ETV Verification Protocol
SolarChill B for domestic and “light” commercial use series

DTI Refrigeration and Heat Pump Technology
J.no. 1101
Test no. 1 – Type-test

Version 1.0

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2 Introduction

Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and quality assurance.

DANETV is a Danish center for verification of environmental technology.

This protocol describes the framework for the verification of the technology product and provides information required for the Test plan.

2.1 Name of the product

The product is the SolarChill B for domestic and "light" commercial use series

2.2 Name and contact of vendor

SolarChill Project Coordinator, Mr. János Maté

Contact: 5106 Walden St., Vancouver, BC., Canada V5W 2V7
Phone: +1-604-327-0943, E-mail: jmate@telus.net

2.3 Name of center/verification responsible

Danish Technological Institute ,Verification Center, Refrigeration and Heat Pump Technology, building 2, Gregersensvej, DK-2630, Taastrup, Denmark.

Verification responsible: Emil Jacobsen (EMJA), e-mail: emil.jacobsen@teknologisk.dk, phone: +45 7220 2323

Internal reviewer: Bjarke Paaske, e-mail: bjarke.paaske@teknologisk.dk, Phone: +45 7220 2037

2.4 Verification and test organization

The verification will be conducted by Danish Technological Institute. The test organization is shown in figure 1.

The verification is planned and conducted to satisfy the requirements of the ETV scheme currently being established by the European Union (EU ETV).

Verification and tests will be performed by Danish Technological Institute under DANETV under contract with SolarChill Project Coordinator, Mr. János Maté

The day to day operations of the verification and tests will be coordinated and supervised by DTI personnel, with the participation of the vendor, SolarChill Project Coordinator, Mr. János Maté

The testing will be conducted at the Danish Technological Institute, Gregersensvej, 2630 Taastrup.

DTI test center test sub-body will perform all samplings during the verification.

SolarChill Project Coordinator, Mr. János Maté will assist when necessary as described in the contract.

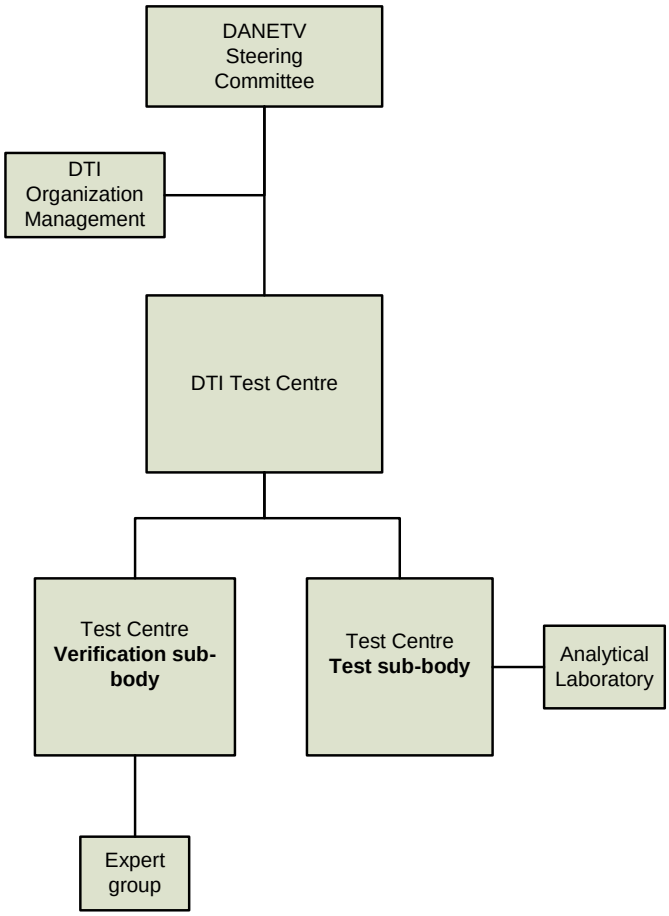

Figure 1 Verification orginization

Table 1 - Responsible personnel in test organization

Unit in test organization	Responsible
DTI Dan ETV steering committee member	Lars Jøker
DTI organization management Refrigeration and Heat Pump Technology	Claus S. Poulsen
DTI Refrigeration and Heat Pump Technology, Verification sub-body	Emil Jacobsen
DTI Refrigeration and Heat Pump Technology, Test sub-body	Bjarke Paaske

2.5 Expert group

The expert group assigned to this verification and responsible for review of the verification plan and report documents includes:

Preben Munter (PM), SEAS-NVE, phone +45 7029 2457, e-mail pm@seas-nve.dk

2.6 Verification process

Verification and tests will be conducted in two separate steps, by the verification sub-body and the test sub-body respectively.

The verification sub-body is responsible for preparation and compilation of the verification protocol and the test report.

The test sub-body is responsible for the test plan and the test report.

The steps in the verification are shown in figure 2.

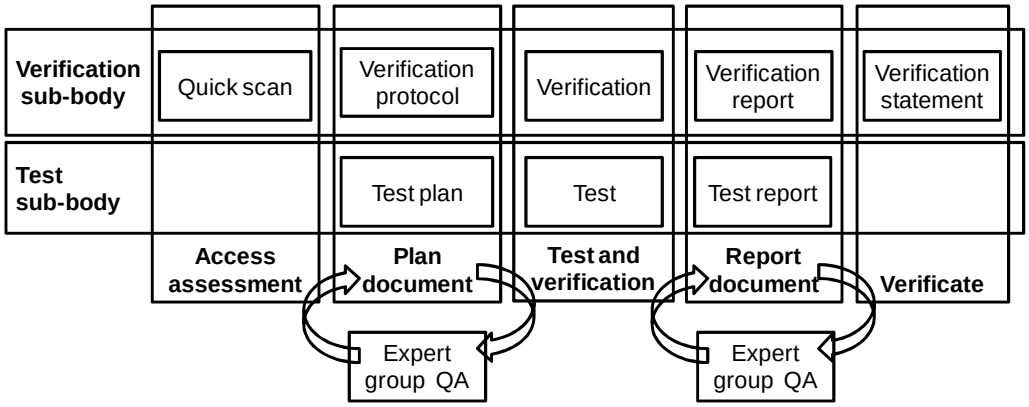

Figure 2 - Verification steps

A DANETV verification statement will be issued after completion of the verification.

3 Description of the technology

SolarChill B

The following technology description is based on the workings of an existing prototype. This description might not be applicable to future models, but is intended to give the reader a basic idea of how the concept of SolarChill B solar powered refrigerators without battery storage work.

The SolarChill B refrigerator series provides cooling by the means of a DC compressor powered by an external PV array. The cooling cycle is a Rankine vapor-compression refrigeration cycle with a natural refrigerant, isobutane (R600a), as working fluid.

The PV array consists of 3 x 60 W modules providing 12 V DC, which can be directly connected to the compressor.

The compressor is equipped with an electronic control with a build-in adaptive speed control known as Adaptive Energy Optimizer – AEO. Thereby the compressor will stepwise speed up from low speed to maximum speed in increments of 12.5 RPM/min. If the power from the PV array is not sufficient the compressor will stop, thereafter it will try to start every minute until the power is sufficient again. The compressor also has a “soft-start” feature, thus requiring a low starting current. The speed range of the compressor is 2000 – 3500 PRM. The compressor is thus enabled to deliver a varying cooling capacity that accordingly utilizes most of the energy potential collected by PV array. The characteristics of the PV array and the implementation of the adaptive speed control ensures that power from the PV array is delivered at the maximum power point (MPP).

When there is no or negligible solar radiation during overcast days or during the nighttime the cooling demand is met by means of convection from a thermal energy storage that consists of ice. The cooling capacity of the refrigerator is principally dictated by the amount of solar radiation being converted into power delivered to the compressor. When the compressors instantaneous cooling capacity exceeds the cooling demand, energy is stored in the thermal energy storage, as ice, for later use. Accordingly, when the cooling demand is higher than the compressors cooling capacity, or when the compressor is turned off, additional cooling capacity is released from the thermal energy storage.

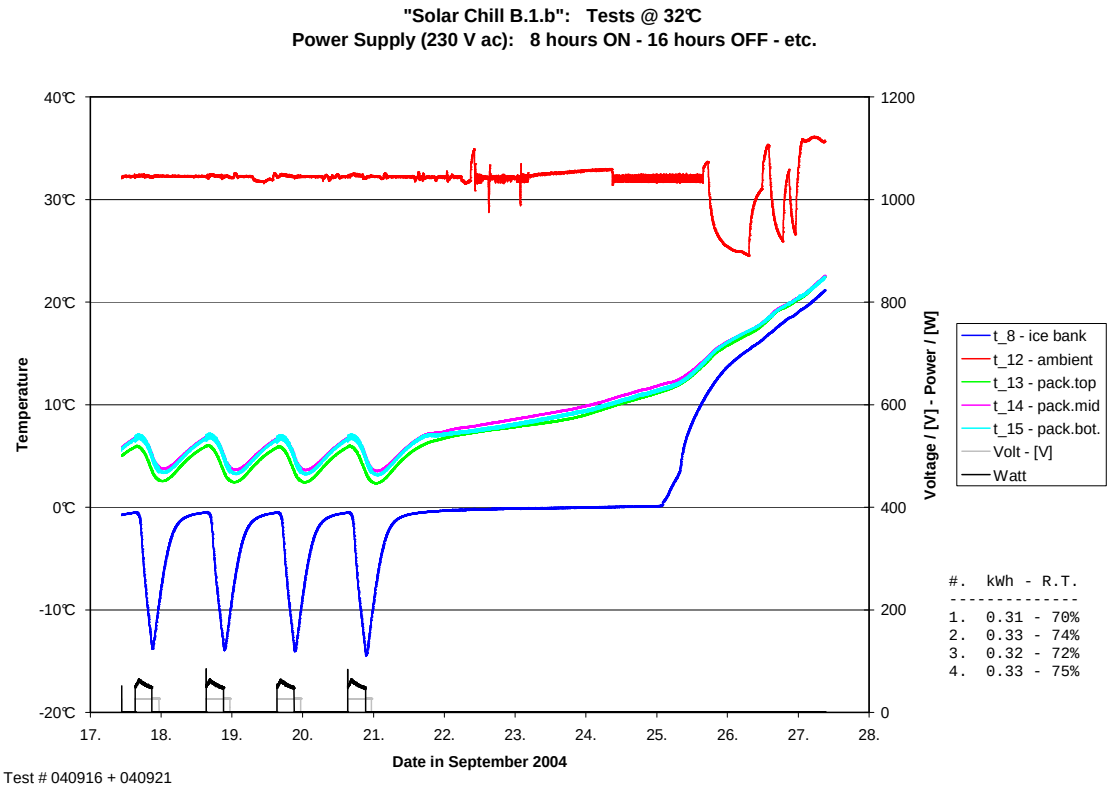

Figure 3 Initial lab test of a SolarChill upright prototype at 32°C ambient temperature. The temperature inside the compartment is between 2.5 and 7.5°C. The compartment contained 10 kg of test packages.

The temperature inside the refrigerator compartment is regulated by a mechanical thermostat with a sensor inside the cabinet. The thermostat can be set by the user. When the temperature gets to cold inside the compartment the compressor is stopped by the thermostat and vice versa.

4 Description of the product

The SolarChill B refrigerator series is characterized by appliances having well insulated cabinets with internal ice storage, and solar powered DC compressors without battery backup. The compressors are filled with a natural refrigerant. The ice storage is placed close to the evaporator, and has the function of a thermal energy storage.

At the moment the SolarChill B refrigerator series consists of a lineup of two different models, an upright type and a chest type, with the possibility of more to come in the future.

The main specifications of the existing models are as follows:

Compressor
Make and model: Danfoss BD35F

Refrigerant:	R600a (isobutane)
Refrigerant charge:	48 – 60 gr.
Speed range:	2000 – 3500 RPM
Operating voltage:	12 – 24 DC
Starting current:	< 3 A
Displacement:	3 cm^3

Electronic control

Make and model:	Danfoss AEO
Operating voltage:	10 – 45 V

Cabinet (chest type, 160 l)

Insulation:	100 mm
Dimensions:	850 x 720 x 600 x mm
Ice storage:	17.5 kg
Condenser:	Extrnal fin and tube
Evaporator:	

Cabinet (upright type, 200 l)

Insulation:	PUR, 80 mm
Dimensions:	1200 x 600 x 600 mm
Ice storage:	12.9 kg
Condenser:	Extrnal fin and tube
Evaporator:	Roll-bond type

5 Application and performance parameter definitions

5.1 Matrix/matrices

The matrix is the type of material the product is intended for.

- Food and drinks.

5.2 Target(s)

A target is defined as the property affected by the product

The target of the product is:

- Adequate cooling of refrigerated products using solar power only.

5.3 Effects

The effects are described as the way the target is affected

The effect of this application is primarily:

- Refrigeration of products without external power supply or batteries.

Secondarily the application will:

- Improve food safety and food hygiene in developing countries.
- Provide refrigeration technology to people with a need or wish to refrigerate food or drinks in parts of the world with no or unreliable electricity supply.
- Provide a more reliable, safer and cleaner form of refrigeration than kerosene refrigerators.
- Provide a refrigeration technology that is environmentally friendly as it does not use any ozone depleting or potent global warming substances.
- Improve on existing solar powered cooling technologies by bypassing the use of conventional lead batteries which have proven to be a major obstacle to the uptake of solar technology in developing countries.

5.4 Performance parameters for verification

The ranges of performance relevant for the application, as derived in Appendix 3, are presented below. These ranges are used for planning the verification and testing only.

Concerning the performance of the PV array the following parameter is measured at different irradiation levels:

- UI-curve

Concerning energy use of the refrigerator the following parameters must be measured:

- Current
- Voltage

Other performance parameters that are measured include:

- Temperature in test packages
- Temperature in climate chamber
- Humidity in climate chamber

All parameters are measured every minute and with a tolerance according to ISO 15502.

Besides the performance parameters to be obtained by testing, compilation of parameters describing user manual and occupational health & safety issues of the product are required as part of the verification.

5.5 Additional parameters

Besides the performance parameters to be obtained by testing, compilation of parameters describing user manual and occupational health & safety issues of the product are required as part of the verification.

6 Existing data

6.1 Summary of existing data

Previously tests of both the current SolarChill B prototypes refrigerators have been conducted. These tests primarily had the aim of final development and adjusting of the prototypes.

The SolarChill B upright prototype was tested in a climate chamber at a 25°C ambient temperature at DTI in Aarhus primo 2004. The compressor was powered by an external power supply simulating a PV array. The cabinet was filled with 10 kg of test packs and the temperature measured inside 3 of the test packs. The main test results from this test are shown in Figure 4, and show that the achievable temperature is adequate for food storage.

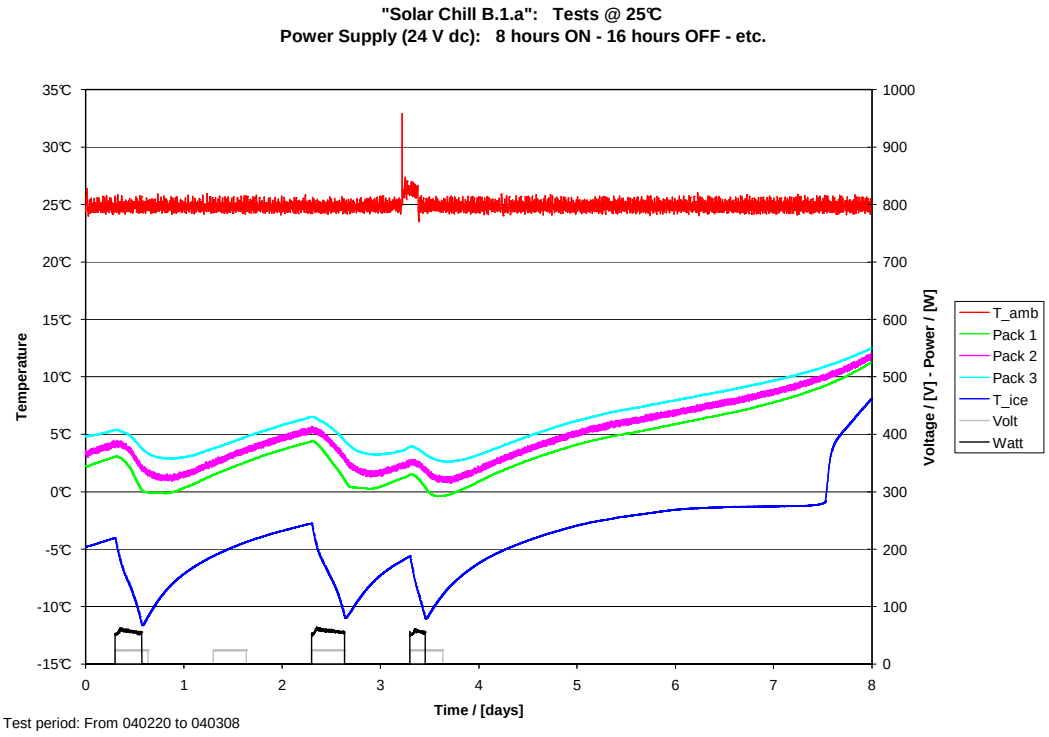

Figure 4 The main test results from the upright prototype tested primo 2004

Similarly a test has been conducted on the SolarChill chest prototype at 30°C ambient temperature, and has again shown the great potential of solar powered refrigerators.

6.2 Quality of existing data

Documentation of previous experiments exists, but the experiments were not intended as an actual type-test, but more a final development and adjusting of the prototypes and a suggestion to a future type-test.

6.3 Accepted existing data

Data from previous experiments is not usable for this verification process.

7 Test plan requirements

7.1 Test design

The type-test is based on existing standard WHO/PQS/E03/RF05-VP.2 (20.05.2010), which is a standard for testing solar powered refrigerators and water-pack freezers without battery storage. The standard deal with performance, quality and safety, and includes tests for evidence of conformity, power consumption, day/night test, and the like.

As the above mentioned standard has been developed for verifying the performance vaccine coolers some alterations to the temperature requirements, test packages, and packing plan have been made. Changes to temperature are based on the existing European Standard EN ISO 15502 clause 6, changes to the test packages are made in accordance with clause 8.5, and changes to the packing plan are made in accordance with clause 13.3.

These alterations have been made to ensure the verification of proper food safety and hygiene, and relevance to the intended use of the product, which is refrigeration of perishable foods and drinks. EN ISO 15502 is a standard test of characteristics for household refrigerating cabinets.

Furthermore, to give a better idea of how the refrigerator will perform in an actual setting only being powered by a PV array, the voltage and current supplied from the PV array will be measured at the maximum power point at different solar radiation levels according to a solar radiation reference period. The measured voltage and current will then be the values used when the refrigerator is supplied by an external power supply during different performance related tests carried out in a climate chamber. Establishing the actual performance characteristics of the PV array prior to the tests in the climate chamber ensures that vendor claims are verified and that tests between different models and makes are comparable.

The solar reference periods used during the test of the PV array and the refrigerator performance tests is based on existing standard IEC 62124, which is a standard PV system design verification.

7.2 Reference analysis

No references are used for this verification process.

7.3 Data management

Data storage, transfer and control must be done in accordance with the requirements of the ETV Quality manual enabling full control and retrieval of documents and records.

7.4 Quality assurance

The quality assurance of the tests must include control of the test system and control of the data quality and integrity.

The test plan and the test report will be subject to review by the expert group as part of the review of this verification protocol and the verification report, see **Figure 2**.

7.5 Test report

The test report must follow the template of the TI verification Center Quality Manual /1/ with data and records from the tests presented.

8 Evaluation

The evaluation includes calculation of the performance parameters, see chapter 5.4 for definition, evaluation of the data quality based upon the test quality assurance, see chapter 7.4 for requirements, and compilation of the additional parameters as specified in chapter 5.5.

8.1 Calculation of performance parameters

All parameters of interest are analyzed and performance parameters concerning energy consumption, adequate cooling, cyclic variations of temperatures, etc. are held up against established acceptance/rejection criteria.

8.2 Evaluation of test data quality

The test report must follow the template of the TI Verification Center Quality Manual /1/.

8.3 Compilation of additional parameters

8.3.1 User manual

The manual shall include information on the system description. In particular, it should bear instructions for:

- Operation of the system
- Prevention of and dealing with incidents
- Occupational health and safety measures
- Service and maintenance
- Surveillance of the installation

8.3.2 Occupational health and environment

Machinery for cooling systems must comply with the Machinery Directive /3/. They must be designed and constructed in such a way that they can be used, adjusted and maintained throughout all phases of their life without putting persons at risk.

In detail the installations must satisfy the essential safety requirements contained in Annex I of the Directive, a correct conformity assessment must be carried out and a “Declaration of Conformity” must be given.

It is the responsibility of the manufacturer, importer or end supplier of the equipment to ensure that equipment supplied is in conformity with the Directive. In addition, Council Directive 89/655/EEC of 30 November 1989 /4/ places obligations on businesses and employers to take into account potential dangers to operators and other persons using or affected by machines and equipment.

In general terms, the directive requires that all equipment provided for use at work is:

Suitable for the intended use; safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case; used only by people who have received adequate information, instruction and training; and accompanied by suitable safety measures, e.g. protective devices, markings, warnings.

In addition, ISO 12100-2:2003 /4/ defines technical principles to help designers in achieving safety in the design of machinery.

The safety instructions must be documented for example in a safety data sheet and must be observed carefully.

9 Verification schedule

The verification is planned for 2010/2011. The overall schedule is given in Table 2.

Table 2 - Verification schedule

Task	**Timing**
Application definition document	Oct. 2010
Verification protocol with test plan	Oct. / Nov. 2010
Test	Jan. 2011
Test reporting	Jan. 2011
Verification	Feb. 2011
Verification report	Feb. 2011
Verification statement	Feb. 2011

10 Quality assurance

The test protocol, test plan, test report and verification report will be reviewed by internal and external experts according to the Quality plan for the verification, see table 3.

Table 3 - QA plan for the verification

Reviewers	**TI**	**Experts**
Plan document with application definition, verification protocol and test plan	BJPA	PM
Report document with test report and verification report	BJPA	PM

Reviews will be done using the TI review report template.

Appendix 1 Terms and definitions used in the verification protocol

Terms and definitions used in the protocol are explained in Table 1:

Table 1 - Terms and definitions used by the DANETV test centers

Word	**DANETV**	**Comments on the DANETV approach**
Analytical laboratory	Independent analytical laboratory used to analyse test samples	The test center may use an analytical laboratory as subcontractor
Application	The use of a product specified with respect to matrix, target, effect and limitations	The application must be defined with a precision that allows the user of a product verification to judge whether his needs are comparable to the verification conditions
DANETV	Danish center for verification of environmental technologies	None
(DANETV) test center	Preliminary name for the verification bodies in DANETV with a verification and a test sub-body	Name will be changed, when the final nomenclature in the EU ETV has been set.
Effect	The way the target is affected	The effect could be reduced energy consumption, better cooling performance etc.
(Environmental) product	Ready to market or prototype stage product, process, system or service based upon an environmental technology	The product is the item produced and sold and thus the item that a vendor submit for verification
Environmental technology	The practical application of knowledge in the environmental area	The term technology is covering a variety of products, processes, systems and services.
Evaluation	Evaluation of test data for a technology product for performance and data quality	None
Experts	Independent persons qualified on a technology in verification	These experts may be technical experts, QA experts for other ETV systems or regulatory

Word	DANETV	Comments on the DANETV approach
		experts
Matrix	The type of material that the product is intended for	Matrices could be cooling systems, cabinets, heat exchangers etc.
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis	An in-house method may be used in the absence of a standard, if prepared in compliance with the format and contents required for standards.
Performance claim	The effects foreseen by the vendor on the target (s) in the matrix of intended use	None
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance of an environmental technology product	The performance parameters must be established considering the application(s) of the product, the requirements of society (regulations), customers (needs) and vendor claims
Procedure	Detailed description of the use of a standard or a method within one body	The procedure specifies implementing a standard or a method in terms of e.g.: equipment used
Producer	The party producing the product	None
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis	None
Target	The property that is affected by the product	Targets could be temperature [° C], energy [kWh] etc.
Test center, test sub-body	Sub-body of the test center that plans and performs test	None
Test center, verification sub-body	Sub-body of the test center that plans and performs the verification	None

Word	DANETV	Comments on the DANETV approach
Test/testing	Determination of the performance of a product for parameters defined for the application	None
Vendor	The party delivering the product to the customer	Can be the producer
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance	None

Appendix 2 References (verification protocols, requirement documents, standards, methods)

1. DANETV. Center Quality Manual, 2008

2. European Parliament and Council. Directive 2006/42/EC of the 17th May 2006 on machinery and amending Directive 95/16/EC (recast).

3. European Council: Directive 89/655/EEC of 30 November 1989 concerning the minimum safety and health requirements for the use of work equipment by workers at work (amended 2007/30/EC).

4. ISO 12100-2:2003: Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles

5. WHO/PQS/E03/RF05-VP.2 (20.05.2010) – Refrigerator or combined refrigerator and water-pack freezer:compression-cycle. Solar direct drive without battery storage.

6. European Standard EN ISO 15502 – Household refrigerating appliances

7. Measurement protocol for energy reductions in Refrigerated display cabinets for ETV tests at DANETV

Appendix 3 Application and performance parameter definitions

This appendix defines the application and the relevant performance parameters application as input for verification and test of an environmental technology following the DANETV method.

A3.1 Applications

A3.1.1 Matrix/matrices

- Food and drinks

A3.1.2 Target(s)

The target of the product is:

- Adequate cooling of refrigerated products using solar power only with no battery storage

A3.1.3 Effects

The effect of this application is primarily:

- Refrigeration of products without external power supply or batteries.

Secondarily the application will:

- Improve food safety and food hygiene in developing countries.
- Provide refrigeration technology to people with a need or wish to refrigerate food or drinks in parts of the world with no or unreliable electricity supply.
- Provide a more reliable, safer and cleaner form of refrigeration than kerosene refrigerators.
- Provide a refrigeration technology that is environmentally friendly as it does not use any ozone depleting or potent global warming substances.
- Improve on existing solar powered cooling technologies by bypassing the use of conventional lead batteries which have proven to be a major obstacle to the uptake of solar technology in developing countries.