European Commission

Preparatory study on Refrigerated Containers

Task 1 and 2 report

1: Scope

2: Market, users and resources

Preliminary suggestions for policy options

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Preface

This report concerns Task 1: Scope, Task 2: Market, users and resources and preliminary conclusions and suggestions for policy options and policy measures for the preparatory study of ecodesign measures for refrigerated containers, also called reefers.

The Ecodesign Directive provides consistent EU-wide rules for improving the environmental performance of products placed on the EU market. The directive sets out minimum mandatory requirements for the energy efficiency of these products. This helps prevent creation of barriers to trade, improve product quality and environmental protection. The Ecodesign Working Plan 2016-2019 has identified refrigerated containers as a potential product group for ecodesign or energy labelling regulation.

This report was intended to report the outcome of task 1-4 of the MEErP methodology to create the basis for discussion at the first stakeholder meeting. However, during the initiation of the study, the European Commission and the study team agreed to focus on task 1 and 2 due to preliminary findings on challenges in establishing ecodesign requirements for refrigerated containers.

Therefore, based on further analyses, outcome of task 1 and 2 and comments from the stakeholders, a conclusion has been made on the feasibility in continuing the study. The analyses include the market of products in scope, specifically the question of containers being considered as means of transport of goods, because the Ecodesign Directive does not apply to means of transport for persons or goods; initial assumptions of the potential in possible ecodesign requirements on transport and stationary refrigerated containers; and possible issues in applying the Ecodesign Directive due to the majority of the containers being placed on the market outside EU.

Task 1 treated in chapter 1 outlines the scope of the regulation and of the review study as well as reports relevant standards and legislations related to refrigerated containers' energy consumption, durability and resource efficiency.

Task 2 treated in chapter 2 gives an overview of the refrigerated container market including sales, stock and base data on consumer costs. This does not include forecasts, but only the retrospect market development covered by available data.

Although only task 1 and 2 are carried out so far, the study team had to include aspects from task 3 and 4 in order to be able to provide a conclusion on the feasibility in continuing the study. The purpose of task 3 and 4 is described below, but the complete tasks will only be carried out if the Commission based on the task 1 and 2 conclusions and stakeholder comments finds worthwhile to continue the study process.

Task 3 regards the user behaviour, in order to suggest representative testing and energy consumption calculation at later stages of the study, end of life aspects, discussion of test standards etc.

Task 4 reviews the technical aspects of refrigerated containers and outlines the current technology levels in terms of average and best available technologies, as well as which technologies are expected to enter the market (best not yet available technology). Besides the energy consumption impact, the technologies are also reviewed in terms of resource efficiency.

Additionally, the report contains preliminary conclusions and suggestions for four alternative policy options:

1. Ecodesign requirements on replacement compressors and cooling units for refrigerated containers
2. Directive on refrigerated containers and ITU (Intermodal Transport Unit)
3. Include refrigerated containers for stationary use in the Regulation (EU) 2015/1095 (ecodesign requirements for professional refrigerated storage cabinets, blast cabinets, condensing units and process chillers)
4. Ecolabel for reefers

A preliminary and rough estimation of potential energy savings is 11 TWh/year of primary energy consumption if the transportation refrigerated container fleet corresponding to the EU share of the world's refrigerated container transport is being replaced with the currently best available technology.

Should half of the average EU stock of refrigerated containers for stationary storage use be exchanged with the currently best available technology saving potentials on 0.2 TWh/year after 2030 are estimated. Should half of the stock of refrigerated transportation containers related to EU for be exchanged with the currently best available technology saving potentials on 11 TWh/year after 2030 are estimated. These figures concern the stock and because the ecodesign requirements relate to the sales, these energy savings are achieved in pace with the replacement of the containers.

The preparatory study follows the seven tasks of the MEErP (Methodology for Ecodesign of Energy-related Products) but deviating as explained above. The seven MEErP tasks are:

- Task 1: Scope
- Task 2: Markets
- Task 3: Users
- Task 4: Technology

- Task 5: Environments and economics
- Task 6: Design options
- Task 7: Scenarios

Task 5 to 7 will be included in final report should the study be carried out fully but are not considered here.

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III. Acronyms and abbreviations used

Abbreviation	Description
AC	Alternating current
Ah	Ampere-hour
APU	Auxiliary power unit
ATEX directives	Directives regarding explosive atmospheres
ATP	Agreement Transport Perishable
BAT	Best Available Technologies
BAU	Business As Usual
CA	Controlled atmosphere
CENELEC	European Committee for Electrotechnical Standardization
CFCs	Chlorofluorocarbons
CSC	International Convention for Safe Containers
DC	Direct Current
DG	Directorate General
DG set	Diesel generator set
EC	European Commission
EEA	European Economic Area
EEE	Electrical and electronic equipment
EN	European Norm
EPA	Environmental Potection Agency
EPAL	European Pallet Association
ErP	Energy related products
EPREL	European product database for energy labelling
ETSI	The European Telecommunications Standards Institute
EU	European Union
EU-28	28 Member States of the European Union
EMC	Electromagnetic compatibility
F-gas	Fluorinated gas
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
HCFCs	Hydrochlorofluorocarbons

IEC	International Electrotechnical Commission
IED	Industrial Emissions Directive
IMO	International Maritime Organization
ISO	International Organisation for Standardization
ITU	Intermodal Transport Unit
kW	Kilo watt
kWh	Kilo watt hours
LVD	Low Voltage Directive
MA	Modified atmosphere
MD	Machinery Directive
MEErP	Methodology for Ecodesign of Energy related Products
MEEuP	Methodology for Ecodesign of Energy-using Products
MJ	Mega joule
MW	Mega watt
MWh	Mega watt hours
NACE	Statistical Classification of Economic Activity
ODP	Ozone depletion potential
OJ or OJEU	Official Journal of the European Union
PED	Pressure Equipment Directive
PEF	Primary energy factor
PTI	Pre-trip inspection
Reefer	Refrigerated container
RoSH	Restriction of Hazardous Substances
T	Ton
TEU	Twenty-foot equivalent unit
TKM	Tonnes-kilometres
TRU	Transport Refrigeration Units (which is powered by an integral diesel generator)
US	United States (of America)
VSD	Variable speed drive
WEEE	Waste electrical and electronic equipment

1. Scope

1.1 Product scope

Refrigerated containers, also frequently called reefer containers or short "reefers", are used to transport or store perishable goods, such as meat, fruits, vegetables, dairy and pharmaceutical products under regulated internal ambient conditions, primarily refrigerating temperature and humidity, from the point of production, harvesting etc. to the destination. The preparatory study for the Ecodesign Working Plan 2016-2019 has identified several environmental impacts of refrigerated containers and therefore listed them as one of the new products groups for which a specific preparatory study should be launched.

As in different businesses the sole term "reefer" is also used ambiguously as abbreviation for other dedicated refrigerated equipment (such as refrigerated trucks, railroad cars, or ships), for simplicity of this report the term "reefer" shall be used in the context of "refrigerated containers".

Refrigerated containers form a subset of ISO 1496 thermal containers[1], which maintain controlled internal ambient conditions, along with other types of thermal containers, such as heated only and insulated only containers. Thermal containers including refrigerated containers further form a subset of ISO 668[2] / ISO 1496 freight containers intended for intercontinental traffic in the context of intermodal transport units (ITUs)[3], which are part of the international intermodal freight transport system. As such, they can be seamlessly

[1] ISO 1496-2:2018 Series 1 freight containers — Specification and testing — Part 2: Thermal containers
[2] ISO 668:2013 Series 1 freight containers — Classification, dimensions and ratings,
[3] Eurostat & Glossary for transport statistics (5TH EDITION 2019)

transported across boundaries by different means of transport, such as ships, trucks, and rail.

Refrigerated containers are therefore similar to standard freight containers (also called "dry containers" or "shipping[4] containers") in their physical characteristics and standards, such as their general design, size, and basic handling procedures, although refrigerated containers require special cooling equipment, external power supply and handling procedures while at land (terminals), sea (shipping), or on the road/rail (trucks and rakes).

Refrigerated containers are available in the standardized sizes of intermodal ISO freight containers in most typical lengths of 20 ft (feet) (6.09 m) and 40 ft (12.18 m). The twenty-foot equivalent unit (TEU) is the indicative standard unit of measurement often used for all intermodal containers, based on the standard 20 ft long container. A 40 ft long unit is considered as two TEUs and so on. In addition, 10 ft (3.04 m) long variants are also available. Again, similar to standard intermodal containers, both 20 ft and 40 ft refrigerated containers are also found as "standard cube", which are 8'6" (8 feet, 6 inches) (2.59 m) high and as taller "high cube" model, which are 9'6" (2.90 m) high. Most refrigerated containers used today are 40 ft high cube models, although there are also 45 ft and (rarely) 53 ft (mainly for "domestic" road and rail transport) variants.

It has to be noted that the term "domestic" might be used ambiguously for different businesses. Especially in EU and US container business the term "domestic" often refers to "non-ISO containers" or other interchangeable units (e.g. "swap bodies" as used in EU) which could be transported on both road and rail transport but not intercontinentally. In contrast to ISO containers intended for intercontinental (maritime) transport, "domestic" containers vary to a large extent from ISO container specifications and, thus, can typically be used only or mainly for intra-national/continental road and rail freight transport. They are optimized for deviating local standards for truck and rail transport, e.g. in the EU to accommodate to optimally the European EUR-pallet (also Euro-pallet or EPAL-pallet) as specified by the European Pallet Association (EPAL). Such "domestic" containers are frequently also not or only very limited stackable.

In other businesses refrigerated cabinets or other refrigeration systems intended for residential or stationary use are referred to as "domestic".

[4] The English term "shipping" is ambiguous, as used also for other types of freight transport than sea shipping

1.1.1 Product categories

a) Prodcom categories

i. Transported goods

Prodcom collects data pertaining to goods transported using all kinds of Intermodal Transport Units (ITUs), which are defined as "standardized transport units suitable for being transported by different modes of transport, comprising ISO freight containers, swap bodies (interchangeable units typically for road and rail transport only) and other standardized (in terms of size) packaging, which can be moved with simple equipment (e.g. cranes)". However, Prodcom does not provide disaggregated data for specific types of ITUs. Thus, units of measure of ITUs differ mainly based on the mode of transport as described below.[5]

Table 1-1: Prodcom units for Intermodal Transport Units

Unit	Description
Tonnes	Gross weight of goods (maritime transport)
Tonne-Kilometres	Gross weight (road transport) / gross-gross weight (rail and inland waterways transport) of goods multiplied by distance in kilometres.
Percentage share of the total	Share of containers (ITUs for rail transport) in total freight transport, measured in tonne-kilometres (in tonnes for maritime transport)

To make the data comparable across these modes of transport, a dataset is provided for comparison of unitization, tonnes-kilometres (TKM) for short sea shipping and deep-sea shipping, and gross weight of goods for rail transport and inland waterways transport as described below:

- Unitisation in the different modes of transport (based on TKM for gross weight of goods) (tran_ui_umod)
- Unitisation road freight transport (based on TKM for gross weight of goods) (tran_im_uroad)
- Unitisation in rail freight transport (based on TKM for gross-gross weight of goods) (tran_im_uroad)
- Unitisation in inland waterways freight transport (based on TKM for gross-gross weight of goods) (tran_im_uiww)
- Unitisation in maritime freight transport (based on tonnes for gross weight of goods) (tran_im_umar)[6]"

[5] https://ec.europa.eu/eurostat/cache/metadata/en/tran_im_esms.htm#unit_measure1563870568547
[6] https://ec.europa.eu/eurostat/data/database

Furthermore, Eurostat compiles indicators on the potential for modal shift in road freight transport. These indicators relate the transport of freight over longer distances (more than 300 kilometres) to the total road ITU transport and to total road goods transport, providing information for analysis of the potential for transferring such long-distance transport of freight from road to other modes of transport:

- Modal shift potential of long-distance road freight in containers (based on TKM) (tran_im_mosptk)
- Modal shift potential of long-distance road freight in containers (based on tonnes) (tran_im_mospt)"

ii. Manufacturing of containers and components

The following table lists out key manufacturing categories under Prodcom that can be related to refrigerated containers or their relevant components. However, Prodcom categories are not specific enough to exclusively address refrigerated containers as distinct own product.

Table 1-2: Prodcom codes and nomenclature related to reefers

Prodcom code	Prodcom Nomenclature (NACE Rev. 2)
27.11	Manufacture of electric motors, generators and transformers
27.11.31.10	Generating sets with compression-ignition internal combustion piston engines, of an output ≤ 75 kVA
27.11.32.35	Generating sets with spark-ignition internal combustion piston engines of an output > 7,5 kVA
28.13.23.00	Compressors for refrigeration equipment
28.25	Manufacture of non-domestic cooling and ventilation equipment
28.25.13.60	Refrigerating furniture with a refrigerating unit or evaporator (excluding combined refrigerator-freezers, with separate external doors, household refrigerators, refrigerated show-cases and counters)
28.25.13.90	Other refrigerating or freezing equipment
28.25.30.70	Parts of refrigerating or freezing equipment and heat pumps, (not elsewhere specified)
29.10	Manufacture of motor vehicles
29.10.41	Goods vehicles, with compression-ignition internal combustion piston engine (diesel or semi-diesel)
29.10.42	Goods vehicles, with spark-ignition internal combustion piston engine; other goods vehicles

Prodcom code	Prodcom Nomenclature (NACE Rev. 2)
29.20	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
29.20.21.00	Containers specially designed and equipped for carriage by one or more modes of transport (including containers for transporting fluids)
29.20.23.00	Other trailers and semi-trailers (not elsewhere specified)
0112300	Refrigerated vessels, except tankers

b) Categories according to EN - or ISO - standard(s)

ISO 668:2013[7] and ISO 830:1999[8] present basic definitions of terms relating to all types of freight containers in general. ISO 6346:1995[9] and ISO 1496-2:2018[10] list various types of thermal (temperature-controlled [11]) containers where controlled internal ambient conditions are required to be maintained, including refrigerated containers (see table below).

Table 1-3: Reefer classification and heat leakage based on ISO standards and codes

Detailed type group and code (ISO 6346: 1995)	Main characteristics	Max. Heat leakage for U_{max} [W/K] (ISO 1496-2:2018)		
		1AAA[7] = 40′ High cube	1AA[7] = 40′	1CC[7] = 20′
R0/RA	Mechanically refrigerated	42	40	
R1/RB	Mechanically refrigerated and heated	42	40	
R2/RD	Self-powered mechanically refrigerated	42	40	
R3/RG	Self-powered mechanically refrigerated and heated	42	40	
H0/HA	Refrigerated and/or heated with removable equipment located externally,	42	40	
H1/HB	Refrigerated and/or heated with removable equipment located internally,	42	40	
H2	Refrigerated and/or heated with removable equipment	42	40	

[7] ISO 668:2013 Series 1 freight containers — Classification, dimensions and ratings
[8] ISO 830:1999(en) Freight containers — Vocabulary
[9] ISO 6346:1995(en) Freight containers — Coding, identification and marking
[10] ISO 1496-2:2018 Series 1 freight containers — Specification and testing — Part 2: Thermal containers
[11] https://www.containerhandbuch.de/chb_e/stra/stra_03_01_01_02.html

H5/HM	Insulated box, coefficient of heat transmission K = 0.4 W/(m²·K)	42	40	
H6/HV	Insulated box, coefficient of heat transmission K = 0.7 W/(m²·K)	42	40	

c) Categories according to refrigeration unit design

Temperature-controlled containers for refrigeration (and/or heating) can be also further categorized, depending on the degree of integration of the equipment used for maintaining the internal temperature conditions. They are either "passive" containers without fixed, inbuilt refrigeration (and/or heating) unit or "active" containers with integral own refrigeration (and/or heating) unit, usually based on vapour compression cycle to regulate the temperature inside the container. Although vapour compression cycle units for "refrigerated" containers are most frequently applied for the purpose of refrigeration, they can be typically also used in reverse mode for heating application.

"Insulated" or "Refrigerated and/or heated with removable equipment" containers (see section above) are examples for passive containers as relying just on their insulation to protect the transported freight and/or need to be connected to an external cooling (and/or heating) unit. E.g. "Porthole containers" are passive containers, as they are used on dedicated cooling container ships connected to a central refrigeration system of the vessel by means of special air ducting, via round openings in the container (due to similarity to the round ship windows, also called "portholes"). Passive porthole refrigerated containers are almost exclusively used for maritime transport purposes on special ships and need removable "clip-on" refrigeration units for temporary temperature control during land storage. This also explains the clear trend of porthole containers getting more and more replaced by more flexible "active" refrigerated containers, which can be used for different applications.

In actively temperature-controlled "Refrigerated", "Refrigerated and heated" and "Self-powered" (see section above) containers used for intermodal transport, the refrigeration and/or heating unit is physically integrated into the container. Accordingly, the refrigeration unit takes some of the internal storage space, but the refrigerated container still fully complies with the outer dimensions and handling requirements of standard intermodal freight containers. Depending on the actual configuration and degree of integration of the refrigeration unit, such "integral containers" (synonym: "integral reefers") are also called sometimes (due to different installation of the refrigeration unit in the container end wall) "picture frame container" or "fully integrated" containers.

As electrical compressors are used in most modern integral containers for refrigeration and/or heating, they are electrically powered by standardized three-phase electrical power supply[12]. On ships, integral containers are typically plugged into the on-board electrical power supply system. During land transit and storage, they are powered by connection to diesel generators (DG sets), batteries, (prospectively fuel cells) or the electric grid that provide three-phase electrical power supply[13].

DG sets as APU (auxiliary power unit) for off-grid operation mainly during land transport can be either fully integrated into integral containers together with the refrigeration unit (also maintaining the outer dimensions of standard intermodal freight containers) or can be attached externally for temporary use (sometimes also called "clipped-on", "front-" or "nose-mounted", due to the mounting typically on front of the container box in the direction of travel, similar to the wording used for dedicated refrigerated trucks). See Figure 1. However, for stationary applications, integral containers are usually electrically powered with three phases standard plug from the grid, when available.

Temperature-controlled integral containers[14]

Temperature-controlled integral container with "clipped-on" DG set[15]

Figure 1: Temperature-controlled integral containers

d) Product categories based on market application

Based on the market application, refrigerated containers can be further classified based on their actual main purpose. While e.g. passive porthole containers are typically used only

[12] Dynamar (2018) REEFER Analysis - Market Structures, Conventional, Containers - https://www.dynamar.com/publications/210
[13] Dynamar (2018) REEFER Analysis - Market Structures, Conventional, Containers - https://www.dynamar.com/publications/210
[14] Pictures: Richard Lawton, Cambridge Refrigeration
[15] Picture: Ursula Horn [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], https://commons.wikimedia.org/wiki/File:MaerskClipOn1_100.jpg

for the purposes of transport, integral containers can be used either for intermodal transport or stationary purposes (such as cold storage) if an electricity supply is available. E.g. institutions in the food sector, hospitals, university and pharmaceutical research labs use integral containers stationary [16] for logistic reasons. They are also used during temporary festivals and sporting events (e.g. Formula One racing and major golf tournaments in EU, US and Australia). Furthermore, special stationary applications include military usage (for sheltering or storage of food, ammunition, and medicine) and offshore containers, which are used in logistics for offshore oilrigs.

Typically, integral refrigerated containers used for intermodal transport and stationary are identical in their general construction, but stationary containers for intended long-term application are usually fitted with relevant additional features such as thermal curtains, larger and more ergonomic handles, wider doors, emergency exit doors and flat floors instead of T-bar floor (cooling ribs) [17]. Overall, integral refrigerated containers for transport purposes and stationary applications are very similar in the basic product design but addresses different market segments[18] (Table 1-4).

Table 1-4: Reefer classification based on market application

Description
Intermodal transportation units (ITUs), "integral containers" (synonym: "integral reefers"), primarily used for the purpose of transportation.
Stationary "integral containers" (synonym: "integral reefers"), primarily used as stationary units for cold storage purposes.

e) Product categories based on internal ambient conditions

Integral refrigerated containers can be also further sub-categorized based on their internal ambient condition requirements, for carrying out various functions that optimally suits the cargo they carry or store, such as single temperature refrigeration, multi-temperature refrigeration, controlled atmosphere (CA) and modified atmosphere (MA). In this context, the share of containers using multi-temperature refrigeration and controlled atmosphere is reported to be negligible in stationary applications compared to transport. In contrast, integral containers for transport are often used to control several or all types of internal ambient conditions, including refrigeration, multi-temperature refrigeration, CA and MA. Dedicated deep freezer containers used for achieving ultra-low freezing temperatures (below typical "frozen") are considered as distinct special application (Table 1-5).

[16] In the current report, the term "stationary reefers" is used, as the sometimes-used term "domestic" for other parts of the business simply means "for EU internal or national/continental use only" or in other businesses refrigerated cabinets for residential use.
[17] Interview dated – 21/05/19 + 27/05/2019
[18] Interview dated –July 1 2019, anonymous, purchase department

Table 1-5: Internal ambient conditions for refrigerated containers

Classification	Typical cargo type / description
Refrigerated / chilled[19]	Fruits, vegetables, dairy products and meat are typically transported in refrigerated conditions at temperature ranges from 0 – 20 °C
Frozen[20]	Meat, fish, ice creams are typically transported in frozen conditions; (Internal temperature can be down to -65 °C for distinct special applications)
Single-temperature refrigeration[21]	In single-temperature refrigeration, all cargo is stored or transported at the same internal ambient conditions
Multi-temperature refrigeration[22]	In multi-temperature refrigeration, partitions are made within the container so that different cargo is stored or transported at different internal ambient conditions.
Controlled Atmosphere (CA)	Besides temperature control, many integral refrigerated containers with controlled atmosphere technology alter the internal air composition in real-time. This helps to extend the storage life of specific cargo, such as fruits and vegetables. This is achieved by measures such as artificial reduction of the level of oxygen and increasing the level of carbon dioxide[23].
Modified Atmosphere (MA)	This technique is similar to CA and is used to extend the storage life of specific cargo, such as fruits and vegetables. However, unlike CA, MA does not happen in real-time. Using modified atmosphere technique, containers are filled once with a specific composition of gases appropriate to the perishable cargo for the full trip to the destination before the doors are sealed[24].

The majority of the refrigerated containers, however, are designed for use for both chilled and frozen application and therefore most are equipped with cooling machines designed for -29 to +29 °C.

1.1.2 Preliminary product scope

As first concluding aspect, it has to be noted that "The ecodesign regulations do not specifically mention whether components of and appliances for means of transport fall under their scope, but the Ecodesign Directive specifies in its Article 1(3) that the directive does not apply to "means of transport for persons or goods". Therefore, products that are specifically constructed only for application as means of transport (including mobile homes and caravans) and no other applications are exempted from ecodesign regulations."[25]

[19] https://www.containerhandbuch.de/chb_e/scha/index.html?/chb_e/scha/scha_16_04.html
[20] https://www.containerhandbuch.de/chb_e/scha/index.html?/chb_e/scha/scha_16_04.html
[21] https://www.thermoking.com/na/en/road/trailers/single-temperature-controlled-units.html
[22] https://www.thermoking.com/na/en/road/trailers/multi-temperature-controlled-units.html
[23] https://www.containerhandbuch.de/chb_e/scha/index.html?/chb_e/scha/scha_16_04.html
[24] http://www.crtech.co.uk/pages/ICCT/ICCT_CA_MA_Guidelines_May_2014.pdf
[25] Frequently Asked Questions (FAQ) on the Ecodesign Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products and its Implementing Regulations, Document date: 29/08/2019 - Created by GROW.DDG1.C.4, (21) Answer on components of and appliances for means of transport

Accordingly, all applications only usable for means of transport would be out of the scope of this study. In contrast, integral refrigerated containers (synonym: "integral reefers") applicable both, for transport and stationary uses, do not fall under the strict category of 'means of transport' as they can be used e.g. for ship, truck and rail transport, but - in combination with external power supply - also stationary as stand-alone product for long-term storage purpose of refrigerated goods.

On this basis, the following is proposed:

The preliminary product scope is integral refrigerated containers (synonym: "integral reefers") with integrated equipment to control the internal temperature, usable for intermodal transport and/or stationary applications and for main purposes of refrigeration and/or freezing, single and multi-temperature.

The following table summarizes products assumed to be out of scope of this study.

Table 1-6: Products assumed out of scope

Products out of scope of this study
• Applications only usable for means of transport (no stationary use) • "Passive" containers without equipment to control the internal temperature • Ventilated only containers • Heated only containers • Military containers • Offshore containers • Unit Load Devices (ULDs) for air cargo

1.2 Review of relevant standards (EU, Member State and third country level)

1.2.1 Standards

1.2.1.1 EN or ISO/IEC standards

Table 1-7: Overview of standards related to refrigerated containers

Component/part Subcategory of product, capacity etc.	Standard
Box - overall reefer	EN ISO 6346:1995/A3:2012 Freight containers - Coding, identification and marking[26]
	EN 13044-1:2011-04

[26] https://www.iso.org/standard/20453.html

	Intermodal Loading Units - Marking - Part 1: Markings for identification
	ISO 668:2013 Series 1 freight containers - Classification, dimensions and ratings[27]
	ISO 830:1999 Freight containers — Vocabulary[28]
	ISO 1496-2:2018 Series 1 freight containers - Specification and testing - Part 2: Thermal containers[29]
	ISO 7010:2019 Graphical symbols - Safety colours and safety signs - Registered safety signs[30]
	DIN EN 45552:2018-11 - Draft General method for the assessment of the durability of energy-related products
	EN 45558:2019 General method to declare the use of critical raw materials in energy-related products[31]
	EN 45559:2019 Methods for providing information relating to material efficiency aspects of energy-related products[32]
Box-construction	ISO 6946:2017 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods[33]
	EN 14509:2013 Self-supporting double skin metal faced insulating panels — Factory made products — Specifications[34]
Box – Insulation	EN 14308:2015 Thermal insulation products for building equipment and industrial installations — Factory made rigid polyurethane foam (PUR) and polyisocyanaurate (PIR) products — Specification[35]
Cooling unit - compressor	EN 12900:2013 Refrigerant compressors. Rating conditions, tolerances and presentation of manufacturer's performance data[36]
	ISO/TR 12942 First edition 2012 Compressors — Classification — Complementary information to ISO 5390[37]
	ISO 1217: 2009

[27] https://www.iso.org/standard/59673.html
[28] https://www.iso.org/standard/1238.html
[29] https://www.iso.org/standard/67458.html
[30] https://www.iso.org/standard/72424.html
[31] https://www.cenelec.eu/dyn/www/f?p=104:110:34926588693401::::FSP_ORG_ID,FSP_LANG_ID,FSP_PROJECT:2240017,25,65687
[32] https://www.cenelec.eu/dyn/www/f?p=WEB:110:34926588693401::::FSP_PROJECT:65688
[33] https://www.iso.org/standard/65708.html
[34] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:38685,6110&cs=1FD1363F1CEF1B46C755921A73286BC63
[35] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:58984,6071&cs=16CF554D76F4CC89B3346DA7715678A6A
[36] https://www.beuth.de/en/standard/din-en-12900/171219223
[37] https://www.iso.org/standard/44633.html

	Displacement compressors - Acceptance tests[38]
	EN 1012-1:2010 Compressors and vacuum pumps, Safety requirements, Part 1: Air compressors[39]
	EN 1012-3: 2013 Compressors and vacuum pumps. Safety requirements. Part 3: Process compressors[40]
	EN ISO 2151:2008 Acoustics - Noise test code for compressors and vacuum pumps - Engineering method (Grade 2)[41]
	EN 378-2:2016 Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation[42]
Cooling unit - Fans	ISO 5801:2017 Fans — Performance testing using standardized airways[43]
	ISO/AWI 12759-1 Fans — Efficiency classification for fans — Part 1: General requirements[44]
Cooling unit - Refrigerant	ISO/FDIS 20854:2019 Thermal containers -- Safety standard for refrigerating systems using flammable refrigerants -- Requirements for design and operation[45]
Electricals and peripherals - All reefer electrical in general including cooling units, fans, controls, DG set	IEC 60309-1: 1999+AMD1:2005+AMD2:2012 Plugs, socket-outlets and couplers for industrial purposes - Part 1: General requirements[46]
	IEC 60309-2:1999+AMD1:2005+AMD2:2012 Plugs, socket-outlets and couplers for industrial purposes — Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories[47]
	IEC 60947-1:2007+AMD1:2010+AMD2:2014 Low-voltage switchgear and control gear — Part 1: General rules[48]
	IEC TR 62635:2012 Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment[49]
	IEC 62321-1-8:2013 series

[38] https://www.iso.org/standard/44769.html
[39] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:27845,6213&cs=1C2F71032598A19EFD13FF97D78A56AD6
[40] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:39205,6213&cs=1092593E11481CC7FD0E23DA5781E86A4
[41] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:30290,6213&cs=187863B503EF74501E1CA796EE82A4BF3
[42] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:36621,6163&cs=1EE095CCECC53B433CDD84523450AC1BE
[43] https://www.iso.org/standard/56517.html
[44] https://www.iso.org/standard/67572.html
[45] https://www.iso.org/standard/69361.html
[46] https://webstore.iec.ch/publication/1318
[47] https://webstore.iec.ch/publication/1323
[48] https://webstore.iec.ch/publication/3966
[49] https://webstore.iec.ch/publication/7292

	Determination of certain substances in electrotechnical products
	EN 50581:2012 Technical documentation for the evaluation of electrical and electronic products with respect to restriction of hazardous substances[50]
Plastics	ISO 11469:2016 Plastics - Generic identification and marking of plastics products[51]
	ISO 1043-2:2011 Plastics — Symbols and abbreviated terms — Part 2: Fillers and reinforcing materials[52]
	EN 50419:2006 Marking of electrical and electronic equipment in accordance with Article 11(2) of directive 2002/96/EC (WEEE)
	EN 50625-1:2014 Collection, logistics & treatment requirements for WEEE - Part 1: General treatment requirements
Data and control	ISO 10368:2006 Freight thermal containers -- Remote condition monitoring[53]

This list is intended to give an indicative overview of potentially relevant standards for refrigerated containers and may also include parts or components that have been excluded after the initial screening from the scope of the study. More details for measurands or other ecodesign relevant performance parameters or metrics would have to be covered in later technical tasks. More detail about the different standards are given below.

ISO 668:2020 Series 1 freight containers - Classification, dimensions and ratings

ISO 668:2020 establishes a classification of series 1 freight containers based on external dimensions, and specifies the associated ratings and, where appropriate, the minimum internal and door opening dimensions for certain types of containers.

These containers are intended for intercontinental traffic. This document summarizes the external and some of the internal dimensions of series 1 containers. The dimensions of each type of container are defined in the appropriate part of ISO 1496, which is the authoritative document for internal container dimensions.[54]

ISO 830:1999 Freight containers — Vocabulary

This international Standard presents definitions of terms relating to freight containers.

[50] https://www.iec.ch/dyn/www/f?p=103:22:2342901039278::::FSP_ORG_ID,FSP_LANG_ID:1314,25
[51] https://www.iso.org/standard/63434.html
[52] https://www.iso.org/standard/50590.html
[53] https://www.iso.org/standard/36595.html
[54] https://www.iso.org/standard/76912.html

ISO 1496-2:2018 Series 1 freight containers — Specification and testing — Part 2: Thermal containers

This document gives the basic specifications and testing requirements for ISO series 1 thermal containers for international exchange and for conveyance of goods by road, rail and sea, including interchange between these forms of transport. The standard provides design requirements pertaining to the exterior structure of temperature-controlled containers, door opening, sanitary and taint-free requirements, and requirements for optional features, such as fork-list pockets, drains, picture frames, modified/controlled atmospheres, fresh air and humidity control, air circulation and electrical aspects. Furthermore, the standard prescribes testing conditions, procedure and other requirements for the following aspects[55]:

- Test no. 13 Airtightness test
- Test no. 14 Heat leakage test
- Test no. 15 a) Test of the performance of a thermal container under refrigeration by a mechanical refrigeration unit (MRU)
- Test no. 15 b) Functional test of a thermal container at high ambient temperatures while being cooled by a mechanical refrigeration unit (MRU)
- Test no. 15 c) Energy consumption of a thermal container at defined ambient temperatures while being cooled by a mechanical refrigeration unit (MRU)
- Test no. 16 Strength of mounting devices for removable equipment (where fitted)

ISO 20854:2019, Thermal containers — Safety standard for refrigerating systems using flammable refrigerants — Requirements for design and operation

This document[56] describes the design of the mechanical refrigeration unit (MRU) and operation of container refrigerating systems in all anticipated operational modes and locations. It describes the industry's best practices for the safe operation of flammable refrigerants in refrigerating systems used in thermal freight containers operated on board ships, in terminals, on road, on rail and on land.

This document addresses the use of flammable refrigerants with classifications defined in ISO 817, defined as 2L, 2 and 3, except R717 (Ammonia). This document describes an operational mode risk assessment (OMRA) which uses methods such as HAZOP (Hazard and operability analysis), FMEA (Failure mode and effects analysis), or FTA (Fault tree analysis) or combination of methods.

This document specifies requirements for the validation and consideration of possible safety concepts and protective devices within the OMRA process, including charge release tests, simulation, and function tests of the associated protective equipment. It defines test requirements for shock, impact, and vibration. A validation procedure is given to

[55] https://www.iso.org/standard/67458.html
[56] https://www.iso.org/standard/69361.html,

demonstrate that risks from hazardous events are investigated and their severity and frequency are meaningfully reduced, with the aim of achieving tolerable risk values. The obligations of the manufacturer, the container owner as well as the responsible operator are described, as well as how stakeholders can investigate and mitigate risks associated with the use of flammable refrigerants. Finally, this document describes the requirements of service and maintenance when working with flammable refrigerants.

This document is restricted to refrigerating systems integrated with or mounted on ISO thermal containers according to ISO 1496-2. It provides minimum requirements for reducing the risk associated with the use of flammable refrigerants. The scope is limited to container refrigerating systems operated in conjunction with the carriage of refrigerated cargo as operating reefer (OR) or when used as a non-operating reefer (NOR) or when empty for positioning — while in intermodal transit. Static land-based continuous operations are excluded.

ISO 10368:2006 Freight thermal containers -- Remote condition monitoring

ISO 10368:2006 establishes the information and interfaces required to permit complying central monitoring and control systems employed by one carrier or terminal to interface and communicate with complying remote communication devices of differing manufacture and configuration used by other carriers and terminals. The data-logging formats and message protocols outlined in ISO 10368:2006 apply to all currently available data rate transmission techniques. These formats and protocols also apply to all future techniques designed to be an ISO International Standard compatible system.

ISO 6346:1995/Amd.3:2012 Freight containers - Coding, identification and marking

The standard provides a system for general application for the identification and presentation of information about freight containers. It specifies an identification system with mandatory marks for visual interpretation and optional features for automatic identification and electronic data interchange and a coding system for data on container size and type[57]. BIC Codes forms an essential part of the ISO 6346 standard[58].

ISO 7010:2019 Graphical symbols - Safety colours and safety signs - Registered safety signs

This document prescribes safety signs for the purposes of accident prevention, fire protection, health hazard information and emergency evacuation.

[57] https://www.iso.org/standard/20453.html
58 https://www.bic-code.org/bic-codes/

EN 13044-1:2011-04: Intermodal Loading Units - Marking - Part 1: Markings for identification

The standard EN 13044-1 introduces an owner-code for the identification of European intermodal loading units (e.g. swap-bodies, semi-trailers), the ILU-Code, which is compatible with the worldwide BIC-Code used for containers according to ISO 6346[59].

DIN EN 45552:2018-11 – Draft - General method for the assessment of the durability of energy-related products

Standard on the general method for the assessment of the durability of energy related products and of the upgradability of energy related products[60].

EN 45558:2019 General method to declare the use of critical raw materials in energy-related products

At the core of circularity and resource efficiency are the critical raw materials, which are crucial to the European economy and essential to maintaining and improving the quality of life. Providing information on the use of critical raw materials (CRMs) within energy-related products will consequently facilitate the move to a more circular economy. EN 45558:2019 distinguishes between regulated and non-regulated CRMs and assist users (manufacturers and their suppliers) to make CRM declarations, giving the supply chain some level of certainty regarding what to report, how to report and a standardized mechanism to communicate the data throughout the supply chain. To achieve this, EN 45558 builds upon EN IEC 62474 standard on material declaration[61].

EN 45559:2019 Methods for providing information relating to material efficiency aspects of energy-related products

EN 45559 establishes a general method, including rules and formats, for the provision of information related to the material efficiency aspects of energy-related products. This method can be used as a basis to develop product publications in gathering all relevant information on material efficiency aspects in a uniform and structured way, taking into consideration not only the material efficiency topic, but also data sensitivity, the target audience and the most suitable communication method. Therefore, EN 45559 supports the development of effective communication strategy for material efficiency, ensuring effective communication by the information provider and, in return, increasing the likelihood of good understanding by the receiver of that information. It also describes how intended audiences (end-users, professionals or market surveillance authorities) should be taken into account, along with data sensitivity levels, as well as the most suitable means of communication and media for providing the material efficiency information. Moreover, this standard is

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59 https://www.ilu-code.eu/en/

60 https://www.din.de/en/getting-involved/standards-committees/nagus/european-committees/wdc-grem:din21:270712555

61 CEN CENELEC, Brief News (2019), https://www.cencenelec.eu/News/Brief_News/Pages/TN-2019-017.aspx

intended to be used by product Technical Committees as input for the development of a communication strategy in horizontal, generic, product-specific, or product-group publications[62].

ISO 6946:2017 Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods

ISO 6946:2017 provides the method of calculation of the thermal resistance and thermal transmittance of building components and building elements, excluding doors, windows and other glazed units, curtain walling, components which involve heat transfer to the ground, and components through which air is designed to permeate. The calculation method is based on the appropriate design thermal conductivities or design thermal resistances of the materials and products for the application concerned.[63]

EN 14509:2013 Self-supporting double skin metal faced insulating panels — Factory made products — Specifications

This European Standard specifies requirements for factory made, self-supporting, double skin metal faced insulating sandwich panels, which are intended for discontinuous laying in the following applications: a) roofs and roof cladding; b) external walls and wall cladding; c) walls (including partitions) and ceilings within the building envelope. The insulating core materials covered by this European Standard are rigid polyurethane, expanded polystyrene, extruded polystyrene foam, phenolic foam, cellular glass and mineral wool[64].

EN 12900:2013 Refrigerant compressors - Rating conditions, tolerances and presentation of manufacturer's performance data

This European Standard specifies the rating conditions, tolerances and the method of presenting manufacturer's data for positive displacement refrigerant compressors. These include single stage compressors and single and two stage compressors using a means of fluid subcooling. This is required so that a comparison of different refrigerant compressors can be made. The data relate to the refrigerating capacity and power absorbed and include requirements for part-load performance where applicable[65].

EN 14308:2015, Thermal insulation products for building equipment and industrial installations — Factory made rigid polyurethane foam (PUR) and polyisocyanaurate (PIR) products — Specification

This European Standard specifies the requirements for factory made rigid polyurethane foam (PUR) and polyisocyanurate foam (PIR) products, with a closed cell content not less

[62] CEN CENELEC, Brief News (2019), https://www.cencenelec.eu/News/Brief_News/Pages/TN-2019-017.aspx
[63] https://www.iso.org/standard/65708.html
[64] https://www.beuth.de/en/standard/din-en-14509/192895241
[65] https://www.beuth.de/en/standard/din-en-12900/171219223

than 90 %, with or without facings, which are used for the thermal insulation of building equipment and industrial installations, with an operating temperature range of approximately, -200 °C to 200 °C. Below an operating temperature of -50 °C, special tests regarding the suitability of the products in the intended application are advised (e.g. liquefaction of oxygen)[66].

ISO/TR 12942 First edition 2012 Compressors — Classification — Complementary information to ISO 5390

ISO/TR 12942:2012 gives a classification of modern compressor types and their definitions. It further presents terms for use in technical and contractual specifications, manufacturer's literature, information searches and data processing systems, patent information, educational publications for students, service and maintenance instructions, industrial statistics and market surveys, as well as in design, quality, safety, testing and other standards, norms, regulations and codes[67].

ISO 1217: 2009 Displacement compressors - Acceptance tests

ISO 1217:2009 specifies methods for acceptance tests regarding volume rate of flow and power requirements of displacement compressors. It also specifies methods for testing liquid-ring type compressors and the operating and testing conditions which apply when a full performance test is specified[68].

EN 1012-1:2010 Compressors and vacuum pumps, Safety requirements Part 1. Compressors

This part of EN 1012 is applicable to compressors and compressor units having an operating pressure greater than 0.5 bar and designed to compress air, nitrogen or inert gases. This standard deals with all significant hazards, hazardous situations and events relevant to the design, installation, operation, maintenance, dismantling and disposal of compressors and compressor units when they are used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer (see clause 4). This part of EN 1012 includes under the general term compressor units those machines which comprise: - the compressor; - a drive system; - any component or device which is necessary for operation[69].

EN 1012-3: 2013 Compressors and vacuum pumps. Safety requirements. Part 3: Process compressors

This European Standard defines relevant requirements set out set out in Annex I of EU Machinery directive 2006/42/EC which apply to machines that are first placed on the European Economic Area (EEA) market, in order to facilitate proof of compliance with these

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[66] https://shop.bsigroup.com/ProductDetail/?pid=000000000030315082
[67] https://www.iso.org/standard/44633.html
[68] https://www.iso.org/standard/44769.html
[69] https://www.beuth.de/en/standard/din-en-1012-1/127479048

requirements. This document deals with all significant hazards, hazardous situations and events relevant to the design, installation, operation, maintenance, dismantling and disposal of process gas compressors and process gas compressor units, when they are used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer[70].

EN ISO 2151:2008 Acoustics - Noise test code for compressors and vacuum pumps - Engineering method (Grade 2)

Describes methods for the measurement, determination and declaration of the noise emission from portable and stationary compressors and vacuum pumps[71].

EN 378-2:2016 Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation

Defines the requirements for the safety of persons and property, provides guidance for the protection of the environment and establishes procedures for the operation, maintenance and repair of refrigerating systems and the recovery of refrigerants.[72]

ISO 5801:2017 Fans — Performance testing using standardized airways

ISO 5801:2017 specifies procedures for the determination of the performance of fans of all types except those designed solely for air circulation, e.g. ceiling fans and table fans. Testing of jet fans is described in ISO 13350. ISO 5801:2017 provides estimates of uncertainty of measurement and rules for the conversion, within specified limits, of test results for changes in speed, gas handled, and, in the case of model tests, sizes are given.[73]

ISO/AWI 12759-1 Fans — Efficiency classification for fans — Part 1: General requirements

Under development

IEC 60309-1999+AMD1:2005+AMD2:2012 Plugs, socket-outlets and couplers for industrial purposes - Part 1: General requirements

This standard applies to plugs and socket-outlets, cable couplers and appliance couplers, with a rated operating voltage not exceeding 690 V d.c. or a.c. and 500 Hz a.c., and a rated current not exceeding 250 A, primarily intended for industrial use, either indoors or outdoors.[74]

[70] https://www.beuth.de/en/standard/din-en-1012-3/194597319
[71] https://infostore.saiglobal.com/en-gb/Standards/EN-ISO-2151-2008-330930_SAIG_CEN_CEN_761172/
[72] https://infostore.saiglobal.com/en-gb/Standards/EN-378-2-2016-329323_SAIG_CEN_CEN_757958/
[73] https://www.iso.org/standard/56517.html
[74] https://webstore.iec.ch/publication/1318

IEC 60309-2 Plugs, socket-outlets and couplers for industrial purposes — Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories

IEC 60309-2:1999+A1:2005+A2:2012 applies to plugs and socket-outlets, cable couplers and appliance couplers with a rated operating voltage not exceeding 1,000 V, 500 Hz and a rated current not exceeding 125 A, primarily intended for industrial use, either indoors or outdoors[75].

IEC 60947-1 Low-voltage switchgear and control gear — Part 1: General rules

IEC 60947-1:2007+A1:2010+A2:2014 is to harmonize as far as practicable all rules and requirements of a general nature applicable to low-voltage switchgear and control gear in order to obtain uniformity of requirements and tests throughout the corresponding range of equipment and to avoid the need for testing to different standards.[76]

IEC TR 62635:2012 Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment

IEC/TR 62635:2012(E) provides a methodology for information exchange involving electronic and electrical equipment manufacturers and recyclers. The standard also provides a methodology enabling calculation of the recyclability and recoverability rates of to facilitate optimized end of life treatment operations.

EN 62321:2013 series - Determination of certain substances in electrotechnical products

The International Electrotechnical Commission (IEC) published the six kinds of regulated substances (lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers) in electrical and electronic products about a concentration measurement with international standards IEC 62321: 2008. It provides a harmonized standard to the regulated substances testing of the electrical and electronic products and promotes vigorously to the global electronics industry on RoHS compliance.[77]

EN 50581:2012 - Technical documentation for the evaluation of electrical and electronic products with respect to restriction of hazardous substances

The EN 50581 standard specifies the technical documentation a producer of EEE has to collect for applicable substance restrictions in order to demonstrate compliance with Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS). The technical documentation required to meet the standard includes:

- A general product description

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75 https://webstore.iec.ch/publication/1323
76 https://webstore.iec.ch/publication/3966
77 https://www.sgsgroup.com.hk/en/news/2013/08/series-of-iec-62321-2013-standards-published

- Documentation of materials, parts and/or sub-assemblies
- Information showing the relationship between the technical documents and respective materials, parts and/or sub-assemblies

ISO 11469:2016 - Plastics - Generic identification and marking of plastics products

Plastics - Generic identification and marking of plastics products. The EN ISO 11469 standard specifies a system of uniform plastic material marking system. The standard does not cover every aspect of marking (e.g. the marking process, the minimum size of the item to be marked, the size of the lettering or the appropriate location of the marking) but the marking system described is intended to help identify plastics products for subsequent decisions concerning handling, waste recovery or disposal. The standard refers to ISO 1043-1 for generic identification of the plastics.

ISO 1043-2:2011 Plastics — Symbols and abbreviated terms — Part 2: Fillers and reinforcing materials

Plastics. Symbols and abbreviated terms. Fillers and reinforcing materials. The EN ISO 1043 standard defines abbreviated terms for the basic polymers used in plastics, symbols for components of these terms, and symbols for special characteristics of plastics.

EN 50419:2006 - Marking of electrical and electronic equipment in accordance with Article 11(2) of Directive 2002/96/EC (WEEE)

EN 50419 contains the product marking requirements needed to ensure compliance with the WEEE Directive. EN 50419 also contains additional information relating to the marking requirements, including positioning, visibility, dimensions, location and referenced documents. The marking requirements are applicable to all manufacturers and producers of electrical and electronic equipment placing products on the EU market.

EN 50625-1:2014 Collection, logistics & treatment requirements for WEEE - Part 1: General treatment requirements

EN 50625 was prepared as part of a series of standards requested in Commission mandate 518 (detailed in section 3.2) which aim to support implementation and effectiveness of Directive 2012/19/EU (WEEE). The standard contains requirements applicable to the treatment of all types of WEEE and addresses all operators involved in the treatment (including related handling, sorting, and storage) of WEEE. In particular, the standard addresses the following issue areas:

- Management principles
  - Technical and infrastructural pre-conditions
  - Training
  - Monitoring
  - Shipments
- Technical requirements
  - General

- Receiving of WEEE at treatment facility
    - Handling of WEEE
    - Storage of WEEE prior to treatment
    - De-pollution (including Annex A normative requirements)
    - De-pollution monitoring (including Annex B normative requirements)
    - Treatment of non-de-polluted WEEE and fractions
    - Storage of fractions
    - Recycling and recovery targets (including Annex C & D normative requirements)
    - Recovery and disposal of fractions
- Documentation

The standard applies to the treatment of WEEE until end-of-waste status is fulfilled, or until the WEEE is prepared for re-use, recycled, recovered, or final disposal.

1.2.1.2 Harmonised standards

A harmonised standard is a European standard developed by a recognised European Standards Organisation: CEN, CENELEC, or ETSI and of which its references are published in the Official Journal of the European Union (OJEU)[78]. It is created following a request from the European Commission to one of these organisations. Manufacturers, other economic operators, or conformity assessment bodies can use harmonised standards to demonstrate that products, services, or processes comply with relevant EU legislation.

Some standards with potential relevance for refrigerated containers have been harmonised for the purposes of already existing ecodesign and energy labelling regulations. Table 1-8 gives an overview of these standards.[79]

Table 1-8: Publication of titles and references of harmonised standards

	Reference and title of the harmonised standard (and reference document)
Electric motors[80]	DIN EN 60034-2-1:2015-02 Rotating electrical machines — Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)
	IEC 60034-30-1:2014, Rotating electrical machines - Part 30-1: Efficiency classes of line operated AC motors (IE code)
Professional refrigerated storage cabinets[81]	EN 16825:2016 - 'Refrigerated storage cabinets and counters for professional use — Classification, requirements and test condition'

[78] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards_en
[79] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign_en
[80] Commission Communication in the framework of the implementation of the Commission Regulation (EC) No 640/2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2012.394.01.0020.01.ENG
[81] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2017.044.01.0001.01.ENG&toc=OJ%3AC%3A2017%3A044%3ATOC#ntr1-C_2017044EN.01000101-E0002

Blast cabinets[82]	EN 17032:2018 - Blast chillers and freezers cabinets for professional use - Classification, requirements and test conditions
Condensing units[83]	EN 13215:2016— 'Condensing units for refrigeration. Rating conditions, tolerances and presentation of manufacturer's performance data'

DIN EN 60034-2-1:2015-02: Rotating electrical machines — Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)

This part of VDE 0530 contains the set of methods for determining the efficiency from tests and specifies measurement methods for recording certain losses. This standard is valid for direct current machines as well as synchronous and induction AC machines of all sizes within the scope of VDE 0530-1.

EN 60034-30:2009: Rotating electrical machines — Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors (IE-code)

This part of IEC 60034 specifies efficiency classes for single-speed electric motors that are rated according to IEC 60034-1 or IEC 60079-0, are rated for operation on a sinusoidal voltage supply.

EN 16825:2016 - 'Refrigerated storage cabinets and counters for professional use — Classification, requirements and test condition'

This European Standard specifies requirements for the construction, characteristics, performance including energy consumption of refrigerated storage cabinets and counters for professional use in commercial kitchens, hospitals, canteens, preparation areas of bars, bakeries, gelateria, institutional catering and similar professional areas.[84] The products covered in this European Standard are intended to store foodstuffs. It specifies test conditions and methods for checking that the requirements have been satisfied, as well as classification of the cabinets and counters, their marking and the list of their characteristics to be declared by the manufacturer. It is not applicable to:

- Refrigerated cabinets used in the direct sale of foodstuffs;
- Cabinets that carry out food processing and not just storage function (e.g. bakery cabinets that chill, heat and humidity);
- Cabinets with water cooled condenser;
- Appliances with remote condensing unit;

[82] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2017.044.01.0001.01.ENG&toc=OJ%3AC%3A2017%3A044%3ATO#ntr1-C_2017044EN.01000101-E0002

[83] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2017.044.01.0001.01.ENG&toc=OJ%3AC%3A2017%3A044%3ATO#ntr1-C_2017044EN.01000101-E0002

[84] https://shop.bsigroup.com/ProductDetail?pid=000000000030394633

- Appliances with open top tables and saladettes for preparation or storage of foodstuffs;
- Cabinet specifically intended for storage of specific foodstuffs (i.e. fresh meat, fresh fish, etc.)
- Chest freezers;
- Appliances intended for short time / intermittent normal operation during the full day;
- Built-in cabinet;
- Roll-in cabinet;
- Pass-through cabinet.

EN 17032:2018 - Blast chillers and freezers cabinets for professional use - Classification, requirements and test conditions

This European Standard specifies the requirements for the construction, characteristics, performance including energy consumption of blast cabinet for professional used in commercial kitchens, hospitals, canteens, institutional catering and similar professional areas[85].

EN 13215:2016 - 'Condensing units for refrigeration. Rating conditions, tolerances and presentation of manufacturer's performance data'

This European Standard specifies the rating conditions, tolerances and presentation of manufacturer's performance data for condensing units for refrigeration with compressors of the positive-displacement type. These include single stage compressors and single and two stage compressors having an integrated means of fluid sub cooling. This is required so that a comparison of different condensing units can be made. The data relate to the refrigerating capacity and power absorbed and include requirements for part-load performance where applicable.[86]

1.3 Review of relevant legislation

1.3.1 EU legislation

The following table lists out regulations that are directly and indirectly relevant in the context of reefers.

This list is intended to give an indicative overview of potentially relevant regulations for refrigerated containers and may also include parts or components that have been excluded after the initial screening from the scope of the study. For the potentially most relevant of the regulations listed below in the context of refrigerated containers, more comprehensive information is given in the following section. However, more concrete details for

[85] https://shop.bsigroup.com/ProductDetail/?pid=000000000030394631
[86] https://shop.bsigroup.com/ProductDetail/?pid=000000000030323332

measurands or other ecodesign relevant performance parameters or metrics are not presented, as those aspects would have to be covered in later technical tasks.

Table 1-9: Relevant regulations for reefers

Reefer compo-nent/part	Regulation	Short description
Reefer box		
Box	International Convention for Safe Containers (CSC) Adoption: 2 December 1972; Entry into force: 6 September 1977[87]	Regulations for the testing, inspection, approval and maintenance of containers, structural safety requirements and tests, details of test procedures including the mandate for CSC Safety-approval Plate
	Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast) [88] (Industrial Emissions Directive)	Main EU instrument for regulating pollutant emissions from industrial installations
	Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel[89]	This Regulation lays down rules for the establishment and application of the voluntary European Union Ecolabel scheme, which applies to any goods or services, which are supplied for distribution, consumption or use on the European Community market[90]. Currently, there are no ecolabel criteria for reefers.
	Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast)[91]	The scope of this directive is to establish a framework for the setting of Community ecodesign requirements for energy-related products with the aim of ensuring the free movement of such products within the internal market and provide for the setting of requirements which the energy-related products covered by implementing measures must fulfil in order to be placed on the market and/or put into service. This framework directive is the background for this study.
	Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy	The EU Parliament has approved an EU energy label reform for home, professional and commercial appliances. The new label will reintroduce the original A-G scale for future labels establish a common product registry database to support market

[87] http://www.bsa-bg.com/images/circs/conta.pdf
[88] OJ L 334, 17.12.2010, http://data.europa.eu/eli/dir/2010/75/2011-01-06
[89] OJ L 27, 30.1.2010, p. 1–19, https://eur-lex.europa.eu/eli/reg/2010/66/oj
[90] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010R0066
[91] OJ L 285, 31.10.2009, p. 10–35, https://eur-lex.europa.eu/eli/dir/2009/125/2012-12-04

	labelling and repealing Directive 2010/30/EU[92]	surveillance. Currently, there are no energy label criteria for reefers.
Insulation	Regulation (EC) No 1005/2009 of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer (recast)[93]	This Regulation lays down rules on the production, import, export, placing on the market, use, recovery, recycling, reclamation and destruction of substances that deplete the ozone layer, on the reporting of information related to those substances and on the import, export, placing on the market and use of products and equipment containing or relying on those substances.
	Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006[94]	To control emissions from fluorinated greenhouse gases (F-gases), including hydrofluorocarbons (HFCs) in refrigeration and foam insulation products.
Electrical - All reefer electrical in general including cooling units, fans, controls, DG set	Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) [95] (Machinery Safety Directive)	This directive aims at the free market circulation on machinery and at the protection of workers and consumers using such machinery. It defines essential health and safety requirements of general application, supplemented by a number of more specific requirements for certain categories of machinery[96].
	Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast)[97] (Electromagnetic Compatibility Directive)	The EMC Directive limits electromagnetic emissions of equipment in order to ensure that, when used as intended, such equipment does not disturb radio and telecommunication as well as other equipment.
	Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast)[98] (Waste Electrical an Electronic Equipment Directive)	The objective of the directive is to promote re-use, recycling and other forms of recovery of waste electrical and electronic equipment (WEEE) in order to reduce the quantity of such waste to be disposed and to improve the environmental performance of the economic operators involved in the treatment of WEEE[99].
	Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain	Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment[101].

[92] OJ L 198, 28.7.2017, p. 1–23, https://eur-lex.europa.eu/eli/reg/2017/1369/oj
[93] OJ L 286, 31.10.2009, p. 1–30, http://data.europa.eu/eli/reg/2009/1005/2017-04-19
[94] OJ L 150, 20.5.2014, p. 195–230, http://data.europa.eu/eli/reg/2014/517/oj
[95] OJ L 157, 9.6.2006, p. 24–86, http://data.europa.eu/eli/dir/2006/42/2019-07-26
[96] https://osha.europa.eu/en/legislation/directives/directive-2006-42-ec-of-the-european-parliament-and-of-the-council
[97] OJ L 96, 29.3.2014, p. 79–106, http://data.europa.eu/eli/dir/2014/30/oj
[98] OJ L 197, 24.7.2012, p. 38–71, http://data.europa.eu/eli/dir/2012/19/oj
[99] https://www.eea.europa.eu/policy-documents/waste-electrical-and-electronic-equipment
[101] https://ec.europa.eu/environment/waste/rohs_eee/legis_en.htm

	hazardous substances in electrical and electronic equipment (recast)[100] (RoHS)	
Cooling unit		
Compressor[102] and fans (evaporator and condenser)	Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000 on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors.[103]	The objective of this directive is to improve the control of noise emission in the environment by equipment for use outdoors[104].
	Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits.[105]	The LVD covers health and safety risks on electrical equipment operating with an input or output voltage of between • 50 and 1,000 V for alternating current • 75 and 1,500 V for direct current It applies to a wide range of electrical equipment for both consumer and professional usage[106].
	Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment (recast)[107]	The Pressure Equipment Directive (PED) (2014/68/EU) applies to the design, manufacture and conformity assessment of stationary pressure equipment with a maximum allowable pressure greater than 0.5 bar[108].
	Directive 2014/29/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of simple pressure vessels[109]	The directive applies to simple pressure vessels manufactured in series. A 'simple pressure vessel' being any welded vessel subjected to an internal gauge pressure of greater than 0.5 bar intended to contain air or nitrogen, which is not intended to be fired[110].
	Regulation (EU) 2016/426 of the European Parliament and of the Council of 9 March 2016 on appliances burning gaseous	The legal framework for the placing on the market and putting into service of gas appliances and their fittings is Regulation (EU) 2016/426 on appliances burning gaseous fuels (GAR)[112].

[100] OJ L 174, 1.7.2011, p. 88–110, http://data.europa.eu/eli/dir/2011/65/2019-07-22
[102] From Final Report Lot 31 – compressors - Task 1 - https://www.eup-network.de/fileadmin/user_upload/FINAL_REPORT_Lot31_Task1-5_20140603.pdf
[103] OJ L 162, 3.7.2000, p. 1–78, http://data.europa.eu/eli/dir/2000/14/2019-07-26
[104] https://osha.europa.eu/en/legislation/directives/directive-2000-14-ec
[105] OJ L 96, 29.3.2014, p. 357–374, http://data.europa.eu/eli/dir/2014/35/oj
[106] https://ec.europa.eu/growth/sectors/electrical-engineering/lvd-directive_en
[107] OJ L 189, 27.6.2014, p. 164–259, http://data.europa.eu/eli/dir/2014/68/2014-07-17
[108] https://ec.europa.eu/growth/sectors/pressure-gas/pressure-equipment/directive_en
[109] OJ L 96, 29.3.2014, p. 45–78, http://data.europa.eu/eli/dir/2014/29/oj
[110] CE Marking Association, UK, Simple pressure vessels (2019), https://www.cemarkingassociation.co.uk/simple-pressure-vessels/
[112] https://ec.europa.eu/growth/sectors/pressure-gas/gas-appliances/regulation_en

	fuels and repealing Directive 2009/142/EC[111]	
	Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)[113]	The ATEX Directive 2014/34/EU covers equipment and protective systems intended for use in potentially explosive atmospheres. The directive defines the essential health and safety requirements and conformity assessment procedures, to be applied before products are placed on the EU market114.
	Commission Regulation (EU) 2019/1781 of 1 October 2019 laying down ecodesign requirements for electric motors and variable speed drives pursuant to Directive 2009/125/EC of the European Parliament and of the Council, amending Regulation (EC) No 641/2009 with regard to ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products and repealing Commission Regulation (EC) No 640/2009[115]	This Regulation establishes ecodesign requirements for the placing on the market and for the putting into service of motors, including where integrated in other products[116].
	Commission Regulation (EU) No 327/2011 of 30 March 2011 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for fans driven by motors with an electric input power between 125 W and 500 kW[117]	This Regulation establishes ecodesign requirements for the placing on the market or putting into service of fans (fans driven by motors with an electric input power between 125 W and 500 kW), including those integrated in other energy-related products as covered by Directive 2009/125/EC[118].
	Commission Regulation (EU) 2015/1095 of 5 May 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for professional refrigerated storage cabinets,	This Regulation establishes ecodesign requirements for the placing on the market of professional refrigerated storage cabinets and blast cabinets. This Regulation shall apply to electric mains-operated blast cabinets, and electric mains-operated professional refrigerated storage cabinets including those sold for

[111] OJ L 81, 31.3.2016, p. 99–147, http://data.europa.eu/eli/reg/2016/426/oj
[113] OJ L 96, 29.3.2014, p. 309–356, http://data.europa.eu/eli/dir/2014/34/oj
[114] https://ec.europa.eu/growth/sectors/mechanical-engineering/atex_en
[115] OJ L 272, 25.10.2019, p. 74–94, http://data.europa.eu/eli/reg/2019/1781/oj
[116] https://www.buildup.eu/en/practices/publications/commission-regulation-ec-no-6402009-22-july-2009-implementing-directive
[117] OJ L 90, 6.4.2011, p. 8–21, http://data.europa.eu/eli/reg/2011/327/2017-01-09
[118] Build UP, The European Portal for Energy Efficiency in Buildings (March 2015), https://www.buildup.eu/en/practices/publications/commission-regulation-eu-no-3272011-30-march-2011-implementing-directive

	blast cabinets, condensing units and process chillers[119]	the refrigeration of foodstuffs and animal feed.
Refrigerant	Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006[120]	To control emissions from fluorinated greenhouse gases (F-gases), including hydrofluorocarbons (HFCs) in refrigeration and foam insulation products.
Auxiliary		
Diesel generator set	Regulation (EU) 2016/1628 of the European Parliament and of the Council of 14 September 2016 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery, amending Regulations (EU) No 1024/2012 and (EU) No 167/2013, and amending and repealing Directive 97/68/EC[121]	Gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery
	Regulation (EU) No 540/2014 of the European Parliament and of the Council of 16 April 2014 on the sound level of motor vehicles and of replacement silencing systems, and amending Directive 2007/46/EC and repealing Directive 70/157/EEC[122]	Regulation on the sound level of motor vehicles and of replacement silencing systems
Others	Council Directive of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (Council Directive 89/391/EEC)[123]	The aim of this directive is to introduce measures to encourage improvements in the safety and health of workers at work. It applies to all sectors of activity, both public and private, except for specific public service activities, such as the armed forces, the police or certain civil protection services.[124]
	Commission Regulation (EU) 2017/1981 of 31 October 2017 amending Annex III to Regulation (EC) No 853/2004 of the European Parliament and of the Council as regards temperature conditions during transport of meat[125]	This regulation lays down specific rules on the hygiene of food of animal origin for food business operators including specific temperature requirements before and during the transport of meat.

[119] OJ L 177, 8.7.2015, p. 19–51, http://data.europa.eu/eli/reg/2015/1095/2017-01-09
[120] OJ L 150, 20.5.2014, p. 195–230, http://data.europa.eu/eli/reg/2014/517/oj
[121] OJ L 252, 16.9.2016, p. 53–117, http://data.europa.eu/eli/reg/2016/1628/oj
[122] OJ L 158, 27.5.2014, p. 131–195, http://data.europa.eu/eli/reg/2014/540/2019-05-27
[123] http://eur-lex.europa.eu/eli/dir/1989/391/2008-12-11
[124] European Agency for Safety and Health at Work, Directive 89/391/EEC - OSH "Framework Directive" (2019) https://osha.europa.eu/en/legislation/directives/the-osh-framework-directive/1
[125] OJ L 285, 1.11.2017, p. 10–13, http://data.europa.eu/eli/reg/2017/1981/oj

1.3.1.1 Ecodesign Directive 2009/125/EC

The scope of this directive is to establish a framework for the setting of Community ecodesign requirements for energy-related products with the aim of ensuring the free movement of such products within the internal market and provide for the setting of requirements which the energy-related products covered by implementing measures must fulfil in order to be placed on the market and/or put into service.[126] Certain product groups relevant for refrigerated containers are already covered by the following ecodesign implementing measures:

- Commission Regulation (EU) 2019/1781 of 1 October 2019 laying down ecodesign requirements for electric motors and variable speed drives pursuant to Directive 2009/125/EC of the European Parliament and of the Council, amending Regulation (EC) No 641/2009 with regard to ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products and repealing Commission Regulation (EC) No 640/2009.[127]
- Commission Regulation (EU) 2019/2024 of 1.10.2019 laying down ecodesign requirements for refrigerating appliances with a direct sales function pursuant to Directive 2009/125/EC of the European Parliament and of the Council. Rules on ecodesign for refrigerating appliances with a direct sales function will apply from 1 March 2021.[128]
- Commission Regulation (EU) 2019/2019 of 1 October 2019 laying down ecodesign requirements for refrigerating appliances pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulation (EC) No 643/2009[129]
- Commission Regulation (EU) No 327/2011, Ecodesign – Fans, Commission regulation (EU) No 327/2011 of 30 March 2011 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for fans driven by motors with an electric input power between 125 W and 500 kW, OJ L90, 6.4.2011.[130]
- Commission Regulation (EU) 2015/1095 of 5 May 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for professional refrigerated storage cabinets, blast cabinets, condensing units and process chillers.[131]

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[126] https://eur-lex.europa.eu/eli/dir/2009/125/2012-12-04
[127] OJ L 272, 25.10.2019, p. 74–94, http://data.europa.eu/eli/reg/2019/1781/oj
[128] OJ L 315, 5.12.2019, p. 313–334, http://data.europa.eu/eli/reg/2019/2024/oj
[129] OJ L 315, 5.12.2019, p. 187–208, http://data.europa.eu/eli/reg/2019/2019/oj
[130] OJ L 90, 6.4.2011, p. 8–21, http://data.europa.eu/eli/reg/2011/327/2017-01-09
[131] OJ L 177, 8.7.2015, p. 19–51, http://data.europa.eu/eli/reg/2015/1095/2017-01-09

1.3.1.2 Energy Labelling Regulation (EU) 2017/1369

Energy labelling rules were first established by "Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances". This directive was repealed by the (recast) Energy Labelling Directive 2010/30/EU adopted by the Council on 19 May 2010, which was repealed in turn by Regulation (EU) 2017/1369.

Regulation (EU) 2017/1369 lays down a framework that applies to energy-related products ('products') placed on the market or put into service. It provides for energy labelling and standard product information requirements regarding energy efficiency, the consumption and other relevant features of usage of products, thereby informing consumers and helping them to choose products that are energy efficient.

With the new regulation (EU) 2017/1369, the energy label has been reformed. The A+, A++ and A+++ classes, introduced by Directive 2010/30/EU, were proven to be less effective and as such the most recent regulation gradually reintroduces a simpler, homogeneous A to G scale. In addition, the new Regulation requires suppliers of products in the scope of delegated acts to upload information about their products into a European product database for energy labelling (EPREL) before placing these products on the European market. This database will be accessible to consumers (public part) and market surveillance authorities (compliance part).

Energy labelling requirements are already in force for a number of products. Certain product groups relevant for refrigerated containers are already covered by the following Delegated Regulations:

- Commission Delegated Regulation (EU) 2015/1094 of 5 May 2015 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of professional refrigerated storage cabinets[132]
- Commission Delegated Regulation (EU) 2019/2016 of 11 March 2019 supplementing Regulation (EU) 2017/1369 of the European Parliament and of the Council with regard to energy labelling of refrigerating appliances and repealing Commission Delegated Regulation (EU) No 1060/2010[133]
- Commission Delegated Regulation (EU) 2019/2018 of 11 March 2019 supplementing Regulation (EU) 2017/1369 of the European Parliament and of the Council with regard to energy labelling of refrigerating appliances with a direct sales function[134]

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[132] OJ L 177, 8.7.2015, p. 2–18, http://data.europa.eu/eli/reg_del/2015/1094/2017-03-07
[133] OJ L 315, 5.12.2019, p. 102–133, http://data.europa.eu/eli/reg_del/2019/2016/oj
[134] OJ L 315, 5.12.2019, p. 155–186, http://data.europa.eu/eli/reg_del/2019/2018/oj

1.3.1.3 Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel

The EU Ecolabel may be awarded as endorsement label to products and services, which have a lower environmental impact than other products in the same group. The label criteria are devised using scientific data on the whole of a product's life cycle, from product development to disposal. The label may be awarded to all goods or services distributed, consumed or used on the Community market whether in return for payment or free of charge. It does not apply to medicinal products for human or veterinary use, or to medical devices. The system was originally introduced by Regulation (EEC) No 880/92 and amended by Regulation (EC) No 1980/2000. The current Regulation (EEC) No 66/2010 aims to improve the rules on the award, use and operation of the label. The label shall be awarded in consideration of European environmental and ethical objectives. In particular:

- The impact of goods and services on climate change, nature and biodiversity, energy and resource consumption, generation of waste, pollution, emissions and the release of hazardous substances into the environment;
- The substitution of hazardous substances by safer substances;
- Durability and reusability of products;
- Ultimate impact on the environment, including on consumer health and safety;
- Compliance with social and ethical standards, such as international labour standards; - taking into account criteria established by other labels at national and regional levels;
- Reducing animal testing.

The label cannot be awarded to products containing substances classified by Regulation (EC) No 1272/2008 as toxic, hazardous to the environment, carcinogenic or mutagenic, or substances subject to the regulatory framework for the management of chemicals.

Currently there are no more valid ecological criteria for the award of the Community eco-label with relevance for refrigerated containers, however the Ecolabel might provide the basis for potential alternative regulation approaches.

1.3.1.4 Regulation (EC) No 1005/2009 of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer (recast)

This Regulation lays down rules on the production, import, export, placing on the market, use, recovery, recycling, reclamation and destruction of substances that deplete the ozone layer, on the reporting of information related to those substances and on the import, export, placing on the market and use of products and equipment containing or relying on those substances.

In this context, it is important to recognize that in the Montreal Protocol on substances that deplete the ozone layer[135], the continued use of hydrochlorofluorocarbons is still permitted, including in the production of intermodal containers. In the European Union, however, the import and placing on the market of intermodal containers containing or relying on such hydrochlorofluorocarbons is prohibited. In that respect, EU policy by means of Regulation (EC) No 1005/2009 is stricter than the Montreal Protocol.

The Commission Opinion of 20 August 2013[136] further clarifies, that the rules in Regulation (EC) No 1005/2009 include intermodal containers with exemption for containers that are not placed on the EU market permanently. The latter applies, as following international trade conventions, such as the Convention relating to Temporary Admission[137], or the Convention on Customs Treatment of Pool Containers used in International Transport[138], that the free movement of intermodal containers should not be restricted. Pursuant to the Convention relating to Temporary Admission, containers used in international transport are to be granted temporary admission. Articles 553, 554, 555 and 557 of Commission Regulation (EEC) No 2454/93[139] (laying down provisions for the implementation of the Customs Code[140]) define a maximum period of 24 months for temporary import, unless specific exemptions are approved by the responsible authorities within the EU. During that period, all containers with granted temporary admission status are not considered to be imported, exported or placed permanently on the EU market and, thus, do not have to comply to specific regulations such as (EC) No 1005/2009.

When intermodal containers used in international transport enter the EU customs area under a temporary import status, they need to be registered in the country where the container arrives. Member States are also responsible to verify that containers entering into the customs territory of the Union under temporary admission actually comply with Articles 553, 554, 555 and 557 of Regulation (EEC) No 2454/93 and also that those containers are not illegally placed permanently on the market in the Union under violation of the temporary admission status. In this context, Directive 2009/125/EC defines permanent "placing on the market" as all activities making a product available for the first time on the Community market with a view to its distribution or use within the Community, whether for reward or free of charge and irrespective of the selling technique[141]. This is even applicable for used containers, which are e.g. already 10 years old and might have entered the EU before under temporary import status many times over their lifetime.

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[135] OJ L 297, 31.10.1988, p. 8.
[136] OJ C 241, 22.8.2013, p. 1–2, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013A0822(01)
[137] OJ L 130, 27.5.1993, p. 4.
[138] OJ L 91, 22.4.1995, p. 46.
[139] http://data.europa.eu/eli/reg/1993/2454/2015-05-01
[140] OJ L 253, 11.10.1993, p. 1,
[141] OJ L 285, 31.10.2009, p. 10–35, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0125

1.3.1.5 Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

Fluorinated gases (‘F-gases’) are a group of synthetic gases used in a range of industrial applications. The EU regulates the use of F-gases as part of its policy to combat climate change. F-gases are often used as substitutes for ozone-depleting substances, because they do not damage the atmospheric ozone layer. However, F-gases are powerful greenhouse gases, with a global warming effect up to 23,000 times greater than carbon dioxide (CO_2). The emissions of fluorinated gases in the EU have risen by 60% since 1990 – in contrast to the emissions of all other greenhouse gases, which are reduced.

F-gases are used in several types of products and appliances, mainly as substitutes for ozone-depleting substances such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and halon, which are being phased out under the Montreal Protocol and EU legislation (i.e. Regulation (EC) No 1005/2009).

Hydrofluorocarbons (HFCs) are used in various sectors and applications, such as refrigerants in refrigeration, air-conditioning and heat pump equipment and as blowing agents for insulation foams.

Hydrofluorocarbons (HFCs) are by far the most relevant F-gas group from a climate perspective,[142] For refrigerated containers, also mainly Hydrofluorocarbons (HFCs) are relevant. The F-gas regulation (EC) No 842/2006 adopted in 2006 which succeeded in stabilising EU F-gas emissions at 2010 levels was repealed by the current Regulation (EU) No 517/2014[143] in January 2015.

The Regulation (EU) No 517/2014 will by 2030 cut the EU’s F-gas emissions by two-thirds compared with 2014 levels. Its main instruments are[144]:

- Most importantly, limiting the total amount of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030;
- Banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available, such as fridges in homes or supermarkets, air conditioning and foams and aerosols;
- Preventing emissions of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.

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[142] https://ec.europa.eu/clima/policies/f-gas_en
[143] OJ L 150, 20.5.2014, p. 195–230, http://data.europa.eu/eli/reg/2014/517/oj
[144] https://ec.europa.eu/clima/policies/f-gas/legislation_en

The requirements are phased in stepwise and from 1 January 2020 the use of F-gases with a global warming potential (GWP) of 2,500 or more, to service or maintain refrigeration equipment with a charge size of 40 tonnes of CO_2 equivalent or more is prohibited. That means that refrigerated container units containing less than the 40-ton CO_2 equivalent threshold are not prohibited by the F-Gas regulation. According to article 11 in the F-gas regulation the restrictions of placing products on the market with F-gasses does not apply to equipment for which it has been established in ecodesign requirements that its lifecycle CO_2 equivalent emissions would be lower than those of equivalent equipment which meets relevant ecodesign requirements and does not contain hydrofluorocarbons.

Article 4 in the F-gas regulation also require operators of e.g. stationary refrigeration and air-conditioning equipment, stationary heat pumps and refrigeration units of refrigerated trucks and trailers that contains 5 tonnes of CO_2 equivalent or more of F-gases, to ensure that the equipment is regularly checked for leaks. However, the leak checks are not required for equipment that contains fluorinated greenhouse gases in smaller quantities than 10 tonnes of CO_2 equivalent if the equipment is hermetically sealed and labelled as such.

Operators of stationary equipment or of refrigeration units of refrigerated trucks and trailers that contain F-gases, other than those contained in foams, shall also ensure that the recovery of those gases is carried out by persons that hold the relevant certificates, so that those gases are recycled, reclaimed or destroyed. Also operators of products and equipment, including mobile equipment, that contain fluorinated greenhouse gases which are not listed in the F-gas regulation shall arrange for the recovery of the gases, to the extent that it is technically feasible and does not entail disproportionate costs, by appropriately qualified natural persons, so that they are recycled, reclaimed or destroyed or shall arrange for their destruction without prior recovery.

Refrigeration air-conditioning and heat pump equipment that contain, or whose functioning relies upon, fluorinated greenhouse gases shall not be placed on the market unless they are labelled. The hydrofluorocarbons charged into this equipment shall be accounted for within the quota system of the regulation to reduce the overall quantity of hydrofluorocarbons placed on the EU market. This shall not apply to producers or importers of less than 100 tonnes of CO_2 equivalent of hydrofluorocarbons per year.

Based on the review clause the Commission shall publish a comprehensive report on the effects of this regulation no later than 31 December 2022, including a review of the availability of technically feasible and cost-effective alternatives to products and equipment containing fluorinated greenhouse gases for products and equipment not listed in Regulation (EU) No 517/2014, Annex III, taking energy efficiency into account.

ANNEX III Placing on the market prohibitions referred to in Article 11(1) with potential relevance for reefers:

Products and equipment		Date of prohibition
8. One-component foams, except when required to meet national safety standards, that contain fluorinated greenhouse gases with GWP of 150 or more		4 July 2008
10. Domestic refrigerators and freezers that contain HFCs with GWP of 150 or more		1 January 2015
11. Refrigerators and freezers for commercial use (hermetically sealed equipment)	that contain HFCs with GWP of 2,500 or more	1 January 2020
	that contain HFCs with GWP of 150 or more	1 January 2022
12. Stationary refrigeration equipment, that contains, or whose functioning relies upon, HFCs with GWP of 2,500 or more except equipment intended for application designed to cool products to temperatures below – 50 °C		1 January 2020
13. Multipack centralised refrigeration systems for commercial use with a rated capacity of 40 kW or more that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1,500 may be used		1 January 2022
16. Foams that contain HFCs with GWP of 150 or more except when required to meet national safety standards	Extruded polystyrene (XPS)	1 January 2020
	Other foams	1 January 2023

Overall, the current F-gas regulation impacts also directly or indirectly the "placing on the market" for refrigerated containers, although the product group is not mentioned explicitly. All products and equipment falling in the scope and definitions by containing high-GWP refrigerants and/or insulation blowing agents, are not allowed to be imported to and marketed in EU anymore, or - if still allowed - are subject to further requirements such as leakage checks for stationary equipment, end of life procedures (F-gas recovery) etc. However, 'mobile' products and equipment, such as potentially refrigerated containers, are subject to less stringent end of life procedures (F-gas recovery), compared to stationary equipment.

Furthermore, Commission Opinion of 20 August 2013[145] concerning Regulation (EC) No 1005/2009 might also be transferable and applicable for Regulation (EU) No 517/2014 which means that refrigerated containers that do not comply with Regulation (EU) No 517/2014, as with all other ISO containers, are allowed to enter the EU under a temporary import permit for 24 months as described in chapter 1.3.1.4.

Kigali Amendment to the Montreal Protocol

Furthermore, the European Union ratified the Kigali Amendment[146] to the Montreal Protocol on 27 September 2018, which will result in a global phasedown of hydrofluorocarbons (HFCs). In response to the rapid growth of HFC emissions, the 197 parties to the Montreal Protocol adopted the Kigali Amendment in 2016 to reduce gradually their global production and consumption. EU Member States are in the process of ratifying the Kigali Amendment individually.

On 1 January 2019 the Kigali Amendment to the Montreal Protocol entered into force. Both developed and developing countries have taken on mandatory commitments to reduce the global production and consumption of hydrofluorocarbons (HFCs). The first reduction step to be taken by the EU and other developed countries is required in 2019, while most developing countries will start their phasedown in 2024.

This agreement is expected to reduce global warming up to 0.4 °C by 2100 compared to BAU, and the goal is to achieve over 80% worldwide reduction in HFC consumption by 2047.

The EU's' F-gas regulation did already in 2014 anticipate the phase-down of HFCs as agreed later under the Kigali Amendment to the Montreal Protocol. This is described in the proposal for the council decision to adopt the Kigali amendment[147]. The enforcement mechanisms of the regulation ensure compliance of the European Union with the obligations under the Montreal Protocol and its Kigali Amendment until 2030, when the last reduction step under the current F-gas regulation comes into force. According to the impact assessment, the

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[145] OJ C 241, 22.8.2013, p. 1–2, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013A0822(01)
[146] https://ec.europa.eu/clima/news/eu-ratifies-kigali-amendment-montreal-protocol_en
[147] COM/2017/051 final - 2017/016 (NLE), Proposal for a COUNCIL DECISION on the conclusion of the agreement to amend the Montreal Protocol on substances that deplete the ozone layer adopted in Kigali https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017PC0051

phase-down schedule is even stricter until 2030 (the last year for which Regulation (EU) No 517/2014 determines a reduction step), than the future control measures under the Kigali Amendment. The reduction schedule beyond 2030 is to be determined on the basis of a review of the F-gas regulation starting in 2022.

According to the proposal for the council decision to adopt the Kigali amendment it is also acknowledged that any technology used to replace HFC in pursuing the objectives of the Kigali Amendment should be at least as energy efficient as the technology replaced. Thus, the foreseen HFC phase-down is also considered to be consistent with the EU energy policy. Moreover, it is expected by the EU that the redesign of refrigeration and air-conditioning systems induced by the necessary replacement of the refrigerants will lead to significant improvements of the energy efficiency, thus making a positive contribution to reaching overall energy and climate targets.

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

The "Machinery Directive" (short "MD") 2006/42/EC[148] provides the regulatory basis for the harmonisation of the essential health and safety requirements for machinery at European Union level. Machinery can be described as "an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application". The essential requirements related to environmental aspects may address noise, vibrations, radiation, emissions of hazardous materials and substances (Annex 1, item 1.5).

Essentially performing a dual function, the directive not only promotes the free movement of machinery within the Single Market, but also guarantees a high level of protection to EU workers and citizens. Being a "New Legal Framework" directive, it promotes harmonisation through a combination of mandatory health and safety requirements and voluntary harmonised standards. Such directives apply only to products, which are intended to be placed (or put into service) on the EU market for the first time.

1.3.1.7 Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast)

The "Electromagnetic Compatibility Directive" (short: "EMC") 2014/30/EU[149] was adopted on of 20 April 2016 and repealed Directive 2004/108/EC. The EMC is in place to ensure

[148] OJ L 157, 9.6.2006, p. 24–86, http://data.europa.eu/eli/dir/2006/42/2019-07-26
[149] OJ L 96, 29.3.2014, p. 79–106, http://data.europa.eu/eli/dir/2014/30/2018-09-11

that electrical equipment is designed such that it does not interfere with or get disturbed by other electrical equipment and thus functions properly. The EMC Directive first limits electromagnetic emissions of equipment in order to ensure that, when used as intended, such equipment does not disturb radio and telecommunication as well as other equipment. The directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions when used as intended. Before equipment is placed on the market (including both apparatus and fixed installations) they must be shown to meet the requirements set out in the EMC Directive. The main objective of the Directive on the harmonisation of the Laws of Member States relating to electromagnetic compatibility (EMC) is thus to regulate the compatibility of equipment regarding EMC:

- Equipment (apparatus and fixed installations) needs to comply with EMC requirements when it is placed on the market and/or taken into service;
- The application of good engineering practice is required for fixed installations, with the possibility for the competent authorities of Member States to impose measures if non-compliance is established.

1.3.1.8 Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)

The European Parliament and the Council Directive 2012/19/EU[150] of 4 July 2012 on waste electrical and electronic equipment (WEEE) applies to electronic and electro-mechanical parts and components, such as compressor, fans, motors, drives, control panel and data monitoring equipment.

The requirements of the Directive are transposed into national law by individual Member States and it is important to be aware of national take back and recycling schemes and arrangements in specific Member States. The Directive requires electrical and electronic equipment to be taken to a suitable authorised treatment facility at the end of its life so that it can be treated e.g. dismantled and materials recovered for recycling where possible. The Directive outlines minimum requirements for the treatment and recovery of WEEE.

The WEEE Directive also requires products to be labelled, in order to identify them as electrical and electronic equipment (EEE), with the aim of minimising the wrong disposal of WEEE. Where it is not feasible to put the label on the actual product it should be included in the documentation accompanying the product. This Directive therefore deals with many of the end-of-life environmental impacts of electrical and electronic equipment.

[150] OJ L 197, 24.7.2012, p. 38–71, http://data.europa.eu/eli/dir/2012/19/2018-07-04

Annex IV of the Directive lists EEE specific to temperature exchange, such as refrigerators, freezers, equipment which automatically delivers cold products, air conditioning equipment, dehumidifying equipment, heat pumps, radiators containing oil and other temperature exchange equipment using fluids other than water for the temperature exchange. Annex IV of the Directive lists EEE specific to monitoring and control instruments such as thermostats, heating regulators, and other monitoring and control instruments used in industrial installations (e.g. in control panels).

1.3.1.9 Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast)

The RoHS Directive 2011/65/EU[151], in tandem with the WEEE Directive prevents the use of certain hazardous materials in new EEE placed on the market. This limits the impact of the EEE at the end of its life and it also ensures harmonisation of legislation on the use of hazardous materials in EEE across all Member States.

In Annex II of the RoHS directive a list of restricted categories for Electrical and Electronic Equipment is given[152]. These substances are:

- Large household appliances.
- Small household appliances.
- IT and telecommunications equipment.
- Consumer equipment.
- Lighting equipment.
- Electrical and electronic tools.
- Toys, leisure and sports equipment.
- Medical devices.
- Monitoring and control instruments including industrial monitoring and control instruments.
- Automatic dispensers.
- Other EEE not covered by any of the categories above.

In Annex II of the RoHS directive a list of restricted substances and maximum concentration values tolerated by weight in homogeneous materials for Electrical and Electronic Equipment is given[153]. These substances are:

- Lead (0.1 %)
- Mercury (0.1 %)
- Cadmium (0.01 %)
- Hexavalent chromium (0.1 %)
- Polybrominated biphenyls (PBB) (0.1 %)
- Polybrominated diphenyl ethers (PBDE) (0.1 %)

[151] OJ L 174, 1.7.2011, p. 88–110, http://data.europa.eu/eli/dir/2011/65/2019-07-22
[152] https://eur-lex.europa.eu/eli/dir/2011/65/2019-07-22
[153] https://eur-lex.europa.eu/eli/dir/2011/65/2019-07-22

- Bis(2-ethylhexyl) phthalate (DEHP) (0.1 %)
- Butyl benzyl phthalate (BBP) (0.1 %)
- Dibutyl phthalate (DBP) (0.1 %)
- Diisobutyl phthalate (DIBP) (0.1 %)

There are exemptions and limit values listed in the Annex to the Directive for some equipment where it is understood that one or more these substances is required for their functioning and no economically viable alternatives exist in sufficient quantity at present. Therefore, some of these substances may still be found in some electrical and electronic equipment. The Annex has been revised on a number of occasions, altering the list of exclusions and limit values. In this assessment it is assumed that that some effects occur from the RoHS Directive to products outside its original scope.

The general review of Directive 2011/65/EU is to be carried out by the Commission no later than 22 July 2021

1.3.1.10 Directive (EU) 2017/2102 of the European Parliament and of the Council of 15 November 2017 amending Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment

Directive 2011/65/EU (WEEE) requests the Commission to examine the need to amend the scope of that Directive in respect of the EEE covered therein and, if appropriate, present a legislative proposal with respect to any additional exclusions related to that EEE.

Following this, the WEEE directive has been amended by Directive (EU) 2017/2102 on the restriction of the use of certain hazardous substances in electrical and electronic equipment[154].

Particularly relevance for this study, secondary market operations for EEE, which involve repair, replacement of spare parts, refurbishment and reuse, and retrofitting, should be facilitated to promote a circular economy in the Union. A high level of protection of human health and the environment should be ensured, including an environmentally sound recovery and disposal of waste EEE. Additionally, any unnecessary administrative burden on market operators should be avoided. Therefore, the prohibition of secondary market operations in the F-gas directive was considered as inconsistent with the general principles underlying Union measures for the approximation of laws relating to products and were therefore removed by Directive (EU) 2017/2102.

[154] OJ L 305, 21.11.2017, p. 8–11, http://data.europa.eu/eli/dir/2017/2102/oj

1.3.1.11 Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000 on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors

The administrative and legal position is given in the Directive 2000/14/EC[155] of the European Parliament and of the Council of 8 May 2000, on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors. Noise emissions of outdoor machinery are regulated by European Directive 2000/14/EC. This directive lays down minimal requirements (such as noise marking, noise emission limits) for outdoor machinery that must be respected before equipment can be placed on the European market. It represents a conventional ("command-and-control") regulatory approach. The directive has been amended by the Directive 2005/88/EC of the European Parliament and of the Council of 14 December 2005[156] , Regulation (EC) No 219/2009[157] and Regulation (EU) 2019/1243[158].

Annex I describes the definitions of equipment including compressor, which is defined as "any machine for use with interchangeable equipment which compresses air, gases or vapours to a pressure higher than the inlet pressure"; and power generator, which is defined as "any device comprising an internal combustion engine driving a rotary electrical generator producing a continuous supply of electrical power".

1.3.1.12 Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits

The Low Voltage Directive (LVD) 2014/35/EU is one of the oldest Single Market Directives adopted before the "New" or "Global" Approach, repealing 2006/95/EC with effect from 20 April 2016. However, it does characterize both with a conformity assessment procedure applied to equipment before placing on the Market and with Essential Health and Safety Requirements (EHSRs), which such equipment must meet either directly or by means of harmonized standards. The LVD ensures that electrical equipment within certain voltage limits both provides a high level of protection for European citizens and enjoys a Single Market in the European Union.

The Directive covers electrical equipment with a voltage between 50 and 1,000 V for alternating current and between 75 and 1,500 V for direct current. It should be noted that these voltage ratings refer to the voltage of the electrical input or output, not to voltages

[155] OJ L 162, 3.7.2000, p. 1–78, http://data.europa.eu/eli/dir/2000/14/2019-07-26
[156] OJ L 344, 27.12.2005, p. 44–46, http://data.europa.eu/eli/dir/2005/88/2005-12-27
[157] OJ L 87, 31.3.2009, p. 109–154, http://data.europa.eu/eli/reg/2009/219/2019-07-15
[158] OJ L 198, 25.7.2019, p. 241–344, http://data.europa.eu/eli/reg/2019/1243/oj

that may appear inside the equipment. For most electrical equipment, the health aspects of emissions of Electromagnetic Fields are also under the domain of the Low Voltage Directive. For electrical equipment within its scope, the Directive covers all health and safety risks, thus ensuring that electrical equipment is safe in its intended use.

1.3.1.13 Directive 2014/29/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of simple pressure vessels

The Pressure Equipment Directive (PED) 2014/29/EU[159] provides the legislative framework for equipment subject to a pressure hazard. The main aims are to harmonise standards regarding the design, manufacture, testing and conformity assessment of pressure equipment and assemblies of pressure equipment. This directive might have potential indirect effects for refrigerated containers, as it forces the components to resist defined maximum pressures, which is influencing especially the costs e.g. in case of a future switch towards new low GWP refrigerants like CO_2 with more demanding pressure conditions.

1.3.1.14 Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)

The "ATEX" Directive 2014/34/EU[160] of the European Parliament and the Council of 26 February 2014 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres. This directive applies to equipment used in hazardous areas (potential for an explosion) including equipment designed to prevent explosions[161]. The safety of workers is covered by a separate directive. The directive only applies to equipment that introduces energy, electrically or mechanically, into a potentially explosive atmosphere. The on-going switch to coolants with low ODP and GWP might require further elaborations in this context.

1.3.1.15 International Convention for Safe Containers (CSC)

International Maritime Organization (IMO), in co-operation with the Economic Commission for Europe, adopted in 1972 the International Convention for Safe Containers (CSC). The requirements of the Convention apply to the great majority of freight containers used internationally, except those designed especially for carriage by air. The scope of the Convention is limited to containers of a prescribed minimum size having corner fittings - devices which permit handling, securing or stacking (such as the intermodal

[159] OJ L 96, 29.3.2014, p. 45–78, http://data.europa.eu/eli/dir/2014/29/oj
[160] OJ L 96, 29.3.2014, p. 309–356, http://data.europa.eu/eli/dir/2014/34/oj
[161] https://www.conformance.co.uk/ce-marking/67-ce-directives/specialisms/229-atex

freight containers including refrigerated containers). The two goals of CSC are to maintain a high level of safety of human life in the transport and handling of containers and to facilitate the international transport of containers by providing uniform international safety regulations, equally applicable to all modes of surface transport. The convention includes two annexes:

- Annex I: Testing, inspection, approval and maintenance of containers. Containers must be safety-approved by an administration of a contracting state or by organization acting on its behalf. The manufacturer must affix a safety approval plate (CSC Safety-approval Plate) to the approved containers with the relevant technical data.
- Annex II: Structural safety requirements and tests[162].

1.3.1.16 IED - Industrial Emissions Directive 2010/75/EC

Industrial production processes account for a considerable share of the overall pollution in Europe (for emissions of greenhouse gases and acidifying substances, wastewater emissions and waste). To take further steps to reduce emissions from such installations, the Commission adopted its proposal for a directive on industrial emissions on 21 December 2007. The Industrial Emissions Directive 2010/75/EC (IED) entered into force on 6 January 2011 and has to be transposed into national legislation by Member States by 7 January 2013.

1.3.1.17 Regulation (EU) 2016/1628 - gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery

Requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for 'non-road mobile machinery', which is defined in the regulation as follows: "any mobile machine, transportable equipment or vehicle with or without bodywork or wheels, not intended for the transport of passengers or goods on roads, and includes machinery installed on the chassis of vehicles intended for the transport of passengers or goods on roads". Typically, integrated, clip on and under mount diesel generator sets for powering refrigerant units might fall under this definition, given their output power capacity.

The limit values of stage V are identical with US EPA Tier 4 limits for engines for non-road mobile machinery (category NRE) in engine power ranges up to 19 kW and above 560

[162] International Maritime Organisation, International Convention for Safe Containers (CSC), http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-Safe-Containers-(CSC).aspx

kW[163]. In power ranges above 19 kW up to 560 kW the limit values for CO, HC and NOx are comparable but the Stage V limits for Particulate Matter (PM) are lower than the PM limits of Tier 4. There are no limits for particle numbers (PN) in US EPA legislation. From January 2018 only Stage V type-approvals of engines can be issued for engines below 56 kW and above 130 kW.

1.3.1.18 Motor vehicle noise: Directive 540/2014

Regulation (EU) No 540/2014 of the European Parliament and of the Council of 16 April 2014 concerns the sound level of motor vehicles and of replacement silencing systems. Has been amended by Directive 2007/46/EC and the repealing Directive 70/157/EEC Text with EEA relevance [164].

This directive may be of indirect interest to reefers as e.g. during road transit they typically form a variable system with some type of an internal combustion engine in the form of a DG set.

1.3.1.19 Safety and health of workers at work: Directive 89/391/EEC

The aim of this Directive is to introduce measures to encourage improvements in the safety and health of workers at work. It applies to all sectors of activity, both public and private, except for specific public service activities, such as the armed forces, the police or certain civil protection services[165].

1.3.1.20 Regulation on transport of meat 2017/1981 amending annex III to regulation No 853/2004

This regulation lays down specific rules on the hygiene of food of animal origin for food business operators including specific temperature requirements before and during the transport of meat.

1.3.2 Third country regulations

1.3.2.1 CARB regulation

The California Air Resources Board (CARB) defines "Transport Refrigeration Units" (TRUs) for the regulations on Mobile and Stationary Source Airborne Toxic control Measures (ATCMs)[166]. The CARB has adopted ATCMs and a certification of for TRUs and TRU generator sets[167].

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[163] https://www.eu-nited.net/municipal_equipment/upload/NRMM_Guide_final_2017-04-13.pdf
[164] https://eur-lex.europa.eu/eli/reg/2014/540/oj
[165] https://osha.europa.eu/en/legislation/directives/the-osh-framework-directive/1
[166] California Environmental Protection Agency, Transport Refrigeration Unit ATCM Tutorial (2011), https://ww3.arb.ca.gov/diesel/tru/documents/tru_tutorial_slides.pdf
[167] California Air Resources Board, Transport Refrigeration Unit (2019), https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit/about

A TRU is in the ATCM regulation a refrigeration system that is powered by an integral diesel engine used in the transport of perishable goods. TRU generator sets are designed and used to provide electric power to electrically driven refrigeration units of any kind including generator sets for shipping reefer containers on ships. The TRU ATCM applies to both TRUs and TRU generator sets.

Refrigeration systems that do not have an integral diesel internal combustion engine are not TRUs. And refrigeration systems that are powered from the vehicle engine or the ship power supply, e.g. reefers on supplied by the container ships power plug are not TRUs. As an example, a refrigerated box with an aircon or cooling unit on a delivery van powered by the engine of the van is not a TRU.

1.3.2.2 Agreement Transport Perishable (ATP)

ATP is an agreement on the International Carriage of Perishable Foodstuffs and on the special equipment to be used for such carriage. It is referred to as the ATP agreement. It was first adopted by the Inland Transport Committee of the United Nations Economic Committee for Europe in 1970-71 and amended on 6th January 2018[168]. ATP provides methods and procedures for measuring and checking the insulating capacity and the efficiency of the cooling or heating appliances of special equipment for the carriage of perishable foodstuffs.

ATP is not applicable for refrigerated containers according to its chapter III, Miscellaneous provisions, Article 5 which defines that it shall not apply to carriage in containers classified as "thermal maritime" by land without transloading of the goods where such carriage is preceded or followed by a sea crossing other than a sea crossing.

Article 3, paragraph 2 of the ATP also defines that these requirements apply to sea crossings of less than 150 km for goods that are shipped in equipment used for the land journey or journeys without transloading of the goods. [169]

[168] Cambridge Refrigeration Technology, What is ATP? (2019), http://www.crtech.co.uk/pages/ATP/what-is-ATP.asp

[169] United Nations, Agreement on the International Carriage of Perishable Foodstuff and on the Special Equipment used for such Carriage (ATP) (2016), https://www.unece.org/fileadmin/DAM/trans/main/wp11/ATP_publication/ATP-2016e_-def-web.pdf

2. Task 2 Market, users and resources

The purpose of task 2 is to assess the European market (EU 28) including sales and stock of refrigerated containers as defined in task 1 and how the products are placed on the market, and identify important trends which potentially could change the market and energy consumption of reefers in the future.

Since Prodcom data, the official source for product data on the EU market, are not available for reefers, the sales and stock data has been obtained by extrapolations from the world market of ISO containers, transport routes for perishable goods and from interviews of actors on the reefer market.

Of the total fleet of containers, approximately 6.3 %[170] - and increasing - are reefers. As described in task 1, a number of subcategories of reefers exist. At the same time since the total sales numbers of reefers are relatively low and since it in many cases does not add value to analyse subcategories in detail, the breakdown of data on different product categories has been minimized. As an example, reefers with the common feature of controlled atmosphere (CA) are not analysed specifically. The controlled atmosphere is an add-on and although it changes the energy performance of the reefer, it does not change the fundamental characteristics of the reefer like the materials used and structure, insulation, cooling. In addition as explained in task 1 the number of CA subcategories is so high, hence the sales numbers in each category so low that conclusions based on estimated sales numbers for the current study would be subject to too high uncertainty, and it would not change the study's overall conclusions about the market size and nature.

This task also draws some preliminary conclusions and recommendations regarding the reefers' way to market and potential policy instruments.

2.1 Generic Economic data

The Prodcom statistics are based on product definitions that are standardised across the EU thus guaranteeing comparability between Member States. Data are reported by Member States to Eurostat.

The Prodcom statistics have some limitations given the complexities in the market and consequently, they are rarely as detailed as necessary to support decision making within ecodesign preparatory studies.

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[170] World Shipping Council and Drewry 2012 (http://www.worldshipping.org/about-the-industry/containers/global-container-fleet)

The following table lists out key manufacturing categories under Prodcom that are likely to be related to reefers or reefer spare parts. The table is an extract of Table 1-2.

Table 2-1: Prodcom codes and nomenclature

Prodcom code	Prodcom Nomenclature (NACE Rev. 2)
27.11	Manufacture of electric motors, generators and transformers
27.11.31.10	Generating sets with compression-ignition internal combustion piston engines, of an output ≤ 75 kVA
27.11.32.35	Generating sets with spark-ignition internal combustion piston engines of an output > 7,5 kVA
28.13.23.00	Compressors for refrigeration equipment
28.25	Manufacture of non-domestic cooling and ventilation equipment
28.25.13.60	Refrigerating furniture with a refrigerating unit or evaporator (excluding combined refrigerator-freezers, with separate external doors, household refrigerators, refrigerated showcases and counters)
28.25.13.90	Other refrigerating or freezing equipment

None of the Prodcom categories presented in Table 1-7 are detailed enough to ascertain if they cover the product in scope. Therefore, it has not been found meaningful to present data on production, import and export for the EU on these categories, since it would likely give a misrepresentation of the reefer market. The Prodcom data might be useful for comparison or in identifying market trends. However, the sheer nature of the reefer market, being a global product that is not linked to a specific market, makes it difficult to associate trends from other refrigerating or freezing equipment.

2.2 Market and stock data

Due to sales data from Prodcom not being very relevant, other sources are used to determine the market and stock data. In this section the different sources and assumptions made to estimate the market and stock data for each of the product types within the scope (presented in Task 1) are presented. In general, these sections present the needed data to determine the stock of equipment in EU. After the estimates on lifespan, the sections are split between reefers for intermodal transportation use, below referred to as shipping reefers, and reefers for stationary use, referred to as stationary reefers.

The motivation for using the term `shipping reefers´ in spite of the definition of the preliminary product scope in chapter 1.1.2 being `integral reefers for intermodal transport’, is that the sources of market data generally uses the term shipping reefers.

2.2.1 Lifespan for shipping reefers and stationary reefers

Data from Dutch based industry analyst Dynamar are the primary source of data for this section[171], when comparing sales and stock data suggest a life span for shipping reefers of 13 years. These findings are very close to other sources suggesting life spans of between 12 and 15 years[172,173,174]. This has also been confirmed by stakeholder interviews. Handling and life of a stationary reefer is very different from the life of a shipping reefer, which is exposed to a great deal of stress under harsh environments and during handling between ship, road and rail.

The more static nature of a stationary container's use patterns limits the risk of damages to the refrigeration unit or damages to the structure that could compromise the seal of the container. Therefore, longer life spans for stationary reefers are expected, which is also supported by the stakeholder interviews indicating life spans of the cooling system of 12 to 20 years and a life span of the box of between 20 and 50 years. Based on the interviews weighted average life span of a functional reefer was calculated to 28 years. This would typically include one replacement of the compressor or the entire cooling unit.

The lifespans and standard deviations (with presumed normal distribution of lifespans) used in this study are shown in Table 2-2.

Table 2-2: Average expected lifetimes and assumed variations used in the stock model, in years

Reefer type	Average lifespan (Years)	Standard variation (Years)
Shipping reefer	13	2
Stationary reefer	28	n.a.

2.2.2 Shipping reefers

2.2.2.1 Global sales

The primary source of sales data is Dynamars most recent analysis of the shipping reefer market[175]. The analysis compiles data on the world maritime global sales and stock from 2001 to 2017 based on a number of different sources within the industry such as manufacturers, container liners and databases. Figure 2 shows the global sales of reefers in the period from 1990 to 2017 of which the study team has estimated the historical sales

[171] Dynamar (2018) Reefer Analysis, Market structure, Conventional, Containers
[172] https://www.mcicontainers.com/news/stories/new-fuel-regulations--increase-pressure--on-energy-efficiency
[173] https://pdfs.semanticscholar.org/a9d3/fc0a02199e87233bcee9a742576570ab82ff.pdf
[174] https://coldstoragecontainers.com/rent/
[175] Dynamar (2018) Reefer Analysis, Market structure, Conventional, Containers

numbers from 1990 to 2000 (blue part of graph) as well as the projected sales towards 2030 (green part) based on the Dynamar data.

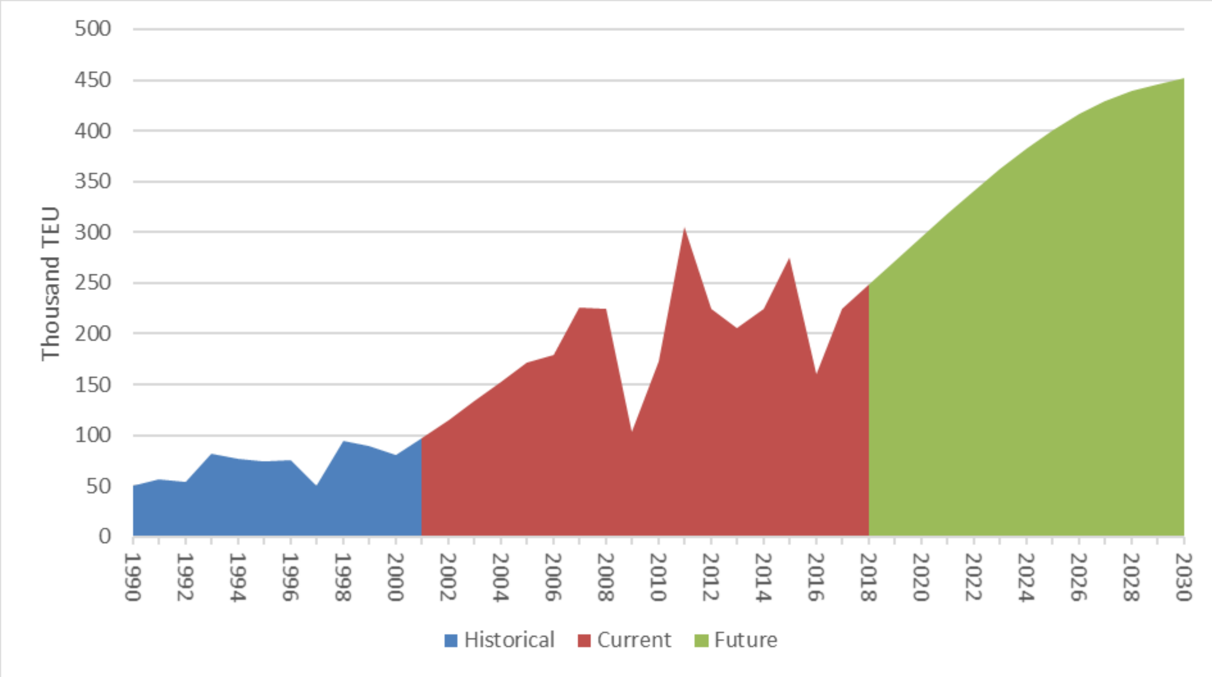

Figure 2: Global sales of shipping reefers in thousand TEU (Source: Based on Dynamar)

Based on the Dynamar data, historical sales from 1990 to 2000 have been established retrospectively by the study team by assuming a reefer lifetime of 13 years coupled with the number of disposed reefers annually from the actual data from Dynamar on the reefer fleet from 2005 to 2017 (marked as "current" in the figure). The number of disposed reefers is the difference between annual sales and the annual stock increase. This means that in the calculations on which the data in the figure is based, the number of disposed reefers in 2013 equals the reefer sales in 2000.

The global sales of reefers in 2017 were 225,000 TEU with an average annual growth rate at about 11 % since 2001. There is a clear drop in sales following the financial crisis in 2008 but was already at a record high in 2011 with annual sales of 305,000 TEUs. In the following years the sales have been fluctuating significantly. World Cargo News compiled similar sales data from box building and leasing industry data and found a global sales volume on 275,000 TEU in 2018, being 10 % higher but still relatively close to the Dynamar data,[176]. This number is in line with predictions from MCI who estimated the number to be 150,000 FEU (Forty-feet Equivalent Units) in 2018[177].

Sales towards 2030 are expected to continue to increase. Primarily due to an increasing trend in trade especially of perishable products both for the developed countries but also

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[176] World Coargo news, Reefer leasing gets back on track, https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track
[177] Lloyd's List Containers, (Nov.-Dec. 2018)

in growing economies with an increasing middle-class. However, it is not considered realistic to expect a continued annual growth of 11 % for the next decade, which will imply a doubling in less than 10 years. Therefore, the model is applied with a declining growth rate reaching 1.5 % in 2030. For further information about market trends see chapter 2.3.

2.2.2.2 EU market allocation

Due to the international character of the shipping industry, sales and market data are either published as global data only or internal non-published on a company level, therefore making it difficult to determine the exact number of reefers which are placed on the market in the EU. The study team has not been able to find any published statistics comprising the import and export of reefers to and from EU harbours. Furthermore, no manufacturers of reefers (intermodal transport units) exist in the EU and as described in chapter 2.3.2 the majority of shipping reefers used in EU are traded and placed on the marked in Asia according to stakeholder interviews.

The global container shipping market is divided between a few very large companies (freight carriers), where the three largest have headquarters in Europe with a total global market share of about 40 %[178]. However, these companies are involved in almost every trading route around the world and it would be misleading to allocate their market share solely to the EU market for the calculations of EU related reefer sales.

The Review of Maritime Transport[179] compiles statistics on container port throughputs for European harbours and estimates it to being 16 % of the global container traffic. However, this number includes all container traffic, meaning reefers as well as dry containers and therefore it might underestimate the reefer volume.

Trade data on perishable products are considered to be the most accurate proxy for determining the reefer shipping market in the EU. Categories on perishable products that are traded worldwide and are very likely to be carried under refrigerated conditions are the following:

- Dairy
- Fishery products
- Fruit
- Meat
- Vegetables

[178] Review of Maritime Transport 2018 (page 33)
[179] Review of Maritime Transport 2018

Other products such as flowers, chemicals and medicine are also likely to be carried under refrigerated conditions but constitutes a small share of the total volume and may also be carried by air. These categories therefore have been left out.

Trade data has been compiled by Dynamar[180] using the following sources: International Trade Organisation, Comstat, Eurostat and Foreign Agricultural Service.

Table 2-3 shows the total trade volumes for perishable products in the EU for import and export respectively. Between 2008 and 2017 the trade volume has increased by 18 % to a total of 35.6 million ton, primarily as a result of increased export.

Compared to world trade volumes the EU's share has increased slightly between 2013 and 2017 to a level of 22.9 %.

Table 2-3: Trade volumes of perishable products in the EU and compared to world levels. See detailed overview on commodity and regional level in Annex III (Source: Based on Dynamar)

Trade volumes	2008 Ton	2013 Ton	2014 Ton	2015 Ton	2016 ton	2017 ton
World	118,807,000	144,847,000	148,996,000	146,597,000	153,072,000	155,249,000
EU	**30,182,000**	**32,224,000**	**33,378,000**	**33,306,000**	**34,722,000**	**35,600,000**
EU – Import	19,673,000	18,248,000	18,316,000	18,616,000	19,644,000	20,658,000
EU – Export	10,509,000	13,976,000	15,062,000	14,690,000	15,078,000	14,942,000
EU share of world	**25.4 %**	**22.2 %**	**22.4 %**	**22.7 %**	**22.7 %**	**22.9 %**

Figure 3 to Figure 6 shows the countries of origin and destination for the EU for import and export respectively and the product categories. In general, imported products are dominated by fruits (primarily bananas) coming from tropical regions – Africa, South America and Central America but also large quantities of fishing products. Exported products are dominated by meats, fruit and vegetables primarily exported to Asia, Africa and rest of Europe (including Russia and Turkey).

[180] Dynamar (2018) Reefer Analysis, Market structure, Conventional, Containers

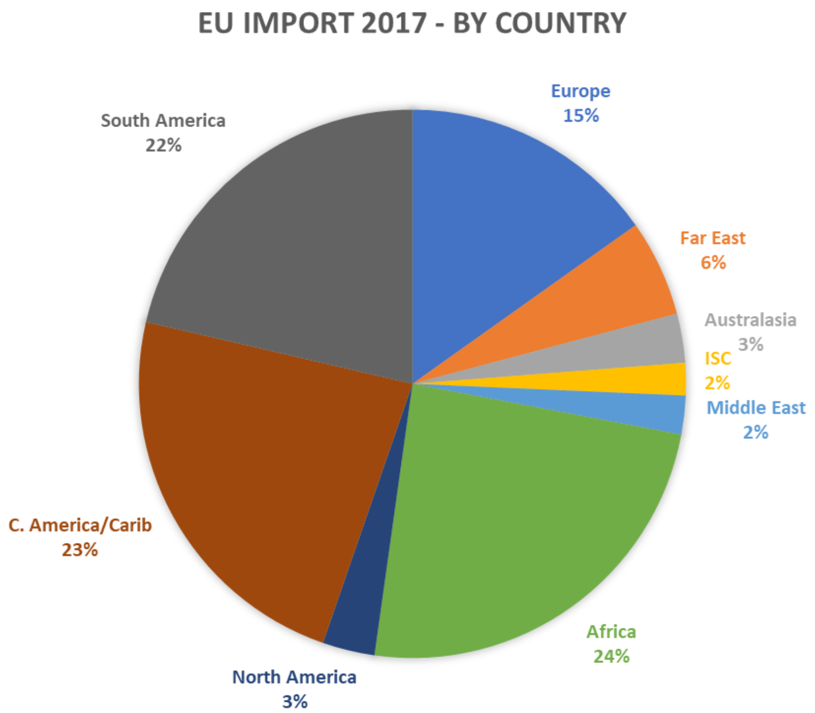

Figure 3: Country of origin of imported perishable products to the EU in 2017. Europe includes Russia and Turkey. ISC includes the Indian SubContinent. See absolute numbers in Annex III (Source: Based on Dynamar)

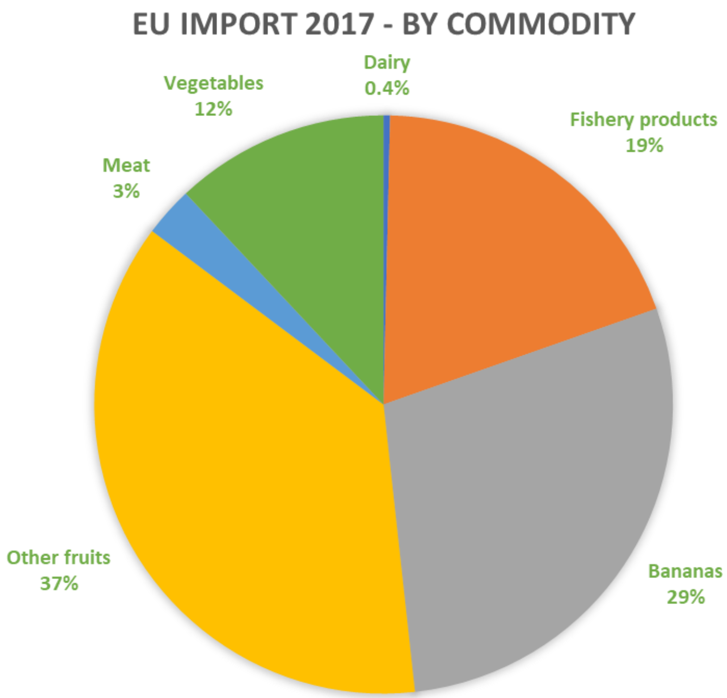

Figure 4: Type of imported perishable products to the EU in 2017. See absolute numbers in Annex III (Source: Based on Dynamar)

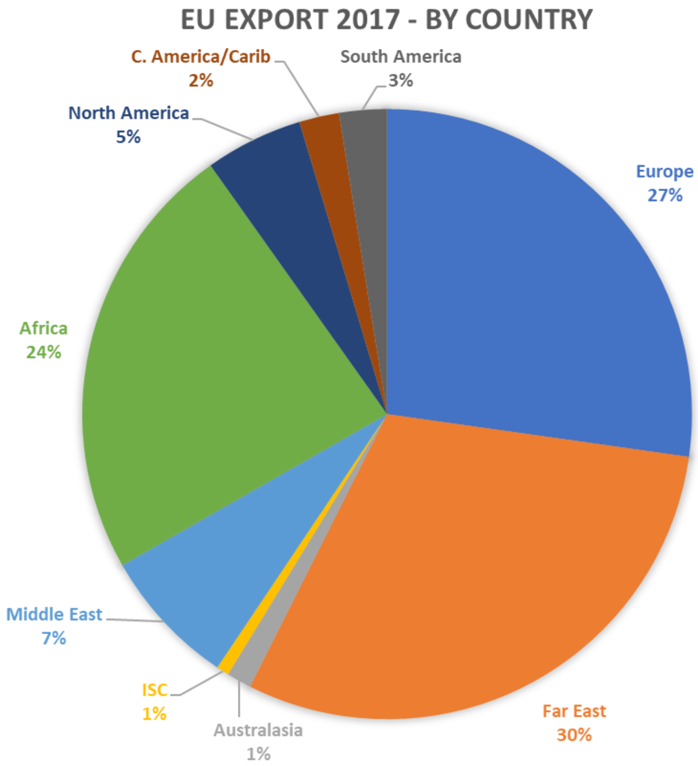

Figure 5: Country of destination of exported perishable products from the EU in 2017. Europe includes Russia and Turkey. ISC includes the Indian SubContinent. See absolute numbers in Annex II (Source: Based on Dynamar)

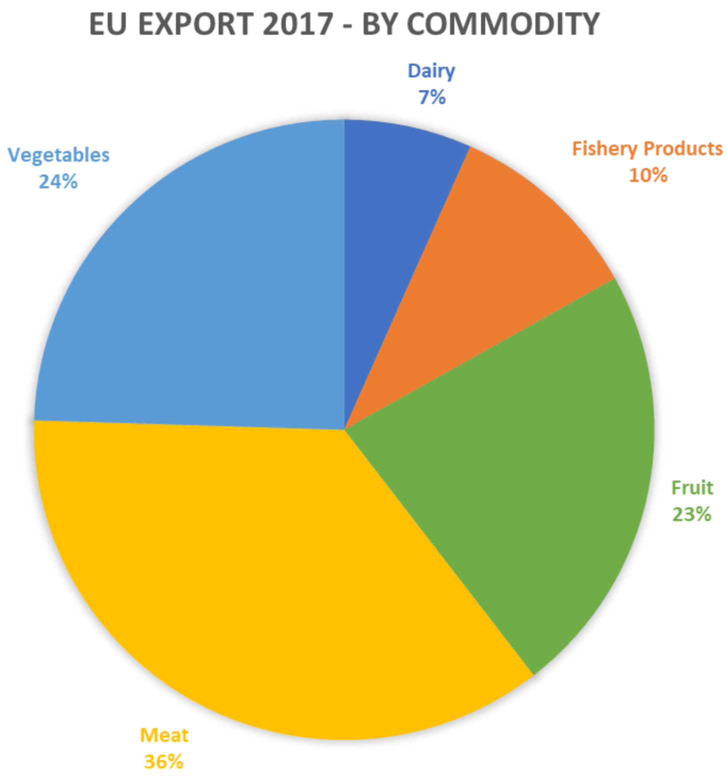

Figure 6: Type of exported perishable products from the EU in 2017. See absolute numbers in Annex II (Source: Based on Dynamar)

Products traded with the rest of Europe are dominated by land-based transport which could imply other means of cold storage equipment than integrated reefers, but still with a large share being transported in reefers either via truck or train. According to Jeschke[181] while container vessels dominate the international shipping freight including the extra-EU transport, the road transport is the dominant transport mode for freight transport internally in EU (Table 2-4).

The three most dominant concepts of land transport are containers, swap-bodies and semitrailers (which include TRUs). Of these, the share of containers and swap-bodies is 75 % and the share of semitrailers is 10 % of the combined transport[182]. For the current study similar shares are expected to apply on the reefer transport.

Table 2-4: Distribution of surface transport across modes in EU (2009, % of tkm) (Source Eurostat 2011). [183]

Transport form	Excl. extra-EU sea shipping	Incl. extra-EU sea shipping
Road	47 %	17 %
Sea shipping	37 %	78 %
Oil pipeline	3 %	< 1 %
Inland waterways	3 %	2 %
Rail	10 %	3 %
Air freight	< 1%	< 1%

2.2.2.3 EU sales – shipping reefers

Based on trade data of goods transported, described in the previous section, a share of the global sales of new containers has been allocated to the EU market including the United

[181] Sabina Jeschke, *Global Trends in Transport Routes and Goods Transport: Influence on Future International Loading Units*, Aachen University (2011), 16. ACEA SAG meeting. https://www.acea.be/uploads/publications/SAG_16_Global_Trends_in_Transport_Routes__Goods_Transport.pdf

[182] Sabina Jeschke (2011), https://www.acea.be/uploads/publications/SAG_16_Global_Trends_in_Transport_Routes__Goods_Transport.pdf

[183] Sabina Jeschke (2011), https://www.acea.be/uploads/publications/SAG_16_Global_Trends_in_Transport_Routes__Goods_Transport.pdf

Kingdom and can be seen in Figure 7. Based on this method the sales of reefers *related* to the EU market could be estimated. This number does not tell the number of reefers actually *placed on* the EU market but is a way of expressing how many of the worlds reefers that is placed on the market because of the EU market, to supply the EU with goods. This is relevant to get an estimate on the reefers that EU may have a theoretical possibility to influence.

The distinction between reefer sales related to and placed on the marked is treated in chapter 2.3.2.

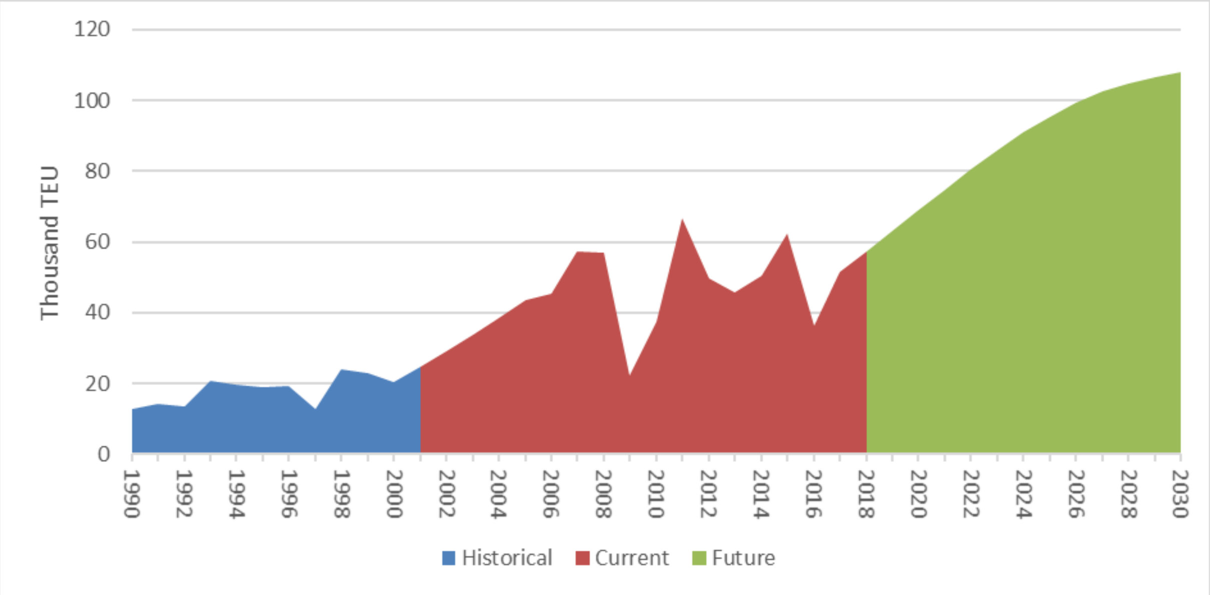

Figure 7: EU related sales of shipping reefers in thousand TEU (Based on Dynamar)

It should be noted that when trade data in mass units (tons) are used for allocating global reefer sales numbers to the EU market, the potentially different density of the product has not been taken into account between EU and the world. For example, one ton of bananas might take up more reefer space compared to one ton of meat. For this study it is assumed, that the EU share of tons of perishable goods trade equals the volumetric share of perishable goods.

The sales of reefers related to the EU market were 52,000 TEUs in 2017 and have seen an average annual growth of 12 %. Slightly higher than for the global sales due to an increased EU market share.

Approximately 98 % of all reefer containers for shipping (counted in TEU) are 40 ft sized container and the remaining 2 % (TEU or 4 % in actual container units) are 20 ft sized containers[184, 185]. Table 2-5 shows the number of units sold for each reefer size in the period 1990 to 2030.

Table 2-5: EU related sales of shipping reefers in units of 20 ft and 40 ft containers respectively (Based on Dynamar)

Units	1990	1995	2000	2005	2010	2015	2020	2025	2030
20 ft	254	376	406	874	752	1,250	1,371	1,828	1,939
40 ft	6,224	9,212	9,958	21,411	18,427	30,614	33,580	44,798	47,503
Total	**6,478**	**9,588**	**10,364**	**22,285**	**19,179**	**31,864**	**34,951**	**46,626**	**49,442**
Total TEU	**12,702**	**18,799**	**20,323**	**43,695**	**37,607**	**62,478**	**69,004**	**95,383**	**108,084**

More than 30,000 units were sold in 2015 and is expected to increase to almost 50,000 sold units per year in 2030. The Ecodesign Directive's article 15[186] specifies a yearly sale of 200.000 units as an indicative lower limit for adopting ecodesign requirements in the combination with a "significant environmental impact" within the Community considering the quantities in which it is placed on the market and/or put into service.

The estimated sales numbers in 2030 are only about 25 % of the indicative minimum number. On the other hand, the energy consumption is more significant compared to many other products in scope of the Ecodesign Directive such as residential products. A reefer with a yearly energy consumption on 50 MWh for instance would consume around 200 times more energy than a typical 200/100 L, A++ residential refrigerator-freezer[187].

Since only one cooling unit is used per container, the yearly sales of cooling units related to EU corresponds not to the to the number of "Total TEU" but to the number of "Total" units of Table 2-5.

2.2.2.4 Stock – shipping reefers

The stock of shipping reefers related to the EU-28 is calculated based on the sales figures and the expected lifespans described previously. Normal distribution of the lifetime was

[184] Email communication with Frans Waals (Dynamar) and stakeholder interviews.
[185] https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track (April 2019)

[186] Directive 2009/125/EC (…) establishing a framework for the setting of ecodesign requirements for energy-related products
[187] https://sparenergi.dk/forbruger/el/koel-og-frys

applied to the sales volume for shipping reefers each year, which yielded the total EU stock shown in Table 2-6. Stock for all years can be seen in Annex III.

Table 2-6: Stock of shipping reefers in units of each size and category related to EU-28 from 1995 to 2030 (Based on Dynamar)

Stock	1995	2000	2005	2010	2015	2020	2025	2030
20 ft	1,997	3,958	6,608	8,068	11,924	14,208	18,271	23,333
40 ft	48,921	107,983	161,896	197,655	292,148	348,100	447,650	571,649
Total	**50,917**	**111,940**	**168,504**	**205,722**	**304,073**	**362,308**	**465,921**	**594,981**
Total TEU	99,838	197,878	330,399	403,377	596,221	710,409	913,571	1,166,630

The total stock of reefers related to the EU market is about 350,000 units (both 20 ft and 40 ft) in 2019 and is expected to grow to almost 600,000 in 2030.
World Shipping Council and the analyst Drewry Maritime Research estimates the global shipping container fleet in 2012 to 32.9 million TEU containers and the share of reefers to be 6.25 %[188], leading to a global shipping reefer fleet on 2.06 million TEU reefers. Using the EU share of reefers on 22.2 % (2013) found in the current study based on the goods transported, the Drewry estimates on the world fleet would lead to the EU related shipping reefer fleet being calculated to approximately 460,000 TEU reefers. This is not far from the numbers found in the current study (Table 2-6) which is approximately 500,000 TEU reefers (average of 2010 and 2015).

The top 25 fleet owners disposed over 2.11 million power plugs for reefer containers in 2018[189]. Compared to the estimated world fleet on 2.06 mill. TEU it corresponds to roughly one plug per TEU reefer. This means that when adding the plugs on-shore, trains, etc. it would be reasonable to consider that the major share of the reefer fleet is in use.

Figure 8 shows the development in sales and stock for the period 1990 to 2030.

[188] http://www.worldshipping.org/about-the-industry/containers/global-container-fleet
[189] Dynamar

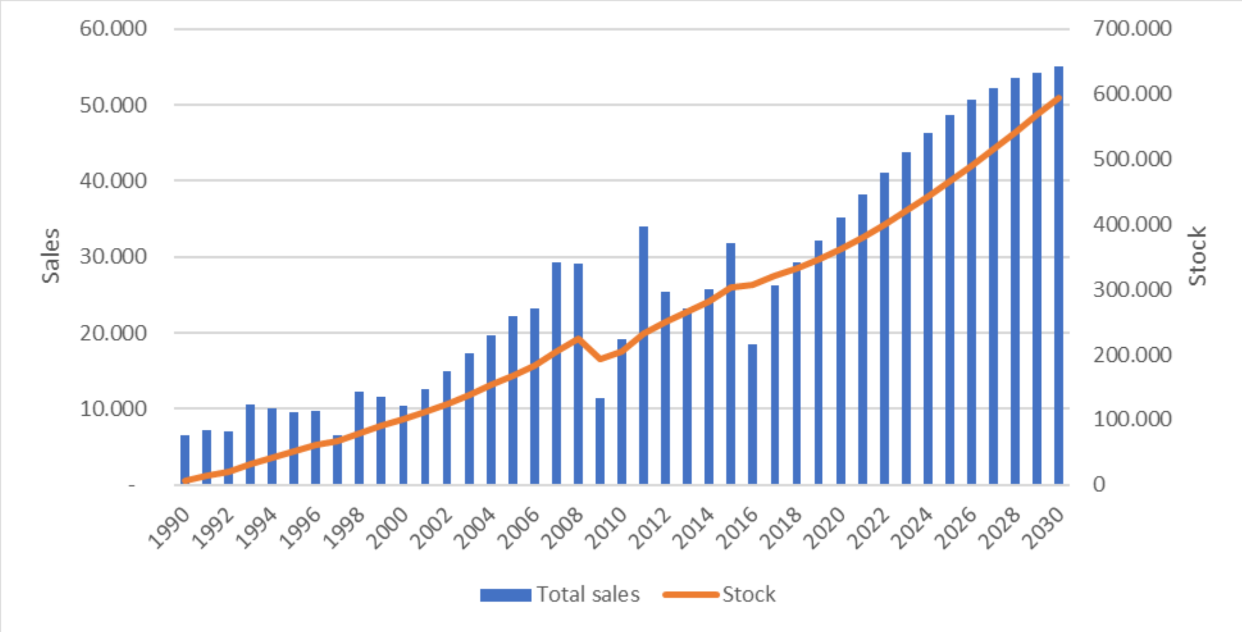

Figure 8: Total annual sales and stock of all shipping reefer units related to EU-28, both 20 ft and 40 ft.

The increase in reefer stock corresponds well with the increase in trade volumes in the EU of both import and export of perishable products (see Figure 9).

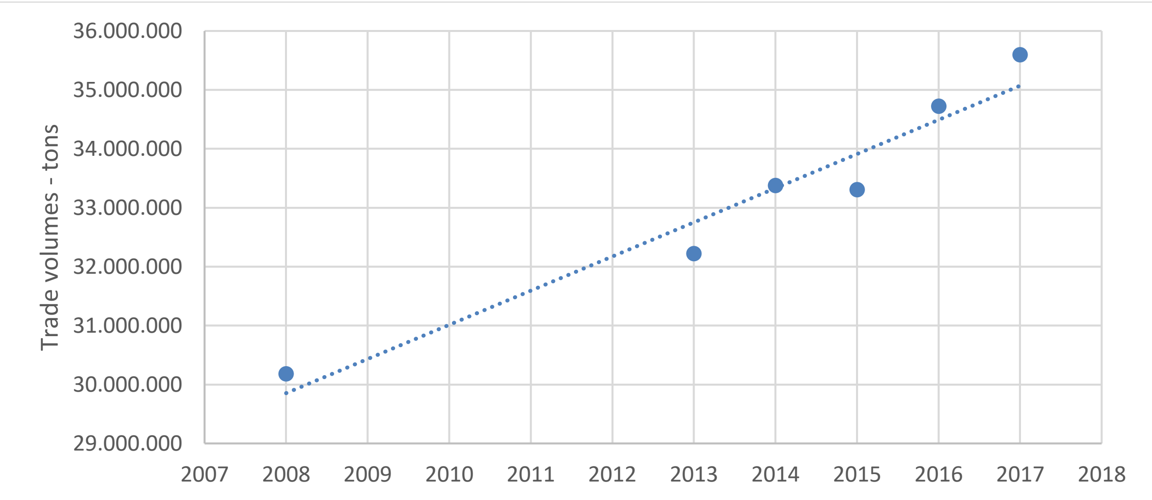

Figure 9: Trade volumes of perishable products in the EU – import and export

Also, the global volumes of perishable products that have been transported by ship have almost doubled between 2000 and 2017 clearly showing an increasing trend (Figure 10).

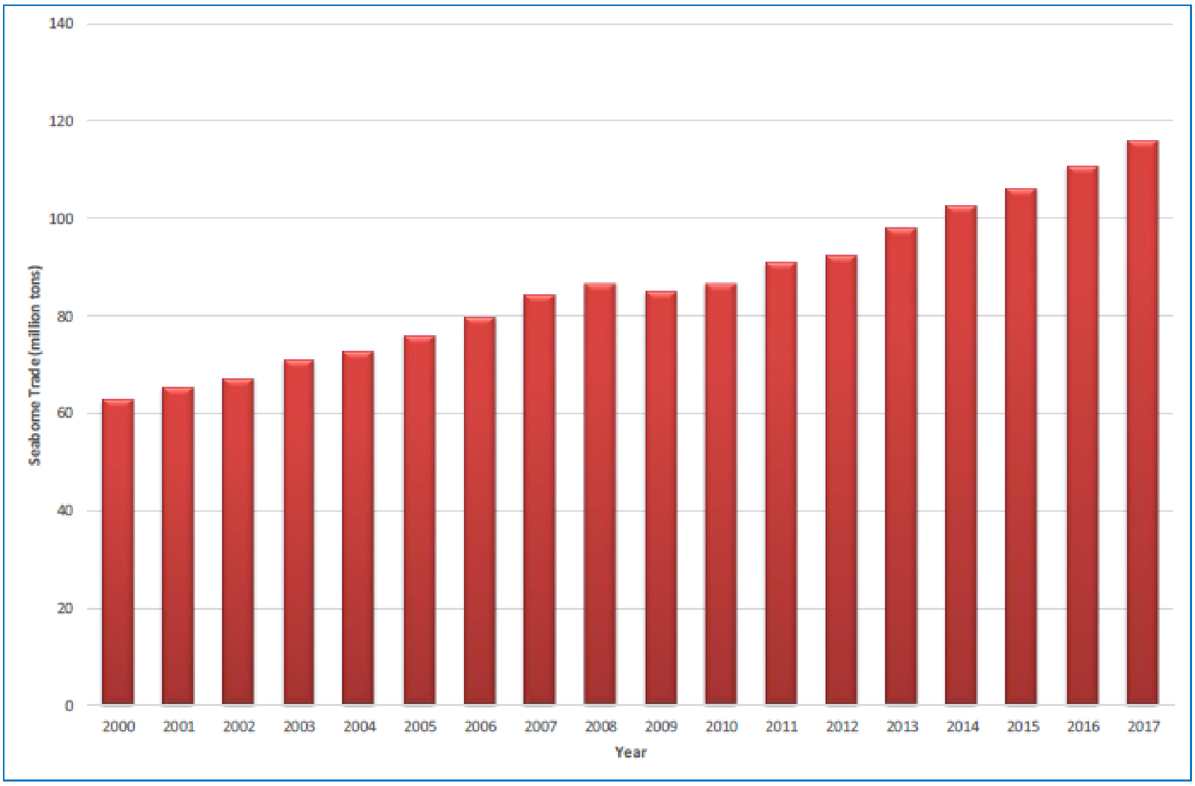

Figure 10: Global seaborne perishables trade, 2000-2017 (Source: Dynamar)

2.2.3 Stationary reefers

All the sources of statistical data found on trade, usage and stock of reefers are related to reefers for intermodal transport applications. The markets and supply changes were found to be different for reefers for stationary purposes compared to the ones for transport purposes. Since there were found no statistical sources on stationary reefers and since data on the stationary product group generally are very limited, the market estimates have been established from stakeholder interviews and desk research.

2.2.3.1 Container sizes

Interviews with stakeholders showed that the container sizes for stationary use varies significantly compared to shipping. For rental and leasing of reefers for the stationary market the dominant reefer size is 20 ft. 10 ft and 40 ft share the rest of the market. As explained the shipping lines in contrast mainly use 40 ft, but as an interviewee explains their typical customers like bakers, butchers or restaurants does not have a chance to use the storage room in a 40 ft reefer.

However also 45 ft high cube versions of reefer containers are marketed but sold in limited numbers[190]. The shipping lines on the other hand do not use 10 ft reefers at all since the price for handling and renting 10 ft, 20 ft and 40 ft reefers are almost equal despite the lower storage capacity. Hence the storage price for transportation purpose would be too high.

The share of 20 ft in the interviewed leasing and rental companies' reefer fleets varied from approximately 60 % to 95 %, the share of 10 ft from 0 to 20 % and the share of 40 ft from 5 to 20 %. A weighted average based on the interviewees fleets sizes suggests the typical stationary reefer rental and leasing market to be as in Table 2-7.

Table 2-7: Estimated market share of stationary reefer categories based on interviews

Container size	10 ft	20 ft	40 ft
Share	15 %	70 %	15 %

2.2.3.2 Sales of reefers for stationary use

Regarding market size some interviewees estimated the market to less than 1 % of the total market leading to yearly sales figures of around 300 units in EU (chapter 2.2.3). As mentioned earlier (Table 2-2) the expected lifetime of reefers for stationary use typically is more than twice of the transportation reefers, meaning the stock relative to the sales is higher than for shipping reefers.

One of the biggest rental companies of primarily stationary containers have 30.000 containers worldwide but mainly in Europe, and half of the companies' turnover is from the reefer business[191].

[190] https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track (April 2019)

[191] Finans.dk, Claus Iversen & Kristoffer Brahm, Operation "blue marlin": Layland Barker lukker pengetank in i sit livsværk (23.12.2019)

Figure 11. 20 feet reefers used permanently as extended refrigerated storage room at food wholesaler

Interviews, sales advertisements on reefer lessors' and brokers own webpages as well as sales portals like Alibaba indicate that transport reefers in many cases are sold for use as stationary reefers, when they are not fit for service in the transport sector, if they have not reached the end of their usable life. One broker of used and new containers for example advertise that "Retired reefer containers are ideal for on-site chiller applications"[192][193]. Since shipping containers mainly are 40 ft high cube containers[194], this second-hand market would mainly (but not only) be 40 ft reefers. The interviews also indicated that these containers are generally not purchased and used by rental and leasing companies. The majority explained that they are buying new reefers and are selling them when they are used in order to ensure safe operation of reefers at their customers. The costumers for the used reefers are mainly individual SMEs like farm shops, food wholesalers and processors and industry and to some extend overlapping with the customers of the leasing companies.

Based on the stakeholder interviews it could be estimated that in Denmark the rental and leasing business consists of a fleet of at least 450-500 reefers. By extrapolating this market to EU size based on the Danish share on 1/74 of EU-28 GDP a total stock of stationary reefers on above 10,000 units today is found (in the explained mix of 10, 20 and 40 ft). The number of reefers that in addition to the organized rental companies are used and owned by individual companies has not been possible to estimate realistically. Perhaps this number also includes products that are import illegally to EU. This potential issue was raised by a container producer in 2013 who estimated the number of refrigerated containers circulation on the EU market illegally to be counted in thousands[195]. Based on

[192] Fricon reefer sales and rentals (dec 2019), http://www.friconreefer.nl/index.php?page=8
[193] ModalART ltd. (dec 2019) https://www.modalart.com/inventoryreefers.htm
[194] WorldCargo news, *Reefer leasing gets back on track*, (April 2019) https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track.
[195] ATN, *Maersk seeks the removal of 'unfriendly' reefers* (2013), https://www.fullyloaded.com.au/logistics-news/1302/maersk-seeks-the-removal-of-unfriendly-reefers

the findings explained above the stock of stationary reefers has been estimated in Table 2-8. The current stock of stationary integral reefers is estimated at about 10,000 TEU and is expected to grow to almost 20,000 in 2030.

Table 2-8: Stock of stationary integral reefers in EU-28 from 1995 to 2030

Stock	1995	2000	2005	2010	2015	2020	2025	2030
Total TEU	998	1,992	3,691	5,128	8,165	10,882	14,536	18,733

Figure 12 shows the development in sales and stock for the period 1990 to 2030.

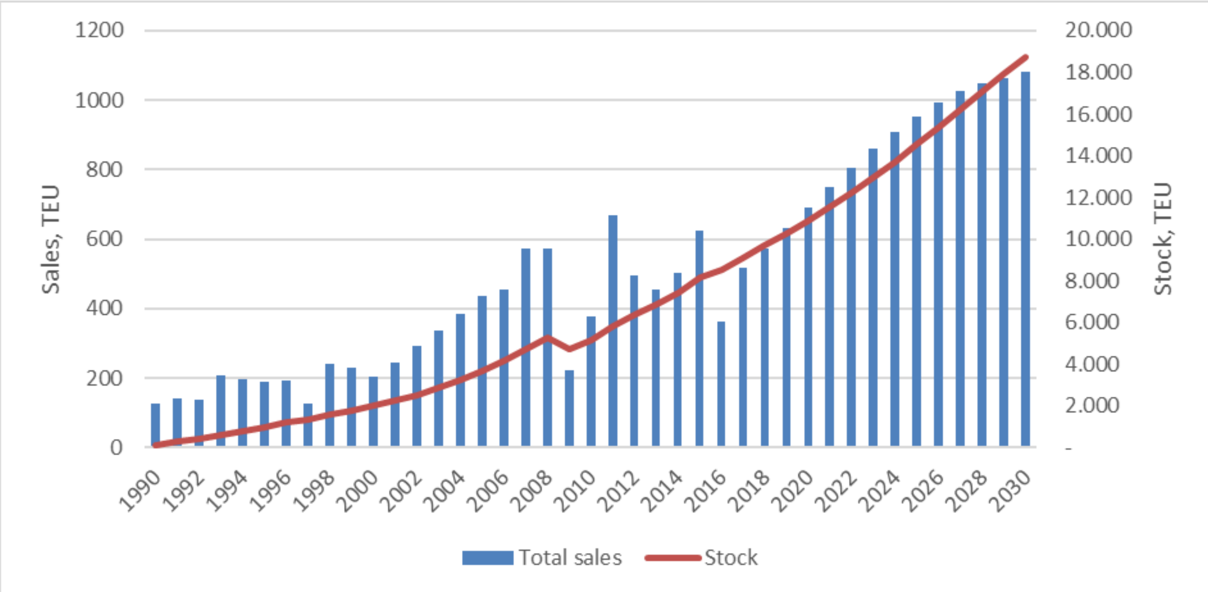

Figure 12: Total annual sales and stock of stationary reefers in EU-28 from 1990-2030 in TEU

2.2.3.3 Discussion

As can be seen, these numbers are growing to a little more than 1000 units sold per year by 2030 and are far below the Ecodesign Directives' limit on 200.000 sold units per year. Even taking their significantly higher energy consumption per unit than ordinary residential appliances into consideration, ecodesign requirements for this group alone would probably not be justified according to the ecodesign regulations requirements.

The methods used for establishing the market estimates; asking a limited number of stakeholders, respectively extrapolating from one small country to the entire EU has its limitations in respect to accuracy. In addition, a number used unit for single industrial users may be added. However, it is concluded that the estimated low numbers of stock and sales compared to ecodesign requirement, are representative for the magnitude for the EU stationary reefer market.

2.3 Market trends

This section presents recent evolution and expected orientation of the market, including a review of the parameters, which are likely to influence product sales and design in the future as well as market structure and channels. It is important to understand such trends to identify products, which might represent a significant or marginal market in the near future.

2.3.1 General market trends

Sales and stock data underline the clear trend that the market for integral reefers for intermodal transport has been growing rapidly both globally and in the EU, from less than 50,000 TEU in 1990 to more than 250,000 TEU in 2019 worldwide. This is a consequence of increasing demand for perishable and frozen commodities world-wide due to population growth and higher living standards and better possibilities of transporting perishable goods over longer distances. This development enables increased cultivation and sales of perishable goods in new parts of the world which not previously has been able to transport the goods to potential customers.

Sales towards 2030 are expected to continue to increase. Primarily due to an increasing trend in trade especially of perishable products both for the developed countries but also in growing economies with an increasing middle-class.

Drewry, an industry analyst, suggests a growth in refrigerated trade of around 3 % in the coming five years[196].

Historically, since the 1960s refrigerated goods have been transported by conventional refrigerated ships. In the 1980s and 1990s also porthole containers for dedicate porthole ships were use. Before the year 2000 this form of transportation was the most dominant but in the last two decades this has changed considerably, and integral reefers are taking over the market. The main reason is the great advantage of a self-contained refrigerated unit that makes it possible to bypass cold storage upon arrival at a destination. Technological innovation also has increased the efficiency of the integral containers making them more competitive. In the 2017 the conventional refrigerated ships only had a market share of about 20 % compared to the reefer containers (see Figure 13).

The decline in conventional refrigerated ships is expected to continue and further exacerbate by 2020 when new sulphur regulation[197] will take effect. The regulation will put stricter requirements on exhaust fumes which is expected to force out large parts of an

[196] https://www.drewry.co.uk/news/news/reefer-container-trade-expansion-to-support-freight-rates
[197] The International Maritime Organisation (IMO), *Amendments to Annex VI to the International Convention for the Prevention of Pollution from Ships* (2008)

aging fleet of conventional refrigerated ships since they will not be able to live up to the new requirements. Containerized reefer traffic is therefore according to some sources expected to grow at 8 % per year or more[198]. It seems that conventional refrigerated ships are more dominant outside EU, which means that the share of reefer containers related to the EU market might be larger than the trade data suggest.

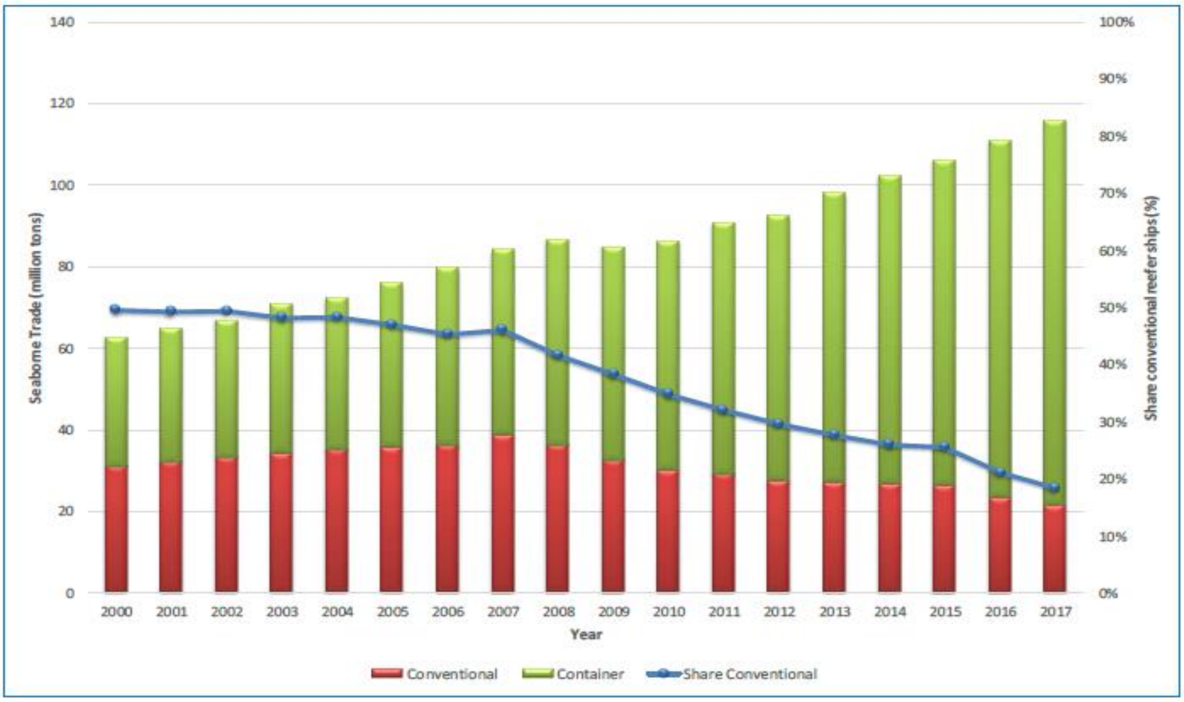

Figure 13: Markets shares of conventional reefer shipping and containerized reefer shipping (Source: Dynamar)

Containerized reefer traffic is also increasing its competitiveness compared to air-freighters by investing development and research into especially controlled-atmosphere systems in order to better control the quality and ripening of products under long distance transportation, and by the development of quicker, more efficient and less complicated transport lines e.g. with new vessels dedicated to reefers and build for sailing at higher speed[199]. At the same time some vessels with mixed freight including dry freight and perishable goods in reefers are sailing slower in order to save fuel. That means we see a development towards slower and cheaper transport on standard container ships as well as quicker vessels targeted refrigerated containers, overall leading to a more diversified reefer transportation market which serves different product categories and customers better.

The transport directorate general of the European Commission is working for a higher share of rail- and waterborne transport compared to road transport as described in the

[198] https://www.porttechnology.org/news/insight_the_rise_of_reefer_shipping/

[199] https://reeferintel.com/

current transport White Paper[200]. Long distance freight transport is specifically addressed, and the target of the European Commission is to shift 30 % of road freight transport over 300 km to other means of transport, such as rail or waterborne transport, by 2030 and more than a 50 % shift by 2050. That means that the transport unit need to be stackable (in two layers for river transport). This may push for higher shares of intermodal freight transport generally, and potentially higher share of ISO container transport, including reefers containers or development of new categories of transport boxes [201].

The Chinese belt and road initiative (new silk road) also could change the transport patterns. The initiative involves China-Europe cargo train connections with routes from central and eastern China to North and central western Europe with Kouvola in Finland and Duisburg in Germany as the main destination. Train cargo could cut down the transport time from 4- 6 weeks to around two weeks (port to port) [202, 203, 204, 205].

The higher transport price of train compared to shipping - in particular for perishable high value goods as typically transported in reefers - could be justified by the speed and may lead to an increased share of rail transport. Faster transport would also result in better utilization of the capacity of reefers resulting in fewer reefers needed. The trade of cargo in reefers may increase, as has been seen historically when the routes have opened new opportunities. In this case, more reefers might will be needed.

2.3.2 Market channels and production structure

Figure 14 illustrates that basically all integral reefers are manufactured in China. Typically, the reefer corpus - the insulated container – respectively the cooling units and other auxiliary equipment for controlled atmosphere, controls etc. are produced by different manufacturers. After the production of the box and individual components the whole reefer unit is assembled by the reefer container manufacturer. In some cases, the manufacturer also produces the cooling units.

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[200] White Paper, *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* (2011), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN
[201] Sabina Jeschke (2011), https://www.acea.be/uploads/publications/SAG_16_Global_Trends_in_Transport_Routes__Goods_Transport.pdf
[202] https://www.shippo.co.uk/faqs/how-long-do-shipments-take/
[203] https://gbtimes.com/new-silk-road-train-link-connects-finland-nordic-countries-with-china
[204] https://gbtimes.com/chinas-belt-and-road-initiative-explained
[205] https://www.forbes.com/sites/jwebb/2017/01/03/the-new-silk-road-china-launches-beijing-london-freight-train-route/

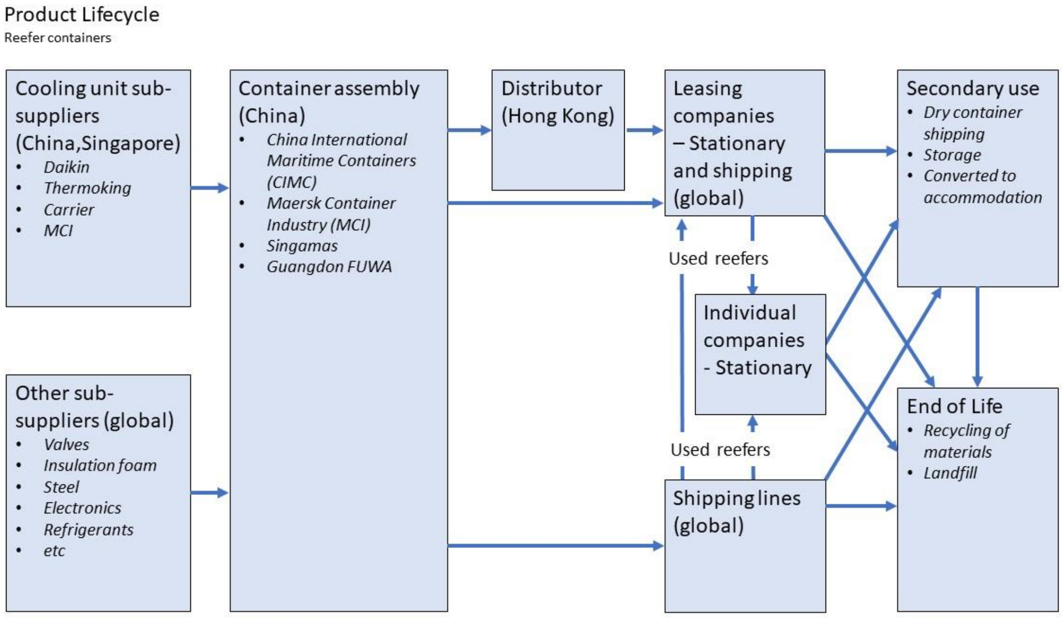

Figure 14: Structure of manufacturing industry and product lifecycle for reefers

The primary buyers and owners of reefers are the large shipping carriers or container leasing companies. These companies generally purchase directly from the suppliers. The production is per order, meaning that there is no or limited production to stock. The reefer is usually bought directly from the manufacturer or from large distributors in Hong Kong and therefore the commissioning and placing on the market technically and formally takes place in China. European distributors that primarily serve smaller carriers or the stationary cold storage market with smaller buying volumes do also exist.

Stationary, and transport reefers share to a large extent the same supply chain, since they are essentially the same product. However, reefers for cold storage purposes (for stationary use) usually require smaller or larger modifications in order to accommodate frequent openings and closures, ensure a safe and efficient working environment for the users and to minimize the energy consumption resulting from the different use pattern. Examples are curtains, led lights, man trap alarm, flat floors, "butcher doors" (smaller doors) and larger and more ergonomic handles.

For shipping, primarily new containers are used. Typically, when a reefer is no longer seen fit for shipping purposes it is bought by traders who either sell them for a second life as reefers for cold storage perhaps after rebuilding them for cold storage purposes or just sell them as insulated boxes, stripped from their technical parts. The used but functional reefers are typically purchased by individual companies in need for refrigerated excess storage room in a longer time or permanently or they are purchased for rental/leasing purposes and in some limited numbers sold via the same companies on their local markets. The used but not functional reefers are stripped from the cooling unit and other auxiliaries to be sold as insulated containers for other storage or rebuilding purpose, sometimes retrofitted with air conditioning (see chapter 2.4.8).

New reefers for stationary use in the rental and leasing business are often bought directly from the manufacturers or from distributors at a "spot-market", where reefers have been stocked at ports around Europe (e.g. Rotterdam or Hamburg). Spot-market transactions are usually cheaper, but it is then also not possible to specify brand and equipment of the container.

Used reefers are in case they are functional sold for use, typically in other businesses and typically they are 15-20 years old according to the interviewed stakeholders. All the reefer renting and/or leasing companies interviewed were trading reefers for single users. All the shipping and rental/leasing companies sold their own used reefer. Most of the rental and leasing companies interviewed also acted as dealers and importers of new reefers. The similar patterns seem to fit many other leasing companies operating on the stationary market, according to companies' web pages.

All products imported from third countries — whether new or used — must meet the provisions of the applicable Union harmonization legislation when placed on the market, i.e. when made available for the first time on the Union market[206].

Based on the above, the process of placing the products on the EU market in the sense of the common framework for the marketing of products[207] follow the below explained tracks for reefers.

- Purchase and transaction in China / Hong Kong. This is the case for the major part of the new shipping reefers. They are purchased by international operators including EU operators and put into service to be shipped around the world. These products are not placed on the market in EU,
- Purchase and transaction in China / Hong Kong by EU based smaller operators outside top 25 operators, transported to Europe with or without goods and used for shipping purpose in EU a significant amount of the time. These products are placed on the market in EU.
- Purchase and transaction in China / Hong Kong of new reefers by a rental and leasing business, sometimes specifically equipped for stationary use and imported to EU. These reefers are made available to the market for rental and leasing and

[206] The 'Blue Guide' on the implementation of EU products rules 2016, EUROPEAN COMMISSION, OJ 2016/C 272/01, p. 20
[207] Decision 768/2008/EC on a common framework for the marketing of products, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008D0768&from=EN

therefore placed on the market in the sense of the regulation the first time they are rented or leased[208].

- Import to EU of used and functional shipping reefers by traders stocked at EU ports and sold to individual companies (farms, supermarkets, groceries etc.) for stationary use mainly. These products are placed on the EU market.
- Purchase in EU from a shipping company of reefers that has been used in international shipping. In this case the reefer is imported to and placed on the EU market by the shipping company.
- Own import of new as well as used and functional shipping reefers by individual companies for their own use as stationary storage reefers. Since the products are bought online and shipped – and the user is not being physically present in the country from which it is purchased - these products are placed on the EU market as well[209].

Conclusion

Reefers used in the shipping industry from major shipping operators are generally not placed on the EU market, reefers that are used by smaller shipping operators sometimes are, and basically all reefers used for stationary purpose in EU are placed on the EU market.

Major manufacturers

Worldwide only four major manufacturers of shipping reefer containers exist:

- China International Maritime Containers (CIMC)
- Maersk Container Industry (MCI)
- Singamas
- Guangdong FUWA

CIMC and MCI are the dominating manufacturers with a market share of 49 % and 39 % respectively (see Table 2-9).

The core business of these four companies is manufacturing of containers specifically for shipping purposes. This includes both dry and refrigerated containers. The study did not identify other manufacturers of refrigerated containers within the product scope of this study.

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[208] The 'Blue Guide' on the implementation of EU products rules 2016, EUROPEAN COMMISSION, OJ 2016/C 272/01

[209] The 'Blue Guide' on the implementation of EU products rules 2016, EUROPEAN COMMISSION, OJ 2016/C 272/01, p. 19

Table 2-9: Market share of the primary manufacturer (Source: Dynamar)

Manufacturer Share %	2015	2016	2017
CIMC	65%	50%	49%
MCI	22%	36%	39%
Singamas	13%	13%	7%
Guangdong FUWA	0%	1%	5%

All four manufacturers have their production facilities located in China where the final reefer is assembled. Only MCI manufacturers both the box and the refrigeration unit. CIMC, Singamas and FUWA are sourcing their refrigeration units from separate companies and assemble them together with the box unit at their factory.

In addition, a great number of manufacturers of refrigeration equipment and cold storage products exist, but they also serve other customer segments such as trailer and trucking. However, worldwide the four main refrigeration unit suppliers are:

- Daikin
- Carrier
- MCI
- Thermoking

All four have a wide variety of products related to the refrigeration industry and have production facilities all over the world. However, refrigeration units specifically for reefers are primarily manufactured in Singapore and China relatively close to the assembly facilities.

Major owners and operators of reefers

The shipping companies either own or lease a large share of the container fleet, which are operated by those companies, including reefer containers. A major share of the world's container fleet and production is hence ordered and owned by the shipping respectively the leasing companies (lessors). It is unclear from statistics how big the share exactly is but according to Dynamar, the top 12 shipping companies operates 86 % of the shipping integral reefer fleet (2018), while the top 10 lessors own 49 % of all shipping reefers (2016, Dynamar) as shown in Table 2-10. The lessors do not operate the containers them-self but lease the containers for shipping companies.

Table 2-10: Left: Top 12 integral reefer fleet operators (2018) and their operating share of the worlds shipping reefer fleet. Right: Top 10 fleet owners among the leasing companies (2016) and their share of ownership of the worlds shipping reefer fleet (Source: Dynamar).

Operator	Share (%)
Maersk Line	27.1
MSC	15.2
CMA CGM	13.8
ONE	9.1
Hapag-Lloyd	7.1
Cosco	5.5
Evergreen	2.7
ZIM	1.5
Yang Ming	1.4
PIL	0.9
Wan Hai	0.9
Hyundai	0.7

Lessor	Share (%)
Beacon	3.6%
CAI	2.0%
Florens	2.0%
SeaCo	12.6%
Seacube	6.9%
Textainer	5.6%
Triton	15.5%
Other	0.4%
Beacon	3.6%
CAI	2.0%

Leasing (Shipping)

The main customers for leasing of shipping containers are shipping lines and international freight transporters. Most shipping companies have a mix of own and leased containers Shipping containers are being leased when the shipping companies need extra capacity or as a means of maximizing operating flexibility and optimizing the amount of fixed assets and cash flow. The big lessors are international companies and reefers are transported all over the world depending on where they are needed.

Leasing and rental companies generally are specialized in either the shipping or the stationary market or have separate product lines.

Of the new build reefers in 2017 leasing companies ordered 26.7 % and in 2018 51.8 %[210].

Leasing and rental (Stationary)

Stationary containers have a wide variety of uses. The main business areas are pharmaceutical and food and beverage including retail and production. The customers can be divided into groups depending on the duration of cooling. Customers with a more permanent cooling demand include pharmaceutical companies, hospitals, laboratories, grocery stores, warehouses and bakeries. In other cases, the need for cooling has a shorter timeframe. These customers include: Large sporting events (golf, tennis, formula 1, etc) and music festivals.

[210] https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track

2.3.3 Trends in product design

In the following, recent product trends for integral refrigerated containers will be described. The focus will be on the specific markets for shipping and stationary use and on the following key components:

- Reefer box
- Refrigeration unit comprising of compressor, refrigerants and fans (evaporator and condenser)
- Controllers and operation
- Data loggers

Further information about technologies is found in Annex I.

Reefer box

The standard reefer dimensions for new and newer reefers are 40 ft high cube reefers while 20 ft are generally with standard cube measures (se also task 1).

In addition, 45 ft high cube reefers are also entering the market although in small sales numbers. World cargo news reported a worldwide sale of 3000 45 ft ––in 2018.[211,212]

The motivation for using 45 ft containers is that their dimensions fit the maximum size for 90 m train wagons as well as euro pallet dimensions better than the standard 40 ft container allowing 33 euro-pallets per container[213].

Compressor

Both reciprocating and scroll compressors are used for refrigeration units for reefers. Currently, there is a marked trend among coolant compressors away from traditional (reciprocating/piston [214]) compressors towards scroll [215] compressors. Compared to traditional compressors, scroll compressors have advantages[216,217,218], such as fewer moving parts, fully air-tight construction, significantly lighter weight and more compact design, volumetric efficiency, higher cooling capacity, faster pull-down to required temperature and generates less noise. The traditional reciprocating compressors on the other hand have the advantages that they could be repaired and renovated and there is an established supply chain of renovated reciprocating compressors. According to an

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[211] https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track
[212] Sabina Jeschke (2011), https://www.acea.be/uploads/publications/SAG_16_Global_Trends_in_Transport_Routes__Goods_Transport.pdf
[213] https://www.k-tainer.eu/de/45ft-pallet-wide-high-cube-reefer-container
[214] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_01.html
[215] https://www.carrier.com/container-refrigeration/en/worldwide/products/Container-Units/PrimeLINE/
[216] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_01.html
[217] https://europe.thermoking.com/genuine-parts/compressors/
[218] Dynamar (2018) REEFER Analysis - Market Structures, Conventional, Containers - https://www.dynamar.com/publications/210

interviewee renovated compressors are a standard product for repairs that are not guaranty repairs.

An increasing number of reefer cooling units have added frequency converters (variable speed control) to drive the compressors for more exact control and for energy savings. The energy savings arises due to the better control and since the compressors with VSDs achieve more continuous operation with less on-off cycles. It seems that the market share of VSDs for scroll compressors is still smaller than it is for VSD's for reciprocating compressors.

Refrigerants

As described in chapter 1.3.1.5 the global market for and the availability of refrigerants has been and is developing due to the restriction on HFC gasses in Montreal protocol and its Kigali amendment as well as the EU F-gas regulations' requirements on refrigerants for cooling equipment. The requirements of the Montreal Protocol to quotas, maximum amount of refrigerant charge, registration and collection of refrigerants and, in some countries, taxes on HFC gasses depending on their GWP is driving the development towards refrigerants with lower GWP as illustrated in Figure 15 and towards smaller refrigerant charges.

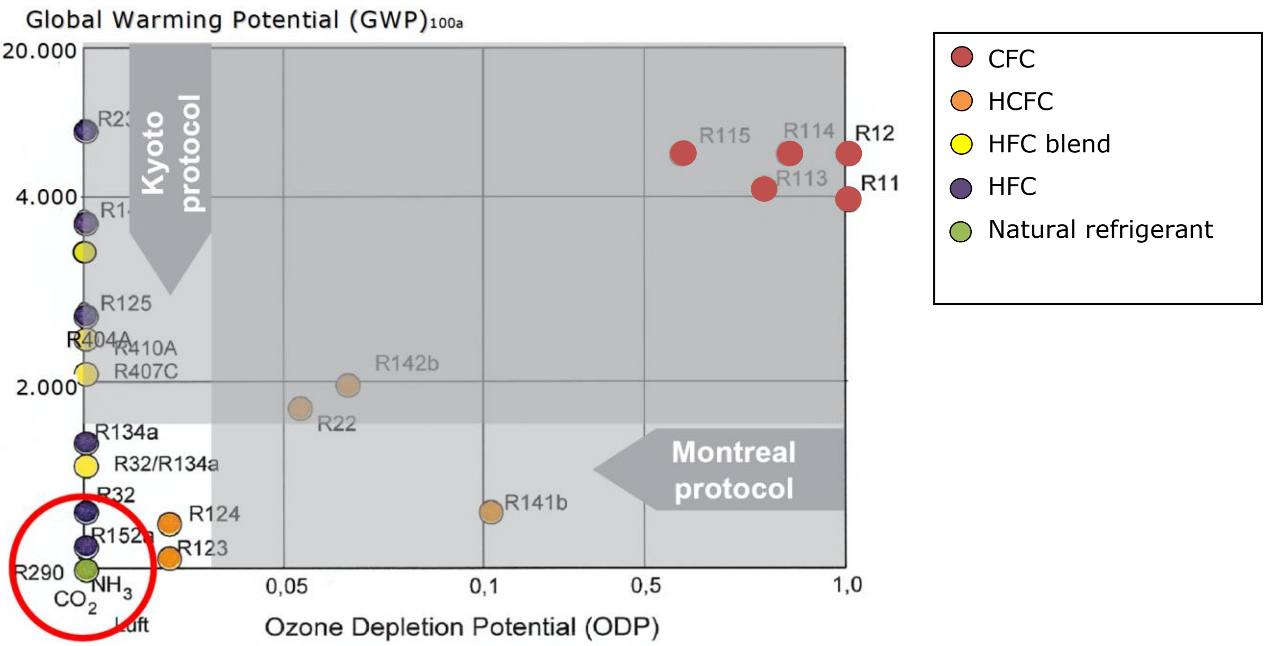

Figure 15: Regulations on refrigerants changes the market.

Consequently, the maximum refrigerant volume per unit has been reduced to e.g. 4.5 kg refrigerant for R134a. The maximum refrigerant charge of 40 tons CO_2-equivalents in the

F-gas regulation from 2020[219] corresponds to almost 28 kg R134a, and a refrigerant charge on 4.5 kg of R134a is far below the threshold limit.

Currently, the main trend is that refrigerants *R404A* and *R407A* are being replaced with new synthetic refrigerant with low ODP and GWP, mainly the HFO refrigerants *R513* and *R452A* but also *R134a*.

The prices on the synthetic refrigerants have been increasing during the last years as shown in Figure 16. Latest price investigations however show that in 2018 and 2019 the refrigerant prices have fallen a bit[220], probably due to alternative refrigerants taking over the market.

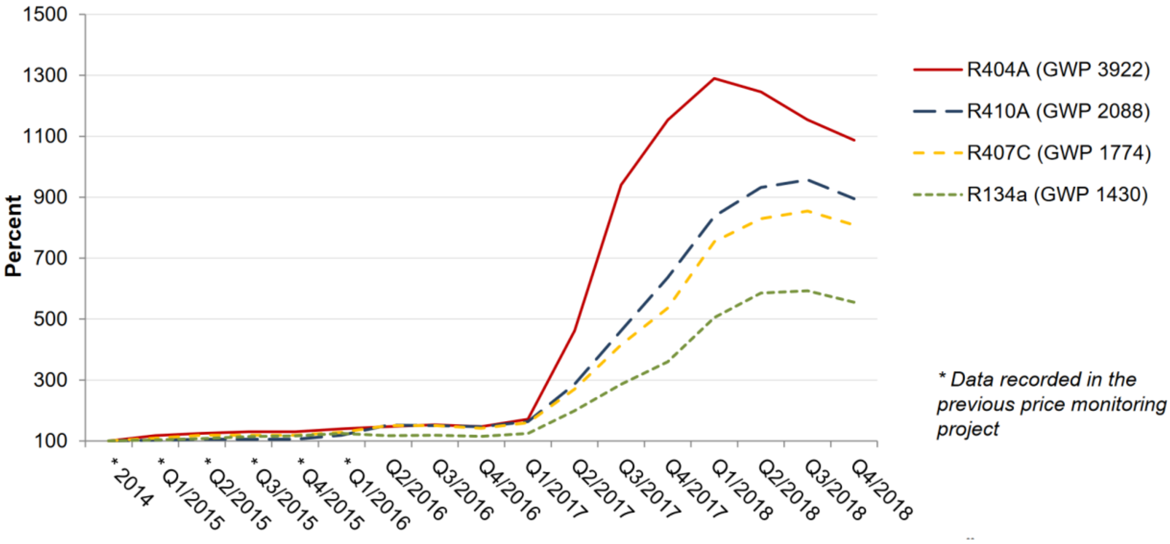

Figure 16: Price index on four HFC refrigerants at service company level (2014 = index 100. Source: Öko-recherche (2019)[221]).

[219]Regulation (EU) No 517/2014 https://publications.europa.eu/da/publication-detail/-/publication/530b03fb-dff1-11e3-8cd4-01aa75ed71a1/language-en

[220] Julia Kleinschmidt, Öko-Recherche GmbH, *Development of HFC prices* (slides for EPEE F-gas Roundtable15 April 2019) EPEE F-gas Industry Roundtable, 15. April 2019, (slides: https://www.epeeglobal.org/wp-content/uploads/EPEE-F-Gas-Industry-Roundtable_15-April-2019_Presentations.pdf)

[221] Julia Kleinschmidt, Öko-Recherche GmbH, *Development of HFC prices* (slides) EPEE F-gas Industry Roundtable, 15. April 2019, (https://www.epeeglobal.org/wp-content/uploads/EPEE-F-Gas-Industry-Roundtable_15-April-2019_Presentations.pdf)

The price development for the alternative refrigerants has been more stable as it is shown in Figure 17.

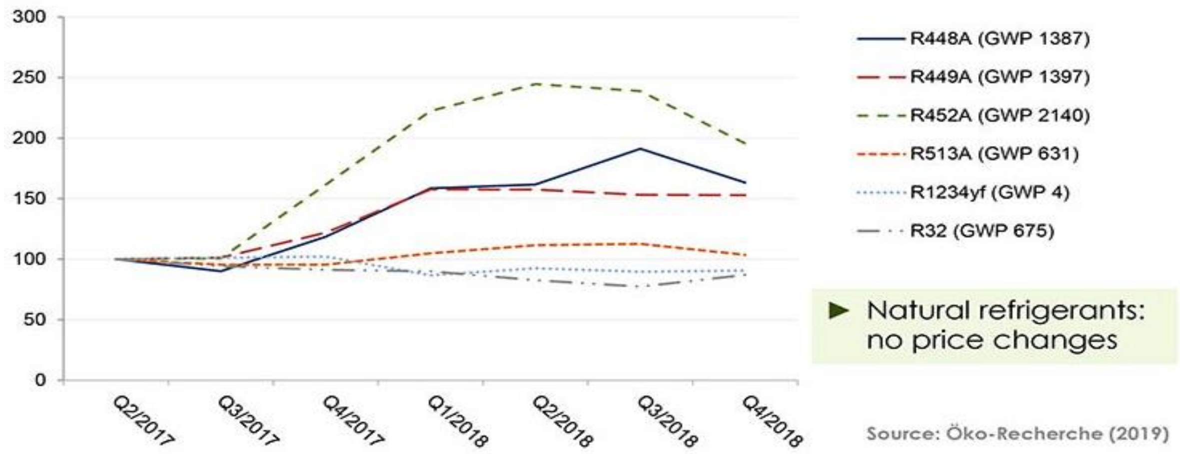

Figure 17: Price index on average purchase prises of various alternative refrigerants (price index Q2, 2017 = 100, source: Öko-Recherche and Coolingpost[222], 2019)

CO_2 as a refrigerant (R 744) is currently commercially available, although still at an early technological stage. One service company informed, they are starting to see the CO_2-compressor more regularly for pre-trip inspection (PTI) while repair and maintenance is still being performed by the suppliers[223]. Chief advantages of CO_2 as refrigerant are (se also Annex I 1.3):

- negligible GWP and no ODP;
- low toxicity and inflammable;
- high refrigeration capacity due to high volumetric cooling and high heat transfer in evaporators and condensers due to high pressure and density;
- inexpensive to produce and widely available;
- no impending legislation phasing down or phasing out R744 so it can be seen as a long-term refrigerant"[224].

However, CO_2 has some disadvantages when compared with typical refrigerants, such as:

- the need for two-step compressors, which are more expensive and makes the system less efficient compared with typical (one step) compressors[225];

[222] https://www.coolingpost.com/world-news/eu-refrigerant-prices-continue-to-decline/
[223] Interview December 2019, Anonymous, service company
[224] Emerson, *CO2 as a Refrigerant — R-744 Advantages/Disadvantages* (2015) https://emersonclimateconversations.com/2015/07/30/co2-as-a-refrigerant-r-744-advantagesdisadvantages/
[225] interview July1., 2019, Anonymous, purchase department

- some limitations for ambient temperatures higher than 20 °C, although they can work up to 50 °C with a bit higher power consumption;
- more hazardous and higher leak potential, which can result in poor performance[226], due to high operating and standstill pressures;
- higher costs and especially at the current stage when it is not widespread technology and special expertise is required for installation, maintenance and repair due to its high pressure, toxicity at high concentration, and potential for dry ice formation which must be taken into account when applying and handling[227].

Propane (C_3H_8) has been developed for many years[228], but did not reach market yet. Flammability is still an issue and the main direction seems to replace R404A with R134a and then in the future by HFO mixtures such as R513A and R452A to cut direct emissions due to leakage of high GWP fluid. The introduction of the standard ISO 20854:2019 specifies how to handle and operate reefers with flammable refrigerants which may lead to higher market penetration of such refrigerant (se chapter 1.2.1 Standards).

Controllers

Refrigeration units are controlled and regulated by electronic controllers which, depending on the features of the device, perform a variety of complex tasks.

The control strategies influence energy consumption and the operation of the reefer could be optimized by more accurate control of fans and less start-stop cycles of the cooling compressor. Lately the development on especially transportation and storage of refrigerated goods is allowing a bigger temperature span for refrigerated goods is being increased. Consequently, the cooling compressor will have less start/stop cycles which is leading to less energy consumption.

2.4 Owners expenditure base data

The average cost of ownership of reefers experienced by the end user throughout the product lifetime are determined by unit prices in the following categories:

- Purchase price
- Repair and maintenance costs
- Installation

[226] https://emersonclimateconversations.com/2015/07/30/co2-as-a-refrigerant-r-744-advantagesdisadvantages/
[227] Emerson, *CO2 as a Refrigerant — Five Potential Hazards of R744* (2015), https://emersonclimateconversations.com/2015/07/02/co2-as-a-refrigerant-five-potential-hazards-of-r744/
[228] WorldCargo news, *MCI puts propane on ice* (2018), https://www.worldcargonews.com/news/news/mci-puts-propane-on-ice-61018

- Energy costs
- End of life cost

Emerson and Blue Canyon Market research investigated the life cost of reefers for shipping and found the main cost items. Below an extract of cost items that are directly related to the reefers them-selves (which mean that cost for vessel, loading / discharging in ports etc., are not included) [229]:

- Handling costs
  - Reefer trip electricity
  - Terminal and on vessel monitoring
- Claims cost (due to potential malfunction)
- Energy cost
  - Vessel
  - Generator set
- PTI (Pre-Trip Inspection), maintenance and repair
  - Labor
  - Parts
  - Reefer trip PTI
  - Reefer trip cleaning
- Capital costs

Being perceived as the main cost drivers it could be expected that the reefer business will focus on minimizing each of them.

2.4.1 Consumer purchase price

Since container trade is mainly an international business the purchase prices for new and used functional reefers are assumed to follow world market and to be relatively uniform all over EU. This assumption is presumed to be valid for all reefer product categories.

A typical market price for a 40 ft reefer for maritime / transport use with basic functionality including cooling system has been declining in 2019 and is reported at around 13,500 EUR 2019[230]) to 15,500 EUR (2014[231]). It is not clear from sources, but probably this is from a manufacturer in China, and not delivered e.g. in Europe. In addition to the given purchase

[229] Robert Svensson, Emerson (2014) *Improving Refrigerated marine container management with pervasive connectivity* (https://climate.emerson.com/documents/webinar-08-%E2%80%8Bimproving-refrigerated-marine-container-management-pervasive-connectivity-en-us-2884860.pdf)

[230] https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track

[231] Robert Svensson, Emerson (2014) Improving Refrigerated marine container management with pervasive connectivity (https://climate.emerson.com/documents/webinar-08-%E2%80%8Bimproving-refrigerated-marine-container-management-pervasive-connectivity-en-us-2884860.pdf)

price, add-ons like controlled atmosphere, improved controllers and sensors will be added. This is not included in the calculations of market values, as this is not part of the scope.

Price checks on Alibaba[232] shows a price level on 13,500 – 16,000 USD for 40 ft reefers as the most found price level (except some out-layers) and that comparable 20 ft reefers are sold at 9,00-1,300 USD less than the 40 ft reefers.

The reported price range of containers equipped for stationary use depend on the market. For companies purchasing reefers in smaller numbers, spot market prices are typically lower than custom manufactured products. One source reported 14,200 – 15,300 EUR as standard prices for a 20 ft. container on spot market, while another reported an average price across sizes (10'-20'-40') on 17,300 EUR for containers specified by the buyer (i.e. not spot market). These prices are from a European supplier.

For the current study the price level is estimated as in Table 2-11 and both for stationary and shipping containers the price difference between 20 and 40 ft containers are estimated at EUR 1,300.

Table 2-11. Estimated average starting price for new reefers (EUR)

Size\ Market	Shipping *	Stationary **
20 ft	13,700	14,700
40 ft	15,000	16,000

*** Delivered in China   **Delivered at EU port and equipped for stationary use**

Table 2-12 shows the estimated value of the EU related market for new shipping reefers. Similar numbers are not calculated for stationary reefers due to the low number of sold units and the relative uncertain estimations of market sizes.

Table 2-12. Market value of EU related sales of shipping reefers in units of 20 ft and 40 ft containers respectively (million EUR)

Value	1990	1995	2000	2005	2010	2015	2020	2025	2030
20 ft	3..810	5.640	6.090	13.110	11.280	18.750	20.565	27.420	29.085
40 ft	85.269	126.204	136.425	293.331	252.450	419.412	460.046	613.733	650.791
Total	**89**	**132**	**143**	**306**	**264**	**438**	**481**	**641**	**680**

232 https://www.alibaba.com/showroom/new+reefer+container+price.html?fsb=y&IndexArea=product_en&CatId=&SearchText=new+reefer+container+price&isGalleryList=G

Regarding installation cost see below.

Rental/leasing prices

The consumer prices for rent and leasing varies depending on duration, size and equipment.

Leasing prices for shipping lines are reported at around US$ 5 (EUR 4.5) per day (2018 average).[233]

Examples for renting for stationary use (excl. delivery) are:

- 13 EUR/day and 400 EUR/month for renting 20 ft reefer equipped for stationary use (Oct. 2019)[234]
- 5 to 9.4 EUR/day. In these cases, the products are second-hand reefers, 20 ft seem to be slightly (15-20 %) lower priced than 40 and 10 ft. At these prices, the containers according to product description and pictures on lessors' web pages are not equipped for stationary use e.g. with flat floor, lighting and safety doors (butcher door) although they are marketed as such[235, 236]
- In addition, start-up costs – one example is 160 €[237] and transportation costs. The PTI typically would be part of the start-up cost.

One interviewee informed that the shipping leasing price is about the double of the price for stationary reefers which is not reflected above. However, the explanation could be that the numbers above reflects the differences between (longtime) leasing and (more short time) rental prices. In addition, taxes on leasing for international shipping business are different than for stationary business. During the recent years the leasing time for shipping has been expanded from five to eight years as the typical renting term[238].

Most interviewees reported that renting prices for 10, 20 and 40 ft were close to equal.

2.4.2 Repair and maintenance cost

The following section describes repair and maintenance practice and costs for the main parts of the reefer:

- Reefer box
- Refrigeration unit
- Controllers

The prices indicated below are based on stakeholder interviews and publicly available price lists from reefer service and maintenance companies[239] unless other is indicated.

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[233] https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track
[234] https://www.alphacontainers.dk/container/koele-og-frysecontainere/
[235] Adaptainer, UK (2019) https://adaptainer.co.uk/container-hire/refrigerated-containers-reefers/
[236] Bimicon, Hamburg DE (2020), https://bimicon.de/container-miete/
[237] Bimicon, Hamburg DE (2020), https://bimicon.de/container-miete/
[238] https://www.worldcargonews.com/in-depth/reefer-leasing-gets-back-on-track
[239] https://bimicon.de/ersatzteile/ (2019) and containercare.dk (2019)

Reefer box

The reefer box could be damaged e.g. by holes from forklifts. If the reefer is damaged and it is a limited damage parts of the inner lining and insulation could be replaced. Some companies are specialized in retrofitting the inner lining of the box.

Door gaskets are being worn down leading to air leakage. They are normally repaired.

Refrigeration unit including the compressor

The most essential mechanical part of the reefer is the cooling unit which depend on the temperature span the given reefer services. According to stakeholders all categories of reefers share the same service organizations, although bigger lessors tend to have their own service staff for stationary used reefers.

Interviews with stakeholders showed that if the compressor or the cooling unit breaks down, this is the most expensive spare part and reparation of a reefer but also a very rare event on newer reefers. There are three possible outcomes if it happens:

- the compressor is changed
- the complete cooling unit is changed
- the container is taken out of service.

The repair price typically could be at the same level as the price of a cheap used and full functional reefer with cooling unit. For old reefers that are broken down or reefers that are generally worn down when the cooling compressor stops functioning it is therefore often found to be too expensive to repair it if the compressor breaks, and in this case the reefer will be taken out of service as a reefer (see also chapter 2.4.8 regarding of life aspects of cooling units in).

On the other hand, sometimes it does make sense to replace the entire cooling unit in a reefer, if the reefer box is in good condition. For instance, one stakeholder replaced a large number of cooling units some years ago on reefer containers that were about 20 years old. The entire operation for replacing the (cooling units only took two hours per reefer. It was possible to do it this quick since the cooling units were fixed with bolts (bolt-on picture frame).

Reported price levels for exchange of reefers' compressors are 3,200 to 4,700 EUR for a new replacement compressor and 6,400 EUR for the entire cooling unit. This is a relative high share of the entire reefer price but the compressor respectively the cooling unit are complex and high-tech electromechanical constructions and control software, versus the reefer body which is a more standardized product where the material cost is the main contributor to the purchase cost.

Some manufacturers sell "remanufactured" cooling compressors at about half price compared to new but with normal factory guaranty, and according to an interviewee, a service company, it is standard procedure to use remanufactured parts when possible, if the reefer has passed the product warranty time.

The time consumption for changing an entire cooling unit depends on the kind of unit. It is much less complicated to change the compressor or cooling unit in a bolt-on picture frame unit than in an integrated construction.

Based on the responses in the stakeholder interviews the frequency of changing the cooling unit is estimated to once every 15th year, which means that less than every tenth of shipping reefers will have this part changed, and that it will happen only once in a reefer's lifetime.

Valves and pistons

Valves and pistons as well as bearings are standard components that can be exchanged.

Fans

Fans break down from time to time, but seldom. They are being exchanged. The price range for exchanging the cooling units' fans is reported to 800-1100 EUR. See also "Other spare parts" below about fan motors.

Controllers.

Controllers are exchanged when they break down. This was not one of the common failures mentioned, but it is a spare part which the service companies have access to and do change. Spare part prices for controller modules or main relay board are 1500 – 2000 EUR from new and around 500 EUR for renovated.

Other spare parts and repair

Among the other parts which may need to be replaced, although seldom according to the stakeholders are

- heater coil for defrosting (cheap repair)
- evaporators mostly because they corrode (800-1100 EUR new / 350 EUR renovated)
- condenser (400 - 700 EUR)
- electric motors for evaporator and condenser fans (300-700 EUR for new motor, 350 EUR for renovated motors)
- and gaskets for doors.

Figure 18. Corrosion on a cooling unit of an old reefer.

Service and maintenance

Typically, a yearly service check is performed on reefers regarding possible cooling agent leaks, heat exchanger cleanliness, function of machine etc. Normally a PTI (Pre-Trip-Inspection) is performed on all rented and leased containers before delivered to a customer. Most reefers today are equipped with a remote-controlled self-diagnostic system. The PTI on newer reefers is performed by means of a computer program like the yearly service for a modern car. On older models the process is performed more manually and on the newest systems the PTI is performed electronically (e-PTI) and with online continuous monitoring.

The main performance criteria to check is the ability to increase and decrease the reefer temperature and to hold 0°C for a period.

The PreTrip Inspection (PTI) is a relatively quick functionality test. Normally on newer reefers it is performed guided from or even automatically by the controller and its diagnostics tool. The PTI could be made more or less in-depth and could include check of the units' refrigeration capacity, heating capacity, temperature control, and individual components like the controller display, contactor, fans, protection devices and sensors including power consumption from components. A quick PTI-test could be performed on ½-1 hour and a more thorough PTI would typically take 2-2½ hour or more depending on automation level, the reefer type and ambient temperature[240, 241].

Price examples on PTI[242]:

- PTI (standard Pre-Trip-Inspection): 90 EUR.

[240] YILPORT Oslo Container Terminal General Tariff (2019), https://www.yilport.com/en/images/PartDocuments/2019yilportoslo_container_terminal_general_tariff.pdf
[241] Thermo King Magnum+ Operators Manual TK 61110-4-OP (Rev. 0, 11/13)
[242] HCCR Standard Depottariff (2015), http://www.hccr.de/dokuments/HCCR%20Standard%20Depottariff.pdf

- Short-PTI (Automatic PTI according to the procedure of the manufactures applied software settings) 40 - 52 EUR.
- Additionally, the service companies charge for handling and electricity; 40 - 90 EUR.

Labour cost

Professional technicians specialized in refrigeration technologies and even in reefers specifically, are needed for repair and maintenance of reefers. The reason is that the cooling units contains relatively complex and expensive technologies and that they contain refrigerants covered by the F-gas regulations.

Generally, the labour cost varies greatly across Europe and are presented in Figure 19.

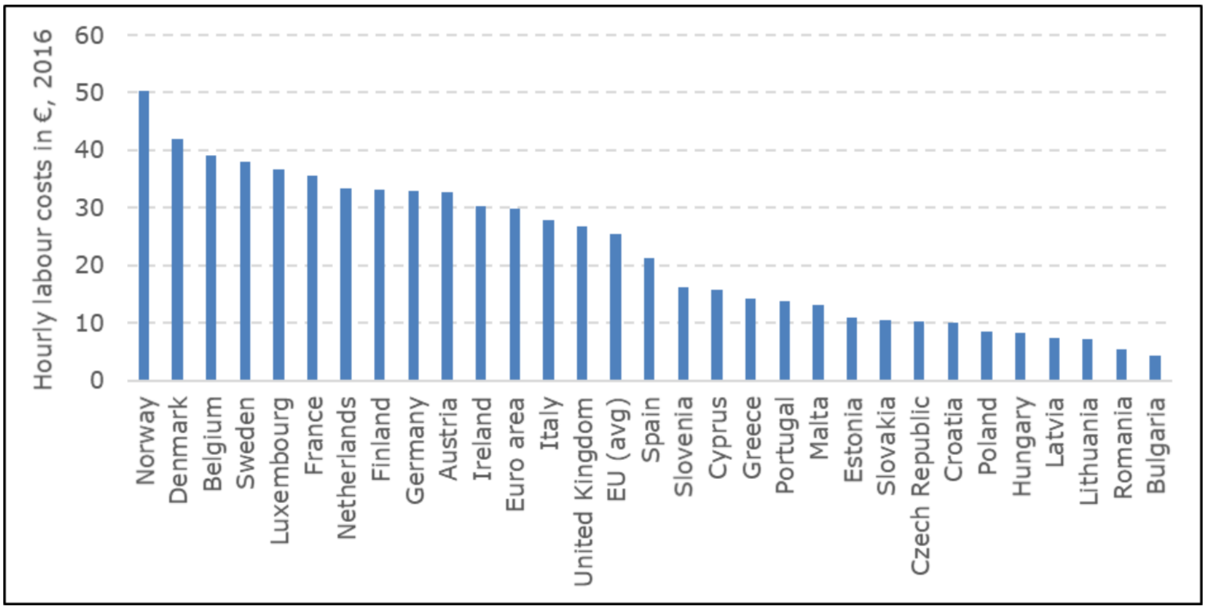

Figure 19: Hourly labour cost in EUR, 2016 for European countries

Installation costs

Reefers are designed for transportation and quick and easy installation and as such by nature plug n' play products with no significant installation costs. Costs of installation are consequently in this study considered negligible, but there are start-up costs related to handling when delivered to a new customer. See the section Rental/leasing prices above regarding start-up costs.

2.4.3 Consumer price of consumables

The main consumables for reefers are refrigerants and compressor oil.

Refrigerants

Refrigerants must be changed regularly since the refrigerants are degraded by aging and becomes polluted.

In addition, there are a number of different ways the equipment leaks and loses refrigerant for the environment:

- all cooling equipment has small leakages (probably close to 0.5 or 1 % leak/year for new products)
- accidental leakage for a limited number of equipment where most of the charge is lost, which all in all makes it difficult to estimate the overall leakage rates.
- a part of the refrigerant is not be recovered from the refrigerant circuit during scrapping.

Regarding end-of-life waste, in some cases for stationary applications the fluid may not always be not recovered as required by (EU)517/2014, since the companies that are scrapping the unit when it is taken out of service are interested in recovering the copper for its value but do not manage the refrigerants properly. Consequently, for some products average recovery rates may still be low. A recent example of refrigerants not being collected as required is a case with 30 companies in the vehicle scrap industry in 2019[243]. For reefers this could be the case for illegally imported reefers and old reefers placed at individual small companies. It also could be the case when operators of products and equipment not listed in paragraph 1 of the F-gas regulation, find that it is not technically feasible and that costs of collecting the F-gasses are disproportionate as described in the regulation.

Historically and for older equipment leak rates on 15 %/year is found according to the preparatory studies for the F-gas regulations [244]. This value probably has improved as the study is related to older systems. The IMO report notices that the classification company DNV GL (in 2012) requests a maximum leak rate on 10 % yearly for EU-fleets following the F-gas regulation[245].

For reefers used in shipping and leasing and rental business, servicing is done by professionals and probably it could be assumed that all fluids that can be recovered are recovered when the reefer is in service and ordinary operation. It means in the area of 90 % of the refrigerant mass is recovered and approximately 10 % are lost. Since these units are serviced regularly it can be supposed that the charge at end of life is the nominal charge.

[243] Scrap firms accused of emitting refrigerants, 7. Dec 2019, Coolingpost.com, https://www.coolingpost.com/world-news/scrap-firms-accused-of-emitting-refrigerants/

[244] Ôko-Recherche, Preparatory study for the review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases - Final Report (2011), https://www.oekorecherche.de/de/preparatory-study-review-regulation-ec-no-8422006-certain-fluorinated-greenhouse-gases-final-report

[245] Third IMO Greenhouse Gas Study 2014, International Maritime Organization (2015), http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf

It could be assumed to be even less for new reefers. The systems are similar to large split systems for buildings where leak rates of new systems are 1-2 % yearly.[246]

This means the average refrigerant leakage could be assumed to be in the interval between

nominal charge x (15 % x Lifetime + 10 %)

and nominal charge x (1 - 2 % x Lifetime + 10 %)

Prices on some common refrigerants are given in Table 2-13

Table 2-13: Refrigerant prices in Q1 2019 as an average of Germany, France and Spain (Source Öko-Recherche and Coolingpost[247])

Price \ Refrigerant	R404a	R410a	R407c	R134a
Euro/kg	57	43	37	29

Compressor oil

The purpose of the compressor oil is to lubricate and cool the moving parts of the compressors and to seal against refrigerant leaks. Both the pistons in a reciprocating and the rotary part of a scroll compressor needs lubrication[248].

Compressor oil addition may be required in case of refrigerant leakage. However, the oil composition ratio (OCR) in the oil and in the refrigerant mixture flowing through the cooling circuit is in modern compressor lower than 1 % by mass. So, the cost for replacing oil is in general neglected as compared to the cost of replacing refrigerant in case of leakage.

2.4.4 Interest and inflation rates (MEErP method for LCC calculation)

All economic calculations will be made with 2018 as base year, as this is the latest whole year for which data is available. HICP (Harmonised Index of Consumer Prices) inflation rates from Eurostat will be used to scale purchase price, electricity prices etc. to 2018-prices. Furthermore, a discount rate of 4 % will be used in accordance with the MEErP methodology.

2.4.5 Energy cost

In this section the cost of energy per unit is found and presented. The energy cost of reefers related to maintaining and to some extent cooling to a stable low temperature is related to the electricity supply. Electricity is supplied either from the grid (when at land in

[246] Kemna and Holstein, VHK, Water Heaters and Storage Tanks Ecodesign and Energy Label Review Study Task 3 (2019) https://www.ecohotwater-review.eu/downloads/Water%20Heaters%20Task%203%20final%20report%20July%202019.pdf
[247] https://www.coolingpost.com/world-news/hfc-refrigerant-prices-continue-to-fall/
[248] https://www.airconditioning-systems.com/compressor-oil.html

a port or when installed as a stationary storage), from a ships' electricity generator or from a small diesel generator powering one or a few reefers (e.g. on train or truck[249] or if stored intermediary in a port with no electricity plug or other means of refrigeration).

2.4.5.1 Electricity prices

Electricity prices for a grid connection are provided by the Commission, which are based on PRIMES (2016)[250]. The electricity prices are presented in Table 2-14. These prices are for purchase from the grid without any premium e.g. imposed by a port, when selling electricity to the ship.

Table 2-14: Electricity prices, in €/kWh

Electricity	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Industry	0.084	0.097	0.097	0.098	0.099	0.100	0.101	0.102	0.101	0.101
Services	0.127	0.148	0.157	0.171	0.176	0.179	0.184	0.182	0.180	0.178

For electricity prices[251] for electricity consumed at ports, industrial prices should be used, but excluding VAT and other recoverable taxes and levies. This price varies depending on the total consumption of the site. For large shipping ports in Europe, it is supposed electricity consumption is either in the IF-consumption band (i.e. for costumers with a yearly consumption > 70 GWh and < 150 GWh) or in IG consumption band (> 150 GWh) consumption band. For these consumption levels, average EU price as 2018 is respectively 0.076 Euro/kWh and 0.069 Euro/kWh.

During transportation and during standby in ports without taking electricity from the grid, the price of the electric kWh consumed varies depending on the situations. Table 2-15 contains calculated prices when burning heavy fuel oil on board or diesel on land.

Table 2-15: Electricity prices depending on production method and fuel source (Annex 1. Primary energy factors and energy prices)

	From ship, produced on fuel oil	From diesel generator truck/rail/port
Euro/kWh	**0.07**	**0.28**

Thus, in the ports, electricity from grid and from ship diesel engine have similar prices in Europe or sometimes it may even be cheaper to use the ships power connection than the land power supply.

[249] https://www.cma-cgm.com/products-services/reefer/containers-fleet
[250] PRIMES 2016
[251] Eurostat, Electricity prices for non-household consumers.

When the containers are placed at supermarkets, food groceries, festivals etc. either as intermediary storage during unloading or permanently the electricity price normally would be electricity for services. If the reefer is placed at a production site, the electricity price could be for industry.

2.4.6 Energy consumption

In order to reach a conclusion regarding the scale of energy consumption and potential improvements from energy efficiency policy measures, preliminary analyses have been performed which would normally be part of a task 3 and 4 of a preparatory study according to the MEErP method. If ecodesign measures are going to be introduced the findings below would need to be further developed.

2.4.6.1 Factors impacting the energy consumption

Average energy consumption per refrigerated container depends on a number of factors including:

- External factors like terminal/site location, external temperature, humidity and weather, storage conditions, etc. may vary significantly depending on country and location in the country. The storage conditions may vary for the same location, e.g. due to stacking geometry and number of stacked layers, or how much of the outer surface of a container is exposed to ambient conditions and sunlight. The more of the outer surface that is surrounded by other containers, the better sheltered the container is and the less heat from the surroundings is transferred into the container and the better are the conditions for the cooling unit. A container which is exposed to the sunlight on the roof requires more cooling than one which is not and containers standing separately with no sheltered surfaces requires the most cooling. [252].
- Technical specifications of the reefer itself like container size, compressor size and type, insulation material, doors and door gaskets, control strategy of cooling unit, general physical condition, age and a range of other variables influence the reefers' performance.
- Use situation and character of perishable goods stored would highly influence the energy consumption. Typical factors are the door opening time (especially for stationary storage use, which typically are more often open), loading temperature of cargo, weight and shape of cargo, packaging materials etc. The requirements to the reefers' operation depend on the perishable cargo. Frozen or chilled? Pull-down

[252] Ludmiła Filina-Dawidowicz & Sergiy Filin, Innovative energy-saving technology in refrigerated containers transportation Springer (2018)

or steady-state due to precooled goods? Does the cargo itself generate heat like apples or bananas?

Due to the higher temperature difference during freezing mode the heat losses are larger than during cooling mode. Despite this physical law the cooling does not always use significantly lower energy than freezing. The reason is, that the temperature tolerances and set point intervals are often narrower for cooling – especially around 0 °C - compared to freezing. This causes the cooling machine to switch on and off more frequently and the fans to run more and at higher air speed. Additionally, some cooling machines are optimized for freezing temperatures.

Door openings. Task 1 mentions the test standard for energy consumption of refrigerated containers ISO 1496-2:2018. This standard defines energy consumption for closed containers without door openings. For shipping containers this is relatively close to the actual use situation since the container ideally will be loaded with cooled down cargo, closed and transported, typically for weeks, and energy consumption will depend to high extend on the compressor efficiency and the heat losses from the box.

For stationary reefers, the use patterns are different than they are for transport reefers. A transport reefer is opened and loaded/emptied at the start and at the end of a trip and between that basically in steady-state operation, although with some variations in ambient conditions.

A stationary reefer is typically used with door openings during the day and will perhaps be loaded and unloaded with new goods.

The test methods are performing the tests at steady state. For comparison, test of residential refrigerator-freezers e.g. in the STEP-project [253] show that the average increased consumption due to door openings were 10 %, in one case 32 %, when compared to testing according to EN62552:2013 which has no door openings. Other studies confirm the level between 8 % and 32 % in increased energy consumption because of door openings in residential cold appliances[254]

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[253] Clasp, ECOS, EBB and topten.eu, (2017), Closing the 'Reality Gap' – Ensuring a Fair Energy Label for Consumers, https://eeb.org/wp-content/uploads/2017/06/Reality-Gap-report.pdf

[254] Trinity University, Wilson Terrell (2006) Energy Requirements of Refrigerators Due to Door Opening Conditions. The introduction presents different studies. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1835&context=iracc.

2.4.6.2 Literature data and stakeholder input

The many factors influencing the energy consumption of reefers makes it complicated to estimate their energy consumption. One option used in the following is to collect and analyze data from studies with real world measurements.

From literature however, there are not many references on research with reported data on actual energy consumption of reefers. A few examples are found in studies of container terminals, which are storing hundreds or thousands of reefers for one to three days. Three examples are from the container terminals in Rotterdam seaport with 18,500 electrical connections for reefers[255]; from terminals in Chile; and from the Otago terminal in New Zealand. The last study also distinguishes between energy consumption for cooling and freezing.

A study by Wild (1999) analyzed the mean electricity consumptions from statistical analysis on the energy usage of approximately 2,300 TEUs in Rotterdam. The study found that the mean energy consumption was around 4 kW in 20 ft containers and 7 kW in 40 ft containers and that the overall mean electricity consumption was around 3.6 kW per TEU. The mean electricity consumption was revised almost ten years later by the author (Wild 2008) to 2.7 kW/TEU[256,257] .

In another study from Chile based on aggregated data from Chilean container terminals, a median energy consumption for reefers of 59 kWh/day per TEU (2.5 kW in median power consumption) was found during the period 2010 – 2014 in container terminals in Chile. The study also mentions that during 2010 – 2013 an energy consumption of 36 kWh/day per TEU (or 1.5 kW in average) has been found for reefers stored at terminals' business outside Chile[258].

The study does not explain the differences, the article focuses on the analyses of the Chilean data. It is however mentioned that even though the Chilean terminals has a higher median energy consumption for reefer cooling than other terminals per storage day, then the total median energy consumption in the Chilean terminals is lower per reefer box handled because the number of days of handling time is lower.

The New Zealand Port Otago measured in August 2009 (winter) the power consumption of six frozen twenty-foot containers set to -20°C and a combination of six frozen twenty-foot

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[255] https://www.portofrotterdam.com/en/doing-business/logistics/cargo/containers/reefer-containers

[256] Warren B. Fitzgerald, Oliver J. A. Howitt, Inga J. Smith & Anthony Hume, Energy use of integral refrigerated containers in maritime transportation baseret på Wild, Y., (2008). Carbon Footprint Workshop, Environmental Aspects of the Transport of Reefer Containers, 3rd Reefer Logistic Conference. Antwerp, 26 June 2008

[257] Wild, Y., Mechsner, A., Raschle, H., Horn. R., 1999. *Transport of Refrigerated Containers in Cargo Holds*. 20th International Congress of Refrigeration, Sydney, Australia

[258] Thomas Spengler & Gordon Wilmsmeier, *Consumption and Energy Efficiency Indicators in Container Terminals,* IAME 2016 Conference Hamburg, Germany (2016)

containers set to -20 °C and four chilled twenty-foot containers set to 0 °C [259]. The mean power consumption by the six frozen containers was 2.7 kW/TEU while the mean power consumption of the ten frozen and chilled containers was 4.4 kW/TEU[260].

Full-year monthly electricity meter readings were also provided by same Port Otago for the year from July 2008 to June 2009. In this case the mean power consumptions were in the interval from 1.29 to 2.28 kW/TEU, although it is not clear from the article if all the reefers were on full time operation, if some were out of service or if the values were corrected for e.g. half days of storage[261].

Filina-Dawidowicz and Filin, mentions that average power consumption in 40′ container ranges from 6 to 9 kW per reefer[262].

One of the reefer rental companies interviewed has measured energy consumption on some 20 ft reefers they have for their own use. The average energy consumption is informed to around 1,000 kWh/month (1.4 kW/TEU in average). The older the reefers the higher consumption, according to the company primarily because the PUR insulations is degrading with the years.

One supplier of electrical and control equipment for refers reports the average consumption of transport reefers to be 3-4 kW per TEU highly dependent on load and other conditions[263].

A service company interviewed for this preparatory study has measured the energy consumption of two different compressors with a controller in economy mode (Table 2-17). The same containers consume 3,8 - 5 kW in average at similar ambient conditions when used for freezing.

Storage conditions: The power consumption of a 40 ft high cube reefer container exposed to the maximum solar radiation as been investigated by Budiyanto and Shinoda. When the container walls were exposed to direct sun with a radiation of about 700 W/m^2 at noon an increased power consumption from approximately 7.3 to 7.5 kW was measured[264].

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259 Warren B. Fitzgerald, Oliver J. A. Howitt, Inga J. Smith & Anthony Hume, Energy use of integral refrigerated containers in maritime transportation
260 Warren B. Fitzgerald, Oliver J. A. Howitt, Inga J. Smith & Anthony Hume, Energy use of integral refrigerated containers in maritime transportation
261 Warren B. Fitzgerald, Oliver J. A. Howitt, Inga J. Smith & Anthony Hume, Energy use of integral refrigerated containers in maritime transportation
262 Ludmiła Filina-Dawidowicz & Sergiy Filin, Innovative energy-saving technology in refrigerated containers transportation Springer (2018)
263 Robert Svensson, Emerson (2014) Improving Refrigerated marine container management with pervasive connectivity (https://climate.emerson.com/documents/webinar-08-%E2%80%8Bimproving-refrigerated-marine-container-management-pervasive-connectivity-en-us-2884860.pdf)
264 Muhammad Arif Budiyanto &Takeshi Shinoda, The Effect of Solar Radiation on the Energy Consumption of Refrigerated Container, Case Studies in Thermal Engineering (2018)

The impact of stacking has been investigated on stacked containers on site in Hakata Island City Container Terminal, Fukuoka, Japan in the summer. In this case the average surface temperatures obtained on the top tier, middle tier, and bottom tier were 45°C, 41°C and 38°C at noon, respectively. The resulting average power consumption from the top tier, middle tier, and bottom tier were 7.7 kW, 7.4 kW and 7.5 kW, respectively[265].

2.4.6.3 Conclusion regarding energy consumption

Based on the above the revised value of energy consumption from Y. Wild (2008) seems to be the best fit and will be used for calculations of energy consumptions. Consequently:

- Average electricity consumption of transport reefers = 2.7 kW/TEU for shipping containers
- Average electricity consumption for 20 ft container is 11 % higher than the general average consumption = 3 kW/TEU in 2008. This could be seen from the electricity consumption in 1999 of 20 ft (4 kW/reefer) vs. the average reefer (3,6 kW/TEU)
- Average electricity consumption for 40 ft container is 3 % lower per TEU than the general average consumption = 2,6 kW/TEU in 2008. This could be calculated from the electricity consumption in 1999 of a 40 ft (7 kW/reefer) vs. the average reefer (3,6 kW/TEU)
- Compensation for door openings for stationary reefers: +15 %
- Compensation for less favourable locations for stationary reefers and more loading/unloading of goods + 10 %
- 95 % of the transport reefer fleet are 40 ft containers
- 70 % of stationary fleet are 20 ft, 15 % are 10 ft and 15 % are 40 ft. Consequently, the consumption of 20 ft containers is a good approximation to average stationary stock.

These numbers are based on the average share of chilled and frozen containers in the ports investigated in the studies.

The electricity consumption per year in MWh per TEU is found by multiplying the power consumption with the number of hours pr. year (365 days x 24 h/day = 8760 h). Table 2-16 gives an overview of estimated real life electricity consumptions.

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[265] Muhammad Budiyanto & Takeshi Shinoda. Stack Effect on Power Consumption of Refrigerated Containers in Storage Yards. International Journal of Technology. 8. 1182. (2017) 10.14716/ijtech.v8i7.771.

Table 2-16: Estimated average electricity consumption in real life for different reefer categories.

Reefer category	Avg. transport	20 ft transport	40 ft transport	20 ft stationary	40 ft stationary
Avg. power consumption [kW per TEU]	2.7	3.0	2.6	3.8	3.3
Energy consumption [MWh/TEU per year]	24	26	23	33	29

Stakeholders from industry inform that the development towards higher energy efficiency continues and that similar analysis of today's average products would find lower energy consumption. This corresponds to the trend seen in the data collected in the current study. It has however, not been possible to find exact data to verify and quantify this expected development.

2.4.7 Energy efficiency

As described in chapter 2.3.3 manufacturers are improving reefers also on energy efficiency and lately particularly better control equipment contributes to energy savings.

2.4.7.1 Opportunities

The consultancy company Cowi A/S and a reefer manufacturer tested five reefers according to ISO 1496-2[266]. The compared products seem to be a premium product from the manufacturer, three average products and a fifth product which consumed almost the double of the presumed average products. The most efficient of the five reefers used approximately 25 % less than the three average reefers. The manufacturer explains the 25 % efficiency improvement mainly by use of better control software.

Also, another manufacturer of cooling units e.g. [267] has introduced improved control systems with more precise control of scroll compressor and airflow. The control is based on monitoring of supply and return air temperature to compensate for both ambient conditions and internal heat load. The claimed energy efficiency improvement is on 25-50 % lower power consumption. Generally, especially the control of fan speed is important.

One supplier of electrical and control equipment for refers suggest that there are potential energy savings from better monitoring and control. The company finds that by remotely controlling economy mode setting and improving analyzes of performance of reefer

[266] MCI, Integrated reefer news 1st quarter 2017 https://ipaper.ipapercms.dk/MCI/IntegratedReeferNews1/IntegratedReeferNews/2017-q1-integrated-reefer-news/?page=2
[267] https://www.daikinreefer.com/2008/10/14/daikin-launches-dtms2/

container fleet including the identification of poor performers for maintenance or retirement higher efficiency could be reached[268].

A service company interviewed for this preparatory study has measured the energy consumption of two different compressors with a controller in economy mode. The energy consumption of the two containers for cooling was significantly lower when they were operated in economy mode compared to standard mode (Table 2-17). When used for freezing application the controllers' economy mode did not result in any improved energy efficiency.

Table 2-17:Impact of a controllers economy mode on energy consumption [kW], 24 h average, chill mode and ambient temperature between 16 and 24 °C.

Compressor Mode of operation	Reciprocating compressor 20 ft	Scroll compressor 40 ft
Standard	3,5	3,2
Economy	1.2	1.3

Some sources are of more anecdotical character like the experience from some of the interviews. One larger lessor of containers mainly for stationary use informed that: *Scroll compressors use less energy and therefore it is the preferred compressor type by our company.* The company has tested an old reefer with a traditional (reciprocating) compressor, and a new reefer equipped with new gaskets, more efficient fan motor and scroll compressor. The energy savings were around 80 % in favor of the new.

One rental company with reefers for stationary storage advertises about typical energy savings of their own new efficient reefers compared to other typical rental market containers on £ 10 per day when running at -25 °C and around £ 5 per day at chill temperatures[269]. Based on the UK average industry electricity price (0.1246 EUR/kWh) it corresponds to savings on around 90 kWh/day respectively 45 kWh/day or 3.8 kW respectively 1.9 kW in average for these 20 ft reefers.

[268] Robert Svensson, Emerson (2014) Improving Refrigerated marine container management with pervasive connectivity (https://climate.emerson.com/documents/webinar-08-%E2%80%8Bimproving-refrigerated-marine-container-management-pervasive-connectivity-en-us-2884860.pdf)
[269] http://arcticstore.co.uk/GL/About%20us.aspx

2.4.7.2 Potentials

The study indicates that several potential improvements on reefers are possible, the main being better controls leading to at least 25 % improved energy efficiency, more efficient fans, incl. for evaporators, better insulation and less air leakage from the reefer body.

Having in mind that these numbers are not analyzed in the technical task 3 and 4 parts of the preparatory study a rough calculation on the savings potential is performed. For the savings potential calculations:

- a conservative estimate on 25 % improvement potential has been selected as BAT
- it is assumed, that the market will develop towards more efficient products and that half of the improvement potential could be reached via policy measures.
- For transportation use it is assumed that 100 % are connected to ship power supply This is an approximation to the average fleet which is mostly supplied from the ships' power grid, to less extend from diesel generator sets which are less efficient than the ships power grid, or on-shore power grid being more efficient.
- For stationary use it is assumed that 100 % are connected to the power grid (PEF (Primary Energy Factor) calculations in annex 2).

2.4.7.3 Conclusions

Based on these assumptions a preliminary and rough estimation of potential energy savings is presented in Table 2-18. The calculations indicate potential energy savings on around 0.2 TWh/year after 2030 if half of the average EU stationary reefer fleet in 2030 is replaced with the currently best available technology and 11 TWh/year if half of the average EU related transportation reefer fleet is exchanged as a result of policy measures on reefers.

Table 2-18. Energy consumption and savings potential

	2020		2030	
	EU low (stationary)	EU transport	EU low (stationary)	EU transport
EU reefer (related) stock, units	10,800	710,400	18,700	1,170,000
Energy consumpt. average container (kW/TEU)	3.8	2.7	3.8	2.7
Energy consumpt. BAT container (-25 %, kW/TEU)	2.8	2.0	2.8	2.0
Energy consumption/year total stock (GWh) average	361	16,800	622	27,600
Energy consumption/year total stock (GWh) BAT	271	12,600	467	20,700
Savings potential = ½ of total difference average and BAT (MWh/yr)	-	-	78	3450
Primary energy factor (Annex 2)	2.1	3.3	2.1	3.3
Savings potential total stock (GWh/yr), Primary energy	-	-	160	11,000

2.4.8 End-of-life costs

2.4.8.1 Upgrade and renovation

The following section describes upgrade and renovation potentials and practice for the components mentioned below:

- Reefer box
- Refrigeration unit
- Controllers

Maintenance and repair are further explained in chapter 2.4.2.

Reefer box

Figure 20. Examples of reefers and containers end-of-life

The reefer box degrades during the years due to diffusion of blowing agents from the insulation, bumps and holes from forklifts and generally being less airtight. If the reefer is damaged and it is a limited damage, parts of the inner lining and insulation could be replaced. Some companies are specialized in retrofitting the inner lining of the box. This happens for instance sometimes when shipping reefers are retrofitted for storage purpose or for repair.

Container homes and conversion. Converting used containers for residential and non-residential purposes is a typical application of containers after they have been discarded from service as transport containers. Reefers could be refashioned for similar purposes. Reefers are pre-insulated, and it provides both an advantage and a disadvantage. As they are pre-insulated, insulating the exterior is saved and they are for example easily sold as insulated boxes for storage. However, when making perforations for fenestrations and services, the insulation has to be carefully handled to avoid poor workmanship and detailing which may lead to air-leakages and thermal bridging.[270]

Compressor*.* Generally based on the interviews, cooling units for reefers are only repaired if the general condition of the reefer justifies it. And often this is not the case due to the price of a new cooling unit compared to the price of a used older reefer (see chapter 2.4.2). One interviewee explained that if the cooling system could no longer be fixed the reefer will be sold as a "dead reefer" (air- and watertight box that can be used for storage). One interviewed lessor on the other hand explained that they had exchanged and upgraded a whole series of clip on cooling unit with new and improved units.

Controllers. On shipping reefers, the controllers could be upgraded and is being if this is justified economically. It often is since the possibilities in new controllers often provide increased control, improved maintenance planning with shorter service down time in ports or even prevents breakdowns.

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[270] http://www.horn-technologies.com/reefer-container/

Recyclability and disposal tariffs

Generally, reefers are stripped for cooling installations and other equipment and sold as insulated storage boxes by the end of their useful life as reefer. After that, when they do not have status as reefers in scope, they contain mostly metals and wall insulation materials.

The equipment from which the reefers are stripped contains F-gasses, valuable metals and WEEE-waste as described on task 1.

F-gases must be recovered from commercial or industrial refrigeration systems, refrigeration systems in trucks, trailers, ships and other vehicles etc. Recovered F-gas must be reclaimed, recycled or destroyed, where technically or economically feasible. Relevant to reefers, these rules apply to all refrigerants and HFCs used in foam insulation. Reclaimed F-gas is reprocessed to the standard of virgin (unused) F-gas and could be used and sold until Jan. 1st 2030[271]. This means that the refrigerants would have a market value (see chapter 2.4.2).

The electronical parts of the reefer are covered by the WEEE Directive and there may be disposal tariffs. So, except from insulations materials there are no tariffs or tax especially for reefers to the author's knowledge at the time of writing the report. [272]

Insulation materials from old reefers may contain CFC gasses as blowing agent. Insulation materials may be covered by local waste disposal tariffs.

On the other hand, the metals are valuable scraps at the end of their life, so it is assumed that the scrap value is higher than the costs. It is therefore assumed that there are no incurred disposal costs for reefers at the end of life.

2.5 Conclusions and recommendations

2.5.1 Refined product scope

The products in scope of this study are proposed to the following:

- Integral picture frame or bolt-on reefers used for either transport or stationary applications for purposes of
  - refrigeration (chilled and freezing applications)
  - single and multi-temperature (i.e. single and multi-compartment)

[271] https://www.gov.uk/guidance/recovering-reclaiming-and-recycling-f-gas
[272] https://www.gov.uk/guidance/recovering-reclaiming-and-recycling-f-gas

For reefers with controlled atmosphere (CA) the CA functionality is exempted from the scope. Although controlled atmosphere does influence reefers energy consumption and is relevant, they are exempted because:

- the number of CA solutions are huge and the variations too;
- the CA application is an add-on, which does not change the basic construction of the reefer units (e.g. reefer box; container stackability, insulation properties, doors and gaskets, cooling unit etc.); and
- the exemption of CA enables a more precise product definition.

Due to very low presence in the market of multi-compartment, where installation of walls and separate climate control systems enables more than one temperature and climate zones in the same reefer, it could be considered to focus on single compartment reefers.

10, 20, 40 and 45 ft reefers are all in scope. However, it could be considered to focus on the most common 20 and 40 ft reefers, and 40 ft as cube and high cube, as the numbers of the other products are found to be insignificant.

Ultra-low temperature, cryogenic, etc. reefers are exempted from the proposed scope.

The industry standard reefers with internal temperature range of -29 °C to +29 °C (also available in a -40 °C to +30 °C version) were found as the most commonly used for both chilled and freezing applications.

The freezer version with internal temperature range of -65 °C to -40 °C were also found to be broadly available, although it was not possible to establish an exact number. It could be subject to further investigation since the freezer reefers and the industry standard reefers are distinguishable e.g. for regulatory purposes in case only one of those types would fall in scope of a regulation.

2.5.2 Preliminary conclusion regarding barriers and opportunities for ecodesign

Integrated refrigerated containers (reefers) are generally used for both transportation (shipping and land) and stationary storage use, although their main purpose is for shipping transportation. Reefers which are mainly used for shipping will to some extent also be used for intermediary storage purposes, either when staying at ports or when they are loaded and emptied. In addition, these reefers often are sold for stationary refrigerated storages purposes for businesses who purchase them for their own use. As such they should not be considered exclusively as "means of transport for persons or goods" to which the ecodesign regulation does not apply (Ecodesign directive article 1).

Shipping reefers are generally not placed on the market in EU but in Asia. A limited number of products are placed on the EU market, mainly for smaller transport companies or for producers of perishable goods. When they are placed on the EU market for the first time, it is as second-hand products and with the purpose to be applied for stationary use.

The study also found that during the last 20 years a new category of refrigerated containers for stationary storage use has evolved. Products which basically share the same container frame and technology but are differently equipped – most significantly with use of plane-floor instead of T-floor - for the purpose of stationary storage. These products are used both intermittent and permanently as alternatives to traditional walk-in freezing and refrigerated rooms or cold storage.

Reefers specifically for stationary storage are equipped differently than transport reefers, and they are placed on the market in EU for sale, lease and rent.

The sales of integrated reefers for shipping purpose is estimated to around 25,000 units in 2020 and 50,000 units in 2030, which is below the ecodesign indicative minimum on 200,000 units per year. This is the number of units related to the EU market, but as described above they are not placed on the market in EU. The EU sales numbers of integrated reefers for stationary use are not even a few thousand and far from the ecodesign indicative minimum.

On the other hand, the energy consumption of each of these products is significantly higher than many other products treated by ecodesign. In addition, the lifetime of the product is 15 – 40 years depending on use situation, which means that the marketing of low performing products will have a long negative impact on the stock. A preliminary and rough estimation of potential energy savings is a saving potential on around 0.2 TWh/year by 2030, should 50 % of the average EU stationary reefer stock be exchanged with the currently best available technology due to policy measures on reefers energy efficiency. For the EU related transportation reefer the saving potential is 11 TWh/year if 50 % of the average fleet is being exchanged by 2030 due to policy measures (see Table 2-18).

Shipping/transport as well as stationary reefers are repaired and maintained in EU when it is necessary, i.e. if they break down or needs service while staying in an EU terminal.

Regarding other environmental parameters than energy consumption one of the main factors of reefers is the use of refrigerants and their global warming potential. Refrigerants are covered by the F-gas regulation and the market research showed that it is driving the market towards more environmentally friendly refrigerants. In addition, there are emissions from diesel generator sets during land transport and from the ships during see transport and in harbours. The last, however, to some extent reduced due to the new sulphur requirements.

The conclusion is that traditional ecodesign measures does not seem to be possible to introduce for:

- the biggest product category of reefers, which are being used for international shipping and transportation primarily, since they are not placed on the EU market, as described in chapter 2.3.2. Hence, a European ecodesign regulation will only target a small part of the integral reefers that are used for transportation on the EU market and consequently a regulation would have a small saving potential in spite of the large energy consumption of the products. The yearly sales of reefers used for transportation related to the EU market (but not placed on the EU market) are about 50.000 (by 2030). This is below the ecodesign requirement on 200.000, but the energy consumption of a reefer is high compared to other products like household appliances covered by ecodesign. These reefers are primarily used for transport and not equipped for permanent stationary storage purpose. However, they could be and are sometimes used for stationary storage purposes as well, either intermediary in their normal lifetime or when they are taken out of operation as transport reefers and potentially sold stationary purposes. Therefore, it was concluded that the products do not fall under the ecodesign exemption related to "means of transportation".
- the smaller product category of integral reefers for stationary use are not relevant for ecodesign since the yearly sales numbers in the area of thousand units as described in chapter 2.2.3.2 are too low.

2.5.3 Alternative policy measures

In order to harvest the energy saving potentials, alternative policy measures could be investigated. The four alternative measures below have been presented and discussed at the first stakeholder meeting:

1. Ecodesign requirements on replacement compressors and cooling units for reefers
2. Directive on refrigerated containers and ITU
3. Include refrigerated containers for stationary use in the Regulation (EU)1095/2015
4. Ecolabel for reefers

2.5.3.1 Alternative policy option #1 - Ecodesign requirements on replacement compressors and cooling units for reefers

As explained, the majority of the refrigerated containers which service the EU market are never placed on the EU market. The products are on the other hand being serviced and when necessary maintained and repaired in EU and this means that the spare parts for this purpose will have to be purchased in EU, hence being placed on the EU market.

This may provide an opportunity of introducing Ecodesign requirements on replacement compressors and cooling units for reefers, which will upgrade reefers that are being repaired in the EU.

Motivation

Reefers are used for many years; this could lead to improvements of existing products during their lifetime from technological and regulatory development. Improvements of compressors and cooling units in operational reefers would impact products being repaired in the EU and used in the EU as well as worldwide

Requirements on replacement parts have the potential to impact a share of the products being used in the EU and worldwide, and it may drive the development worldwide towards more efficient technologies.

Discussion

Minimum efficiency requirements on key mechanical parts like compressors or cooling units which are used for repair and replacement as well could push the existing fleet towards higher efficiency. In fact, it is already happening to some extent via the Ecodesign Regulation on Fans, (EU) No. 327/2011 and the F-gas Regulation (EU) No 517/2014 as explained in chapter 1.3.1. It may be too difficult to require such upgrades of specific cooling components; would for example a certain compressor type designed for a specific cooling unit and its control system always have an appropriate replacement if new requirements are introduced?

Another constraint toward this approach could be that, for older reefers, spare parts are often refurbished, and in such case, they may not be considered as being placed on the EU market. Also, requirements on components could would not influence the general degradation of reefer bodies insulation, gaskets etc. which is another important factor in the increased energy consumption of older reefers. Stakeholders mention that since a reefer is a system where the performance of reefer body itself and the impact of wear on it should be considered it would be more relevant to apply regulations on the entire unit. However, it could be argued, that sincethe overall energy consumption is higher for inefficient reefers, the saving potential would be equivalently higher from efficient cooling equipment even if requirements are only applied on component level.

Additionally, such requirements may let the shipping companies consider to place maintenance work outside EU. Probably this would not be the case, the cost of withdrawing non-functional reefers from operation to transport for repair outside of EU would be too high compared to a limited extra purchase costs for an efficient and compliant spare part.

All stakeholders consider this option as being problematic or challenging due to the explained technical aspects. One NGO nevertheless were in favor of working with this solution due to the potential impact. Some stakeholders also foresee potential market surveillance problems and expressed concerns regarding the fact that this will impact reefers that have not been placed on the EU market.

2.5.3.2 Alternative policy option #2 – Directive on refrigerated ITU

Refrigerated ISO freight containers designed for intercontinental transportation and other refrigerated intermodal transport units typically designed for road, train and river transport (below: ISO ITU vs. non-ISO ITU), which are used for regional transportation of goods share to some extent purpose and functional parameters regarding refrigeration.

A specific directive on refrigerated ITUs - ISO as well as non-ISO – could be considered to cover these large quantities of refrigerated goods transportation on the European market.

Motivation

For the domestic European transportation of refrigerated goods, ISO ITUs are mainly used when transportation on container ships is involved. A large share of the EU continental transportation of perishable goods is carried out in refrigerated non-ISO ITUs like refrigerated swap bodies and refrigerated trailers.

In particular swap bodies might also form some kind of "grey zone" with integral reefers, depending on their respective design.

The tyre regulation (EC) No 1222/2009 solved a problem for a transportation product category, and this may be an inspiration for other transportation related products as refrigerated ITUs.

Discussion

The use of ecodesign measures for these several categories of ITUs might not be possible, therefore a specific directive could be relevant, as there is precedence of specific directives from tyre regulation to overcome limitations in ED and EL.

However, specifically for reefers (the refrigerated ISO ITU) the main regulatory problem would still be is the low share of products being placed on the EU market. The purpose of ISO-ITUs and non-ISO-ITUs is overlapping and a requirement to refrigerated non-ISO ITUs without ISO ITUs may open a loophole.

Reefers and other refrigerated ITUs are having rather different supply chains. One industrial stakeholder recommends not to mix the two products in the same regulation.

None of the stakeholders expressed that they were in favour of policy option #2 and some were against. The first main concern was related to the potential problems with market surveillance due to the 24 months rules of temporary admission status (chapter 1.3.1). The concern was that even if this issue is solved only a small share of the reefers that are used in EU is placed on the marked. The other main concern was that the markets of ISO ITUs and other refrigerated non-ISO ITUs are too different which will make it complicated to cover those products in the same regulation.

2.5.3.3 Alternative policy option #3 - Include refrigerated containers for stationary use in the Regulation (EU)1095/2015

The reefers being used for stationary storage purpose are in principle being used as a refrigerated walk-in cabinet. It could be considered to include the product group `refrigerated containers for stationary use´ in the Regulation (EU)1095/2015 for professional storage cabinets as a subcategory of walk-in cabinets.

Motivation

An increasing number of old reefers are placed on the EU market and for new reefers an increasing number of products and solutions specialized for stationary use are introduced to the market. The expected second-life of used reefers as cold storage room is around 10 years and for new products the average lifetime is estimated to 28 years.

Regulation (EU)1095/2015 regards professional storage cabinets. The next time the regulation is subject to review walk-in cold rooms could be part of the review process. Potentially, reefers could be included as a subcategory of walk-in cold-rooms for this review. Should it be decided to include walk-in cold rooms in the amended regulation (EU)1095/2015 there is a risk that the use of reefers for the same purpose could end up as a loophole.

To include reefers for stationary use in the other regulation could allow policy measures for these products when placed on the EU market at potentially lower administrative costs than in a new specific regulation hence perhaps justifying regulating these products and closing a potential loophole.

Discussion

The inclusion of stationary reefers in the regulation for professional storage cabinets will only directly impact containers for storage use, not the major part being used for transportation.

Feedback from stakeholders point to this solution as the preferred for further exploration of the four mentioned policy options although concerns were raised if the cost-benefit ratio would justify such measures.

2.5.3.4 Alternative policy option #4 – EU Ecolabel for reefers

The EU Ecolabel has proven for some product categories to be a market driver towards more environmentally optimal solutions, where hard requirements are not considered to be appropriate. Since for reefers for transportation seems to be difficult to regulate the voluntary Ecolabel could be considered for reefers to push the market towards the environmentally optimal products.

Motivation

Ecolabel could be relevant if customers and suppliers could see a value by signalling environmentally friendly CSR policy and be used as a guideline for customers to select the environmentally best option. At the same time the introduction of an ecolabel on refrigerated containers transport could provide a guideline for customers to select the environmentally best option and especially a guideline for public procurement.

Discussion

The question is whether a label could generate market value by signaling environmentally friendly CSR policy and in such case if the market sees the benefit and is ready for this. None of the stakeholders were in favor of this solution. Arguments presented by industrial stakeholders were that:

- neither the users of refrigerated containers nor their clients would be prepared to pay an additional price premium for refrigerated containers compliant with such higher environmental standards,
- the value would be low since the current market of reefers is already driven towards reduced energy consumption.
- the market is a typical B2B market, where the use of incentive schemes and tax reductions are not really existing, and
- the global logistics environment is characterized by tight price competition.

Annex I

1. Description of products

In the following, integral refrigeration containers will be described in more detail to provide explanation of the terms used in the report. Integral reefer equipment contains the following key components:

1. Reefer box
2. Refrigeration unit comprising of:
    a. Compressor
    b. Refrigerant
    c. Fans (evaporator and condenser)
3. Controllers and operation
4. Data loggers
5. Diesel generator (especially for nose-mounted reefers and during road/rail transit)

1.1 Reefer box

Almost all reefer manufactures and suppliers are located in Asia. Reefers and refrigeration units are built and assembled in China, while refrigeration units are also manufactured in Singapore and shipped to China for assembly[273]. Typically, exterior walls of the container are made of low grade/MSG grade stainless steel and the interior walls are made of food grade stainless steel. The space between the exterior and interior is filled with insulation foam of about 60 mm thickness. Ceiling and deck are made of aluminium. For picture-frame reefers, the refrigeration unit and the reefer box frame are riveted together.

1.2 Refrigerant compressor

Both reciprocating and scroll compressors are used refrigeration units in reefers. Currently, there is a marked trend among coolant compressors away from traditional (reciprocating/piston[274]) compressors towards scroll[275] compressors, although not without exceptions, since e.g. MCI with a large market share uses speed-controlled piston compressors. There has been much efforts put into cutting energy consumption and chilled mode power consumption significantly decreased. 20 years ago, part load control was done using hot gas bypass (highly inefficient), now it is either by cycling, scroll unloading (Emerson / Copeland) or using inverter-controlled compressor. When compared to traditional compressors, scroll compressors have advantages[276,277,278], such as fewer moving parts, fully air-tight construction, significantly lighter weight and more compact

[273] interview dated July1., 2019, Anonymous, purchase department
[274] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_01.html
[275] https://www.carrier.com/container-refrigeration/en/worldwide/products/Container-Units/PrimeLINE/
[276] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_01.html
[277] https://europe.thermoking.com/genuine-parts/compressors/
[278] Dynamar (2018) REEFER Analysis - Market Structures, Conventional, Containers - https://www.dynamar.com/publications/210

design, volumetric efficiency, higher cooling capacity, faster pull-down to required temperature and generates less noise.

According to one stakeholder, the market share of variable speed compressors is significant around 15 %.

1.3 Refrigerant

Earlier, almost all refrigerated containers were operated using the refrigerant R11 (Trichlorofluoromethane) and R12 (Dichlorodifluoromethane). After the destruction of the ozone layer became an issue and consequently the Montreal Protocol banned these coolants, a number of manufacturers switched briefly to R22 (Chlorodifluoromethane) as a substitute coolant. However, as this is also being phased out, the two coolants R134A and R404A, which have zero ozone depletion potential (ODP) are now generally used instead. Currently, however, R404A will also be phased out by 2019 for its high global warming potential (GWP) and R404A would no longer be services in the EU after 2020 and then be banned at a later date, leaving R134a as the mainstay refrigerant used in reefers.

Refrigerant units are also optimized for R513A, which is currently the prime choice of refrigerant to reduce the carbon footprint of reefer containers[279]. In addition, reefers with CO_2 as a refrigerant are also available and being actively developed[280]. According to one stakeholder, so far only a few thousands CO_2 units are sold (2019), although the CO2 compressors according to an interviewee from a service company are now recieved more regularly for PTI. Although CO_2 as a refrigerant is sought for its negligible GWP, for outdoor temperatures above about 30 °C, its performance is lower, and it works at high pressures. Furthermore, stakeholders suggest that refrigeration technologies sought for stationary and transport purposes differ for reasons, such as interior and exterior operating conditions, handling, serviceability etc.[281]. Propane has also long been envisaged as an alternate refrigerant but it has not yet been fully developed and adopted because of it high flammability issue[282].

[279] https://www.mcicontainers.com/products/star-cool/refrigerants
[280] https://www.carrier.com/container-refrigeration/en/worldwide/products/Container-Units/NaturaLINE/
[281] Interview dated July 1., 2019
[282] https://www.worldcargonews.com/news/news/mci-puts-propane-on-ice-61018

Table 1: Refrigerants used in Reefers

Refrigerant code	GWP	ODP	Comments/remarks
R404A - Pentafluoroethane, 1,1,1-Tetrafluoroethane, 1,1,1,2-Tetrafluoroethane	3922	0	To be phased out by 2019; R404a would no longer be serviced in the EU after 2020 and then banned at a later date”
R134A - 1,1,1,2-Tetrafluoroethane	1430	0	Currently, the mainstay refrigerant;
R513A (56% R1234yf and 44% R134a)	573	0	Compatible with existing equipment design/lubricants, for retrofit and new systems; Excellent capacity and energy efficiency match to R134a
CO_2	1	0	Natural refrigerant; however, comparatively, current cost and technical complexity is high

1.4 Fans

Cooling, and where necessary fresh air, is provided in the reefer units by means of forced convection using circulating fans. The mode of circulation of air around the goods in the container depends on the nature of goods. In addition to the external heat gains in the reefer, internal heat gains due to respiration has to be removed when transporting or storing goods such as fruits and vegetables. In case of pre-cooled frozen goods, such as meat only external heat gains have to be removed. However, in both cases heat addition due to the fan motor has to be removed. In addition to convective heat exchange, fresh air is also allowed in controlled manner as per the requirements of the goods to influence and extend the shelf lives of the goods.

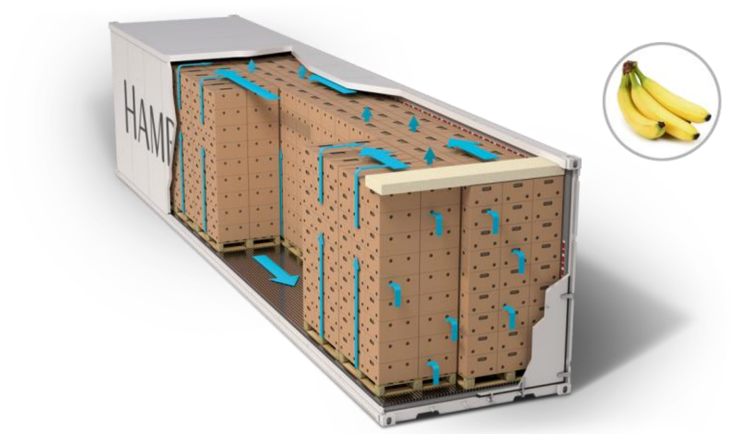

Figure 21: Airflow in an integral refrigerated container[283]

[283] https://www.hamburgsud-line.com/liner/en/liner_services/services_products/reefercargo/index.html

1.5 Controllers – capacity control and operation

Electronic controllers are used for the control and regulated of refrigeration units. Depending on the features of the controller it performs a variety of complex tasks from general control to automatic PTI and diagnosis. Faulty controllers on the other hand could be the source of damage to the transported goods or even the refrigeration system, refrigeration itself and the peripherals associated with it (e.g. sensors). Therefore, the controller design must be as robust as possible and able to withstand the prevalent ambient conditions in terms of heat, cold and moisture[284].

A number of factors influence the level of heat which has to be removed from a container i.e. the operating status, the internal and external temperature, or the sort of the goods that is currently loaded. Maximum heat values usually only occur in cooling operation if the goods do not have their nominal temperature and are generating extra heat due to biological processes[285].

In addition to the factors described above the actual power consumption of a reefer depends on ambient conditions and its operating status. The internal temperature of the container determines the required evaporation temperature of the refrigerant. Generally, for a fixed speed compressor vapour compression refrigeration cycle, the higher the internal temperature, the higher the electrical power consumption, the higher the refrigeration capacity that is available for the same reefer and the higher its efficiency[286]. For example, the cooling capacity of Daikin Zesita series for an ambient temperature of 38 °C and an internal temperature of 2 °C and -18 °C is 12 kW and 6.5 kW, respectively[287].

The main reason for this contra-intuitive behaviour of energy consumption vs. refrigerated temperature is that cargo temperature control dead bands are stricter. It is not possible to freeze a cargo that is supposed to be maintained close to 1 °C for instance. For freezing on the other hand, it is always possible to operated at lower temperature than the set-point temperature. Consequently, for refrigerated mode close to zero °C the on/off cycle period is shorter for chilled cargo with more cycling losses. In addition, air flow has to be maintained (and fan power is significant) in chilled mode, while in frozen conditions, it can be reduced[288].

The most important operating modes are outlined in the table below.

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[284] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_01.html
[285] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_03_01.html
[286] https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_01_02.html
[287] https://www.daikinreefer.com/zestia/specifications-options/
[288] Interview, Cambridge Refrigeration Technology (2019)

Table 2: Operating modes in reefers

Operating mode	Description
Operation for frozen goods	During low temperatures operation (approximately below -10°C), small fluctuations in temperature are insignificant impact on the goods. The cooling compressor used to regulate the temperature is therefore switched on and off in this mode. The circulating fans are operated at low speed, thereby reducing their power consumption. Traditionally the temperature is regulated by means of the return air temperature, i.e. the temperature of the air coming out of the cargo. If this temperature exceeds the nominal value by e.g. 1 °C, cooling starts (the compressor is switched on), and when the temperature falls e.g. 0.2 °C below the nominal value, it is switched off again. To prevent the compressor from constantly switching on and off, a minimum period must have elapsed between at the two switching operations[289] or alternatively a VSD could be uses.
Operation for chilled goods	Operation in chilled mode requires more precise temperature control than operation in frozen mode, especially at about -10 °C. Also, circulating fans operate at higher speeds and the internal temperature is regulated by means of supply air temperature. To neither freeze nor explore positive temperatures, compressor runs constantly to limit such temperature fluctuations[290].
Defrosting	When the ambient temperature is going to approximately +10 °C, the air cooler is defrosted at regular intervals, since the surface temperature on the air cooler can be below 0 °C from this temperature. The defrosting interval could be controlled by a timer or a temperature sensor. During defrosting, the circulating fans in the container and the cooling circuit are stopped. The air cooler and the drip tray are electrically heated.

Compressor that are powered via a frequency converter – variable speed control drive (VSD) can achieve more precise temperature control and energy savings[291]. VSDs enables the compressor to run at lower and higher speeds and thus use enough power required to reach the desired temperature, instead of turning the compressor on and off when the inside temperature exceeds the desired temperature set-points. VSDs are available for both scroll[292] and reciprocating[293] compressors. Also, multi-stage compressors are used to maximize capacity while minimizing power consumption[294][295]. However, there is a tendency that customers are less interested in the energy consumption of the reefer, because the reefers energy consumption is not measured and/or it is often little expenditure compared to the total setup[296].

289 https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_07_01.html
290 https://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_07_01.html
291 „
292 https://www.daikinreefer.com/zestia/technologies/
293 https://www.mcicontainers.com/products/star-cool/compressor
294 https://www.mcicontainers.com/products/star-cool/compressor
295 https://www.carrier.com/container-refrigeration/en/worldwide/products/Container-Units/NaturaLINE/
296 Interview dated 04/06/2019

Further competing technologies for capacity control are:

- Hot gas bypass: Very inefficient but allows accurate temperature control in chilled condition
- On-off cycling: Not so inefficient but problem to manage accurate temperature control in chilled condition
- Scroll unloading (Digital scroll Emerson or other two stage scroll compressor options): Better than on-off cycling, allows accurate temperature control in chilled conditions.
- VSD: Refrigerant flow rate reduction allows to operate continuously at low load with thus lower DT at heat exchangers and thus lower pressure difference. Performance improves as compared to full load operation.
- Multi compressor has the same type of advantage as VSD (with lower performance improvement) but is not common in this capacity range.

To supply any load level, combinations are possible, and technologies used for chilled / frozen conditions may vary.

1.6 Data logger and temperature records

Because of quality assurance, regulation and insurance claim purposes internal temperature records of reefers are maintained. Generally, the temperature log covers a period of thirty-one days. Digital data loggers are used, which can record and store their measured values, and also for longer periods of up to one year[297]. In addition, increased use of more effective monitoring such as remote monitoring of all reefers from a single location in the ship are used. An addition to save time, these methods increases the crew response and reaction time in an event of a refrigeration failure[298]. There are also pilot projects that integrate reefers to cloud based systems to enable even more remote monitoring of the reefers from any point in the world.

1.7 Diesel generator

Reefer units are typically operated using a 3-phase A.C. power supply, which is typically supplied by the ships' power supply, from the grid when at land, or alternatively by a diesel generator (DG), which is either clipped on to the refrigeration unit (for example, Carrier POWERLINE® RG15 TIER 4[299], KLINGE Dual refrigerated containers[300] etc.), or integrated (Mostly for trailer units, but could be also used for stationary units, when not connected to AC mains.) with the refrigeration unit under a single casing (for example, All S-Series Trailer Units of Thermo King) or mounted under the trailer unit (for example, Carrier POWERLINE® UG15 TIER 4[301]). In addition, although they are not considered as reefers,

[297] https://www.identecsolutions.com/wp-content/uploads/2018/08/PR_PT_Ship-and-Offshore_SmartShip_JUNY18.pdf
[298] https://www.coolingindia.in/remote-temperature-monitoring-of-reefer-containers/
[299] https://www.carrier.com/container-refrigeration/en/worldwide/products/generator-sets/rg15-tier-4/
[300] https://klingecorp.com/
[301] https://www.carrier.com/container-refrigeration/en/worldwide/products/generator-sets/ug15-tier-4/

TRUs can also have self-powered diesel units, i.e., cooling compressor is run by the diesel engine, with an option for electric backup.

Table 3: Output power of DG sets used to power reefer refrigeration units

	Apparent power	**Output power**	**Examples**	**Typical Industry Compliance**
Clip on DG set for AC supply	18.75 kVA	15 kW	Carrier POWERLINE® RG15 TIER 4[302]; SG-3000 Series Generator Sets	U.S. Environmental Protection Agency (EPA) Tier 4
Under mount DG set for AC supply		15 kW	Carrier POWERLINE® UG15 TIER 4[303]; SG-3000 Series Generator Sets[304]	U.S. Environmental Protection Agency (EPA) Tier 4
Integrated DG set with Cooling compressor		kW < 19 19 < kW < 37	Yanmar Engine in Thermo King Unit Model - TriPac, Heat King, All Self-Powered Truck Units[305], and All C-Series Units. - All S-Series Trailer Units.	EPA Tier IV and CARB compliance

[302] https://www.carrier.com/container-refrigeration/en/worldwide/products/generator-sets/rg15-tier-4/
[303] https://www.carrier.com/container-refrigeration/en/worldwide/products/generator-sets/ug15-tier-4/
[304] https://thaireefer.co.th/wp-content/themes/transport/pdf/genset/TK_60222_Genset_SG-3000_12-2007-EN.pdf
[305] Truck units are self powered diesel units, i.e., cooling compressor is run by the diesel engine, with an option for electric backup

Annex II Primary energy factors and energy prices

1. Introduction

Depending on situations, electricity required by the refrigerated containers can be supplied by:

- A ship diesel engine burning heavy fuel oil.
- Electricity (ship at port and connected to the mains, or reefer at port and waiting next transportation step). Average EU electricity mix is used here.
- Diesel generator burning diesel fuel

For each situation, the primary energy content and the price of the electric kWh consumption of the refrigerated container is investigated.

2. Primary energy factors

2.1 Primary energy calculation of the working plan study[306]

$$E_{fuel,final} = \frac{E_{el,final}}{\eta_{mot}\,\eta_{gen}}$$

And

$$E_{prim} = E_{fuel,final} \times \frac{E_{fuel,prim}}{E_{fuel,final}}$$

Table 57: Primary energy needed per final energy of different fuels for diesel and gasoline engines[109]

Fuel	Expended primary energy units per unit final energy $\frac{E_{prim}}{E_{fuel,final}}$	Typical engine efficiencies η_{mot}	Typical generator efficiencies η_{gen}	Primary energy needed for 1 kWh of final energy consumption (in MJ)
Diesel	1.18-1.23	0.5	0.8	10.8
Gasoline	1.16-1.21	0.38	0.8	14.0
Electricity	2.5	n.a.	n.a.	9.0

Approximate primary energy consumption kept: 10 MJ/kWh (close to average between 10.8 for diesel engine and 9 for grid electricity)

[306] Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC, Task 3 Final Report.

Reference used in the Working plan study for that calculation is (although it is not mentioned what is used exactly in this reference): JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, Well-to-Tank Report Version 4.a, Appendix 2: Summary of energy and GHG balance of individual pathways, Well-to-wheels analysis of future automotive fuels and powertrains in the European Context, 2014.

2.2 About the primary energy factor for EU electricity

This coefficient has been reviewed recently. The value kept is 2.1 [307]. Note that this coefficient does not consider the energy required for extraction, import, refining or distribution of coal, gas or fuel oil. It does not consider either the electric grid losses. It is however the initial choice made in the ErP methodology. Hence, for electricity, primary energy factor would rather be today: 3.6*2.1=7.56 or around 7.6 MJ/kWh.

2.3 About the primary energy factor for diesel engine

To get comparable figures, the « Expanded energy units per unit final energy » factor should not be considered either in that case, as it is not considered for electricity.

Generator efficiency of 0.8 is much too low. 0.95 seems more reasonable[308].

Diesel engine efficiency may vary importantly depending on its size.

To nominal efficiency and generator conversion (95 % efficiency supposed), it is necessary to add inefficiencies due to part load conditions, which are stronly dependent of the real factor of use of each motor. For older ships (1992 with 3 motors for 2000 TEU refrigerated containers), we have an estimate at 25 % efficiency loss[309] and which corresponds to 42 to 48 % average load.

For diesel motor on ship: In average a TEU is transported by a Panamax size container ship of say 4000 TEU ; secondary engine, supposing 15 plugs/100 TEU (Dynamar study 2018, MCI lines) at 10 kW each is 15/100 x 10 x 4000 / 1000 (MW) or about 7 MW. This can be a very efficient motor with nominal efficiency above 50 % [310,311]. Say 50 %. However, average load is low because it must be sized to face high outdoor temperature and more chilled containers. With 25 % degradation and 95 % alternator efficiency, this leads to: 0.5 x 0.95 x 0.8 = 0.38. Corresponding primary energy factor is:

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[307] Revised Energy Efficiency Directive
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.328.01.0210.01.ENG
[308] http://www.effship.com/PartnerArea/MiscPresentations/Dr_Wild_Report.pdf
[309] http://www.effship.com/PartnerArea/MiscPresentations/Dr_Wild_Report.pdf
[310] http://www.effship.com/PartnerArea/MiscPresentations/Dr_Wild_Report.pdf
[311] https://www.mandieselturbo.com/docs/default-source/shopwaredocumentsarchive/two-stroke-low-speed-diesel-engines.pdf The reference is for stationary electricity generation, and thus includes alternator conversion inefficiencies. However, large ship motors are smaller so 50 to 55 % is considered without considering the alternator conversion.

1 /0.38*3.6=9.5 MJ/kWh

When used on truck or rail or in stationary mode at port relying on diesel generator, a dedicated small size engine is used of few 10 kW. Efficiency is lower, typically 35 to 40 %. Load ratio is not better than for large motors, so overall efficiency will be closer to 0.4 x 0.95 x 0.8 = 0.306. Corresponding primary energy factor is 1/ 0.306 x 3.6=11.8 MJ/kWh.

3. Energy prices

The price of the electric kWh consumed varies depending on the situations.

In the table below, prices are computed when burning heavy fuel oil on board or diesel on land.

	Fuel oil from ship	**Diesel generator truck/rail/port**
Brent price (USD/bbl)	60	60
Conversion EUR / USD	0,91	0,91
Oil price correction	0,75	2,44
bbl/t conversion	7,6	7,6
LHV (MJ/t)	41000	43000
Motor av. efficiency	38%	31%
Consumption (MJ)	3,6	3,6
EUR/kWh	**0,07**	**0,28**

Sources for fuel prices:

- IFO380 price (IFO380 is the standard heavy fuel oil for shipping) is normally about 75 % of the Brent crude oil price[312];
- Diesel price is extracted from "The European Commission's Oil Bulletin"[313]; latest price without VAT (October 7 2019 bulletin) has been used or 1.14 EUR/L. The correction of 2.44 (ratio of this price to the Brent price after conversions) includes taxes (other than VAT) in Europe plus transportation, refining and distribution costs of crude oil.

Regarding electricity prices[314] for electricity consumed at port, industrial prices should be used. Prices (excluding VAT and other recoverable taxes and levies) vary depending on the total consumption of the site. For large shipping ports in Europe, it is supposed electricity consumption is either in IF (energy consumption in the interval > 70 and < 150 GWh) or

312 https://shipandbunker.com/news/world/802738-bunker-prices-unusually-high-relative-to-crude-as-hfo-discount-to-brent-disappears
313 http://data.europa.eu/euodp/en/data/dataset/eu-oil-bulletin/resource/e1f9f44f-f5ae-4a55-b4c8-6ae85ee67d9c
314 Eurostat, Electricity prices for non-household consumers.

in IG (energy consumption > 150 GWh) consumption band. For these consumption levels, average EU price as 2018 is respectively 0.076 Euro/kWh and 0.069 EUR/kWh. Thus, electricity from grid and from ship diesel engine have similar prices in Europe.

Annex III

EU and World trade data both import and export on perishable goods (dairy, fishery products, fruit, meat and vegetables) (Data from Dynamar).

IMPORTS – EU	2008	2013	2014	2015	2016	2017
Region	tons	tons	tons	tons	tons	tons
Europe	2,345,000	2,542,000	2,654,000	2,818,000	3,056,000	3,136,000
Far East	1,472,000	1,254,000	1,180,000	1,114,000	1,158,000	1,178,000
Australasia	897,000	683,000	675,000	665,000	692,000	597,000
ISC	297,000	317,000	345,000	302,000	360,000	394,000
Middle East	618,000	584,000	474,000	458,000	483,000	472,000
Africa	4,294,000	4,141,000	4,090,000	4,292,000	4,565,000	5,010,000
North America	652,000	577,000	628,000	629,000	653,000	638,000
C. America/Carib	4,017,000	3,827,000	4,067,000	4,200,000	4,471,000	4,816,000
South America	5,081,000	4,323,000	4,204,000	4,138,000	4,206,000	4,415,000
Total imports	**19,673,000**	**18,248,000**	**18,316,000**	**18,616,000**	**19,644,000**	**20,658,000**

IMPORTS – EU	2008	2013	2014	2015	2016	2017
Commodity	tons	tons	tons	tons	tons	tons
Dairy	150,000	117,000	127,000	86,000	92,000	75,000
Fishery products	3,725,000	3,661,000	3,840,000	3,835,000	3,934,000	3,979,000
Fruit	12,341,000	11,506,000	11,548,000	11,923,000	12,749,000	13,556,000
Meat	796,000	609,000	603,000	610,000	604,000	574,000
Vegetables	2,662,000	2,356,000	2,198,000	2,161,000	2,266,000	2,475,000
Total imports	**19,673,000**	**18,248,000**	**18,316,000**	**18,616,000**	**19,644,000**	**20,658,000**

IMPORTS – EU	2008	2013	2014	2015	2016	2017
Region	tons	tons	tons	tons	tons	tons
Bananas/plantains	4,618,000	4,892,000	5,121,000	5,281,000	5,524,000	5,917,000
Fish	2,722,000	2,704,000	2,823,000	2,816,000	2,906,000	2,920,000
Oranges	816,000	886,000	830,000	890,000	949,000	1,051,000
Pineapple	866,000	853,000	935,000	833,000	847,000	942,000
Grapes	577,000	576,000	598,000	603,000	609,000	666,000
Molluscs	529,000	534,000	562,000	564,000	569,000	587,000
Tomatoes	445,000	441,000	487,000	481,000	525,000	568,000
Lemons & Limes	421,000	441,000	360,000	441,000	553,000	501,000
Avocados	217,000	252,000	303,000	343,000	447,000	486,000
Crustaceans	430,000	423,000	455,000	455,000	458,000	472,000
Apples	504,000	669,000	495,000	455,000	445,000	448,000
Other fruit	312,000	332,000	330,000	298,000	404,000	429,000
Potatoes	349,000	455,000	285,000	306,000	376,000	429,000
Melons	353,000	338,000	361,000	382,000	379,000	411,000
Other vegetables	333,000	363,000	373,000	311,000	207,000	402,000
Other	4,708,000	4,090,000	3,999,000	4,158,000	4,444,000	4,428,000
Total imports	**19,673,000**	**18,248,000**	**18,316,000**	**18,616,000**	**19,644,000**	**20,658,000**

EXPORTS - EU	2008	2013	2014	2015	2016	2017
Region	tons	tons	tons	tons	tons	tons
Europe	5,581,000	6,534,000	5,746,000	4,565,000	4,082,000	4,070,000
Far East	1,711,000	2,596,000	3,336,000	3,607,000	4,675,000	4,511,000
Australasia	89,000	134,000	164,000	184,000	197,000	196,000
ISC	23,000	24,000	74,000	64,000	78,000	100,000
Middle East	549,000	820,000	1,058,000	1,176,000	1,177,000	1,097,000
Africa	1,890,000	2,983,000	3,535,000	3,734,000	3,451,000	3,498,000
North America	390,000	474,000	586,000	666,000	716,000	776,000
C. America/Carib	191,000	171,000	253,000	261,000	291,000	316,000
South America	86,000	240,000	312,000	433,000	413,000	378,000
Total exports	**10,509,000**	**13,976,000**	**15,062,000**	**14,690,000**	**15,078,000**	**14,942,000**

EXPORTS - EU	2008	2013	2014	2015	2016	2017
Commodity	tons	tons	tons	tons	tons	tons
Dairy	699,000	907,000	867,000	902,000	1,004,000	997,000
Fishery Products	1,366,000	1,385,000	1,611,000	1,414,000	1,394,000	1,526,000
Fruit	2,537,000	3,944,000	4,341,000	3,996,000	3,702,000	3,385,000
Meat	2,976,000	4,189,000	4,365,000	4,613,000	5,558,000	5,372,000
Vegetables	2,932,000	3,551,000	3,877,000	3,766,000	3,421,000	3,662,000
Total exports	**10,509,000**	**13,976,000**	**15,062,000**	**14,690,000**	**15,078,000**	**14,942,000**

EXPORTS - EU	2008	2013	2014	2015	2016	2017
Commodity	tons	tons	tons	tons	tons	tons
Swine	2,562,000	2,605,000	2,648,000	2,913,000	3,696,000	3,402,000
Poultry	1,271,000	1,264,000	1,324,000	1,322,000	1,433,000	1,481,000
Fish	1,377,000	1,277,000	1,498,000	1,305,000	1,285,000	1,403,000
Apples	1,552,000	1,507,000	1,736,000	1,735,000	1,564,000	1,284,000
Onions & Shallots	762,000	768,000	804,000	967,000	891,000	1,024,000
Cheese and curd	765,000	782,000	719,000	717,000	797,000	826,000
Seed Potatoes	635,000	651,000	736,000	761,000	664,000	687,000
Potatoes	598,000	486,000	715,000	630,000	571,000	571,000
Bovine	287,000	274,000	349,000	345,000	393,000	438,000
Other Vegetables	298,000	339,000	340,000	318,000	289,000	387,000
Pears and quinces	406,000	351,000	473,000	362,000	298,000	339,000
Oranges	287,000	318,000	342,000	302,000	317,000	299,000
Peaches	366,000	307,000	357,000	297,000	226,000	251,000
Kiwi	239,000	222,000	207,000	196,000	242,000	178,000
Butter	126,000	124,000	149,000	185,000	207,000	171,000
Other	2,057,000	2,703,000	2,665,000	2,336,000	2,205,000	2,203,000
Total exports	**10,509,000**	**13,976,000**	**15,062,000**	**14,690,000**	**15,078,000**	**14,942,000**

TOTAL EU TRADE	2008	2013	2014	2015	2016	2017

Region	tons	tons	tons	tons	tons	tons
Europe	7,926,000	9,076,000	8,400,000	7,383,000	7,138,000	7,206,000
Far East	3,183,000	3,850,000	4,516,000	4,721,000	5,833,000	5,689,000
Australasia	986,000	817,000	839,000	849,000	889,000	793,000
ISC	320,000	341,000	419,000	366,000	438,000	494,000
Middle East	1,167,000	1,404,000	1,532,000	1,634,000	1,660,000	1,569,000
Africa	6,184,000	7,124,000	7,625,000	8,026,000	8,016,000	8,508,000
North America	1,042,000	1,051,000	1,214,000	1,295,000	1,369,000	1,414,000
C. America/Carib	4,208,000	3,998,000	4,320,000	4,461,000	4,762,000	5,132,000
South America	5,167,000	4,563,000	4,516,000	4,571,000	4,619,000	4,793,000
Total trade	**30,182,000**	**32,224,000**	**33,378,000**	**33,306,000**	**34,722,000**	**35,600,000**

TOTAL EU TRADE	2008	2013	2014	2015	2016	2017
Commodity	tons	tons	tons	tons	tons	tons
Dairy	849,000	1,024,000	994,000	988,000	1,096,000	1,072,000
Fishery Products	5,091,000	5,046,000	5,451,000	5,249,000	5,328,000	5,505,000
Fruit	14,878,000	15,450,000	15,889,000	15,919,000	16,451,000	16,941,000
Meat	3,772,000	4,798,000	4,968,000	5,223,000	6,162,000	5,946,000
Vegetables	5,594,000	5,907,000	6,075,000	5,927,000	5,687,000	6,137,000
Total trade	**30,182,000**	**32,224,000**	**33,378,000**	**33,306,000**	**34,722,000**	**35,600,000**

TOTAL EU TRADE	2008	2013	2014	2015	2016	2017
Commodity	tons	tons	tons	tons	tons	tons
Bananas/plantains	4,618,000	4,892,000	5,121,000	5,281,000	5,524,000	5,917,000
Fish	4,099,000	3,981,000	4,321,000	4,121,000	4,191,000	4,323,000
Oranges	1,103,000	1,204,000	1,172,000	1,192,000	1,266,000	1,350,000
Pineapple	866,000	853,000	935,000	833,000	847,000	942,000
Grapes	577,000	576,000	598,000	603,000	609,000	666,000
Molluscs	529,000	534,000	562,000	564,000	569,000	587,000
Tomatoes	445,000	441,000	487,000	481,000	525,000	568,000
Lemons & Limes	421,000	441,000	360,000	441,000	553,000	501,000
Avocados	217,000	252,000	303,000	343,000	447,000	486,000
Crustaceans	430,000	423,000	455,000	455,000	458,000	472,000
Apples	2,056,000	2,176,000	2,231,000	2,190,000	2,009,000	1,732,000
Other fruit	312,000	332,000	330,000	298,000	404,000	429,000
Potatoes	947,000	941,000	1,000,000	936,000	947,000	1,000,000
Melons	353,000	338,000	361,000	382,000	379,000	411,000
Other vegetables	631,000	702,000	713,000	629,000	496,000	789,000
Other	6,765,000	6,793,000	6,664,000	6,494,000	6,649,000	6,631,000
Swine	2,562,000	2,605,000	2,648,000	2,913,000	3,696,000	3,402,000
Poultry	1,271,000	1,264,000	1,324,000	1,322,000	1,433,000	1,481,000
Onions & Shallots	762,000	768,000	804,000	967,000	891,000	1,024,000
Cheese and curd	765,000	782,000	719,000	717,000	797,000	826,000
Seed Potatoes	635,000	651,000	736,000	761,000	664,000	687,000
Bovine	287,000	274,000	349,000	345,000	393,000	438,000
Pears and quinces	406,000	351,000	473,000	362,000	298,000	339,000

Peaches	366,000	307,000	357,000	297,000	226,000	251,000
Kiwi	239,000	222,000	207,000	196,000	242,000	178,000
Butter	126,000	124,000	149,000	185,000	207,000	171,000
Total trade	**31,788,000**	**32,227,000**	**33,379,000**	**33,308,000**	**34,720,000**	**35,601,000**

WORLD TRADE	2008	2013	2014	2015	2016	2017
Commodity	tons	tons	tons	tons	Tons	tons
Diary	2,709,000	3,347,000	3,394,000	3,301,000	3,377,000	3,344,000
Fishery products	16,738,000	20,817,000	21,844,000	20,973,000	21,453,000	21,415,000
Fruit	49,565,000	60,047,000	61,217,000	61,076,000	63,665,000	64,981,000
Meat	22,687,000	27,213,000	28,301,000	27,436,000	29,116,000	29,630,000
Vegetables	27,108,000	33,422,000	34,240,000	33,812,000	35,461,000	35,878,000
Total trade	**118,807,000**	**144,847,000**	**148,996,000**	**146,597,000**	**153,072,000**	**155,249,000**

EXPORTS	2008	2013	2014	2015	2016	2017
Region	tons	tons	tons	tons	Tons	Tons
Europe	17,532,000	25,468,000	27,098,000	27,175,000	28,046,000	28,876,000
Far East	21,385,000	26,674,000	27,846,000	26,953,000	27,668,000	28,948,000
Australasia	5,334,000	6,010,000	6,344,000	6,557,000	6,424,000	6,318,000
ISC	4,515,000	7,270,000	6,860,000	6,341,000	7,328,000	6,169,000
Middle East	4,832,000	6,384,000	5,830,000	5,564,000	5,556,000	4,459,000
Africa	9,754,000	11,568,000	12,075,000	11,772,000	12,484,000	13,110,000
North AMerica	24,142,000	28,168,000	28,443,000	28,119,000	29,729,000	30,773,000
C. America/Carib	11,352,000	12,252,000	13,065,000	12,383,000	13,480,000	13,978,000
South America	19,961,000	21,053,000	21,435,000	21,734,000	22,359,000	22,617,000
Total Exports	**118,807,000**	**144,847,000**	**148,996,000**	**146,597,000**	**153,072,000**	**155,249,000**

IMPORTS	2008	2013	2014	2015	2016	2017
Region	tons	tons	tons	tons	tons	Tons
Europe	38,240,000	37,458,000	37,107,000	35,068,000	35,393,000	37,561,000
Far East	28,793,000	36,817,000	38,970,000	39,968,000	43,239,000	45,235,000
Australasia	975,000	1,205,000	1,220,000	1,177,000	1,197,000	1,217,000
ISC	2,165,000	2,456,000	2,899,000	2,919,000	2,640,000	2,542,000
Middle East	9,932,000	13,376,000	14,204,000	14,542,000	15,364,000	13,476,000
Africa	5,672,000	9,063,000	10,083,000	9,722,000	9,848,000	9,105,000
North America	20,680,000	29,280,000	30,253,000	31,444,000	33,080,000	33,661,000
C. America/Carib	3,381,000	3,336,000	3,647,000	3,594,000	3,565,000	3,682,000
South America	2,295,000	3,236,000	3,221,000	3,240,000	3,456,000	3,484,000
Total Imports	**112,133,000**	**136,228,000**	**141,605,000**	**141,672,000**	**147,782,000**	**149,963,000**

Annex IV

Stock of shipping reefers in units of each size related to EU-28 from 1990 to 2030 (based on Dynamar)

	20 ft - units	40 ft - units	Total - units	Total - TEU
1990	254	6,224	6,478	12,702
1991	539	13,195	13,734	26,928
1992	813	19,917	20,730	40,647
1993	1,230	30,124	31,354	61,478
1994	1,621	39,709	41,330	81,039
1995	1,997	48,921	50,917	99,838
1996	2,380	58,318	60,698	119,015
1997	2,637	64,595	67,232	131,827
1998	3,118	76,381	79,499	155,880
1999	3,569	87,438	91,007	178,444
2000	3,958	96,960	100,918	197,878
2001	4,407	107,983	112,390	220,373
2002	4,906	120,201	125,107	245,308
2003	5,438	133,238	138,676	271,914
2004	6,002	147,057	153,060	300,117
2005	6,608	161,896	168,504	330,399
2006	7,202	176,447	183,649	360,095
2007	8,003	196,083	204,086	400,169
2008	8,783	215,177	223,960	439,137
2009	7,585	185,830	193,415	379,245
2010	8,068	197,655	205,722	403,377
2011	9,121	223,453	232,573	456,026
2012	9,813	240,428	250,242	490,670
2013	10,397	254,716	265,112	519,828
2014	11,028	270,189	281,217	551,407
2015	11,924	292,148	304,073	596,221
2016	12,057	295,386	307,442	602,828
2017	12,565	307,831	320,395	628,226
2018	13,064	320,058	333,122	653,180
2019	13,605	333,319	346,923	680,242
2020	14,208	348,100	362,308	710,409
2021	14,892	364,857	379,749	744,606
2022	15,659	383,642	399,301	782,944
2023	16,490	404,012	420,502	824,514
2024	17,364	425,415	442,779	868,194
2025	18,271	447,650	465,921	913,571
2026	19,219	470,858	490,077	960,935
2027	20,211	495,163	515,374	1,010,537
2028	21,240	520,385	541,626	1,062,011
2029	22,283	545,944	568,228	1,114,172
2030	23,333	571,649	594,981	1,166,630