

## 10.1 The current situation in Sudan

As Sudan does not have a MEPS system in place, appliances in use have lower energy performance compared to international good practice and the more advanced developing countries. Similarly, there is no uniform labelling system established in Sudan and end-users are lacking clear guidance to energy-efficient appliances. Importers, resellers, and manufacturers have little incentive to place more energy-efficient appliances on the market, as un-informed end-users tend to purchase the appliances with the lowest up-front price.

One of the key reasons for the lack of MEPS and labelling systems is the limited institutional capabilities for the introduction of effective such systems. There are no national laboratories for the energy performance testing of the in-scope appliances. The installation of national labs for energy performance testing is recommended for effective market surveillance to ensure that the proposed MEPS and labels are correctly applied. Besides the labs, it will be important to establish the required institutions and personal capacities for the effective implementation of the system.

Currently, there is no central product database established with shared information among the relevant institutions and stakeholders on key data for approved appliance (including the relevant performance data, label, refrigerant, annual sales, etc.).

## 10.2 Electricity Regulatory Authority (ERA) – Leadership focal for all energy efficiency activities in Sudan - (DEL4-T6-Act6.2)

The Electricity Regulatory Authority (ERA) was established in accordance with the Electricity Act (2001) under the direct supervision of the Minister of Energy and Oil. The ERA has been developed over the years until it has had its current complete form. Figure 1 shows the up-to-date organizational structure of the ERA.

### 10.2.1 ERA's role

The current role of the Electricity Regulatory Authority is to:

1. Prepare the general policies and rules pertaining to the generation, transmission, and distribution of electric energy, and submit them to the Minister for approval,
2. Organize and control activities, relating to generation, transmission, and distribution of electric energy, in consultation and coordination with the bodies concerned, subject to the government strategies and the policies in the field of electric energy,
3. Provide technical advice, to the governmental departments, in matters relating to the electricity industry,
4. Help persons and bodies desirous of investment in the field of electricity in obtaining the licenses for exemptions, facilitations, and lands necessary for the business thereof, in coordination with the bodies concerned with investment,
5. Recommend the appropriate prices of electric energy to the Minister for approval,
6. Lay down specifications patterns and technical standards for equipment, plants, and machinery for securing unification of electricity standards and system, in the Sudan,
7. Specify conditions and issue the necessary instructions, in consultation with the concerned bodies, which have to be satisfied by electricity utilities and companies in electrical constructions for public safety, operation & maintenance, and other electrical works.

### 10.2.2 ERA's role in the energy efficiency project's implementation

The ERA, with its current position in the Sudan Energy Efficiency of Appliances and Lighting (SEEAL) project, is eligible and shall continue to be the focal point of the project strategic implementation plan. ERA, with its originated foundation responsibilities and organizational structure as well as its involvement in the energy efficiency project, has gained broad experience, is qualified to assume this role. Therefore, we propose that a specialized functions unit shall be formed under the umbrella of the ERA to act as a focal point to implement the energy efficiency project strategies. This unit shall take full authorities and responsibilities to lead the coordination activities in the energy efficiency project implementation work plan. The success of this proposed approach requires careful designation of the governmental and nongovernmental entities (partners/stakeholders) that shall be involved in the work. Government's entities include Sudan Electricity Holding Co. (SEHC) and its subsidiaries companies, SSMO, Customs Authority, and the Commission of Tax. The nongovernmental bodies include Electric Appliances Importers and/or manufacturers Unions, Consumer Protection Authority, and the Services and Changes Committees. These partners shall work collectively in collaboration to achieve the strategic goals elaborated in the energy efficiency project that led to realizing the country national security and interests. The mandates, roles, and responsibilities of each and every entity shall be clearly identified and spelled out in laws and regulations. It is of great importance that these entities shall meet, with good representation and clear purpose, in workshops and training sessions to streamline the work and mitigate any cross functional issues that may occur during and after the implementation processes.

The ERA's role and responsibilities of the energy efficiency project, as mentioned above, shall be assigned to the proposed ERA focal point. These commitments dictate the need for generous financial support and highly qualified and skilled human resources. In this, to achieve the former, we propose means for financial funds. The ERA's energy efficiency project focal point shall initially and continuously be funded by the government through the ministry of energy and oil. The ministry of energy and oil can be relieved from funding when the energy regulatory authority, with broad mandates and responsibilities, is formed and got an independent status. During the energy efficiency strategic implementation extra funds shall be sought from other means. These include, but not limited to, funds that can be collected or received from; (i) issuing energy efficiency compliance certificates, (ii) testing laboratories fees, (iii) approving, per energy efficiency compliance, import and/or manufacturing licenses, (iv) imposing noncompliance energy efficiency penalty fees, (v) portion of high customs fees to deter the importation of less efficient, but permissible, electrical appliances, (vi) united nations organizations that work in the energy and/or environment sectors, and (vii) the World bank. The staff of the ERA's focal point that are responsible for the energy efficiency project shall be put under customized and intensive trainings and workshops programs. A roadmap shall later be drawn to formulate the capacity building programs of the ERA's focal point personnel. The needs of these capacity building programs shall be identified by a team of consultants and be approved by ERA

### 10.2.3 Key accomplishments

ERA's roles and responsibilities involve the followings activities and accomplishments:

1. Prepared and amended the electricity generation, transmission, and distribution licensing bylaws and submitted them to the Minister for approval,
2. Introduced, e.g., in 2018 ERA, new items that serve energy efficiency in the electricity and renewable energy acts, to improve the performance of the services provided in the electricity sector. The aim of these acts is to promote free competition and creating opportunities and conditions that attract investments,
3. Conducted a study on the cost and tariff of electricity, introducing technical rules of the network (codes), and standard specifications,
4. Initiated and prepared, in cooperation with the Global Environment Facility (GEF), a project to develop the Sudanese market strategy for high efficiency electrical equipment. The project was drafted, under the UNDP supervision, to establish an energy efficiency strategy in Sudan. This consultancy work is the core of the project: "Sudan Energy Efficiency of Appliances and Lighting (SEEAL)".
5. Engaged in a partnership and still working in close collaboration with SSMO in adopting the IEC standards and preparing and issuing electric power supply and national electric appliances standards.

### 10.2.4 The Legal Status

The legal status of the Electricity Regulatory Authority states that ERA shall be an independent entity that carries out the activities and tasks mentioned above. The law shall guarantee the necessary powers to perform its work in a manner that ensures the interests of the consumer. The law on the role of the body as a reference authority to ensure a balanced relationship between the interests of consumers and the parties of the electricity utilities and investors. However, this isn't the case. Because ERA is currently ruled and governed under the umbrella of the ministry of energy and oil, it doesn't have the power to exercise its full capacities stated in its establishment laws.

### 10.2.5 Summary and Recommendations

The above shows that ERA - Sudan:

- Is a well-formed body that is working diligently to meet its stated objectives,
- Covers most of its functions in its current status, mainly, on the consumers part,
- Limited accomplishments on the electricity utilities side (electricity generation, transmission, and distribution).

As its law states, ERA shall be an independent entity that carries out activities and tasks to meet its main objectives. We do recommend a leadership position for ERA for all energy efficiency related matters. In that sense we recommended to:

1. Take ERA out of its current position in the ministry of energy and oil and to assume a new legal national body reporting to the office of the Prime Minister.
2. Change the so specific and limited "**Electricity Regulatory Authority**" be reformed, keeping the same abbreviation, to a more general and inclusive "**Energy Regulatory Authority**". The electricity regulatory authority is most likely the qualified entity in the country to expand to the broader energy activities e.g., MEPS and labels for electrical appliances. This will not only enable it to build on the experience of its technical and administrative professional human resources, but also to serve other important energy sectors.
3. A well-organized coordination between the new proposed "**Energy Regulatory Authority**" and others energy-related public and private sectors should be formulated.

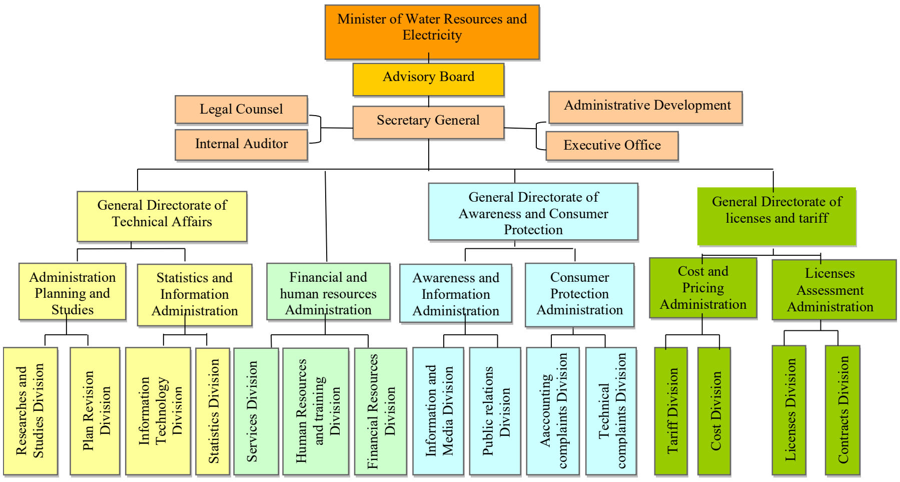



*Figure 80:Organizational Structure of the Electricity Regulatory Authority – Sudan[1].*

[1] The ministry in charge now is: The Ministry of Energy and oil.

## 10.3 Implementation of a MEPS and labelling system

The following points provide a list of activities for the timely implementation of a MEPS and label system in Sudan:

1. Adoption of **mandatory safety and energy testing standards**. These standards are greatly advanced compared to the previous standards and are adopted quickly by a growing number of countries and manufacturers.
2. Adoption of a **mandatory MEPS** levels as detailed in chapter 5 for the 5 in-scope subsectors together with a clear timetable for introducing and updating these MEPS and labels:
   a. For **domestic refrigerators**: two tier efficiency levels based on the U4E Model Regulation metrics, R = 0.63 in 2024 and R=1 in 2027
   b. For **domestic room ACs**: three tier Seasonal Efficiency levels based on the climate 0B from the U4E Model Regulation (CSPF), with a CSPF=2.5 in 2024, a CSPF=3.1 in 2026 and a CSPF=3.7 in 2028
   c. For **evaporative air coolers**, the recommended MEPS and labelling levels are in Table 77.

*Table 77: Recommended MEPS and labels for EACs.*

| EER | Category |
|---|---|
| >65 | A |
| Between 58.5 and 65 | B |
| Between 52 and 58.5 | C |
| Between 45.5 and 52 | D |
| Between 39 and 45.5 | E |
| Between 32.5 and 39 | F |
| Between 26 and 32.5 | G |

d. For the **lighting** sectors we recommend a ban of incandescent lamps as soon as 2022, together with a MEPS level and years of applications as shown in the Table 78 below.

*Table 78: Proposed lighting MEPS.*

| Minimum efficacy levels (lm/W) | Bulb efficacy (lm/W) | Linear lamps efficacy (lm/W) | Street lighting luminaire efficacy (lm/W) |
|---|---|---|---|
| years 2024-2025 | ≥ 50 | ≥ 70 | ≥ 90 |
| years 2026-2027 | ≥ 70 | ≥ 90 | ≥ 110 |
| years 2028-2029 | ≥ 110 | ≥ 130 | ≥ 140 |
| years 2030-2031 | ≥ 125 | ≥ 145 | ≥ 160 |
| years 2032 | ≥ 140 | ≥ 160 | ≥ 180 |

The recommended labelling tiers are per the Table 79.

*Table 79: Labelling tiers for the lighting sector.*

| Levels | bulb | linear | street |
|---|---|---|---|
| Tier 1 | ≥ 160 lm/W | ≥ 180 lm/W | ≥ 200 lm/W |
| Tier 2 | ≥ 150 lm/W | ≥ 170 lm/W | ≥ 190 lm/W |
| Tier 3 | ≥ 140 lm/W | ≥ 160 lm/W | ≥ 180 lm/W |
| Tier 4 | ≥ 125 lm/W | ≥ 145 lm/W | ≥ 160 lm/W |
| Tier 5 | ≥ 110 lm/W | ≥ 130 lm/W | ≥ 140 lm/W |
| Tier 6 | ≥ 70 lm/W | ≥ 90 lm/W | ≥ 110 lm/W |
| Tier 7 (MEPS) | ≥ 50 lm/W | ≥ 70 lm/W | ≥ 90 lm/W |

Electricity consumption for lighting is subject to natural increase due to higher electrification rate of the country in the coming years, projected to be 22 TWh in 2050. MEPS enforcement will help mitigate that increase by 2/3 in 2050, keeping the overall consumption for lighting at 7.3 TWh per year, representing a power saving of 4,882 MW. It will also lead to mass adoption of LED products meeting the international standards. the recent increase in the electricity tariffs will reduce the government incentives, shifting to LED is a quick win for consumers as well as for the government budget due to saved subsidies.

e. MEPS (tier 7) and tiers values for **comfort fans** are recommended per Table 80.

*Table 80: MEPS and tiers values for comfort fans.*

| Minimum Service Value (m3/min/W) | Stand fans | | Ceiling fans | |
|---|---|---|---|---|
| Sweep diameter | < 500 mm | ≥ 500 mm | < 1 200 mm | ≥ 1 200 mm |
| **Tier 1** | ≥ **2.5** | ≥ **3** | ≥ **5.1** | ≥ **6** |
| Tier 2 | ≥ 2.3 | ≥ 2.8 | ≥ 4.6 | ≥ 5.5 |
| **Tier 3** | ≥ **1.65** | ≥ **2.65** | ≥ **4.1** | ≥ **5** |
| Tier 4 | ≥ 1.15 | ≥ 1.7 | ≥ 3.6 | ≥ 4.5 |
| **Tier 5** | ≥ **1.08** | ≥ **1.65** | ≥ **3.1** | ≥ **3.45** |
| Tier 6 | ≥ 0.95 | ≥ 1.43 | ≥ 2.93 | ≥ 3.32 |
| **Tier 7** | ≥ **0.9** | ≥ **1.3** | ≥ **2.79** | ≥ **3.15** |

For fans, MEPS enforcement represents 52 % of energy saved by 2035 and 66 % by 2050 compared to the Business-as-Usual scenario. MEPS and labels are proposed for the next 15 years based on the MEPS and label from the main countries of origin. Compared to the BAU scenario, MEPS enforcement will compensate the growing fans' electrical demand caused by the growing number of households.

3. Identifying **ERA**, in a leadership role, as the national body for setting and coordinating the National Energy Efficiency Strategy for Sudan.
4. Identify **SSMO** as the national agency for equipment's certification and market monitoring and enforcement (MVE).
5. It is recommended to establish a **national certification scheme for service technicians**. Such curriculum to include information on MEPS, labels, proper maintenance of appliances to keep up with high energy efficiency levels and the proper handling of low GWP, flammable refrigerants. The training could be integrated into existing training schemes such as the HPMP trainings.
6. Establishing an effective **product registration and market surveillance mechanism**:
    a. Adopt a national product database for RAC and lighting appliances, whereby manufacturers and importers register their appliances and report their annual sales.
    b. Grant access to the database to the relevant government institutions for market monitoring and surveillance.
    c. Upgrade the capacity of customs controls on the import of appliance below the future MEPS level and to ban and control the import of second-hand appliances. The training of customs officers could be linked to any running activities under the HPMP.
7. Establish a **working group**, within SSMO's relevant Technical Committee, that would meet bi-annually and discuss any amendments or improvements to standards.
8. Develop **financial support mechanisms**, for manufacturers and end-users, supporting energy-efficient appliances.
9. Develop national **awareness campaigns** and Green Procurement schemes to accelerate the market penetration of EE appliances with low GWP refrigerants for the cooling and refrigeration appliances.
10. In the relevant sectors, it is recommended to technically support local manufacturer to upgrade their **testing capacity** to comply with the new energy efficiency testing standards and requirements.
11. From the above-mentioned product database, relevant information should also be made **available to the public**, e. g. comparative information on the upfront prices and the LCC of appliances through a central internet portal or mobile apps.

## 10.4 Off-grid lighting

Off grid lighting devices are disconnected from the electricity grid and are not consuming electricity of the national network. Those lighting products are autonomous using renewable energy, it consumes the electricity collected during the day by photovoltaic panels and stored in batteries.

According to Lighting Global, an initiative from the World bank, about 789 million people worldwide live without access to affordable, reliable, and safe modern energy. The majority of those living without modern energy services rely on kerosene, candles, battery torches, or other fossil fuelpowered technologies for lighting. These traditional solutions are expensive, harmful to health, hazardous and polluting, and can't power communication technologies. They resign the poorest people on the planet to a life of energy poverty which constrains economic development and impedes access to education, health, and basic services including communications, water, and transportation.

Off grid lighting could be of particular interest for Sudan where the electricity demand is particularly high compared to the existing power capacity and where the natural irradiation is high. Moreover, off grid devices are not subject to electricity fluctuation of the grid. Indeed, with the development of LED lighting and progress in the battery technologies and management, off grid lighting could be considered as a valuable replacement of on grid lighting.

Two types of off grid lighting products are nowadays widely used: pico solar lighting for domestic application and street lighting poles for public spaces.

**Pico solar lighting**

Pico solar products are portable system that produces light using LED and solar energy. Most of the products have the option of mobile charging through an appropriate connector. Hence those products have:

a. A photovoltaic solar panel capable of charging an energy storage device,
b. a battery as an energy storage device,
c. one or several LED lamps or modules as loads,
d. as optional, a connector for mobile charging,
e. a peak power rating of 10 Watt or less.

Figure 81 represents a typical pico solar with three LED bulbs.

*Figure 81: SHENZHEN LEMI TECHNOLOGY DEVELOPMENT CO., LTD. - MODEL: LM-LI010.*

One may ensure that the system is reliable and well designed, i.e., the solar panel is able to collect sufficient electricity, the battery is able to store and restore a sufficient quantity of electricity, and the LED light efficiency is sufficient to provide the required amount of light with the restored electricity.

The Lighting Global initiative proposed a Lighting Global Quality Standards for pico-solar products. In January 2020, Lighting Global, CLASP, and the Schatz Energy Research Center launched VeraSol, an independent quality assurance program ready to respond to the market's growing needs. Verasol proposes an updated version of that quality standard.

**Solar street lighting**

Autonomous solar systems represent a formidable tool for economic and social development, which is addressed to rural areas without access to electricity, peri-urban areas where the electricity network is absent or intermittent or urban for the sake of energy savings.

Quality of life can be strongly improved in remote areas:

- Better safety for mobility and decrease the number of accidents,
- Better safety of people, especially women at night,
- Improve social connection at night,
- Support the economy activity through the increase of possible hours of activity or even the possible provision of additionally potential money-making services (phone charging…) by stocking electricity in the batteries.

Solar street lighting poles represents a big opportunity for Sudan. A solar lighting installation should be carefully designed with different stakeholders, to assess the need and the feasibility. The system should also be carefully designed so that it takes into account local conditions like dust and heat.

Photovoltaic panel: it should be able to collect sufficient energy during a day to stock in the battery to allow the LED luminaire to provide the light during the night. It depends on the irradiation, on its surface and on its efficiency.

In Sudan, for example, the city of Dongola, the horizontal daily solar irradiation is in average 5 $kWh/m^2$ in December. A solar panel of 250 Wc is able to produce the electricity needed for supplying an 80-Watt LED luminaire during two consecutive nights of 8 hours (considering one cloudy day, without enough sun to reload the battery).

Battery: three main types of batteries are used for autonomous street lighting pole, lead batteries, nickel batteries (NiMH) and li-ion batteries (LiFePO4). Lead batteries are not recommended due to their low acceptable depth of discharge leading to oversized batteries or short lifetime. Moreover, lead has a strong negative impact on environment. Keep in mind, those batteries, whatever technology is used, should be collected and recycled appropriately at the end of their useful life.

LED luminaire: LED luminaires for solar street lighting poles are usually more efficient than traditional ones since the control gear does not need to convert the alternative current into direct current to supply the LED. On can reasonably expect an efficacy of 130 lm/W.

**Conclusion**

Solar lighting represents a great opportunity for Sudan, in the residential and public lighting sectors. It is an off-grid lighting and is pertinent in remote areas where there is no or limited access to the national grid. Use of solar lighting could be a complement for the electrification of the country.

## 10.5 Financing the market transformation

Financial mechanisms increase the market share of efficient, clean technologies, displacing the purchase of inefficient and climate-polluting appliances and so helping to reduce emissions. By making efficient appliances more widely affordable, they also increase access to cooling and provide the associated development benefits.

The EES proposes an incentive and financing scheme on transformational changes for a low carbon pathway for the RAC sector in Sudan. These schemes incorporate national and international funding and financing sources to move towards affordable and highly energy-efficient appliances and systems as supported by the targeted introduction of a MEPS and labelling system, the transition to low GWP refrigerants, the exchange of old and inefficient appliance, their environmentally sound recycling, and the replacement to top labelled energy-efficient appliances.

The outlined incentive system has been proposed in a way to be financially viable and that the available cost of the program will be sustainable covered through the identified funding and financing options.

### 10.5.1 Incentivizing the market introduction of low emission appliances

The funding mechanism is based on (1) a proposed energy consumption related import levy for refrigerators and room AC as the most used cooling appliances in the country and (2) an import tax on the import of HFC refrigerants based on their GWP weight.

Both the energy consumption-based import levy and the HFC import tax will fund or co-fund the administration and the monitoring, verification and enforcement (MVE) of the energy efficiency incentive systems.

The effects, of increased energy efficiency, for the country, will result in further benefits such as shifting off-peak demand, reducing power outages, lowering subsidies and allowing Sudan to meet its NDC targets or enhancing its NDC targets. The proposed HFC tax will provide an incentive to replace high GWP refrigerants even before the Kigali Amendment's reduction path kicks in.

The replacement program, which will increase the price of inefficient equipment and high GWP HFCs, as well as incentivize the proper disposal of decommissioned appliances will create regulatory, managerial and marketing efforts, which need to be covered. Further, the cost of the incentives provided during the course of the nine-year program, will accrue as shown in the following Table 81.

*Table 81: Cost overview.*

| Activity | Cost (USD) |
|---|---|
| **Regulatory implementation and management of the replacement program** | 4,153,000 |
| **Awareness creation and marketing** | 1,072,000 |
| **Replacement program implementation (Payment of incentives)** | 5,279,000 |
| **Installation of a disposal and recycling facility** | 177,000,000 |
| **Total cost** | **187,504,000** |

Funds to cover the cost outlined in Table 81 will primarily come from the collected HFC tax and the import tax. These funds will sufficiently cover the cost, as shown in Table 82.

*Table 82: Overview of annual revenues.*

| Annual revenues - USD | |
|---|---|
| **Import taxes** | 155,678,667 |
| **HFC tax** | 250,656,960 |
| **Total annual revenue** | **406,335,627** |

For the recycling and disposal facility, a baseline and carbon credit program had been proposed as an additional measurement for the funding of a take-back, replacement and environmentally sound recycling. If the baseline and carbon credit program is designed in a way that the disposal of HFC's at the end of their useful life are targeted, the carbon credit program will be additional and strongly supporting the environmental integrity requested under the market mechanisms of the Paris Agreement. The carbon credit proceeds can be sufficient to finance or at-least co-finance the operational cost of a recycling and disposal facility.

The proposed funding scheme will support the EES's objective of bringing the RAC sector on a low carbon pathway.

### 10.5.2 Funding EES integration into the NDC

The EES implementation could be financed through the GCF. At the 25th Conference of the Parties in Madrid, the GCF announced its updated funding budgets, and that the introduction of low carbon cooling solutions is one of their goals. We hence recommend preparing a GCF proposal for the EES implementation, which could cover the initial funding needs of the set-up of the proposed tax and incentive system. For the development of such a GCF proposal, the proposed tax and incentive scheme needs to be refined in close collaboration and agreement with local stakeholders. Funding for this intermediate step could be provided through the GEF, already very active in Sudan[58] or the K-CEP NDC facility, where under a competitive process, Sudan can apply for funding for the implementation of GHG mitigation measures under its NDC in the cooling sector.

### 10.5.3 Implementation options

The proposed funding scheme will strongly push the deliverable of the EES, bringing the RAC sector on a low carbon pathway with multiple-co benefits. It is suggested to fully integrate the EES into the NDC, with a comprehensive financing package including supporting sources from GEF, GCF, etc. complementing national co-funding with the proposed tax and incentive scheme with additional GEF; GCF funding for its proper implementation.

For the implementation of an incentive system and replacement program, we suggest following a 2-step approach. Direct rollout to the entire country would be challenging. Therefore, a pilot program tried first to obtain experience to fine-tune a full programme. This pilot phase could be operated in greater Beirut, be limited to refrigerators and UAC and financed as a project through the MLF and/ or GEF. If a GCF proposal is prepared to finance a full roll-out, the pilot phase would be a good start to demonstrate the case for a strong proposal.

[58] GEF Operational Focal Point Sudan: H.E. Mr. Fady Jreissati - Ministry of Environment - Lazarieh Building – Downtown – Beirut - Sudan Tel: +961 1 976 555 ext 501 / +961 1 976 510 - Email: n.khoury@moe.gov.lb; z.chaib@moe.gov.lb; manal.moussallem@undp.org
GCF focal point: Ministry of Environment - Ms. Samar Malek - UNFCCC National Focal Point, Acting Head of the Service of Environmental Technology

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