Global LEAP Off- and Weak-Grid Refrigerator Test Method

Version 3

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Contents

1 Scope

This document defines methods to evaluate the quality, energy consumption and performance of refrigerating appliances intended to be used with a PV module, a solar home system, or with the mains power in the weak grid context.

The test method consists of the following major components:

- Overall **product quality** inspection and evaluation
- Evaluation of **energy performance**
- Evaluation of **temperature performance**

The following international test procedures have been referenced in the preparation of this document:

- IEC 62552-1,-2,-3: 2015: Household refrigerating appliances – Characteristics and test methods
- ISO 22044[1]: Commercial beverage coolers – Classification, requirements and test conditions
- IEC 62257-9-5 Recommendations for renewable energy and hybrid systems for rural electrification - Part 9-5: Integrated systems - Laboratory evaluation of stand-alone renewable energy products for rural electrification
- EN 50530: 2010: Overall efficiency of grid connected photovoltaic inverters
- WHO/PQS/E003/RF05-VP.5: Refrigerator or combined refrigerator and water-pack freezer: Solar direct drive without battery storage
- WHO/PQS/E003/RP03-VP.3: Refrigerator or combined refrigerator and water-pack freezer: intermittent mains-powered, compression cycle
- IEC 62124: 2004: Photovoltaic (PV) stand alone systems – Design verification
- IEC 60335-2-24: 2017: Household and similar electrical appliances - Safety - Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances and ice makers

A technical working group was convened in late 2016 to further develop test method for off-grid and weak grid appropriate refrigerators. The authors express their gratitude to the many experts from around the world who contributed their time and expertise to this document.

[1] Note that this specific standard is an official draft at the date of publication of this protocol.

2 Definitions

2.1 Refrigerating appliance

Insulated cabinet with one or more compartments that are controlled at frozen and unfrozen compartment temperatures and are of suitable size and equipped for household or small commercial use, cooled by a natural or forced convection air flow inside the compartment typically using vapor compression or thermo-electric refrigeration technology.

2.2 Refrigerator

Refrigerating appliance having one more unfrozen compartments.

2.3 Refrigerator-freezer

Refrigerating appliance having at least one unfrozen compartment and at least one frozen compartment.

2.4 Freezer

Refrigerating appliance having one or more frozen compartments.

2.5 Multi-Temperature Refrigerator

Refrigerating appliance that has one compartment with a multi temperature compartment that can be operated either as an unfrozen compartment or as a frozen compartment.

2.6 Unfrozen compartment

Compartment for the storage and preservation of unfrozen products where the storage compartment reference temperature is above 0°C.

2.7 Frozen compartment

Compartment for the storage and preservation of frozen products where the storage compartment reference temperature is equal or below 0°C.

2.8 Fresh food compartment

Compartment for the storage and preservation of unfrozen food, where the reference temperature is 4.0°C.

2.9 8°C compartment

Compartment primary designed for food and beverages to be stored at a reference temperature of 8.0°C.

2.10 Cellar compartment

Compartment primary designed for food and beverages to be stored at a reference temperature of 12.0°C.

2.11 Zero-star compartment

Relatively small compartment generally resides in a fresh food compartment, in which the temperature is not warmer than 0 °C and which can be used for the production and storage of ice (e.g. ice cubes).

2.12 One-star compartment

Compartment where the storage temperature is not warmer than –6°C.

2.13 Two-star compartment

Compartment where the storage temperature is not warmer than –12°C.

2.14 Three-star compartment

Compartment where the storage temperature is not warmer than –18°C.

2.15 Thermal battery

Component used for the purpose of storing and releasing thermal cooling energy. Storage of cooling energy is generated when electrical supply is present. Release of cooling energy is provided when electrical supply is low or not available. Note that the supply can be generated by a solar driven system or by the electrical grid.

2.16 Electrical battery

Component used for the purpose of storing and releasing electric energy.

2.17 Continuous supply refrigerating appliance

Refrigerating appliance designed for continuous (24/7) AC or DC power supply, generally without an integrated thermal or electrical battery.

2.18 Solar Direct Drive (SDD) refrigerating appliance

DC supply refrigerating appliance designed for direct connection with a photovoltaic solar panel, generally containing an integrated thermal battery to allow autonomous operation during the night. Note that some SDD appliances may have a small electrical battery to supply internal lighting, fans or electronics.

2.19 Weak-grid refrigerating appliance

Refrigerating appliance designed for intermittent AC power supply, generally containing an integrated thermal and/or electrical battery allowing autonomous operation during periods when electrical mains supply is lacking.

2.20 Solar panel

Photovoltaic solar panel, which converts energy from sunlight into electrical energy.

2.21 Power outage class

Supply voltage class defining the minimum power outage time per day for which a weak-grid refrigerating appliance is designed.

3 Normal temperature specifications of compartments

Compartment and measurements	Ambient temperature [°C]	Minimum compartment temperature of each temperature sensor [°C]	Maximum compartment temperature of each temperature sensor [°C]	Reference compartment temperature [°C] (*)	Compartment test load
Fresh food, energy consumption	32	0.0	8.0	4.0	Empty
Fresh food, storage temperature and energy consumption	43				
8°C compartment, energy consumption	32			8.0	Empty
8°C compartment, storage temperature and energy consumption	43				
Cellar compartment, energy consumption	32			12.0	Empty
Cellar compartment, storage temperature and energy consumption	43				
One-star, energy consumption	32			-6.0	Empty
One-star, storage temperature and energy consumption	43		-6.0		Tylose packages
Two-star, energy consumption	32			-12.0	Empty
Two-star, storage temperature	43		-12.0		Tylose packages
Three-star, energy consumption	32			-18.0	Empty
Three-star, storage temperature	43		-18.0		Tylose packages

(*) the time-based average during the test time of the instantaneous average of all specific compartment temperature sensors

4 Testing and evaluation definitions

4.1 Quality inspection

Subjective verification of the packaging, product marking, user manual, user safety, cabinet design and durability, serviceability and maintenance and environmental impact considerations.

4.2 Volume

Volume of a specific compartment calculated according to IEC 62552-3: 2015, Annex H.

4.3 Maximum current

The electrical current present when the compressor of the refrigerating appliance is started.

4.4 Pulldown time unfrozen compartment

Cooling time of an unfrozen empty compartment from 32°C to:

- 12°C for a cellar compartment
- 8°C for a 8°C compartment
- 4°C for a fresh food compartment

4.5 Pulldown time frozen compartment

Cooling time of a frozen empty compartment from 32°C to:

- 0°C for a zero-star compartment
- -6°C for a one-star compartment
- -12°C for a two-star compartment
- -18°C for a thee-star compartment

4.6 Energy consumption

Reference energy consumption value at 32°C and 43°C ambient, defined at the coldest nominal temperature specification determined for each ambient condition[2].

- 4.0°C for a fresh food compartment
- 8.0°C for an 8°C compartment
- 12.0°C for a cellar compartment

[2] This has the consequence that the compartment reference temperature may be different for the 32°C test compared to the 43°C test. It is for example possible that a refrigerator can only maintain fresh food temperatures at 32°C ambient. For this case the 32°C test will be performed according to fresh food temperature specification, while the 43°C test could be performed according to 8°C-compartment or cellar compartment temperature specifications.

- 0.0°C for a zero-star compartment
- -6.0, -12.0 or -18.0°C for respectively a one, two or three-star compartment

4.7 Storage temperature performance

Refrigerated appliance temperature performance at 43°C ambient.

4.8 Under voltage

Input voltage operation set 10% lower than the rated voltage, or in case an input voltage range is rated then 90% of the lowest value of the rated voltage range. Note that this only applicable to continuous and weak-grid refrigerating appliances.

4.9 Over voltage

Input voltage operation set 20% higher than the rated voltage, or in case an input voltage range is rated, then 120% of the highest value of the rated voltage range. Note that this only applicable to continuous and weak-grid refrigerating appliances.

4.10 Voltage protection device

Automatic device switching off the input voltage supply of a refrigerator at high and/or low voltages.

4.11 Autonomy time unfrozen compartment

Duration of time of an empty compartment from its reference temperature to:

- 8°C for a fresh food compartment
- 12°C for a 8°C compartment
- 16°C for a cellar compartment

after the sample is disconnected from the power supply at 32.0°C ambient. This test simulates how an unfrozen food compartment operates in absence of electrical power input, taking into account a thermal or/or electrical battery, if present.

4.12 Autonomy time zero-star compartment

Since a zero-star compartment is generally not temperature controlled and placed inside a fresh food compartment, the autonomy time is not determined. Instead, the compartment temperature rise must be presented in a graph.

4.13 Autonomy time frozen compartment

Duration of time of a frozen food compartment filled with Tylose packages:

- from -18.0 to -9.0°C warmest package for a three-star compartment
- from -12.0 to -6.0°C warmest package for a two-star compartment
- No requirement for a one-star compartment[3]

after the sample is disconnected from the power supply at 32.0°C ambient.

This test simulates how a frozen compartment operates in absence of electrical power input, taking into account a thermal or/or electrical battery, if present.

4.14 Ambient temperature

Temperature of the air surrounding the refrigerating appliance during the test. This temperature is generally 32.0°C, except for the storage temperature test which requires an ambient temperature of 43.0°C.

4.15 Power outage class

The following Power Outage classes apply to weak-grid refrigerator energy consumption tests:

PO Class	Power Outage Time per Day [h]
O4	More or equal than 4 hours, but less than 8 hours
O8	More or equal to than 8 hours, but less than 12 hours
O12	More or equal than 12 hours

[3] Due to the melting process of Tylose packages, a proper test is not possible.

5 Test conditions and measurement uncertainty

5.1 Instruments, accuracy and precision of measurements

For the electrical energy consumption, length, mass, temperature, time, voltage and frequency, reference is made to IEC 62552-1: 2015, Annex A, Chapter A2.

The requirement measurement uncertainty of the maximum (inrush) current measurement should be better than ± 5%. Note that the recommended measurement frequency should be 10kHz or higher.

5.2 General test conditions

For test conditions related to the ambient temperature, ambient humidity and electricity supply, reference is made to IEC 62552-1: 2015, Annex A, Clause A.3.

5.3 Ambient conditions

Ambient conditions are intended to simulate product operation in typical off and weak-grid operating conditions of 32°C or 43°C.

5.4 Test setup

a) Remove any accessories, loose trays, bins or containers that have no dedicated position or essential function during normal use, as specified in the instructions.

b) Remove any thermal storage devices (e.g. ice-bricks or similar) that are removable without the use of a tool, irrespective of any instructions in the product manual for all tests, except for the pulldown and autonomy test.

c) Configure the sample using the power cable included in the product package, as follows:

   i) If an AC or DC cable is provided with the product, use this cable and a suitable power supply for testing corresponding with the rated input voltage

   ii) If an AC or DC cable is not provided the input voltage should be measured at the inlet of the appliance, thereby ensuring that possible cable losses do not apply. Note that this is more relevant for DC supplied appliances.

   iii) If an AC/DC converter (rectifier) is provided with the product, test with the converter

   iv) If an DC/AC converter (inverter) is provided with the product, test with the converter

d) The sample shall be placed in the climate room with a rear clearance / distance of 100mm between the back of the appliance and the back wall.

e) Record the following data for each test run (as applicable):

i) Number of cooling system duty cycles and a graphical display of on/off cycles

ii) Ambient temperature and humidity of the test room

iii) Settings of any user-adjustable temperature control devices and any other user-adjustable controls, dampers, etc.

iv) Diagram showing locations of the temperature sensors in all compartments as applicable

f) For purposes of this test method, stabilization is determined based on IEC 62552-3:2015, unless otherwise stated in this document.

6 Test procedure

6.1 Quality assessment

1) Take digital photographs of the sample packaging, including all identifying marks.
2) Unpack the sample and install the sample using the manufacturer's installation instructions. Record any problems encountered.
3) Check the sample for defects or damage or any problem which make it difficult or impossible to conduct testing. Record any problems encountered. Record any differences between the refrigerator planned to be tested and the sample received.
4) Review and photograph all supporting documents (e.g. user manual, warranty card, etc.) that are packaged with the product. Fill out the Quality Inspection Checklist according to Annex A of this test method.
5) Take the following digital photographs of the product:
    i) A three-quarter view photograph of the sample with the door open
    ii) All external surfaces of the sample, the interior layout, and the compressor compartment
    iii) A close-up of the product rating plate, other identifying marks and other indicators including lights, the user controls, and any special features or identified weaknesses of the product
6) The following aspects are evaluated based on the visual inspection of the product:
    i) General product information
    ii) Quality assessment
        (1) Packaging
        (2) Product marking
        (3) User manual
        (4) User safety
        (5) Design and durability
        (6) Maintenance and reparability
        (7) Environmental impact considerations

6.2 Volume

Objective: Determination of the internal volume of the refrigeration appliance

Minimum Requirement: None

Applicable To: All refrigerating appliances

Test procedure

Determine the volume according to IEC 62552-3: 2015, Annex H for each compartment of the refrigerator.

6.3 Maximum current

Objective: Determination of the maximum current (inrush current), which the refrigerating appliance requires for proper operation.

Minimum Requirement: None

Applicable To: All refrigerating appliances

Test procedures

a) Ensure that proper measurement equipment[4] is selected to measure the maximum (inrush) current of the compressor during the start of the test.

b) Connect the power supply and current measurement equipment and switch on the sample.

c) Switch on the sample applying the rated input voltage or the lowest input voltage rated in case an input voltage range is specified.

d) Measure the maximum current and determine whether an inrush current is present. Repeat this procedure 5 times.

e) Data to record:

- Maximum current of the 5 measurements [A]
- Average current of the 5 measurements [A]

6.4 Pulldown test

Objective: Determination of the cooling time of a refrigerating appliance to reference temperatures, after initial installation applying the coldest thermostat setting possible.

Minimum Requirement: None

Applicable To: All refrigerating appliances

Test procedure

[4] With inrush current trigger option

a) Prepare the sample according to IEC 62552-1: 2015, Clause D.3.

b) In case the sample contains a thermal and/or electrical battery, ensure that the test is started with an empty battery. Place any removable thermal battery in the dedicated position.

c) For compartments which are temperature controlled, apply the coldest thermostat setting.

d) With the test chamber ambient temperature set to 32°C, leave the door/lid open for at least 6 hours.

e) Switch on the sample and apply appropriate input voltage and current type:

- Use the rated input voltage when a single value is specified (e.g. rated input voltage = 12Vdc).
- In case a DC input voltage range is specified:
  - Use a 12Vdc voltage value, in case 12Vdc is within the range. For example, if rated input voltage range is 6-24Vdc, then 12Vdc should be applied.
  - In case 12Vdc is not within the range, the minimum voltage should be applied. For example, if rated input voltage range = 24-48Vdc, then 24Vdc should be applied.
- In case an AC input voltage range is specified:
  - Use a 230V voltage value, in case 230V is within the range. For example, if rated input voltage range is 220-240V, then 230V should be applied.
  - In case 230V is not within the range, the minimum voltage should be applied. For example, if rated input voltage range = 110-120V, then 110Vshould be applied.
  - Note that the rated frequency should always be applied.

f) Monitor the average temperature for each compartment present and determine:

- The cooling times until average compartment temperature reaches:
  - 12°C for an unfrozen compartment
  - 8°C for an unfrozen compartment, if possible
  - 4°C for an unfrozen compartment, if possible
  - 0°C for a frozen compartment
  - -6°C for a frozen compartment, if possible
  - -12°C for a two star compartment, if possible
  - -18°C for a three star compartment, if possible
- The time until any thermal and/or electrical battery is fully loaded[5].

g) Data to record from the start of the test until steady state operating conditions:

[5] In practice this could be when the compressor of such as fridge switches off for the first time

- Average compartment temperatures [°C]
- Supply voltage [V] and frequency [Hz]
- Input power [W] and input current [A]
- Ambient temperature [°C]
- Pull down time [hours]

6.5 Continuous supply energy consumption

Objective: Determination of the energy consumption at normal ambient conditions, applying the coldest compartment temperature specification possible

Minimum Requirement: The nominal temperature specifications in Chapter 3 at 32°C ambient temperature

Applicable to: Continuous supply refrigerating appliances

Test procedure

Several tests using different temperature control settings are allowed, to obtain the energy consumption measurement values. Interpolation is also allowed to determine the energy consumption at the nominal reference temperatures, for example at exactly +4.0°C for a fresh food compartment temperature. Reference is made to IEC 62552: 2015, part 3, Annex I (Worked examples of energy consumption calculations), clause I.3.2.2 (Single compartment example) for detailed calculation methodology.

a) The test determines the temperature performance and reference energy consumption at 32°C at the coldest reference temperature possible.

b) Prepare the sample according to IEC 62552-1: 2015, Clause D.3.

c) Set the test chamber ambient temperature to 32°C.

d) Apply the same input voltage as required for the pulldown test

e) Follow the energy consumption procedure described in IEC 62552-3:2015.

f) Data to record:

- Average compartment temperatures [°C]
- Supply voltage [V] and frequency [Hz]
- Input power [W] and input current [A]
- Integrated energy consumption [kWh]

- Ambient temperature [°C]

6.6 Solar direct drive refrigerator energy consumption

Objective: Determination of the energy consumption at normal ambient conditions, applying the coldest compartment temperature specification possible

Minimum Requirement: The nominal temperature specifications in Chapter 3

Applicable to: Solar direct drive refrigerators

Test procedure

a) The test determines the temperature performance and reference energy consumption at 32°C during a 24 hours test with a 12 hours day / 12 hours night cycle at the coldest reference temperature possible.

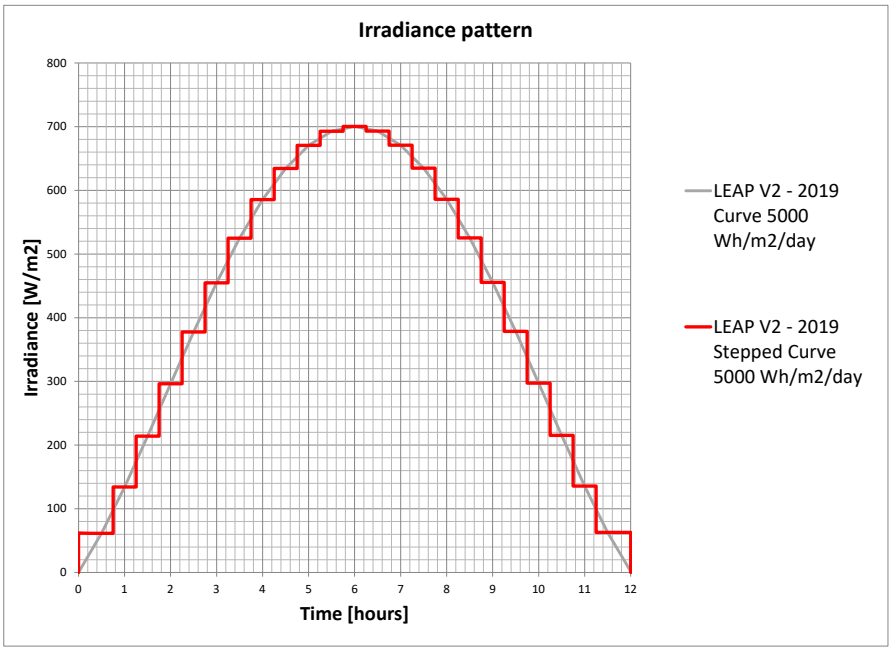
b) Prepare the sample according to IEC 62552-1: 2015, Clause D.3.

c) Set the test chamber ambient temperature to 32°C.

d) Ensure than any internal thermal and/or electrical battery is fully loaded.

e) Ensure that the DC power supply with built-in solar array simulation is suitable to generate IV curve signals according to EN 50530.

f) Apply the stepped solar irradiance pattern of LEAP V2 - 2019. See below the graphical presentation of this pattern. Note that Annex C: (x,y) points stepped curve LEAP 2019 provides the (x,y) points of the stepped curve.



IV curves calculated according to EN 50530, with the following input parameters:

(1) The following solar panel specifications:

(a) In case a solar panel is supplied with the cabinet: the nominal voltage and maximum peak power (corresponding with an irradiance of 1000 W/m^2) of the solar panel.

(b) In case a solar panel is not supplied with the cabinet: the recommended nominal voltage and the recommended maximum peak power of the solar panel which should be connected to the cabinet.

g) Apply the following input signal to the sample:

Time [hours]	Input signal	Remark
0	-	Fully loaded thermal or electrical battery
0-12	IV curve according to EN 50530	Stabilization phase
12-24	0	Stabilization phase
24-36	IV curve according to EN 50530	Testing phase
36-48	0	Testing phase

a) Data to record from the start of the test until steady state operating conditions:

- Average compartment temperatures [°C]

- Supply voltage [V] and frequency [Hz]
- Input power [W] and input current [A]
- Integrated energy consumption [kWh]
- Ambient temperature [°C]

The energy consumption is determined over the 24 hours of both testing phases in [kWh/24h].

6.7 Weak grid refrigerator energy consumption

Objective: Determination of the energy consumption at normal ambient conditions, applying the coldest compartment temperature specification possible.

Minimum Requirement: The nominal temperature specifications in Chapter 3

Applicable to: Weak-grid refrigerators

Test procedure

a) The test determines the temperature performance and reference energy consumption at 32°C at the coldest reference temperature possible, during a 24-hour test with pre-defined supply and no-supply cycles that simulate power outage conditions in the weak-grid areas.

b) Prepare the sample according to IEC 62552-1: 2015, Chapter D.3.

c) Set the test chamber ambient temperature to 32°C.

d) Ensure than any internal thermal and/or electrical battery is fully loaded.

e) Apply the same input voltage as required for the pulldown test

f) Supply the following voltage signal to the sample:

- In case the appliance can maintain cooling for 4 hours or more, but not equal or more than 8 hours, the O4 requirements from the table below
- In case the appliance can maintain cooling for 8 hours or more, but not equal or more than 12 hours, the O8 requirements from the table below
- In case the appliance can maintain cooling for 12 hours or more, the O12 conditions from the table below.

Power outage class				
O4	**O8**	**O12**		
Time [hours]			**Input signal**	**Remark**
0			-	Fully loaded thermal or electrical battery
0-20	0-16	0-12	Input voltage [V]	Stabilization phase

20-24	16-24	12-24	0	Stabilization phase
24-44	24-40	24-36	Input voltage [V]	Testing phase
44-48	40-48	36-48	0	Testing phase

g) Data to record from the start of the test until steady state operating conditions:

- Average compartment temperatures [°C]
- Supply voltage [V] and frequency [Hz]
- Input power [W] and input current [A]
- Integrated energy consumption in [kWh]
- Ambient temperature [°C]

The energy consumption is determined over the 24 hours of both testing phases in [kWh/24h].

6.8 Under- and over-voltage test

Objective: Verification of performance and energy consumption impacts with high and low input voltage levels.

Minimum Requirement: Proper performance at 20% above the maximum rated voltage and at 10% below the minimum rated voltage

Applicable to: Continuous supply and weak-grid refrigerating appliances

Test procedure

a) The test verifies whether a stabilised product in operation is able to perform and function normally, maintaining its cold compartment temperatures at high and low input voltage operation, when operated at an ambient temperature of 32°C

b) Prepare the sample according to IEC 62552-1: 2015, Clause D.3.

c) Check for the presence of a high voltage protection device and record the voltage at which it is designed to be triggered.

d) If the high voltage protection device is present, verify whether this device is functioning.

e) Check for the presence of a low voltage protection device and record the voltage at which this is designed to be triggered.

f) If the low voltage protection device is present, verify whether this device is functioning.

g) Operate the product at the maximum rated voltage and measure the energy consumption during stable temperature conditions applying at least 5 compressor on/off cycles.

h) Increase the power supply voltage to 20% higher than the maximum rated voltage[6]. Note that this verification is not required in case the high voltage protection device switches off the sample at a value lower than voltage level required for this test. Measure the energy consumption during stable temperature conditions applying at least 5 compressor on/off cycles.

i) Operate the product at the minimum rated voltage and measure the energy consumption during stable temperature conditions applying at least 5 compressor on/off cycles.

j) Decrease the power supply voltage to 10% lower than the minimum rated voltage[7]. Note that this verification is not required in case the low voltage protection device switches off the sample at a value higher than voltage level required for this test. Measure the energy consumption during stable temperature conditions applying at least 5 compressor on/off cycles.

k) Data to record from the start of the test until steady state operating conditions:

- Average compartment temperatures [°C]
- Supply voltage [V] and frequency [Hz]
- Input power [W] and input current [A]
- Ambient temperature [°C]

6.9 Storage temperature performance and energy consumption (continuous supply refrigerators)

Objective: Determination of the energy consumption and storage temperatures at extreme ambient conditions, applying the coldest compartment temperature specification possible

Minimum Requirement: None

Applicable to: Continuous supply refrigerators

Test procedure

a) The test determines the coldest nominal temperature specifications possible at this ambient condition.

b) Set the test chamber ambient temperature to 43°C depending on the rated climate class.

c) For frozen compartments, load the sample with Tylose packages according to IEC 62552: 2015 – 2, clause 6.3.3.3 and 6.3.3.4.

d) Apply the procedure of Chapter 6.5, Continuous supply energy consumption.

[6] Example: In case the input voltage range is 12 – 24V, the over voltage test will be performed at 1.2 x 24V = 28.8V

[7] Example: In case the input voltage range is 12 – 24V, the under voltage test will be performed at 0.9 x 12V = 10.8V

6.10 Storage temperature and energy consumption performance (solar direct drive refrigerators)

Objective: Determination of the energy consumption and storage temperatures at extreme ambient conditions, applying the coldest compartment temperature specification possible

Minimum Requirement: None

Applicable to: Solar direct drive refrigerators

Test procedure

a) The test determines the coldest nominal temperature specifications possible at this ambient condition.

b) The appliance preparation is similar to Chapter 6.9, applying the irradiance pattern as described in Chapter 6.6.

c) Apply the procedure of Chapter 6.6.

6.11 Storage temperature performance and energy consumption (weak-grid refrigerators)

Objective: Determination of the energy consumption and storage temperatures at extreme ambient conditions, applying the coldest compartment temperature specification possible

Minimum Requirement: None

Applicable to: Weak-grid refrigerators

Test procedure

a) The test determines the coldest nominal temperature specifications possible at this ambient condition.

b) Set the test chamber ambient temperature to 43°C depending on the rated climate class.

c) For frozen compartments, load the sample with Tylose packages according to IEC 62552: 2015 – 2, clause 6.3.3.3 and 6.3.3.4.

d) Apply the procedure of Chapter 6.7.

6.12 Autonomy test

Objective: Determination of the compartment temperature rise of a refrigerating appliance during a power outage

Minimum Requirement: None

Applicable to: All refrigerators

Test procedure

The appliance preparation and ambient conditions are similar to Chapter 6.9, applying the voltage as described in Chapter 6.5.The test determines the coldest nominal temperature specifications possible at a 32°C ambient condition.

a) Prepare the refrigerating appliance
   - For unfrozen compartment in empty conditions with temperature sensors according to IEC 62552-1: 2015, Chapter D.3.
   - For frozen compartments load the sample with Tylose packages according to IEC 62552: 2015 – 2, chapter 6.3.3.3 and 6.3.3.4.

b) Set the test chamber ambient temperature to 32°C.

c) For refrigerating appliances that have an integrated thermal and/or electrical battery, make sure the battery is fully loaded and allow the sample to stabilise and then operate normally for 2 hours with:
   - an average fresh food compartment +4.0°C or colder
   - an average 8°C-compartment temperature of +8.0°C or colder
   - an average cellar compartment temperature of +12.0°C or colder
   - a two-star compartment of -12.0°C warmest package or colder
   - a three-star compartment of -18.0°C warmest package or colder

d) Switch off the power supply and record the time:
   - to 8.0 °C for a fresh food compartment
   - to 12.0°C for an 8°C-compartment
   - to 16.0°C for a cellar compartment
   - from -12.0 to -6.0 °C for a two-star compartment
   - from -18.0 to -9.0°C for at three-star compartment

e) Data to record from the start of the test until steady the moment that the autonomy end temperature are achieved:
   - Average compartment temperatures [°C]
   - Supply voltage [V] and frequency[Hz]

- Ambient temperature [°C]
- Range of temperature rising [°C - °C]
- Autonomy time [hours]

6.13 Testing overview table

Test / Evaluation	Target Refrigerators	Ambient Conditions	Target Temperature	Compartment Test Load
Maximum current	All	N.A.	N.A.	Empty
Pulldown	All	+32°C ≤75%	Reference temperatures	Empty
Continuous supply energy consumption	All	+32°C ≤75%	Coldest reference temperature possible, See table Chapter 3	Empty
SDD energy consumption	Solar Direct Drive refrigerators	+32°C ≤75%		Empty
WG energy consumption	Weak Grid refrigerators	+32°C ≤75%		Empty
Storage temperature and energy consumption	Continuous supply refrigerators	+43°C ≤75%		Empty for unfrozen and zero-star compartments Tylose packages for frozen compartments
SDD storage temperature and energy consumption	Solar Direct Drive refrigerators	+43°C ≤75%		
WG storage temperature and energy consumption	Weak Grid refrigerators	+43°C ≤75%		
Under/Over voltage	All	N.A.	N.A	Empty
Autonomy	All	+32°C ≤75%	Fresh food: 8°C 8°C compartment: 12°C Cellar: 16°C Two-star: -12.0 to -6.0°C Three-star: 18.0 to -9.0°C	Empty

Annex A: Quality inspection checklist

Use the checklist below to document observations and results of quality inspection.

General Product Information

Sample model	
Legal manufacturer or reseller	
Product Type/Description	
Country of Origin	
Conformity assessment rating	
Warranty time [years]	
Serial number	
Height [cm]	
Width [cm]	
Depth [cm]	
Weight [kg]	
Power supply type [AC or DC]	
Rated voltage range [V]	
Rated power range [W]	
Rated current [I]	
Rated frequency (if product is AC)	
Rated volume unfrozen compartment [litres]	
Rated volume frozen compartment [litres]	
Maximum storage of 330ml cans [-]	
Climate class declared	

Rated temperature range unfrozen compartment	
Rated temperature range frozen compartment	
Refrigerant	
Total mass of refrigerant [grams]	
Compressor model	

Product Photographs

Picture of the sample with the door(s) closed	
Picture of the sample with the door(s) open	
Left side picture	
Back side picture	
Right side picture	
Picture of the rating plate	
Picture of controller or control display	
Warmest setting possible	
Coldest setting possible	
Picture of compressor compartment	
Picture of condenser	
Picture of sample damage (*if applicable*)	
Transport packaging	

Quality Assessment

In this section, the quality assessment is rated based on poor, fair, and good based on the following criteria.

No.	Aspect	Poor	Fair	Good
1	Quality related evaluation	Substantially worse compared to general products (conventional and off grid) present on the market	Corresponding to general products present on the market	Substantially better compared to general products present on the market
2	Risk of human accidents	High	Low	No risk
3	Risk of appliance damage	High	Low	No risk
4	Risk of decreased appliance lifetime	High	Low	No risk
5	Risk of inferior performance	High	Low	No risk
6	Key information (user manual)	Missing	Limited available	Present

Packaging

Wooden box used	[yes/no]
Carton box used	[yes/no]
Proper protection material used inside carton box (eg. PS)	[yes/no
Plastic foil used around the sample to protect the sample from liquid ingress	[yes/no]
Pallet used	[yes/no]
Sample package mounted fixed on a pallet	[yes/no]
Sample mounted on a pallet avoiding tumbling risk	[yes/no]
Loose components such a shelves and baskets protected from movement inside the sample	[yes/no]
Proper transport signs on shipment package applied	[yes/no]
Remarks	
Relevant aspects defining the score	
Score	**[Poor / Fair / Good]**

Product Marking[8]

Sample marked with rated voltage of rated voltage range	[yes/no]
Sample marked with the nature of supply (AC or DC) unless the rated frequency is present	[yes/no]
Sample marked with rated power in Watts or rated current in Amperes	[yes/no]
Sample marked with the name, trade mark or identification mark of the manufacturer or responsible vendor	[yes/no]
Samples which can be mains and battery operated, marked with the battery voltage	[yes/no]
Sample marked with caution “RISK OF FIRE” (only applicable for flammable refrigerants and flammable blowing agents)	[yes/no]
Remarks	
Relevant aspects defining the score	
Score	**[Poor / Fair / Good]**

[8] Referencing requirements in IEC 60335-1 and IEC 60335-2-24

Assessment of User Manual

Operation manual included		[yes/no]
Language	Instruction in English	[yes/no]
	Other language(s) used	[list all languages]
Instructions on Installation	Unpacking	[yes/no]
	Door removal, levelling, and alignment	[yes/no]
	Rear condenser vane required between the sample and the back wall described	[yes/no]
	Handle installation and removal	[yes/no]
	Explanation of door lock	[yes/no]
	Location Requirements	[yes/no]
	Electrical Requirements	[yes/no]
	Additional requirements for compression type of refrigerators using flammable refrigerants according IEC 60335-2-24, 7.12	[yes/no]
Instruction on Product Use	Instructions on using the controls	[yes/no]
	Switching on procedure	[yes/no]
	Switching off procedure	[Yes/no]
	Cooling down time	[yes/no]
	Use of temperature controller	[yes/no]
	Indication lights and other displays	[yes/no]
	Connection to power source	[yes/no]
	Compatibility with solar systems	[yes/no]
Maintenance and cleaning	Cleaning the interior	[yes/no]
	Cleaning the condenser	[yes/no]
	Defrosting the evaporator	[yes/no]

	Changing the internal lighting[9]	[yes/no]
	Preventive maintenance checks	[yes/no]
Diagnostic / repair procedures		[yes/no]
Disposal / recovery / recycle procedure		[yes/no]
Remarks		
Relevant aspects defining the score		
Score		**[Poor / Fair / Good]**

[9] Remark IEC 60335-2-24, 7.12

Assessment of after sales and warranty information

Warranty information attached to the sample		[yes/no]
Photograph of warranty information		
Warranty time [years]		
Warranty information described in the user manual [yes / no]		[If no, describe how and where the warranty information is provided]
Warranty Language	Instruction in English	[yes/no]
	Other language(s) used	[list all languages]
Warranty information	Warranty conditions described	[yes/no]
	Does the warranty information describe how it can be accessed?	[yes/no] [If yes, mention how it can be accessed.]
Spare parts information attached to the sample		[yes/no]
Photograph of spare parts information		
Spare part information described in the user manual [yes / no]		[If no, describe how and where the spare parts information is provided]
Parts list language	Instruction in English	[yes/no]
	Other language(s) used	[list all languages]
Part list information	Parts list components described	[yes/no]
	Does the part list information describe how spare parts can be arranged?	[yes/no] [If yes, mention how it can be accessed.]
Relevant aspects defining the score		
Score		**[Poor / Fair / Good]**

User safety assessment

Internal lighting switches on when the door is open	[yes/no]
Outside finishing sharp edges[10]	[yes/no]
Fan(s) protected with protection grid	[yes/no]
Power switch accessible to the user without tools	[yes/no]
Power switch protected from accidental changes in position	[yes/no]
Grounding present (for AC only)	[yes/no]
Pull relief main supply plug present	[yes/no]
Decent electrical cable finishing	[yes/no]
Electrical scheme present on the cabinet	[yes/no]
Remarks	
Relevant aspects defining the score	
Score	**[Poor / Fair / Good]**

[10] IEC 60335-1, 22.14: Appliances shall have no ragged or sharp edges, other than those necessary for the function of the appliance that could create a hazard for the user in normal use or during user maintenance

Assessment of design and durability

Sample Housing (door excluded)	Robustness of refrigerator housing	
	Robustness of wheels	
	Remarks	
	Relevant aspects defining the score	
Refrigerator housing Score		**[Poor / Fair / Good]**
Cooling System	Refrigerant tubes decently mounted and soldered	
	Compressor suction and discharge tubes mounted flexible to reduce the risk of tube leakages due to compressor vibrations	
	Mounting quality of the compressor	
	Remarks	
	Relevant aspects defining the score	
Cooling System Score		**[Poor / Fair / Good]**
Door	Robustness of door hinge	
	Robustness of door handle	
	Door sealing quality	
	Door opening side adjustable	
	Door mounted flush	
	Remarks	
	Relevant aspects defining the score	
Door Score		**[Poor / Fair / Good]**
General Design and Durability remarks		
General Design and Durability score		**[Poor / Fair / Good]**

Assessment of Serviceability and Maintenance

Maintenance and cleaning	Cleaning the cabinet	
	Cleaning the condenser	
	Defrosting the evaporator	
	Changing the internal lighting[11]	
	Diagnostic / repair procedures	
	Spare parts list	
	Preventive maintenance checks	
Serviceability evaluation	Replacing the door lock	
	Replacing compressor	
	Replacing the condenser fan	
	Replacing the evaporator fan	
Remarks		
Relevant aspects defining the score		
Score		**[Poor / Fair / Good]**

[11] Remark IEC 60335-2-24, 7.12

Environmental impact considerations

Natural refrigerant applied	[yes / no]
Refrigerator designed for safe and easy disassembly and disposal i.e. could a trained professional with limited set of tools disassemble the product?	
Thermal insulation blowing agent complies with Montreal Protocol requirements	
Lead (except in batteries), mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated biphenyl ethers (PBDE) present	
Remarks	
Relevant aspects defining the score	
Score	**[Poor / Fair / Good]**

Annex B: Background information related to solar irradiance patterns

The graph presents irradiance patterns used in international standards as well as the assumed LEAP 2019 irradiance curve.

The standards used are:

- **Applicable to the LEAP 2021 protocol**A: IEC 62257-9-5 Integrated systems – Laboratory evaluation of standalone renewable energy products for rural electrification ; being a 7 hours step pattern, with a maximum peak value of 1000 W/m^2 and a daily irradiance of 5000 W/m^2
- WHO/PQS/E003/RF05-VP.4; Refrigerator or combined refrigerator and waterpack referring to IEC 62124 Photovoltaic (PV) stand alone systems – Design verification; being a 12 hours step pattern, with a maximum peak value of 700 W/m^2 and a daily irradiance of 6000 W/m2
- The irradiance LEAP 2019 curve

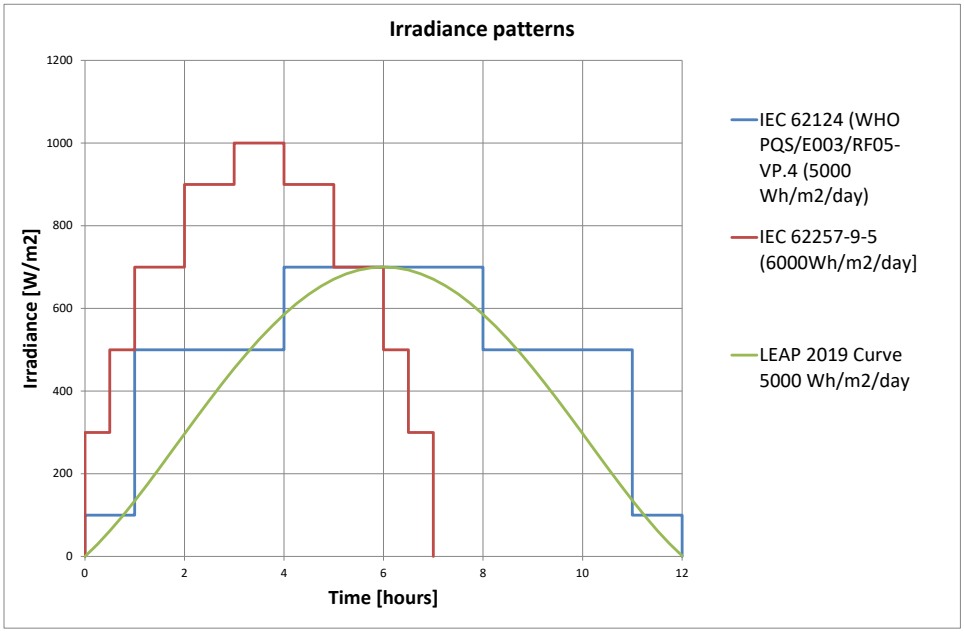


Figure 1; Irradiance curves

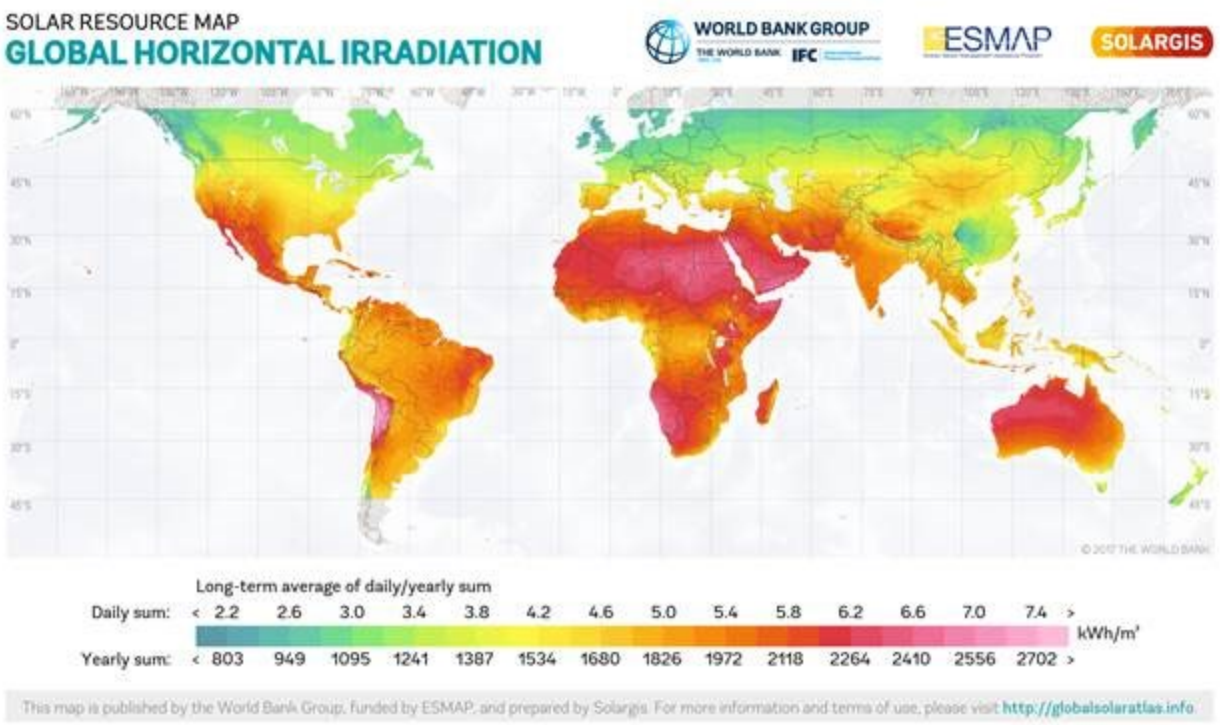


Figure 2; Global irradiance levels

Annex C: (x,y) points stepped curve LEAP 2019

Time [h]	Irradiance [W/m2]
0	0
0	62
0.25	62
0.75	62
0.75	134
1.25	134
1.25	214
1.75	214
1.75	296
2.25	296
2.25	378
2.75	378
2.75	455
3.25	455
3.25	525
3.75	525
3.75	585
4.25	585
4.25	634
4.75	634
4.75	671
5.25	671
5.25	693
5.75	693
5.75	700
6.25	700
6.25	693
6.75	693
6.75	671
7.25	671
7.25	635
7.75	635
7.75	586
8.25	586
8.25	525
8.75	525
8.75	456
9.25	456
9.25	379
9.75	379
9.75	297
10.25	297
10.25	215
10.75	215
10.75	136
11.25	136
11.25	63
11.75	63
12.00	63
12.00	0

Annex D: Background information related to power outages in sub-Saharan African countries

The graph provides information about the average duration and average number of power outages in Sub-Saharan African countries.

Source: World Bank group, Enterprise surveys:

http://www.enterprisesurveys.org/data/exploretopics/infrastructure#sub-saharan-africa

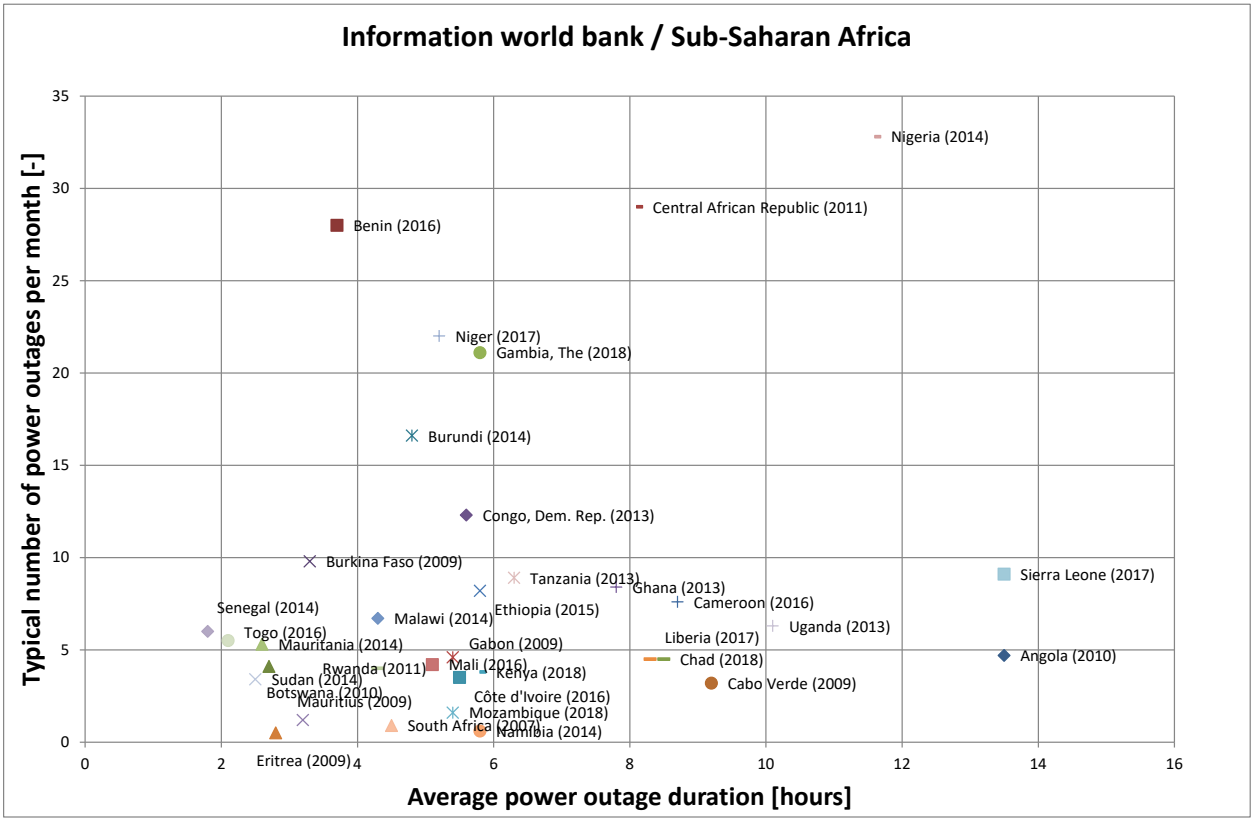


Figure 3; Power outages in Sub-Saharan Africa

Annex E: Conversion table from °C to °F.

°C	°F
-18.0	-0.4
-12.0	10.4
-9.0	15.8
-7.0	19.4
-6.0	21.2
-3.0	26.6
0.0	32.0
1.0	33.8
2.0	35.6
4.0	39.2
5.0	41.0
7.0	44.6
8.0	46.4
9.0	48.2
32.0	89.6
43.0	109.4

Annex F: Document revision table

Version	Date of publication	Remark / Changes	Authors
1.0	2017	• First version	E. Lai & P. Beks
2.0	April 28, 2019	• Energy consumption test at 16°C removed. • Load processing test added. • General improvements	E. Lai & P. Beks
3.0	June 28th , 2021	• General improvements. • Cellar compartment added. • Load processing and freezing test removed. • Procedures for freezer compartments added. • Power outage classes added. • After sales and warranty evaluation added.	E. Lai & P. Beks