TOSHIBA
Leading Innovation

Frequently Asked Questions

1. How will the new F-gas regulation affect the choice of refrigerant for heat pump air conditioners?

Heat pump air conditioning systems are impacted by the new F-gas regulation, the gradual phase down of HFC's quantities on the market will push the industry to use lower GWP refrigerants. Since 2017 the price of HFC's has started to rise significantly, especially for those gases with high Global Warming Potential (GWP).

Note: In the new F-gas regulation, the use of HFC's with GWP greater than 750 will be prohibited from 2025 for mono split-system room air conditioners containing less than 3 kg of refrigerant.

2. What is Toshiba's refrigerant of choice as a replacement for R-410A heat pump air conditioners?

R-410A alternatives must provide an acceptable compromise in terms of GWP, human safety, energy efficiency, and system cost. After several years of research and evaluation, Toshiba along with other air conditioner manufacturers are switching from R-410A to R-32 (Difluoromethane HFC32) refrigerant which has a lower Global Warming Potential (GWP), is better for the environment and delivers greater energy efficiency. However this gas is mildly flammable (A2L safety class) and does require some redesign change. These changes will be seen in our new range of R32 residential and light commercial heat pump air conditioning systems.
The benefits of HFC R-32 are:-

- Zero Ozone Depletion
- 1/3 GWP of HFC 410A (GWP675 v GWP2088)
- Superior energy efficiency
- High refrigeration capacity and thermal conductivity
- Low pressure drop
- Single component refrigerant easy to handle and recover
- Low toxicity
- Readily available

R32 is classified as A2L "lower flammability" according to the International Standard for Refrigerant Designation: -

- Safety Classification: ISO 817:2014
- REACH Registration number: 01-2119471312-47

International Standard ISO 817:2014 segregates the flammability class of refrigerants into 4 categories: -

- (Class 1)	no flame propagation	non flammable
- (Class 2L)	lower flammability	mildly flammable
- (Class 2)	flammable (Class 2)	flammable
- (Class 3)	higher flammability	highly flammable

Refrigerants are divided into two groups according to toxicity: -

- (Class A) signifies refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm
- (Class B) signifies refrigerants for which there is evidence of toxicity at concentrations below 400 ppm

3. How easy is R-32 to ignite?

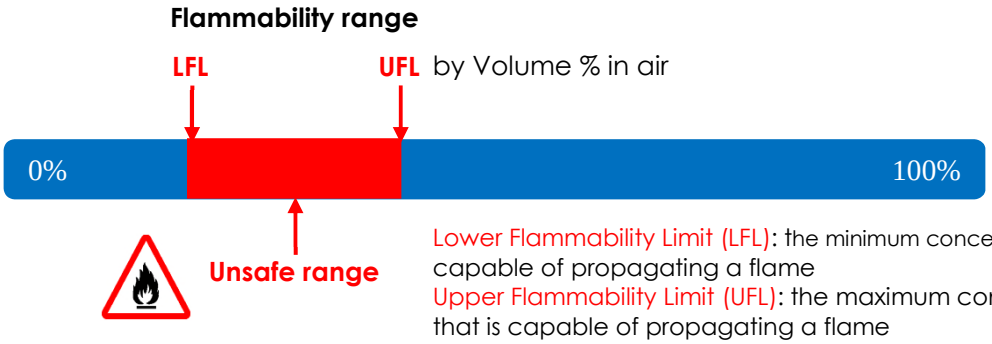
For a gas mixture to ignite, 3 specific conditions must be met simultaneously.

1) The concentration of the flammable gas must lie between the Lower and Upper Flammability Limit (LFL and UFL) for the particular gas. For R-32 this is between 14% volume and 29% volume (300 grams/m^3 and 620 grams/m^3 respectively). It should be noted that a 14% concentration of any foreign gas in air is the accepted oxygen deprivation safety limit.

2) The second requirement is that the flammable gas mixture must have a velocity lower than 3 to 4 times its laminar burning velocity for R-32 this is 6.7 cm/second. In the case of a wall mounted split system, because R-32 is heavier than air any leaked refrigerant leaving the unit will exceed 4 times its burning velocity due to gravity within 40 cm. Furthermore, measurements and computational fluid dynamic modelling has shown that even a rapid R-32 leak of 1000 grams in one minute will not present a flammable mixture outside of the wall unit due to dilution and the falling velocity of the refrigerant.

3) The third requirement for ignition to take place is an ignition source of sufficient energy. Unlike common flammable gases such as propane, R-32 cannot be ignited by the usual static electricity we experience. Tests by independent laboratories in Japan and America[1] have demonstrated that sparks from light switches or contactors in residential appliances do not have sufficient energy to ignite R32. Therefore, the most likely source of ignition in a residential application is an open flame such as a candle, combustion heater or gas cook top.

Therefore, if an accidental release of R32 refrigerant occurs from a cylinder or piping, the velocity will be too high to ignite near the release point and the concentration will be too low where the velocity becomes low enough. So, ignition of R-32 is difficult even if it is attempted intentionally. Even if all 3 criteria are met simultaneously, other characteristics such as quenching distance can limit propagation should ignition occur. For example, if ignition occurred inside a large commercial circuit breaker, the flame will not propagate outside the circuit breaker enclosure unless the enclosure has openings bigger that the quenching distance 5-6 mm for R-32.



Lower Flammability Limit (LFL): the minimum concentration of the refrigerant that is capable of propagating a flame
Upper Flammability Limit (UFL): the maximum concentration of the refrigerant that is capable of propagating a flame

All flammable refrigerants must be handled with precautions and in accordance with local regulations, In accordance with operation and installation manuals and safety standards. Manufacturers' refrigerant charge limits must always be complied with when installing and servicing equipment.

4. Are they specific safety requirements to install heat pump air conditioners with A2L refrigerants

It is mandatory to comply with safety requirements from local building safety codes with regard to the installation and operation of heat pump air conditioning equipment containing A2L mildly flammable refrigerants for human comfort in buildings and design, installation and maintenance must comply with safety requirements from EN378: 2016.

All refrigerant gasses classified in ISO 817 can initiate some form of adverse health effect if the concentration is high enough, therefore it is technically incorrect to claim any classified refrigerant as "non-toxic". However, compared to all other common refrigerants, R-32 requires the highest concentration level to cause any adverse health effect. International Standard ISO 817 defines 2 toxicity classes for refrigerants:-

- (Class A) Lower Chronic Toxicity
- (Class B) Higher Chronic Toxicity

R32 is categorized as Class A. Class A refrigerants are called non-toxic and Class B are called toxic.

Compared to all other Class A (Lower Toxicity) refrigerants such as R-22, R-410A, R-134a, R-290 (Propane) and R-600a (Isobutane), R-32 has the highest (safest) Acute Toxicity Exposure Limit (ATEL) of 220,000 ppm. R-32 has the highest ATEL of the 99 refrigerants designated in Table 5 of ISO 817.

5. What is produced when R-32 decomposes?

As is the case with all fluorinated refrigerants, R-32 will decompose and produce toxic by-products such as hydrogen fluoride and carbon dioxide when burnt. The likelihood of R-32 being present within its flammable range and then being ignited is extremely rare. The most probable (but still extremely unlikely) cause of R-32 thermal decomposition would be a leak into an enclosed space that has an open flame source such as an electric or gas heater close to floor level. In this scenario, with a wall mounted split system mounted directly above the heater, testing has demonstrated that production of hydrogen fluoride from leaked R-32 is no more than the hydrogen fluoride produced by non-flammable refrigerants such R410A. Further, laboratory measurements of decomposition products from contact with a hot surface rather than a high temperature flame demonstrated that a 5% R-32 in air mixture exposed to a red hot wire produced significantly less hydrogen fluoride (less than 5ppm) than an equivalent mixture of R-22 (more than 70ppm of hydrogen fluoride).

Analysis of R-32 exposed to a variable temperature heater revealed that hydrogen fluoride started to be produced when the temperature was in the range of 570°C to 590°C. Note that R-410A, R-407C, R-404A, R-134A, R-22 and other commonly used non-flammable refrigerants also start to decompose at around the same temperature at which R-32 starts to decompose. Hydrogen fluoride has a very foul odour. It would be expected that if an R-32, R-22 or R-410A leak occurred in a room with a combustion source the smell would alert occupants to leave the room before they are exposed to dangerous levels of hydrogen fluoride.
As HCFC and HFC refrigerants have been used in air conditioners for close to 50 years without major concern about the toxic by-products of combustion, any risk associated with the decomposition of R-32 can be managed in the same manner as existing fluorinated refrigerants.

6. Can we retrofit an R-410A heat pump air conditioners with a lower GWP refrigerant?

No, for now, all R-410A alternatives are mildly flammable (A2L safety class) and cannot be used to retrofit existing equipment designed to operate with non-flammable R-410A refrigerant. Retrofitting R-410A systems with mildly flammable refrigerants should not be attempted to avoid damaged to equipment and potential damage to property and or possible injury to humans or animals.

7. Will it be possible to service heat pump air conditioners using R-410A in the future?

In the new F-gas regulation there are no restrictions on the use of R-410A refrigerant for servicing refrigeration or air conditioning equipment. The new regulation introduces a gradual phase down of HFC's quantities (in tons of C02 equivalent) with 21% of the reference level still available after 2030 to service equipment. Therefore, it should be possible to service heat pump air conditioners with R-410A for the foreseeable future.

8. I have heard about possible taxes on HFC's, can you tell me more?

Several governments, e.g., Denmark, Norway and Spain have introduced taxes on HFC's. Some schemes tax all sales of refrigerant, others only tax refrigerant used for the servicing of equipment. The level of tax is typically related to the GWP of the refrigerant (for example; 20 € per ton of CO2 equivalent in Spain). The French government is also evaluating the implementation of a tax on HFC refrigerants from 2019. With uncertainties on refrigerant prices, we should anticipate that the quantity of refrigerant in a unit and the GWP of the refrigerant are becoming significant market drivers for customers who will operate heat pump air conditioners for the next 15/20 years.

9. How do you expect HFC prices to change in the future?

With the gradual reduction of HFC quotas in tons of CO2 equivalent (see F-gas regulation) refrigerant suppliers have to lower the overall GWP of all refrigerants they place on the market while delivering the same quantities of refrigerant (the market demand in tons of refrigerant is supposed constant). To achieve this target, refrigerant suppliers have increased the price of refrigerants with high GWP's to push customers to use alternative gases with lower GWP's. Between 2016 and 2018 prices of refrigerant used for heat pump air conditioners increased by approximately 500%

10. What are the alternatives to R-410A for new equipment?

There are multiple solutions to replace R-410A. Medium GWP HFCs (GWP 300 - 750), R-32 and R32/HFO blends (R-452B or R-454B) are potential candidates to replace R-410A. All are mildly flammable (A2L safety class). All these substances are subject to the HFC phase down of the F-gas regulation, therefore they are considered as transitional refrigerants. Hydrocarbons, such as propane, have very low GWP's (GWP < 10) but are highly flammable (A3 safety class). As such, they could be acceptable for small outdoor systems with limited refrigerant charge. ***HFO refrigerants such as R-1234zd Class A1 with nearly zero GWP*** are long term solutions but they will require the development of new compressor technologies.

Caution: retrofitting R-410A systems with mildly flammable refrigerants should not be attempted to avoid damaged to equipment and potential damage to property and or possible injury to humans or animals.

11. I have heard about constraints for importers of HVAC equipment made outside Europe

According to the new F-gas regulation from January 2017 importers of HVAC equipment made outside the EU shall ensure that the refrigerant contained in the equipment is covered by F-gas quotas. In practical terms importers of equipment shall purchase from a refrigerant producer or importer in Europe an authorization to use its quotas. The cost of the authorization will represent a non-negligible asset for the importer and will have an impact on the price of the equipment. In addition every year the importer shall request an accredited auditor to reconcile the quantity of refrigerant allowed by the authorization with the actual quantity placed on the market in products. In conclusion since 2017 it is complex and more costly to import HVAC equipment into the EU.

12. Can we use CO2 as refrigerant for heat pump air conditioners?

Although CO_2 (R-744) is a very effective refrigerant for commercial refrigeration, it is not suitable for heat pump air conditioning applications because of its low efficiency. However, CO2 can be a good solution for high temperature heat pumps such as those intended for domestic hot water production.

GLOSSARY

13. HCFC refrigerant

HCFC stands for hydrochlorofluorocarbons. HCFC's like R-22 refrigerant are substances depleting the ozone layer. HCFC's are being phased out under the Montreal Protocol. In Europe since the 2000's HCFC refrigerants are prohibited in new equipment and their production banned since 2010.

14. HFC refrigerant

HFC stands for hydrofluorocarbons. They belong to the family of fluorinated gases. HFC's have been developed by the industry to replace substances depleting the ozone layer. HFC's are mainly used as refrigerant for refrigeration & air conditioning equipment, aerosols sprays and insulation foams. HFC's are non-toxic and have zero ozone depletion potential. All HFC's are potent greenhouse gases.
R-32, R-32/HFO blends and R-134a/HFO blends are lower GWP alternatives to R-410A & R-134a however they still fall into the basket of fluorinated gases controlled by the F-gas regulation and therefore seen as transitional refrigerants

15. HFO refrigerant

HFO stands for hydrofluoroolefin. It's the latest generation of synthetic refrigerants. Pure HFO's have zero impact on the ozone layer (ODP) and nearly zero global warming potential (GWP). HFO's are non-toxic; however in certain conditions most of them are mildly flammable when mixed with air. HFO R-1234yf has been designed as a substitute of HFC R-134a for the car industry. HFO refrigerants developed for the HVAC industry are R-1234zd, R-1234ze(E) and R-1233zd(E) with nearly zero GWP, pure HFO's are not subject to the measures of the F-gas regulation and are therefore long term refrigerant solutions.

16. HFC/HFO blend refrigerant

HFCs can be mixed with HFOs to offer lower GWP alternatives with close thermodynamic properties to existing HFC refrigerants. R32/HFO blends designed as an alternative to R-410A, e.g.: R-452B, R-454B are mildly flammable while R-134a/blends, e.g. R-450A, R-513A, are non-flammable. It is important to note that all HFC/HFO blends are on a regulatory point of view HFCs. All HFC/HFO blends fall into the basket of fluorinated gases controlled by the F-gas regulation and are therefore seen as transitional refrigerants.

17. EN 378 standard

The European technical standard EN378 relates to safety and environmental requirements in the design, manufacture, construction, installation, operation, maintenance, repair and disposal of refrigerating systems and appliances including heat pumps. It consists of four parts:

Part 1: Basic requirements, definitions, classification and selection criteria
Part 2: Design, construction, testing, marking and documentation
Part 3: Installation site and personal protection
Part 4: Operation, maintenance, repair and recovery

The last edition EN378: 2016 includes the new 2L safety classes

18. Building safety codes

National building safety codes are setting mandatory safety requirements for buildings, for HVAC equipment they often refer to EN378 technical standard. In certain markets, e.g. Italy, France, Spain... national building codes can set more stringent safety requirements than the EN378 standard.

19. Refrigerant safety class

EN378 technical standard sets refrigerant safety classes depending on their flammability and toxicity. Substances with lower toxicity are classified from A1 non-flammable to A3 highly flammable while substances with higher toxicity are classified from B1 non-flammable to B3 highly flammable.
In 2006 new A2L & B2L classes were introduced for mildly flammable refrigerants with a burning velocity < 10cm/second.

Safety classes of main refrigerants

	LOWER TOXICITY		HIGHER TOXICICITY	
	Class	**Refrigerants**	**Class**	**Refrigerants**
NON FLAMMABLE	A1	R-22, R-407C, R-410A, R-134a, R-450A, R-513A, R-744 (CO2)...etc.	B1	Seldom used
MILDLY FLAMMABLE (NEW) (burning velocity < 10cm/s)	A2L	R-32, R-452B, R-454B HFO R-1234yf & R1234ze...etc.	B2L	R-717 (ammonia)...etc.
FLAMMABLE	A2	R-152A...etc.	B2	Seldom used
HIGHLY FLAMMABLE	A3	R-290 (propane) R-600a (isobutane)...etc.	B3	No refrigerants

20. Refrigerant GWP

GWP stands for Global Warming Potential. It is a relative index to quantify the amount of heat trapped in the atmosphere by a greenhouse gas. By definition the GWP of carbon dioxide (CO2) is equal to 1. Example: - R-134a with GWP 1430 means that 1kg of R-134a has the same impact on global warming as 1430kg of CO2. GWP values are calculated over a period of 100 years and are updated by the Intergovernmental Panel on Climate Change (IPCC) on a regular basis. Thus GWP values may slightly differ in the different publications. Refrigerants can be classified in 3 main categories

1) Legacy refrigerants with high GWP >750
2) Transitional refrigerants with medium GWP 750 to 300
3) Long term refrigerants with very low GWP < 150

GWP VALUES OF MAIN REFRIGERANTS			
Refrigerant	**Type**	**GWP**	**GWP category**
R-404A	HFC	3920	high > 750
R-410A	HFC	2088	High > 750
R-134a	HFC	1430	High > 750
R-407C	HFC	1774	High > 750
R-452B	HFC	698	High > 750
R-32	HFC	675	Medium 750-300
R-513A	HFC	631	Medium 750-300
R-450A	HFC	604	Medium 750-300
R-454B	HFC	466	Medium 750-300
R-1234zd	HFO	4.5 (<1)	Very Low < 150
R-1234ze(E)	HFO	7 (<1)	Very Low < 150
R-1234yf	HFO	4 (<1)	Very Low < 150
R-1233zd(E)	HFO	4.5 (1)	Very Low < 150
R-717 (NH3)	Natural	0	Very Low < 150
R-744 (CO2)	Natural	1	Very Low < 150
R-290 (propane)	Natural	3	Very Low < 150

Notes: GWP values based on International Panel Climate Change (IPCC) 4th Assessment Report and 2014 F-gas regulation. For HFOs values indicated into bracket are based on IPCC 5th Assessment Report

21. New F-gas regulation

The first European regulation on fluorinated gases (F-gas) was adopted in 2006 to reduce the emission of fluorinated gases with high global warming potential and thus to protect the environment. Since 1st January 2015 the new F-gas regulation N° 517/2014 is applicable in all EU member states.
The new F-gas regulation introduces three key measures:

a) A phase down mechanism with a freeze of HFC quantities placed on the market in 2015 followed by a gradual reduction down to 21% in 2030. To implement the phase down, the European Commission allocates yearly quotas to refrigerant producers and importers for selling refrigerants on the market. To neutralize the GWP value of each gas, quotas are expressed in tons of CO2 equivalent (the mass of refrigerant multiplied by the GWP value)

HFC phase down (tons of CO2 equivalent)							
Year	**2015**	**2016**	**2018**	**2021**	**2024**	**2027**	**2030**
Quantity	100%	93%	63%	45%	31%	24%	21%

Note: 2015 base line = average quantity sold in 2009-2019

b) Bans on the placing on the market of the following products

Commercial refrigerators & freezers (hermetic systems) than contain	GWP ≥ 2500	January 2020
	GWP ≥ 150	January 2022
Stationary industrial & commercial refrigeration (exclusive of chillers) that contain	GWP ≥ 2500	January 2020
Multipack centralized commercial refrigeration with a capacity > 40 kW (except primary circuit of cascade system with GWP < 1500) that contain	GWP ≥ 150	January 2022
Movable room air conditioners that contain	GWP ≥ 150	January 2020
Single split system air conditioner with a charge less than 3 kg that contain	GWP ≥ 750	January 2025

c) Bans on the use of HFC's with very high GWP > 2500 (R404A...) to service equipment

Virgin refrigerant with GWP > 2500 to service equipment	January 2020
Recovered or recycled refrigerant with GWP > 2500 to service equipment	January 2030

22. Refrigerant charge limits for R-32

Maximum allowable charge size for R-32 M_{max} (kg)				
Height Factor (m)	**0.6**	**1.0**	**1.8**	**2.2**
Area (m^2)	**Floor Mounted M_{max} (kg)**	**Window M_{max} (kg)**	**Wall Mounted M_{max} (kg)**	**Ceiling Mounted M_{max} (kg)**
9	1.03	1.71	3.09	3.77
12	1.19	1.98	3.56	4.35
13.8	1.27	2.12	3.82	**4.67**
15	1.33	2.21	3.98	4.87
18	1.45	2.42	4.36	5.33
21	1.57	2.62	4.71	5.76
24	1.68	2.80	5.04	6.16
27	1.78	2.97	5.34	6.53
30	1.88	3.13	5.63	6.88
33	1.97	3.28	5.91	7.22
36	2.06	3.43	6.17	7.54
39	2.14	3.57	6.42	7.85
42	2.22	3.70	6.66	8.15
45	2.30	3.83	6.90	8.43
48	2.37	3.96	7.12	8.71
51	2.45	4.08	7.34	8.98
54	2.52	4.20	7.56	9.24
57	2.59	4.31	7.76	9.49
60	2.66	4.43	7.97	9.74
63	2.72	4.53	8.16	9.98
66	2.78	4.64	8.35	10.21
69	2.85	4.75	8.54	10.44
72	2.91	4.85	8.73	10.66
75	2.97	4.95	8.91	10.88
78	3.03	5.05	9.08	11.10
81	3.09	5.14	9.26	11.31
84	3.14	5.24	9.42	11.52
87	3.20	5.33	9.59	11.72
90	3.25	5.42	9.76	11.92
90.7	3.26	5.44	9.79	11.97

Indicates values for largest SDI RAV-GP1401AT-E with maximum charge to 75m

Minimum floor area for R-32 A_{min} (m^2)				
Height Factor (m)	**0.6**	**1.0**	**1.8**	**2.2**
Charge (kg)	**Floor Mounted Minimum Floor Area (m2)**	**Window Minimum Floor Area (m2)**	**Wall Mounted Minimum Floor Area (m2)**	**Ceiling Mounted Minimum Floor Area (m2)**
< 1.8	**No Volume Restriction**			
1.8	27.6	9.9	3.1	2.1
1.9	30.7	11.1	3.4	2.3
2.0	34.0	12.3	3.8	2.5
2.1	37.5	13.5	4.2	2.8
2.2	41.2	14.8	4.6	3.1
2.3	45.0	16.2	5.0	3.3
2.4	49.0	17.6	5.4	3.6
2.5	53.2	19.1	5.9	4.0
2.6	57.5	20.7	6.4	4.3
2.7	62.0	22.3	6.9	4.6
2.8	66.7	24.0	7.4	5.0
2.9	71.6	25.8	8.0	5.3
3.0	76.6	27.6	8.5	5.7
3.1	81.8	29.4	9.1	6.1
3.2	87.2	31.4	9.7	6.5
3.3	92.7	33.4	10.3	6.9
3.4	98.4	35.4	10.9	7.3
3.5	104.3	37.5	11.6	7.8
3.6	110.3	39.7	12.3	8.2
3.7	116.5	41.9	12.9	8.7
3.8	122.9	44.2	13.7	9.1
3.9	129.4	46.6	14.4	9.6
4.0	136.2	49.0	15.1	10.1
4.1	143.1	51.5	15.9	10.6
4.2	150.1	54.0	16.7	11.2
4.3	157.4	56.7	17.5	11.7
4.4	164.8	59.3	18.3	12.3
4.5	172.3	62.0	19.1	12.8
4.6	180.1	64.8	20.0	13.4
4.675	186.0	67.0	20.7	13.8
4.7	188.0	67.7	20.9	14.0
4.8	196.1	70.6	21.8	14.6
4.9	204.3	73.6	22.7	15.2
5.0	212.8	76.6	23.6	15.8

Indicates values for largest SDI RAV-GP1401AT-E with maximum charge to 75m

23. F-Gas Training for HFC blends using Hydrocarbons

Toshiba recommends that all installation and service work for R-32 heat pump air conditioners should only be undertaken by responsible persons who have attended a training course for the safe use and handling of HFC's containing hydrocarbons. A "City and Guild 6187-21" course will be available and will include: -

- 1 day training in total that will include a multiple choice written assessment and practical assessment.
- Mixture of theory in classroom and practical assessment in workshop.
- Practical work consisting of brazing a test joint, pressure testing, charging and recovery of refrigerant.
- City & Guilds 6187-21 Hydrocarbon Safe Handling qualification.

Training will be conducted on a basis of one qualified trainer and a maximum of two trainee delegates per day. Course fees vary dependent on national locations but typically range between £225 to £375 excluding VAT and delegates will learn about: -

- GWP & ODP what are they
- Introduction to Hydrocarbons
- Physical properties of Hydrocarbons
- Saturated pressure and temperature details
- Condensing pressures with HC Refrigerants
- Temperature glide and superheat settings
- Lubricants, materials, desiccants and oils
- Flammability and charge size calculations
- Appliance considerations
- Safe working environment and safe practise
- Leak testing, brazing & charging
- Venting and recovery
- Handling, storage and transporting