UN environment programme

MODEL QUALITY AND PERFORMANCE GUIDELINES FOR OFF-GRID REFRIGERATING APPLIANCES

Model Quality and Performance Guidelines for Off-Grid Refrigerating Appliances

ISBN: 978-92-807-4093-6
Job number: DTI/2584/NA

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Suggested citation: United Nations Environment Programme (2023). *Model Quality and Performance Guidelines for Off-Grid Refrigerating Appliances*. Nairobi.

Production: United Nations Environment Programme's United for Efficiency (U4E)

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ACKNOWLEDGEMENTS

These Model Quality and Performance Guidelines for Off-Grid Refrigerating Appliances were developed by the United Nations Environment Programme (UNEP) United for Efficiency (U4E) initiative, in collaboration with Lawrence Berkeley National Laboratory, with funding from the U.K. Department for Environment, Food and Rural Affairs and the Clean Cooling Collaborative.

The authors, Won Young Park, Nihan Karali, Peng Peng, Sun Hee Baik, and Nihar Shah (LBNL) and Brian Holuj and Marco Duran (U4E) thank each of the experts listed below for their reviews and recommendations to improve the Guidelines following the initial draft and through the subsequent revisions which led to this final publication.

In addition, we wish to recognize the efforts of Leo Blyth (World Bank & ESMAP Efficient Clean Cooling Program), Elisa Lai (CLASP/VeraSol), Patrick Beks (Re/Gent B.V.) and Jeremy Tait (Tait Consulting GmbH) who provided foundational insights and advice from the very outset of this project which were instrumental in getting the first draft off the ground.

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Cover images: © Efficiency for Access

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ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AEC	Annual Energy Consumption
AEC_{Max}	Maximum Annual Energy Consumption
AV	Adjusted Volume
DC	Direct Current
EC	Energy Consumption
EEI	Energy Efficiency Index
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
IEC	International Electrotechnical Commission
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
K	Volume Adjustment Factor
kWh	Kilowatt-hour
L	Litre
LEAP	Lighting and Energy Access Partnership
ODP	Ozone Depletion Potential
OEM	Original Equipment Manufacturer
PV	Photovoltaic
R	Energy Consumption Index
U4E	United for Efficiency
Wh	Watt-hour
WHO	World Health Organization

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ABOUT UNITED FOR EFFICIENCY

U4E (united4efficiency.org) is a global initiative led by UNEP, supported by leading companies and organizations with a shared interest in transforming markets for lighting, appliances and equipment, by encouraging countries to implement an integrated policy approach to energy-efficient products so as to bring about a lasting, sustainable and cost-effective market transformation.

The approach focuses on the end-user market and targets the five main components of the value chain for an energy-efficient market:

- Standards and regulations.
- Supporting policies, including education, information and training.
- Market monitoring, verification and enforcement.
- Finance and financial delivery mechanisms, including incentives and public procurement.
- Environmentally sound management and health.

U4E provides countries with tailored technical support through its in-house international experts and specialized partners, to get the most out of countries' electricity by accelerating the widespread adoption of energy-efficient products, allowing monetary savings on consumer electricity bills, helping businesses thrive through greater productivity, enabling power utilities to meet growing demands for electricity and assisting governments in reaching their economic and environmental ambitions. The initiative is present in more than 30 countries worldwide.

Based on each country's circumstances, U4E works with any of the following products: Lighting, Refrigerators, Room Air Conditioners, Electric Motors and Distribution Power Transformers – the five products that together consume more than half of the world's electricity. Such support is available at three levels: global, regional and national; providing tools and resources and supporting multiple stakeholders on international best practices, regional policy roadmaps and harmonization process recommendations through guidelines and publications, such as energy efficiency Policy Guides, Global Model Regulations Guidelines, Model Public Procurement Specifications and Financing Guidelines.

In addition, the initiative provides capacity building and education, policy tools and technical resources which include Country Savings Assessments completed for more than 155 countries showing the significant available financial, environmental, energy and societal benefits that are possible with a full transition to more energy-efficient electrical products. This growing suite of tools and resources equips policymakers to understand the significant opportunities and the steps needed to start transforming their markets to eco-efficient appliances and equipment.

1 INTRODUCTION

These "Model Quality and Performance Guidelines for Off-Grid Refrigerating Appliances" (Guidelines) complement United for Efficiency's (U4E) "Model Regulation Guidelines for Refrigerating Appliances," which apply to grid-connected products, and other supporting resources[1]. This voluntary guidance is intended to inform market transformation efforts in developing and emerging economies that support the adoption of new off-grid refrigerating appliances with recommended parameters for quality assurance, energy efficiency, and use of refrigerants and foam-blowing agents with a lower global warming potential (GWP) than typical legacy refrigerants.

Refrigerating appliances are among the most desirable but expensive appliances that small enterprises and households aspire to own, once electricity becomes available and incomes rise beyond subsistence. While research indicates a large market opportunity for off-grid refrigerating appliances, observed market penetration is still very low, with annual sales estimated at roughly 12,000 to 32,000 units, compared to around 200 million grid-connected units worldwide. This is due to many barriers including a lack of affordable products and access to financing; the high cost of energy supply; the difficulty of last-mile transport; user hesitancy due to concerns about product failure; and a lack of after-sales service and maintenance, among others.

Refrigerating appliances, while only part of the overall cold chain needed for maintaining proper conditions for food and medicine, are invaluable for the health and well-being of consumers and are emerging in a variety of settings, including as an enabler and enhancer of services provided by food and beverage vendors in a retail setting or for fisherfolk after a catch. Expanding access to energy-efficient refrigeration with lower GWP refrigerants is critical for reducing food loss and waste, improving income-generating opportunities, and enhancing food security, while increasing people's climate resilience and adaptability and mitigating impacts on energy supplies, the environment and the planet.

The scope of this guidance covers refrigerating appliances commonly used in residential and light commercial applications[2] (not including walk-in cold rooms) in off-grid locations. The accompanying Supporting Information Annex[3] provides additional context about the rationale and methodologies underpinning this guidance. Policy design for grid-connected appliances should avoid harming emerging markets for appliances designed specifically for off-grid use. Further, definitions should be crafted so that off-grid appliances are not inadvertently covered by a scope tailored for grid-connected appliances, as the use cases, technology readiness, cost implications, availability and other aspects may vary significantly.

While many countries set minimum energy performance standards (MEPS) and energy labelling requirements for grid-connected refrigerating appliances as markets mature, those are not yet applicable to the off-grid domain where requirements must be tailored to the unique technology and use-case considerations pertinent to this segment. In most markets for off-grid appliances, there remains a significant need to expand access as technologies, companies, business models and policy development

[1] Available at https://united4efficiency.org/resources/publications/?fwp_products=refrigerators. Also see Efficiency for Access publications at https://efficiencyforaccess.org/publications/technology/refrigerators.
[2] These refrigerating appliances are designed to efficiently maintain the temperature and condition of perishable goods such as fruits, vegetables, dairy products beverages, etc., typically found in residential or commercial settings. However, they may not be suitable for specific industrial applications that require very rapid temperature pull-downs. Users are recommended to verify and ensure compliance with their local food safety standards and regulations.
[3] Available at https://united4efficiency.org/resources/model-quality-and-performance-guidelines-for-off-grid-refrigerating-appliances/

are nascent. Affordability is one of the biggest challenges prohibiting refrigerators from reaching off-grid consumers at a greater scale. Consequently, voluntary procurement and incentive programmes, donations for institutional applications, and other approaches are often used as first steps to facilitating broader adoption by creating an enabling environment to reach scale.

The development of these Guidelines has drawn heavily on the experience and expertise provided by dozens of experts from various sectors and regions to incorporate best practices from practical applications, market insights and technology developments. The contents are intended as a starting point rather than a final template for implementation and do not obviate the need for assessment of local conditions and thorough consultations with stakeholders. The overriding aim is to assist in accelerating the growth of more energy-efficient and climate-friendly products in this segment while mitigating adverse impacts on the upfront costs and availability of such products, which provide essential refrigeration services.

The contents are intended to support interested governments, development specialists, and donors considering voluntary programmes or incentives that commence as early as 2024, but the timing and text should be adjusted whenever and however is most appropriate for the application in question. Also, markets and technologies are dynamic, so adaptations will be necessary over time to keep pace with such changes. For example, existing test standards are referenced, but as of this writing a new international test standard (IEC 63437) is under development, and these Guidelines may be updated when practicable to keep pace with major developments of this sort.

Those committed to comprehensive market development and prepared to invest in the requisite market assessment, impact analyses, stakeholder consultations, monitoring, awareness-raising and beyond should consider certification, procurement, incentives and other pathways to foster market growth. The Guidelines can be used to develop consistent approaches across countries, which in turn encourages economies of scale for products that save consumers money on energy costs and enable greater access to electricity. U4E hopes that this guidance is helpful in unlocking the many benefits of quality-assured, energy-efficient and climate-friendly off-grid refrigeration.

2 SCOPE OF THESE GUIDELINES

The Guidelines apply to refrigerating appliances (refrigerators, refrigerator-freezers and freezers) intended for use on, and/or compatible with, off-grid electricity systems, including low-voltage direct current (DC) systems, solar home systems, and DC or alternating current (AC) mini-grids, offered for sale or installed in residential or light commercial applications.

The Guidelines do not cover:

a) Products within the scope covered by the U4E Model Regulation Guidelines for Refrigerating Appliances,[4] or other energy efficiency standards for refrigerating appliances that are intended for use in AC electric mains-connected systems (except for mini-grids)[5]
b) Appliances where the primary function is not the storage of foodstuffs through refrigeration
c) Walk-in cold rooms
d) Other products that do not meet the definition of a refrigerator, refrigerator-freezer or freezer in this document.

[4] See Model Regulation Guidelines for Energy-Efficient and Climate-Friendly Refrigerating Appliances – United for Efficiency, https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficient-and-climate-friendly-refrigerating-appliances.
[5] This implies typical grids that meet the quality requirements of International Electrotechnical Commission (IEC) TS 62749: 2020 Assessment of power quality – Characteristics of electricity supplied by public networks.

3 TERMS AND DEFINITIONS

This document refers to the following standards and guidelines:[6]

a) Draft working document of IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods (May 2023)

b) U4E Model Regulation Guidelines for Climate-Friendly and Energy-Efficient Refrigerators (September 2019)[7]

c) Global Lighting and Energy Access Partnership (Global LEAP) Award Off- and Weak-Grid Refrigerator Test Method Version 3 (July 2021)[8]

d) IEC 62552-1, -2, -3: 2015 Household Refrigerating Appliances – Characteristics and Test Methods

e) IEC 62552-1, -2, -3: 2015/AMD1: 2020 Household Refrigerating Appliances – Characteristics and Test methods

f) ISO 22044: 2021 Commercial Beverage Coolers – Classification, Requirements and Test Conditions

g) IEC 62257-9-5: 2018 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

h) IEC TS 62257-9-8: 2020 Renewable Energy and Hybrid Systems for Rural Electrification – Part 9-8: Integrated Systems – Requirements for Stand-alone Renewable Energy Products with Power Ratings Less Than or Equal to 350 W

i) EN 50530: 2010: Overall Efficiency of Grid-connected Photovoltaic Inverters

j) WHO/PQS/E003/RF05-VP.5: Refrigerator or Combined Refrigerator and Water-pack Freezer – Solar Direct Drive Without Battery Storage

k) WHO/PQS/E003/RP03-VP.3: Refrigerator or Combined Refrigerator and Water-pack Freezer – Intermittent Mains-powered, Compression Cycle

l) IEC 62124: 2004 Photovoltaic (PV) stand-alone systems – Design verification

m) IEC 60335-2-24: 2010/AMD: 2017 Household and Similar Electrical Appliances – Safety – Part 2-24: Particular Requirements for Refrigerating Appliances, Ice-cream Appliances and Ice Makers

n) VeraSol Draft Version 0.1 Requirements for VeraSol Certification of Refrigerators (June 2022)[9]

o) IEC 60335-1:2020 Household and Similar Electrical Appliances – Safety – Part 1: General Requirements

p) IEC 60335-2-75:2012/AMD2:2018 Amendment 1 – Household and Similar Electrical Appliances – Safety – Part 2-75: Particular Requirements for Commercial Dispensing Appliances and Vending Machines

q) IEC 60335-2-89:2019 Household and Similar Electrical Appliances – Safety – Part 2-89: Particular Requirements for Commercial Refrigerating Appliances and Ice-makers with an Incorporated or Remote Refrigerant Unit or Motor-compressor

r) U4E Green Public Procurement Technical Guidelines and Specifications for Energy-efficient Refrigeration Appliances[10]

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[6] A new IEC standard (IEC 63437: Test standard for refrigerated appliances for use with off grid or weak grid), under development at the time of this writing, will be referenced upon its release.

[7] b) refers to standards d) and m).

[8] c) refers to standards d) and f) to m).

[9] n) refers to standards b), c), and o) to q). n), under development at the time of this writing, will be referenced upon its release.

[10] r) refers to b) and d).

Table 1, Table 2 and Table 3 provide the definitions of the relevant terms in this document. Unless otherwise specified, these definitions are harmonized with one or more of the standards listed above.

Table 1: Definitions of select terms in refrigerating appliances and compartments

Term	Definition
Refrigerating appliance	Insulated cabinet with one or more compartments that are controlled at frozen or 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.
Off-grid refrigerating appliance	Refrigerating appliance intended for use on, and/or compatible with, off-grid energy systems, including low-voltage DC systems, solar home systems and mini-grids.
Solar direct drive refrigerating appliance	DC-supply refrigerating appliance designed for direct connection with a defined photovoltaic solar panel, generally containing an integrated thermal battery to allow autonomous operation during the night. Note that some solar direct drive appliances may have a small electrical battery to supply internal lighting, fans or electronics.
Refrigerator	Refrigerating appliance having one or more unfrozen compartments.
Refrigerator-freezer	Refrigerating appliance having at least one unfrozen food compartment and at least one frozen compartment.
Freezer	Refrigerating appliance having one or more frozen compartments.
Variable temperature refrigerator	Refrigerating appliance that has one compartment with a variable temperature compartment that can be operated either as an unfrozen compartment or as a frozen compartment.
Compartment	An enclosed space within a refrigerating appliance, which is directly accessible through one or more external doors, which may itself be divided into sub-compartments.
Unfrozen compartment	Compartment for the storage and preservation of unfrozen products where the storage compartment reference temperature is above 0°C and zero-star compartments, i.e., any of the following compartment types: zero-star, 8°C, fresh food, cellar.
Frozen compartment	Compartment for the storage and preservation of frozen products where the storage compartment reference temperature is equal or below -6°C, i.e., any of the following compartment types: one-star, two-star, three-star, four-star.
Freezer compartment	Compartment that meets three-star or four-star requirements (in certain instances, two-star sections and/or sub-compartments are permitted within the compartment).
Fresh food compartment	Compartment for the storage and preservation of unfrozen food, where the reference temperature is 4.0°C.
8°C compartment	Compartment primarily designed for food and beverages to be stored at a reference temperature of 8.0°C.
Cellar compartment	Compartment primarily designed for food and beverages to be stored at a reference temperature of 12.0°C.
Zero-star compartment	Relatively small compartment, generally residing in a fresh food compartment, in which the temperature is not warmer than 0°C and can be used for the production and storage of ice (e.g., ice cubes).
One-star compartment	Compartment where the storage temperature is not warmer than -6°C.
Two-star compartment	Compartment where the storage temperature is not warmer than -12°C.
Three-star compartment	Compartment where the storage temperature is not warmer than -18°C.
Four-star compartment	Compartment where the storage temperature meets three-star conditions and where the minimum freezing capacity meets the requirements of Clause 8 of IEC 62552-2:2015.
Variable temperature compartment	Compartment that is intended for use as two (or more) alternative compartment types (e.g., a compartment that can be either a fresh food compartment or frozen compartment) and can be set by a user to continuously maintain the operating temperature range applicable for each compartment type claimed.

Table 2: Definitions of select terms in energy systems

Term	Definition
Electrical battery	Component used for the purpose of storing and releasing electrical energy.
Solar panel	Photovoltaic solar panel, which converts energy from sunlight into electrical energy.
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. Cooling energy is released when electrical supply is low or not available. Note that the electricity can be supplied by a solar-driven system or mini grid.

Table 3: Definitions of select terms in testing and evaluation

Term	Definition
Quality inspection	Subjective verification of the packaging, product marking, user manual, user safety, cabinet design and durability, serviceability, maintenance and environmental impact considerations.
Ambient temperature	Temperature in the space surrounding the refrigerating appliance under test or assessment.
Reference ambient temperature	Representative ambient temperature during the year for a specific region.
Compartment volume	Volume of a specific compartment calculated according to IEC 62552-3: 2015, Annex H.
Refrigerating appliance volume	The sum of all compartment volumes of the refrigerating appliance
Adjusted volume	Volume for the storage of foodstuff adjusted for the relative contribution to the total energy consumption according to the different temperatures of the storage compartments.
Autonomy	Duration of time of a compartment from its reference temperature to its target temperature after the refrigerating appliance is disconnected from the power supply at 32°C ambient temperature.
Automatic defrost	Defrosting where no action is necessary to initiate the removal of frost accumulation at all temperature-control settings, to dispose of the defrost water or to restore normal operation.
Manual defrost	Defrost that is not automatic defrost.
Maximum current	The electrical current present when the compressor of the refrigerating appliance is started.
Under voltage	Input voltage operation set lower than the rated voltage, or where an input voltage range is rated lower than the lowest value of the rated voltage range.
Over voltage	Input voltage operation set higher than the rated voltage, or where an input voltage range is rated higher than the highest value of the rated voltage range.
Run time	The time that a refrigerating appliance actively maintains its internal temperature.
Refrigerant	Fluid used for heat transfer in a refrigerating system that absorbs heat at a low temperature and at a low pressure of the fluid and rejects heat at a higher temperature and at a higher pressure of the fluid, usually involving changes of phase of the fluid.
Global warming potential (GWP)	A measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to an equal mass of carbon dioxide in the atmosphere. GWPs in this document refer to those measured in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report[a] over a 100-year time horizon.
Ozone depletion potential (ODP)	Amount of degradation to the stratospheric ozone layer an emitted refrigerant causes relative to trichlorofluoromethane (CFC-11). ODPs in this document refer to the Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer, Twelfth Edition, Annexes A, B, C and F.

[a] The Kigali Amendment to the Montreal Protocol includes a list of 18 HFCs that are defined as controlled substances under Annex F of the Protocol, and the GWP values used in the Protocol for those 18 substances are still based on the 100-year GWP values in the IPCC Fourth Assessment Report. However, there is ongoing research into the appropriate ways to measure and compare the climate impact of different substances, hence the GWP values may be subject to future revision.

4 QUALITY AND PERFORMANCE

Refrigerating appliances falling within the scope of Section 1 and the definitions of Section 2 shall meet the requirements of Section 3. The requirements in this section are intended as a starting point for programme design, rather than as a final set of requirements for implementation, and do not obviate the need for assessments of local conditions and thorough consultations[11].

4.1 Detailed knowledge of the commodity

Refrigerating appliances shall meet the following in accordance with the Requirements for VeraSol Certification of Refrigerators:[12]

- Reporting requirements
- Run time requirements for refrigerators included with solar home system kits or solar home system kit families
- Advertisements and specifications
- Autonomy performance requirements (for solar direct drive type only)

4.2 Climatic zone

Refrigerating appliances shall be categorized according to their capability to maintain the target temperatures in different climatic zones, as shown in Table 4.

Table 4: Climatic zones for refrigerating appliances (IEC 62552: 2015)

Description	Class	Ambient temperature range
Extended temperature	SN	10°C to 32°C
Temperate	N	16°C to 32°C
Subtropical	ST	16°C to 38°C
Tropical	T	16°C to 43°C

[11] The terms “shall” and “requirement” in this section could be used to convey criteria to be met under a voluntary programme (e.g., so vendors know whether their product may qualify for a new incentive scheme). These terms are not intended to infer a regulatory approach. The Guidelines are an illustrative starting point for adaptation as suits the entity referencing these contents, so such terms should be revised as needed for local application.

[12] Based on draft version 0.2 (June 2022) at the time of writing this document. The Guidelines will be updated to reflect progress in VeraSol’s quality standard development.

4.3 Performance tests

Performance tests recommended for refrigerating appliances are as follows:

4.3.1 Ambient temperature and relative humidity

These environmental conditions help determine whether refrigerating appliances can maintain the desired internal temperature effectively and efficiently, ensuring food safety and optimal storage conditions, in the energy consumption and storage temperature performance tests.

- Test conditions related to the ambient temperature refer to IEC 62552-1: 2015, Annex A, Clause A.3.2.
- Test conditions related to the ambient relative humidity refer to IEC 62552-1: 2015, Annex A, Clause A.3.6.

4.3.2 Volume

A standardized method for measuring compartment volume of refrigerating appliances ensures that different manufacturers and models are measured and reported in a consistent manner, allowing for reliable, fair and accurate comparisons between products, and thus helps consumers make informed choices when purchasing refrigerating appliances.

- Determine compartment volume per IEC 62552-3: 2015, Annex H for each compartment.

4.3.3 Maximum current

This test is useful for protecting electrical components, ensuring compatibility with the photovoltaic or solar home system, addressing concerns such as temporary voltage drops in the system. It helps manufacturers deliver reliable, safe and efficient products that can integrate with photovoltaic or solar home systems.

- Determine the maximum current (inrush current) required for proper operation per IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods.
- If the final version of IEC 63437 is not available, the test refers to the latest draft document, or Global LEAP Award Off- and Weak-Grid Refrigerator Test Method Version 3.

4.3.4 Pull-down

This test measures the time taken by a refrigerating appliance to lower the temperature of its storage compartment from an initial higher temperature to a desired lower temperature, and helps assess how quickly it can bring the compartment to the desired temperature. A faster pull-down time indicates efficient cooling performance, which is essential for maintaining food safety and preserving perishable items.

Empty pull-down

- Determine the cooling time of a refrigerating appliance to reference temperatures, after applying the coldest possible thermostat setting upon initial installation, per IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods.
- If the final version of IEC 63437 is not available, the test refers to the latest draft document, or Global LEAP Award Off- and Weak-Grid Refrigerator Test Method Version 3, and additionally Clause D.3 of IEC 62552-1: 2015.

Beverage pull-down

- Determine the pull-down time of a refrigerating appliance loaded with 330 milliliter cans to reference temperatures, applying the coldest thermostat setting possible, per IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods, and Clause 6.3.5 of ISO 22044: 2021.
- If the final version of IEC 63437 is not available, the test refers to the latest draft document of IEC 63437.

4.3.5 Energy consumption

This test helps ensure consistent and comparable measurements across different appliance models and brands. It allows for fair and accurate comparisons of energy efficiency performance, enabling consumers to make informed purchasing decisions.

- Determine energy consumption at normal ambient conditions, applying the coldest compartment temperature specification possible, per IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods.
- If the final version of IEC 63437 is not available, the test refers to the latest draft document, or Global LEAP Award Off- and Weak-Grid Refrigerator Test Method Version 3, and Clause D.3 of IEC 62552-1: 2015, and IEC 62552-3: 2015.

The ambient temperature condition for the energy consumption test is 32°C.

Solar direct drive refrigerating appliances

- Determine energy consumption per IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods.
- If the final version of IEC 63437 is not available, the test refers to the latest draft document.

4.3.6 Storage temperature performance

This test helps ensure that the appliance is capable of maintaining the desired temperature range consistently and that stored food remains fresh and safe for consumption. Different types of food have specific temperature requirements for optimal preservation. By conducting storage temperature performance tests, manufacturers can verify that their refrigerating appliances can maintain the appropriate temperatures for various food categories and identify any potential issues with temperature control early on, reducing the risk of product failures or malfunctions. This enables consumers to make more informed decisions to select appliances that meet their specific storage needs. When appliances deliver reliable and consistent temperature control, this fosters consumer trust and satisfaction.

- Determine energy consumption and storage temperatures at extreme ambient conditions, applying the coldest compartment temperature specification possible per IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods.
- If the final version of IEC 63437 is not available, the test refers to the latest draft document, or Global LEAP Award Off- and Weak-Grid Refrigerator Test Method Version 3.

4.3.7 Under- and over-voltage

Under- or over-voltage conditions can put stress on electrical components within refrigerating appliances, such as compressors, motors and control systems. Testing appliances under such conditions helps assess their ability to withstand voltage fluctuations and ensures that the components are designed and rated to handle variations in voltage without damage or malfunction. This protects refrigerating appliances from potential failures and extends their lifespan. Voltage fluctuations can affect the performance and efficiency of refrigerating appliances. Off-grid photovoltaic or solar home systems may experience voltage fluctuations that lead to inadequate cooling, increased energy consumption and/or reduced overall appliance performance. By testing appliances under different voltage conditions, manufacturers can assess the impact of voltage fluctuations. This information enables them to optimize designs, implement voltage regulation mechanisms and incorporate protective features to ensure optimal performance under varying voltage conditions.

- Verify performance and energy consumption impacts of high- and low-input voltage levels per IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods.
- If the final version of IEC 63437 is not available, the test refers to the latest draft document, or Global LEAP Award Off- and Weak-Grid Refrigerator Test Method Version 3.

4.3.8 Autonomy

This test helps ensure that refrigerating appliances can operate reliably and maintain proper cooling functionality even when disconnected from external power sources for an extended period. Off-grid refrigerating appliances often rely on energy storage systems, such as thermal or electric batteries, to store and provide power when the primary energy source is not available. The autonomy test evaluates the efficiency of the appliance energy management system by measuring how long the appliance can sustain its operation solely on stored energy. This test helps manufacturers optimize the energy consumption and management of the appliance, ensuring that it maximizes the use of available power resources and minimizes energy waste, which is particularly needed by users in remote or energy-constrained situations.

- Determine the compartment temperature rise of a refrigerating appliance during a power outage per IEC 63437 Off- and Weak-Grid Refrigerating Appliances – Characteristics and Test Methods.
- If the final version of IEC 63437 is not available, the test refers to the latest draft document, or Global LEAP Award Off- and Weak-Grid Refrigerator Test Method Version 3, and additionally Clause D3 of IEC 62552-1: 2015 (for unfrozen compartment) or Clauses 6.3.3.3 - 6.3.3.4 of IEC 62552-1: 2015 (for frozen compartment).

4.4 Energy use calculation

Annual Energy Consumption (AEC)[13] is calculated per Equation 1:

Equation 1. $AEC = EC_{32} \times (365/1000)\ in\ kWh\ per\ year$

where EC_{32} is energy consumption in watt-hours (Wh) per 24 hours based on an ambient temperature of 32°C, rounded to the nearest integer.

[13] The energy consumption measured at standard test conditions may be different from that in actual use case conditions where refrigerating appliances could further draw power by repeated opening of the door and re-stocking with warm contents.

AV is Adjusted Volume, as calculated per Equation 2:

Equation 2. $\boldsymbol{Adjusted\ Volume\ (AV) = \sum_{i=1}^{n}(Volume_i \times K_i)}$

where K_i is volume adjustment factor, calculated per Equation 3 and rounded to two decimal places.

Equation 3. $\boldsymbol{K = \frac{T_1 - T_c}{T_1 - T_2}}$

for fresh food compartments, *K*=1

for other compartments, T_1 is reference ambient temperature selected by the country, T_2 is temperature of fresh-food compartment (4°C), and T_c is standard reference temperature of the individual compartment concerned in Table 5.

Table 5: Examples of volume adjustment factor (K) calculation

Reference temperature	Fresh food compartment	Frozen food compartment	
T_1=32°C	K=1 (T_2=4°C)	T_c=-6°C	K=1.36
		T_c=-12°C	K=1.57
		T_c=-18°C	K=1.79

Reference Annual Energy Consumption (AEC_{ref}) is an indicative AEC for refrigerating appliances to meet at the higher end.

Table 6: AEC_{Max} Requirements for VeraSol Certification of Refrigerators

Product Category	Reference Annual Energy Consumption (AEC_{ref})
Refrigerators	0.220×AV+137
Refrigerator-freezers	0.288×AV+210
Freezers	0.268×AV+247

Where:

Reference ambient temperature is 32°C.
The AEC_{Max} calculation shall be rounded off to the nearest kWh per year. If the calculation is halfway between the nearest two kWh per year values, the AEC_{Max} shall be rounded up to the higher of these values.

The energy efficiency index (EEI) is defined as Equation 4.

Equation 4. $\boldsymbol{EEI = \frac{AEC}{AEC_{ref}}}$

EEI=1 is where AEC is equivalent to AEC_{ref}

An alternative energy performance index, R, is defined as Equation 5.

Equation 5. $R = \frac{AEC_{ref}}{AEC}$

R = 1 where AEC is equivalent to AEC_{Max}

4.5 Performance requirements

4.5.1 Temperature

Appliances, excluding cellar compartments, shall maintain a temperature ≤ 8°C with +/-1°C tolerance at an ambient temperature of 43°C.

Freezers shall maintain a temperature ≤ 0°C with +/-1°C tolerance at an ambient temperature of 43°C.

The pull-down time required to lower the temperature of the refrigerating appliance, except for solar direct drive, to its advertised temperature class shall be < 8 hours with a 15% tolerance.

The temperature inside the fresh food compartment of the refrigerating appliance shall be adjustable to +4°C with +1°C tolerance, at an ambient temperature of 32°C, as described in IEC 62552-3.

The temperature inside the freezer compartment of the refrigerating appliance shall be adjustable between -6°C and -18°C, at an ambient temperature of 32°C, as described in IEC 62552-3.

All refrigerating appliances shall have an integrated temperature thermometer.

4.5.2 Voltage

Refrigerating appliances shall operate appropriately in the range of +20%/-10% of the rated voltage.

4.5.3 Energy consumption

AEC, as calculated per Equation 1, shall be less than or equal to AEC_{Max}, as calculated per Table 6.

For a product to meet the high efficiency grade, its performance shall be calculated per either Equation 4 or Equation 5, rounded to two decimal places, and it shall meet the requirements in Table 7.

Table 7: Energy performance label requirements

	Reference	High Efficiency Requirements	
		Intermediate	High
Refrigerators	EEI=1.00	EEI=0.65	EEI=0.40
Refrigerator-freezers	EEI=1.00	EEI=0.85	EEI=0.65
Freezers	EEI=1.00	EEI=0.85	EEI=0.65

The EEI equivalent R values are calculated as Equation 5. The reference value is equivalent to the Low requirement of the U4E Model Regulation Guidelines for (grid-connected) Refrigerating Appliances. The Intermediate and High requirements represent high efficiency levels that can be encouraged by policy programmes such as procurement and incentive programmes.

4.5.4 Refrigerants and foam-blowing agents

Refrigerants and foam-blowing agents shall meet requirements for their ODP and GWP over a 100-year time horizon according to the limitations specified by local legislation or listed in Table 8[14]. Refrigerant GWP values refer to those in the IPCC's Fourth Assessment Report (see the note on Table 3).

Table 8: Reference values for refrigerant and foam-blowing agent characteristics

	Maximum	Encouraged
ODP	0	0
GWP	1 500	20

Note: Numbers shown are upper limits)

Products using hydrocarbon (HC) refrigerants shall comply with IEC 60335-2-24:2010/AMD:2017, or a subsequent revision, or a nationally modified edition of IEC 60335-2-24.

4.6 Product information

The original equipment manufacturer (OEM) shall provide a label to the importer, product retailer or installer before the product enters the market.

The label shall indicate:

a) Model name / number
b) Country where the product was manufactured
c) Power input (AC and/or DC; Input voltage range; frequency for AC)
d) Maximum power (W) / current (A)
e) Withstand voltage (V), if applicable
f) Nominal rated power (W) / voltage (V) / current (A)
g) Volume of the different compartments
h) Temperature classification of each compartment
i) Rated (reference) ambient temperature in °C or °F
j) Rated energy performance grade, if applicable
k) Daily energy consumption in Wh or kWh at rated ambient temperature
l) Refrigerant and foam-blowing designation, in accordance with ISO 817 or ASHRAE 34, including ODP and GWP, and mass
m) Pull-down time
n) Maximum autonomy time
o) Recommended photovoltaic system size

All representations of energy performance shall indicate how the performance rating was obtained (e.g., by referring to a test method or rating conditions, etc.) and that such rating may not be representative of actual annual energy consumption in all situations.

The label shall be affixed on the product in a location that is readily visible by the consumer.

[14] Set the date by which these requirements come into effect based on the availability and cost of viable refrigerant gases, which may not coincide with the availability and cost of meeting energy efficiency requirements.

Products that meet the higher performance grade requirements per Section 4 of this document are eligible for [TBD by programme administrator].

4.7 Repairability

Repairability requirements may apply specifically to off-grid refrigerating appliances or align with other product groups whose technical similarities allow for common requirements. Repair and refurbishment options applicable to malfunctioning or broken products should be within their useful lifetimes[15].

4.7.1 Availability of spare parts

The manufacturer or supplier shall provide information on the supply of the following essential spare parts.

For professional repairers:[16]

- Thermostat
- Temperature sensors
- Printed circuit boards
- Light sources
- Fans

For professional repairers and end users:

- Door handles and door hinges
- Trays and baskets
- Door gaskets

The manufacturer or supplier shall specify how professional repairers and end users are able to order/purchase spare parts.

The manufacturer or supplier shall ensure that these spare parts can be delivered in a reasonable period from the date of order and replaced with the use of commonly available tools and without damage to the appliance.

4.7.2 Access to repair and maintenance information

Apart from making available the spare parts listed above, if requested by qualified professional repairers, the manufacturer or supplier shall provide access to the following appliance repair and maintenance information:[17]

- Qualification requirements of maintenance personnel
- Unequivocal appliance identification
- A disassembly map or exploded view
- List of necessary repair and test equipment
- Component (e.g., part number) and diagnosis information (e.g., minimum and maximum theoretical values for measurements)

[15] Typically assumed to be 10-12 years from the date of manufacture, unless specified by manufacturers.
[16] To access repair and maintenance information, the professional must have the technical competence to repair refrigerating appliances and to comply with applicable regulations for repairers of electrical equipment in the country of application.
[17] Manufacturers, importers or authorized representatives may charge reasonable and proportionate fees for access to the repair and maintenance information or for receiving regular updates. A fee is reasonable if it does not discourage access by failing to account for the extent to which the professional repairer uses the information.

- Wiring and connection diagrams
- Diagnostic fault and error codes (including manufacturer-specific codes, where applicable)
- Data records of reported failure incidents stored on the refrigerating appliance (where applicable)
- Access to professional repair, such as internet webpages, addresses, contact details
- The minimum period during which spare parts, necessary for the repair of the appliance, will be available

The manufacturer or supplier shall give all necessary information to all users to optimize the operation and minimize the environmental impact of the refrigerating appliance. Instruction manuals for installers and end users shall include the following information:

- Combination of drawers, baskets and shelves that result in the most efficient use of energy
- Recommended setting of temperatures in each compartment for optimum food preservation
- Instructions for correct installation and end-user maintenance, including cleaning of the appliance and circuit components (e.g., number of times per year to clean the condenser to maintain energy-efficient performance)

4.8 Packaging

Packaging shall be the minimum possible to facilitate handling of the equipment and to protect its integrity during transport and storage. It should also be recyclable or reusable. Manufacturers or suppliers are encouraged to use packaging with at least one of the following characteristics:

- Does not contain styrene (e.g., Styrofoam, polystyrene, expanded polystyrene [EPS])
- Maximizes post-consumer recycled content
- Minimizes the contents of lead, cadmium, mercury and hexavalent chromium
- Packaging remains the property of the supplier and not the recipient

The packaging of new refrigerators and freezers must be separated from other waste materials. If an extended producer responsibility system is established for these packaging materials, it shall be managed by the entity supplying the appliances[18]. Otherwise, packaging waste shall be delivered directly to the local recycler or waste management facility.

4.9 Quality standards for solar home system kits

Solar home system kits covered by the standards must have a peak power of 350 watts or less and a DC voltage of 35 volts or less per Lighting Global Solar Home System Kit Quality Standards Version 2.5 (2018), or the latest version, institutionalized in IEC TS 62257-9-8, which sets a baseline level of quality, durability and truth in advertising to protect consumers.

Conformance with the Quality Standards is evaluated based on results from laboratory testing according to the Quality Test Method (QTM) as defined by IEC/TS 62257-9-5. Products that meet the Quality Standards are issued a Specification Sheet and Verification Letter and posted on a digital product database.

[18] For products addressed by an extended producer responsibility policy, the producer (e.g., manufacturer, retailer or importer) is responsible for costs that can include requirements related to recycling and/or preparation for reuse. Usually, the producer charges this cost to its client in the initial price of the product.

5 DECLARATION OF ELIGIBILITY

Fulfilment of the requirements of Section 3 and any additional optional claims shall be demonstrated in the performance and quality assessment report, which:

- Demonstrates that the product model fulfils the requirements of the programme
- Provides any other information needed for the technical documentation file
- Specifies the reference setting and conditions in which the product complies with the programme
- Includes a report from an ISO-accredited test lab (which can be identified from the VeraSol test lab network)

The report shall be submitted to [programme administrator name] for review prior to making the product eligible for the programme. If the report is approved, this approval shall be confirmed by written correspondence from [programme administrator name]. After that, the product shall be listed on the designated platform [product registration system], and it is eligible for [the programme].

If a report is rejected, a written explanation will be provided by the [programme administrator] to the submitter. All aspects identified in the written explanation shall be addressed in a revised report. Until the report is approved, the product is ineligible for [the programme].

The report is valid for the designated model for 24 months. An updated report or a notice of withdrawal shall be submitted to [agency name] at least 90 days prior to the change in specifications or cancellation of production of the approved product.

6 REVISION

The requirements shall be updated by [a simple administrative rulemaking] based on an updated market assessment conducted on the cost and availability of new technologies once every [three] years after this programme goes into effect.

Annex A: Examples of Energy Consumption Calculations

A-1. Refrigerator

The default refrigerating appliance is a refrigerator with a fresh food compartment only.

Step 1: Adjusted Volume

At reference ambient temperature 32°C

	Volume (L)	Volume Adjustment Factor (K)	Adjusted Volume (L)
Fresh food storage	92	$\frac{32-4}{32-4} = 1.00$	$(92 \times 1.00) = 92$
Frozen food storage	–	–	

Step 2: Annual Energy Consumption

Measurement temperature	°C	32	
Temperature control settings	(Graduated dial)	5.9	5.7
Temperature in fresh food compartment	°C	3.7	4.9
Energy consumption per 24h	kWh/24h	0.874	0.785
Energy consumption by interpolation*	kWh/24h	0.852	
Annual energy consumption at 32°C (AEC_{32})	kWh/y	311	

* Multiple tests using different temperature control settings can be conducted to estimate the energy consumption when the fresh food compartment is at exactly +4°C. Reference IEC 62552: 2015, Part 3, Annex I (worked examples of energy consumption calculations), Section I.3.2.2 (single compartment example) for detailed calculation methodology.

Step 3: Energy Efficiency (Performance) Index

Reference temperature	32°C
Volume (L)	Fresh food compartment (92)
AV (L)	92
EC (kWh/d)	0.852
AEC (kWh/y)	$0.852 \times 365 = 311$
EEI	$\frac{311}{0.220 \times 92 + 137} = 1.98$
R	$\frac{0.220 \times 92 + 137}{311} = 0.51$

The energy consumption of this model exceeds the maximum annual energy consumption requirements – i.e., EEI > 1 (R < 1) – and hence the model does not meet the Intermediate energy performance requirement.

A-2. Refrigerator-freezer

The default refrigerating appliance is a frost-free (automatic defrost) refrigerator-freezer with a fresh food compartment and a freezer compartment.

Step 1: Adjusted Volume

At reference ambient temperature 32°C

	Measured volume (L)	Volume Adjustment Factor (K)	Adjusted Volume (L)
Fresh food storage	137	$\frac{32-4}{32-4}=1.00$	$137\times1.00+63\times1.79\times1.1=261$
Frozen food storage	63	$\frac{32-(-18)}{32-4}=1.79$	

Step 2: Annual Energy Consumption

Measurement temperature	°C	32	
Temperature control settings	(Graduated dial)	4.9	4.6
Temperature in fresh food compartment	°C	3.7	4.9
Temperature in frozen food compartment	°C	-21.6	-20.4
Energy consumption per 24h	kWh/24h	0.739	0.679
Energy consumption by interpolation*	kWh/24h	0.724	
Annual energy consumption at 32°C (AEC_{32})	kWh/y	264	

* Multiple tests using different temperature control settings can be conducted to estimate the energy consumption when the fresh food compartment is at exactly +4°C. Reference IEC 62552: 2015, Part 3, Annex I (worked examples of energy consumption calculations).

Step 3: Energy Efficiency (Performance) Index

Reference temperature	32°C
Volume (L)	Fresh food compartment (137), Frozen food compartment (63)
AV (L)	261
EC (kWh/d)	0.724
AEC (kWh/y)	$0.724\times365=264$
EEI	$\frac{264}{0.288\times261+210}=0.93$
R	$\frac{0.288\times261+210}{264}=1.08$

The energy consumption of this model meets the maximum annual energy consumption requirements – i.e., EEI = 0.93 (R = 1.08) – and hence the model does not meet the Intermediate energy performance requirement.

A-3. Freezer

The default refrigerating appliance is a freezer with a freezer compartment only.

Step 1: Adjusted Volume

At reference ambient temperature 32°C

	Volume (L)	Volume Adjustment Factor (K)	Adjusted Volume (L)
Fresh food storage	-	-	$295 \times 1.79 = 528$
Frozen food storage	295	$\frac{32-(-18)}{32-4} = 1.79$	

Step 2: Annual Energy Consumption

Measurement temperature	°C	32	
Temperature control settings	(Graduated dial)	3.5	3.0
Temperature in fresh food compartment	°C	-	-
Temperature in frozen food compartment	°C	-18.4	-17.7
Energy consumption per 24h	kWh/24h	1.330	1.294
Energy consumption by interpolation*	kWh/24h	1.309	
Annual energy consumption at 32°C (AEC_{32})	kWh/y	478	

* Multiple tests using different temperature control settings can be conducted to estimate the energy consumption when the freezer compartment is at exactly -18°C. Reference IEC 62552: 2015, Part 3, Annex I (worked examples of energy consumption calculations), Section I.3.2.2 (single compartment example) for detailed calculation methodology.

Step 3: Energy Efficiency (Performance) Index

Reference temperature	32°C
Volume (L)	Frozen food compartment (295)
AV (L)	528
EC (kWh/d)	1.309
AEC (kWh/y)	$1.309 \times 365 = 478$
EEI	$\frac{478}{0.268 \times 528 + 247} = 1.23$
R	$\frac{0.268 \times 528 + 247}{478} = 0.81$

The energy consumption of this model exceeds the maximum annual energy consumption requirements – i.e., EEI = 1.23 (R = 0.81) – and hence the model does not meet the Intermediate energy performance requirement.

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