Department of Housing and Public Works
Building Industry and Policy Division
Technical Services

Management guideline for the phase-out of Refrigerant R22

Impacts and strategies for building owners and facility managers

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Queensland Government

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Executive summary

This guideline provides advice relating to the use of refrigerant R22, a commonly used refrigerant found within many air conditioning and refrigeration systems.

R22 is an ozone depleting substance that is progressively being phased out in accordance with Australia's obligation to the *Montreal Protocol on Substances that Deplete the Ozone Layer,* which has been in place since 1987.

Since that time the Commonwealth Government has had in place a phase-out strategy and various laws to restrict the production and importation of a range of ozone depleting substances (particularly refrigerants) in Australia. The aim is to gradually reduce supply of all significant ozone depleting substances to nil by 2030.

Under the Commonwealth Government strategy those refrigerants with very high ozone depleting potential have now been phased out in Australia. The next stage of the phase-out strategy is now impacting the availability of R22, which has a lower ozone depleting potential.

The phase-out of R22 is being applied via a reduction in allowable imports of R22 into Australia. In 2014, Australia's import quota was reduced by 75% compared to that of 2013, to be followed by a further reduction in 2016 when imports will remain at a minimum level until complete phase-out occurs in 2030.

The continued use of R22 presents a risk to owners and/or managers of building assets. The ongoing reduction in imports is resulting in reduced availability and an elevated cost for this refrigerant, where obtainable. Availability of the refrigerant is expected to be highly constrained from 2016 onwards, when the import quota reduces to its lowest level.

There are four management options available for R22-charged equipment: retain and manage the equipment, retrofit the equipment with an alternative refrigerant, renew with like-for-like equipment, or upgrade the system after an engineering analysis.

While retrofitting equipment to use a different refrigerant is possible, this option has limited application. The success of retrofitting will depend on a variety of considerations including the retrofit refrigerant used, system capacity, seals, valves and component changes, warranty requirements and ongoing parts availability. In many cases upgrading to new equipment may be the only acceptable solution when it can no longer be maintained or repaired.

There are numerous factors such as funding, procurement method, engineering design and equipment lead-time which can add considerable time and affect the chosen strategy for the management of R22-charged equipment. A management strategy needs to consider not only the technical solutions, but also the business priorities and needs of the owner, such as the intended future usage for affected buildings.

Building owners and facility managers are encouraged to carry out audits of their buildings and develop registers of R22-charged equipment. The management strategy adopted can be prioritised based on key characteristics such as age of equipment, criticality of the site and other factors, in order to reduce risk and proactively future-proof the adversely affected mechanical services within buildings.

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Purpose of this guideline

This guideline aims to provide advice to building owners and facility managers of the issues associated with the continued use of refrigerant R22 in air conditioning and refrigeration systems, and to encourage the development of strategies for the planned management, recovery, reclamation or safe destruction of this ozone depleting substance.

Who should use this guideline?

Owners, operators and facility managers of buildings and other facilities with air conditioning or refrigeration systems that contain equipment which operates using R22.

Scope

This guideline provides background information, outlines the challenges faced and offers technical options for managing R22. It is designed to assist building owners, operators and facility managers to assess key management considerations, develop audit procedures and to offer technical options for R22-charged equipment:

1. Retain and manage the equipment;
2. Retrofit the equipment with an alternative refrigerant;
3. Renew with like-for-like equipment; or
4. Upgrade the system after an engineering analysis.

This guideline applies to vapour compression cycle refrigeration and air conditioning systems — such as window-mounted room air conditioners, split systems, package units and chilled water production machines (chillers), as well as commercial and industrial refrigeration systems including storage cases and cool rooms — that currently operate with R22 refrigerant.

This guideline does not apply to motor vehicle air conditioning, domestic refrigerators and freezers, or equipment operating on an absorption refrigeration cycle.

Glossary

ARCtick – A licence scheme introduced by the Australian Government in response to Australian obligations under the Montreal Protocol. Under the scheme the Australian Refrigeration Council Ltd (ARC) administers refrigerant handling licences and refrigerant trading authorisations on behalf of the Australian Government, for professionals in the refrigeration and air conditioning industry.

Chlorofluorocarbon (CFC): CFCs are fluorocarbon compounds in which all the hydrogen atoms of a hydrocarbon are replaced with atoms of chlorine and fluorine. Previously used as working fluids in vapour-compression cycle air conditioning and refrigeration equipment until their phase-out under the Montreal Protocol in the early 1990's (e.g. R12).

Collected refrigerant: The process of a wholesaler taking back recovered refrigerant, where the refrigerant is destined to be reclaimed or destroyed.

Destroyed refrigerant: Used refrigerant that has been broken down in a dedicated industrial process.

Global Warming Potential (GWP): A relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. It is calculated over a specific time interval, (20, 100 or 500 years). GWP is expressed as a ratio to carbon dioxide (whose GWP is standardised to 1).

Note: the GWP data provided in this guide is for information only and is based on the fifth *IPCC assessment report*. Other guides and standards may cite different GWP data sourced from earlier IPCC assessments.

Hydrochlorofluorocarbon (HCFC): HCFCs are CFCs with hydrogen reintroduced to reduce the molecular stability of the compound (which means it is more liable to break down before reaching the ozone layer). Used as working fluids in vapour-compression cycle air conditioning and refrigeration equipment, (common HCFCs include HCFC-22 (R22), HCFC-123, HCFC-144, HCFC-141b and HCFC-142b).

Hydrofluorocarbon (HFC): A class of fluorocarbon compounds that contain the carbon–fluorine bond. These substances do not deplete the ozone layer as they do not contain chlorine or bromine. Used as working fluids in vapour-compression cycle air conditioning and refrigeration equipment. High-GWP HFC refrigerants may be the subject of future usage controls.

ODP tonne: An ODP tonne is the quantity of the HCFC that results from multiplying its mass in tonnes by its ozone depleting potential. Note that this amount, when referring to HCFC import quotas, includes all HCFC refrigerants, not just R22.

Ozone: Ozone (or trioxygen O_3) is a triatomic molecule, consisting of three oxygen atoms.

Ozone Depleting Potential (ODP): The ODP of a chemical compound is the relative amount of degradation to the ozone layer it can cause, with trichlorofluoromethane (R-11 or CFC-11) the reference, being standardised to an ODP of 1.0.

Ozone Depleting Substances (ODS): Substances that deplete the ozone layer and are widely used in refrigeration, air conditioning, fire extinguishers, as solvents for cleaning, electronic equipment and as agricultural fumigants. The most potent ODS are controlled by the Montreal Protocol.

Ozone layer: A portion of the stratosphere with a higher concentration of ozone (from 2 to ~ 8 ppm) and prevents damaging ultraviolet light from reaching the Earth's surface.

Recovered refrigerant: Used refrigerant that has been extracted from air-conditioning or refrigeration equipment. Refrigeration technicians recover refrigerant during the course of their work, which could be through repair, maintenance or decommissioning of plant, and store it in provided gas cylinders which are typically between 10 to 20 kilograms in capacity.

Reclaimed refrigerant: Used refrigerant that has been undergone a process of cleaning and purifying (removing impurities, moisture and acids, etc) to restore it to an as-new condition. The term *recycling* can also apply to this process. *Reclamation* is solely used in this document for clarity.

Refrigerant R22: Chlorodifluoromethane or difluoromonochloromethane. This colourless gas is a hydrochlorofluorocarbon (HCFC). It is commonly used as a propellant and refrigerant. *ODP = 0.055, GWP = 1810*.

Reused refrigerant: Used refrigerant that is inserted into an air-conditioning or refrigeration system, without undergoing a relamation process. Reused refrigerant is usually tested for moisture and acidity before being reused to ensure it is not contaminated.

Refrigerant classification: The ISO 817 system of classifying refrigerants into safety groups according to health and safety risks assessed on the basis of flammability and toxicity. Classifications include A and B for toxicity and 1, 2, 2L and 3 for flammability. The safety classification system is used when designing equipment, determining maximum refrigerant charge sizes and defining the applications and locations in which they can be used.

Temperature glide: Temperature glide occurs in near-azeotropic and zeotropic mixtures**.** It is the temperature difference that occurs between the vapour state and liquid state during evaporation or condensation at constant pressure, i.e. the temperature in the evaporator and condenser is not constant, as it is for a pure refrigerant or azeotropic mixture of refrigerants.

Vapour-compression refrigeration cycle: A thermodynamic refrigeration cycle where a circulating refrigerant is used as the medium that absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere (usually to the ambient environment).

Working fluid: The working fluid is the pressurised gas or liquid that is used as a medium in a thermodynamic cycle. In an air conditioning, refrigeration or heat pump system, the working fluid is a liquid or gas refrigerant that absorbs or transmits energy as it evaporates (heats) and condenses (cools).

Background

What is R22?

R22 is a manufactured compound designed for use as the working fluid in refrigerative systems. It is a commonly used refrigerant gas contained within many existing air conditioning and refrigeration systems manufactured prior to 2005.

The R22 gas is contained inside a sealed refrigeration system. The R22 'charge' makes possible the cooling process for air conditioning (in summer) and can also enable heating (in winter) for some air conditioners. It is also used in commercial and industrial refrigeration.

R22 is a hydrochlorofluorocarbon (HCFC). It is one of a number of ozone-depleting substances (ODS) identified by the international community as harmful to the environment. R22 is also known as HCFC-22.

Phase-out of R22

The *Montreal Protocol on Substances that Deplete the Ozone Layer* (Montreal Protocol) is a protocol to the *Vienna Convention for the Protection of the Ozone Layer.* It is an international treaty designed to protect the ozone layer by progressively phasing out the production and use of numerous substances responsible for ozone depletion.

R22 and other HCFCs such as R123 are being phased out from use under the Montreal Protocol. Australia is a signatory to the Montreal Protocol, as is essentially every other developed country in the world (197 signatories in total), and therefore is required to abide by the Protocol's requirements.

Legislative requirements

Australia has adopted an advanced phase-out schedule for ozone depleting substances (ODS) including HCFCs. The phase-out schedule is specified in the Commonwealth Government's *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (The Act).

The Act is the legislative mechanism under which Australia meets its obligations to phase-out ODS under the Montreal Protocol, and limits greenhouse gas emissions by controlling the use of synthetic greenhouse gases under the *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. The Act controls the import, export, manufacture, acquisition, use, storage, handling and disposal of these substances. The Act specifies the limit of HCFC imports allowable for each calendar year.

In 2012 and 2013 the phase-out schedule reduced imports to only 16% of pre-phase-out importation levels. In 2014 and 2015 the quota is cut a further 75% — down to 4% of pre-phase-out imports by 2016. The import quota from 2016 to 2030 will remain at a stable minimum amount until final phase-out in 2030. From 2030 there will be no allowable imports of the refrigerant. Refer to Appendix A for full phase-out details and what these percentages mean in terms of future quantities of R22 available to the market.

Preventable emissions of R22 are prohibited. The Australian Refrigeration Council Ltd (ARC) administers refrigerant handling licences and refrigerant trading authorisations under the ARCtick licensing scheme. Any person handling R22 must hold the correct and current ARCtick licence.

Potential risks for building owners, operators and maintainers

R22 is the working fluid for an estimated 30% of all air conditioning and refrigeration systems in Australia, so the import quota reduction occurring now creates certain risks for building owners, operators and maintainers.

Due to the quota reduction many suppliers have advised that the sale of R22 to new customers has substantially reduced from January 2014 and will essentially cease in January 2016. As a consequence, beginning in 2014, it will progressively become more difficult to maintain R22-charged equipment due to the scarcity and cost of the refrigerant.

The purchase price of R22 has substantially increased in the last few years and is likely to continue to rise. Current market prices depend on commercial arrangements with suppliers and the quantity purchased. Current trade prices (October 2014) range from $115 to $230 per kilogram, retail prices are higher due to supplier mark-up. To put refrigerant replacement cost into perspective, at a supplied cost of $200/kilogram, a small single split-system air conditioner could be storing 3 kilograms or $600 worth of R22, a medium sized package unit could be storing 30 kilograms or $6,000 worth of R22, while a large chiller plant could be holding over 100 kg of refrigerant costing more than $20,000 to replace. It is also important to note that R22 prices will continue increasing as import quotas are reduced and the market supply is further restricted.

Equipment in air conditioning and refrigeration systems can require maintenance for various reasons, however 'breakdown maintenance' (i.e. unplanned repairs) involving a leak of some or all of the refrigerant charge is the major concern.

It is estimated that up to 8% of all R22 in use across facilities in Australia is lost to the atmosphere each year through equipment failure, thus requiring repair and recharge with new refrigerant. This could be a system developing a small leak and requiring repair and top-up of R22, or a system could suffer a catastrophic fracture of a component thus requiring repair and full restoration of the refrigerant charge. Older equipment is more prone to fatigue failure and loss of charge.

Some of the key risks that owners, operators and maintainers face moving forward are:

- Aging R22-charged equipment experiencing more frequent maintenance issues and/or failures;
- Scarcity of R22 resulting in exorbitant maintenance costs when refrigerant purchase is required;
- Increased scarcity of parts for R22-charged equipment , making maintenance more difficult;
- Possible unavailability of R22 (especially in remote areas) leading to an inability to repair equipment; and
- Business disruptions due to downtime of failed equipment that is not able to be repaired and/or re-charged.

Technical options for managing R22 equipment

There are four technical options available for managing R22-charged equipment.

The option most suitable for a particular item of equipment or a system will depend on the specific factors relevant to that equipment, as well as the building or site where it is located.

The factors most likely to dictate the selected option are age of equipment, plant condition, size of plant, geographical location and criticality of function served.

Figure 1 provides a summary of the available management options.

Figure 1: Technical options for addressing R22-charged equipment

Factors for Consideration	Technical options	Typical application
• Equipment Age • Plant condition • Capacity of plant • Geographical location • Criticality of function • Cost of option	Option 1: **Retain and manage** existing systems using enhanced maintenance procedures and updated leak prevention practices, until failure occurs (i.e. ‘run-to-fail’ strategy).	Systems that are not serving critical functions, are in good condition, and have significant remaining economic life. Reasonable surety of access to an ongoing supply of R22 despite import reductions.
	Option 2: ***Retrofit*** existing system with an alternate, non-ozone-depleting, non-flammable refrigerant (e.g. blended HFC refrigerants).	Systems where retrofit offers a cost effective short-medium term solution, that are in good condition and have significant remaining economic life,
	Option 3: ***Renew*** with like-for-like equipment which uses non-ozone-depleting refrigerant (i.e. similar cooling capacity and future-proof refrigerant where possible).	Smaller and less-complex systems that are aged, in poor condition, and whose function has not changed greatly since the original design and installation.
	Option 4: ***Upgrade*** the system after an engineering analysis. (i.e. New non-ozone-depleting equipment design and occupied space analysis; future-proof refrigerant where available).	Larger and complex systems that are old, in poor condition, and whose function, heat load or occupancy has changed since the original design and installation.

Applying the technical options and associated issues

Retain and manage equipment

The most passive management approach is to continue to run and maintain the R22-charged equipment until eventual failure occurs, before renewal. This is not a long-term solution; it can be used as an interim method to allow time to plan and fund a more proactive management approach. It will also allow the owner or operator to exploit the full economic life of the equipment.

The retain and manage option requires an enhanced maintenance regime with a leak prevention focus, including regular leak checks on high risk components where leaks commonly occur. The maintenance regime must also ensure the system is maintained to run as efficiently as possible as older equipment has higher ongoing operating costs.

This is the highest risk strategy and can expose the owners and operators to higher maintenance costs, refrigerant recharge costs, potential environmental harm, loss of provision of service and risk of business disruption.

This management approach is generally not recommended for refrigeration applications where a loss of service or a disruption to the continuity of service results in loss of essential product (e.g. frozen food, blood storage, etc.).

Stockpiling

Stockpiling virgin or recycled R22 refrigerant may be a way to help secure or guarantee a future supply of R22 to meet their service and maintenance needs. Legislative requirements exist for entities acquiring, possessing and disposing of HCFCs. Australian Standards apply to refrigerant storage facilities. A service company may be able to secure an on-going supply on your behalf.

From an environmental perspective, the stockpiling of R22 from decommissioned units for subsequent reuse in existing, still operating equipment is not a preferred option. Re-use of R22 is contrary to the intent of Australia's commitment to the Montreal Protocol, specifically that R22 is internationally recognised as an environmentally harmful substance that should not be permitted for widespread use. Systems using R22 are typically older and more prone to failure and leakage, reusing R22 in such systems increases the risk of environmental harm due to eventual atmospheric release.

Retrofit equipment with an alternative refrigerant

Where the existing R22-charged equipment has received effective maintenance and is in good condition, a short-to-medium term management approach is to retrofit the equipment to operate on a HFC-based refrigerant specifically designed as a replacement for R22. Retrofitting can be cost-effective for systems where the replacement cost of the equipment is far higher than the cost to retrofit. Retrofitting enables the owner to exploit the full economic life out of the installed equipment, but with reduced refrigerant availability risk.

The cost and the extent of modifications required for the retrofit process will depend on system parameters, equipment components and the retrofit refrigerant chosen for the application.

Retrofitted equipment will not normally be provided with an equipment warranty although there may be some limited warranty for the retrofit works. Retrofitted older equipment does not negate potential parts availability and support issues, as it continues to age.

Refer to Appendix B for more technical detail on the retrofit option and a summary of common retrofit refrigerants.

Renewal with like-for-like or engineered system upgrade

The long-term and proactive management approach is to renew R22-charged equipment by installing new low-GWP equipment. Systems that have reached the end of their economic life, in poor condition, uneconomical to retrofit, or serve critical functions should be renewed.

The benefits from like-for-like renewal or engineered system upgrades include:

- Minimised equipment downtime with a planned renewal (rather than breakdown failure)
- Less exposure to unplanned capital expenditure
- Improved reliability, resulting in lower maintenance costs
- Significantly energy-efficiency improvement of modern equipment
- New equipment warranty.

Long term energy cost savings exist where new equipment is more efficient than that which it replaces. Ongoing energy savings can offset the capital cost of installation, allowing funding to be directed to further R22 management works in the future.

Engineered system upgrades

An ‘engineered’ system upgrade (as opposed to a like-for-like equipment replacement) takes into consideration the variables of the conditioned space that determine the calculated cooling capacity of the new equipment. For example, in an air conditioned space some factors may have changed since the air conditioning equipment was originally installed. Changes that can be accommodated in an engineered design and selection process include:

- Greater use of computers and servers may mean the heat load has increased (existing air conditioning might not be coping in summer, therefore a like-for-like replacement will not cope either).
- Passive design changes or building modifications such as window shades and extra roof insulation may in fact result in a reduced heat load, thus enabling installation of a smaller (i.e. lower capacity) air conditioning system.
- The building may have been modified – e.g. rooms added, areas demolished, layout altered, functional usage changes, walls added or removed, etc.
- The occupancy volume may have changed – more or less people in the same space means different loads on the air conditioning due to a change in outdoor air requirements under Australian Standard 1668.2-2012.
- Technological changes in the types of equipment available – some equipment selections and system configurations may change due to advances in equipment designs and capabilities. This may have impacts on the need (or not) for plantroom space, access, services etc. Some older system designs may no longer be suitable and may require substantial re-engineering.

Key management considerations

There are many factors to be taken into account when developing a strategy to address the risks presented by the R22 phase-out. Although this subject is largely a technical one, management decisions for the implementation of such a strategy will be required, taking into consideration factors such as:

- Impact of business interruptions. For example, a retain and manage (to failure) strategy for equipment in an air conditioning system may carry the risk of an occupied space being without air conditioning for the time it takes to repair or obtain new air conditioning — which may mean the space is temporarily unsuitable for occupancy, or a critical function cannot be served.
- Time taken to carry out life-cycle assessment to determine the best choice for new equipment.
- Allowing enough time for professional engineering design and documentation to be prepared (particularly for complex sites with chillers).
- Allowing sufficient time for tendering and procurement processes.
- Allowing for equipment delivery lead time. For example, new chillers can sometimes have a lead time of four months.
- Technical assessment of brand and product selection. For example, the capital cost of equipment, its reliability, spare parts availability, after-sales service, energy efficiency and network compatibility should all be considered when selecting new equipment.
- Logistical efficiencies. For example, it may be more cost-effective to group works occurring in similar geographical areas together, especially in more remote locations.
- Management of asbestos and other workplace hazards. For example, if penetrations through walls are required to install new equipment, professional asbestos removal may need to take place first.
- Installation of new equipment should adhere to the current technical and performance requirements as outlined in the National Construction Code and various applicable Australian Standards. As an example, equipment that is currently roof-mounted and needs full replacement may now require roof walkways, handrails, safe access ladders and harness attachment points; which could potentially add substantial cost to the upgrade of roof-mounted equipment. In such situations a redesign to accommodate ground-mounted or plant room installed equipment may be beneficial.

Importantly, consideration needs to be given to funding proposed equipment upgrades and/or retrofit projects. Where costs are prohibitive or available funding is constrained, it may be useful to develop costed work programs and include them into annual financial budgetary cycles over a number of years. Such works should form part of, or be co-ordinated in with, capital works, minor works or maintenance works programs.

Auditing and prioritisation to manage risk

Risk management of R22-charged equipment is centred on knowing the extent of such equipment (i.e. having an accurate R22 register/asset list), selecting the appropriate technical option and prioritising implementation. A flowchart is provided in Figure 2 which summarises the recommended process.

Audit of assets

Desktop audit

Initially a *desktop audit* should be carried out to identify those sites and/or buildings suspected or known to be utilising air conditioning and refrigeration equipment charged with R22. Contributing information can be gleaned from sources such as:

- Building asset registers;
- Plant and equipment registers;
- Operation and maintenance (O&M) manuals;
- Servicing and maintenance contract agreements;
- Servicing and maintenance records or log books;
- Manufacturers' literature;
- Project specifications or commissioning documentation; and
- Tender, workshop or as-installed drawings and other technical documentation, such as those found in HPW Eplan.

Valuable information can also be gained from operational personnel such as on-site managers, facilities managers, or maintenance staff.

Detailed audit

The *desktop audit* can assist to conditionally prioritise sites for further evaluations. There will be many unknowns however, and ultimately a *detailed audit* may be required to clarify and confirm the presence of R22 in each item of equipment. In many cases this will include a site visit or contact with someone at the site to visually confirm the type of refrigerant in use.

Note: Air conditioning and refrigeration equipment is generally required to clearly display the type of refrigerant it uses. It can often be found marked on the compressor or on the name plate. Where the identity of the refrigerant in use in a system is unknown, a refrigerant sample analysis can be undertaken.

Key items of additional information that should be collected during the *detailed audit* are:

- Details of the equipment – make and model, cooling capacity;
- Function served – Description of the area and function served by the system (e.g. office, workshop, refrigeration store or cold room) and an assessment of its importance (i.e. a critical function or not?);
- Type of equipment – air conditioning or refrigeration, air or water cooled, chiller, package, split package, split system, room air conditioner or other;
- Age of the equipment and date of installation;

- Kilograms of refrigerant charge inside the system overall;
- Safety issues – these may have changed since the original installation;
- Location of equipment and ease of access – e.g. rooftop-mounted, wall-mounted;
- Any requirement for access equipment to facilitate an upgrade or ongoing maintenance (such as cranes, ladders, safety harness attachment points);
- Performance of the equipment (e.g. reliability, capacity problems, energy consumption).

Ideally this process will produce an R22 inventory that can assist future management, irrespective of the management strategy, or mix of strategies, applied. Often organisations don't move away from R22 in one step; management of R22 phase-out generally takes time and the R22 inventory is a useful management tool to assist this process.

Prioritisation of equipment for upgrade

Once a *detailed audit* has been completed, it allows R22-related works to be managed according to priority. Some equipment may need to be given a higher preference over other equipment depending on factors such as:

- The age of the equipment — older equipment is more likely to fail, has a limited supply of spare parts, and may be at the end of its economic life.
- Amount of refrigerant charge (kilograms) in the overall system — larger refrigerant charges carry more risk regarding damaging the ozone layer while also exposing building owners to high refrigerant replacement costs.
- Critical sites — sites which require constant provision and precise control of space conditions (e.g. archives, laboratories) usually need to maintain spare cooling capacity at all times. This may elevate the need to proactively manage the R22-charged equipment at these sites.
- Location — remote areas may have more difficulty in obtaining R22 and therefore it may be more important to contend with these sites first.

Destruction or Reclamation of R22

As a guiding rule, recovered R22 should not remain with the mechanic or contractor for reuse in subsequent R22 equipment repairs. Recovered R22 can be either destroyed or reclaimed by an approved processor.

Destruction

The destruction of recovered R22 ensures the removal of this ODS from the environment entirely. Persons involved with project works (i.e. engineers, designers, project managers, contractors, and refrigeration mechanics) should be made aware of any preference for R22 destruction during R22 upgrade or retrofit works. This requirement should be noted in contract documentation and specifications relating to the project.

Recovered R22 can be deposited at one of more than 250 collection points across Australia. A rebate is paid (currently $3.00 per kilogram) for the deposit of the refrigerant (based on weight) by Refrigeration Reclaim Australia (RRA).

RRA is a not-for-profit organisation that destroys surplus and unwanted ozone depleting and synthetic greenhouse gas refrigerants. The refrigerant is processed, tested and destroyed, using technologies that transform the refrigerants into harmless salts.

Reclamation

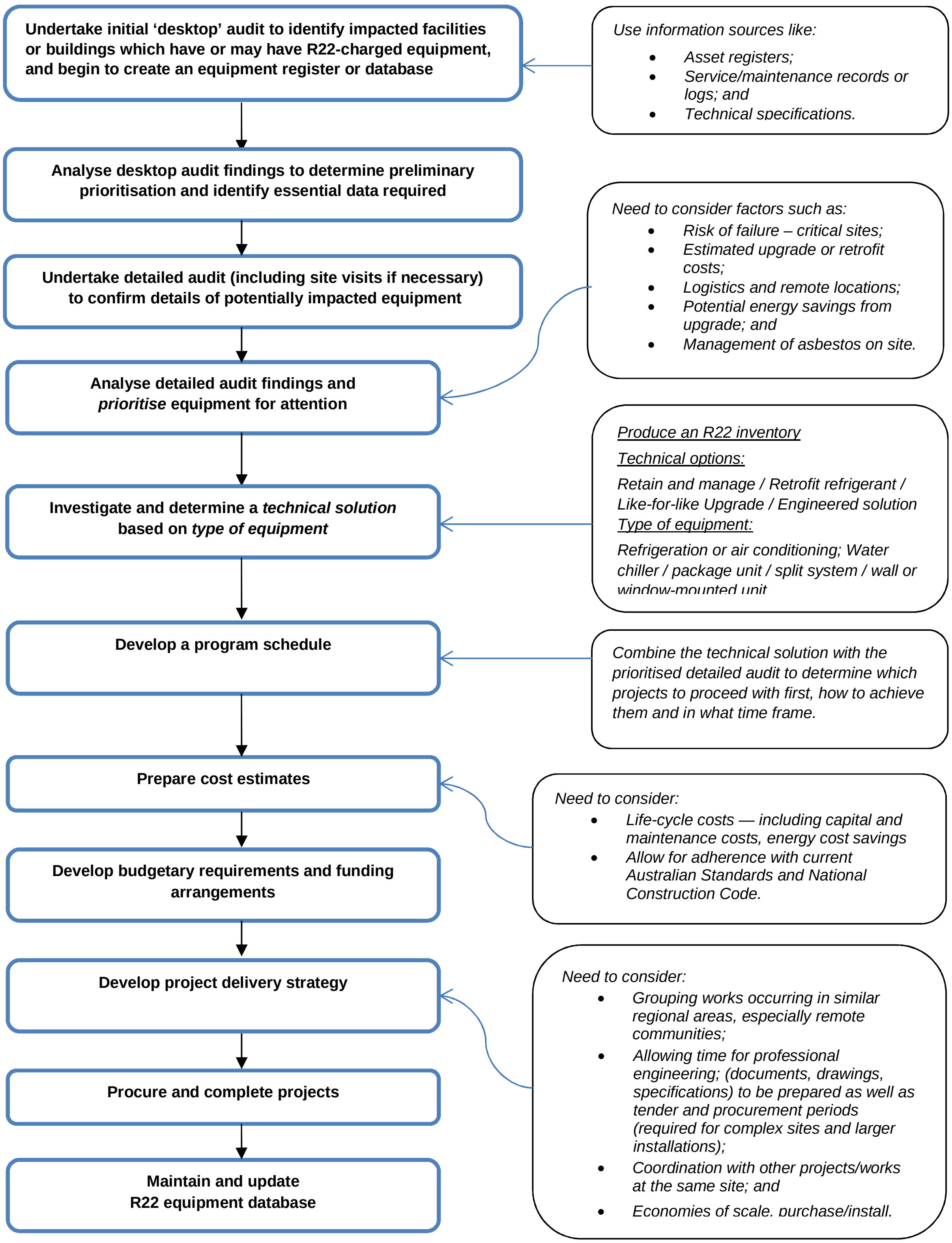
Recovered R22 can be reclaimed instead of being destroyed, depending on its condition.

Reclamation is the process of cleaning and purifying refrigerant back to an as-new condition based on the standard AHRI 700 *Standard for Specifications of Fluorocarbon Refrigerants*. A high quality feed stock, typically with a purity of more than 95%, is required for the successful and cost effective reclamation of refrigerant to return it to new specification.

The use of R22 reclaimed to a recognised standard was embraced in Europe as part of their phase-out strategy. Reclamation can insulate building owners, operators and maintainers against the impact of supply scarcity due to the ongoing phase-out; however using reclaimed R22 in aging equipment increases the possibility of atmospheric release at some point in the future, and is at odds with the intent of the *Montreal Protocol*.

The reuse of recovered refrigerant that has not been reclaimed can be detrimental to a vapour compression system. Used refrigerant can contain moisture, oils, acidity, particulates and non-condensable gasses. Reusing this refrigerant may cause corrosion to copper and aluminium components, shortening the life of heat transfer coils and compressors. Reusing refrigerant that has not been reclaimed may void equipment warranty.

Figure 2 — Recommended risk management strategy



Further information on the topic

- The Commonwealth Government Department of the Environment monitors the history of imports of ODS into Australia, manages the import and use of refrigerants and is responsible for the implementation of and compliance with the Montreal Protocol in Australia: http://www.environment.gov.au/protection/ozone/montreal-protocol

- Refrigerant Reclaim Australia (RRA) is the product stewardship organisation for the Australian refrigerants industry. RRA is a not-for-profit organisation created to work nationally with industry to share the responsibility for, and costs of, recovering, reclaiming and destroying surplus and unwanted refrigerants.

  RRA's aim is to improve the industry's environmental performance by reducing the level of emissions of refrigerants through its take-back program. Since being established in 1993, RRA has become integral in the management of used and unwanted refrigerant, and the reduction in emissions of ozone depleting and synthetic greenhouse gas refrigerants. https://refrigerantreclaim.com.au/

- The *Montreal Protocol on Substances that Deplete the Ozone Layer*: http://ozone.unep.org/new_site/en/montreal_protocol.php

- *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*: http://www.comlaw.gov.au/Details/C2013C00235

- *Cold Hard Facts II* http://www.environment.gov.au/system/files/resources/fa48d00d-1fb9-4797-90f4-47a6eed2c9c7/files/cold-hard-facts2.pdf
- *A study into HFC consumption in Australia*, Peter Brodribb and Michael McCann 2014, Canberra. http://www.environment.gov.au/system/files/resources/5c47433d-fd84-495f-adce-3484e0bc208e/files/hfc-consumption-australia-2013_0.pdf
- *UNEP's Report of The Technology And Economic Assessment Panel* (TEAP) May 2013 Volume 2 - Task Force Report - Additional Information to Alternatives on ODS

The Australian Institute of Refrigeration, Air conditioning and Heating (AIRAH) has produced a range of information relevant to R22 phase-out:

- *AIRAH Flammable Refrigerant Safety Guide* — contains a comprehensive list of the standards, regulations, and procedures that need to be considered when using flammable refrigerants. The guide is supplemented by three fact sheets and a video. http://www.airah.org.au/Flammable-Refrigerant-Safety-Guide-2013.pdf
- *AIRAH Methods of Calculating Total Environmental Warming Impact (TEWI) Best Practice Guideline*: http://www.airah.org.au/Best_Practice_Tewi_June2012.pdf
- Five HFC refrigerant levy fact sheets — These fact sheets also address replacement of R22 equipment, alternative and natural refrigerants, leak prevention strategies and energy efficiency: http://www.airah.org.au/HFC_Refrigerant_Levy
- Industry publication by AIRAH regarding R22 phase-out, April 2014: http://www.airah.org.au/HVACRNation/2014/04-14-HVAC&R-001.pdf

Appendix A HCFC phase-out

HCFCs and the Montreal Protocol

The Montreal Protocol addresses HCFCs in Annex C Group I and II for production and consumption control measures. The production and consumption base level tonnages and reduction schedules are different (allowable production levels are higher) because a signatory to the Montreal Protocol may be manufacturing and exporting HCFCs to other countries to allow them to use their consumption quotas.

The Ozone Protection and Synthetic Greenhouse Gas Management Act 1989, Part IV — HCFC quotas, Section 24 outlines the HCFC industry limits (imports) in Australia as shown in the following Table:

	HCFC Industry limit **(**Quantity of HCFCs in ODP tonnes per year**)**
1996~1999	250 *(pre phase-out usage)*
2000~2011	*(continued reduction, not shown/relevant)*
2012, **2013**	40
2014, 2015	10 (current year)
2016~2029	2.5
2030	0

ODP tonnage and refrigerant tonnage

The majority of HCFC imports into Australia are R22 and R123 (every kilogram of R123 imported means less R22 can be imported).

Using the ODP of R22 at 0.055 — The maximum actual tonnage (as opposed to ODP tonnage) amount that can be imported during these periods could be considered to be approximately:

2012 – 2013:	727 tonnes per annum
2014 – 2015:	181 tonnes per annum
2016 – 2029:	45 tonnes per annum
2030:	0 tonnes

As a comparison, and to put these import quantities into perspective, the working bank of HCFC refrigerants contained in operational equipment was estimated in 2013 to be in excess of 11,428 metric tonnes of refrigerant.

Appendix B Retrofit refrigerants

Retrofitting existing R22-charged equipment with alternative refrigerants specifically designed for the purpose can be very cost effective where the replacement cost of the unit is higher than the cost to retrofit.

R22 can be recovered from equipment and an alternative retrofit refrigerant used in its place, however these refrigerants are not simple ‘drop-in’ replacements. A drop-in replacement implies no system changes, whereas using R22 ‘retrofit refrigerants’ usually require numerous system changes.

Retrofitting may not be worthwhile for smaller equipment which is likely to be over six years old and may have an economic life of only seven to twelve years (depending on location and servicing), unless the equipment has already lost its full charge via leakage.

Technical considerations

Most common R22 retrofit refrigerants are hydrofluorocarbon (HFC) blends. Blended refrigerants are made by mixing several refrigerants together in specific proportions in order to create the desired operating characteristics. As a consequence, they behave differently to single-component refrigerants like R22. Blends can fractionate when leaking, each refrigerant that makes up the blend will leak independently (at different rates) which will alter the refrigerant’s overall composition. The fractionation effect is dependent on temperature glide. Where a leak of HFC blend has occurred, the entire refrigerant charge may need to be recovered and renewed with virgin blend refrigerant to ensure the correct blend ratio (and hence system performance) is maintained. This can be an expensive maintenance practice, especially for some larger air conditioning chillers, which can contain more than 100kg of refrigerant.

Mineral oils and alkylbenzene lubricants, which have traditionally been used with R22, are immiscible with the retrofit refrigerants, and in almost all cases must be renewed with miscible lubricants such as polyol esters. Some retrofit refrigerants contain hydrocarbons in the blend, such as isobutane, which will assist with the compatibility with mineral oil however polyol ester oils are generally recommended.

Every chiller or item of equipment that is to be considered for refrigerant retrofit, needs to be assessed individually — different types of evaporators have different needs. Single-pass evaporators (refrigerant or water), counter flow, DX, tube-in-tube, tube-in-shell and plate types may require a different refrigerant blend than multi-pass (refrigerant or water) and flooded evaporators. Also, some heat exchanger configurations can suffer a significant drop in performance with refrigerants that exhibit temperature glide.

R22 interacts strongly with many elastomers causing significant swelling and often, over time, a measurable increase in hardness in the system elastomeric seals. HFC blends do not have as strong an effect on the elastomers commonly used as seals in refrigeration systems. As a result, when retrofitting an R22 system with an alternative HFC blend, it is possible for leaks to occur at elastomeric seals that have been previously exposed to R22 refrigerant.

Replacing elastomeric seals should be addressed as part of the retrofit process. Components commonly affected are Schrader core seals, liquid level receiver gaskets, solenoid valves, ball valves, flange seals, and some shaft seals on open drive compressors. It is recommended to actually replace the valves in question with new valves rather than using seal kits, as this will help remove a potential leak path from ageing equipment.

Other system changes can include adjusting the superheat setting, changing the filter-dryer, resetting or renewing the thermal expansion valve, and recovering and renewing the oil. A suction filter may be required to trap the dirt due to the cleaning ability of the retrofit refrigerant and oil combination.

Typical retrofit refrigerants

There are a number of refrigerants that are suitable for R22 retrofitting purposes, the most common are listed below.

Market forces and concerns regarding HFC refrigerant GWP may see the range of products available for this type of retrofit diminish, so it is important to consider the current and future availability and cost of the selected refrigerant.

R407C — *ODP = 0, GWP = 1610*.

This is a ternary blend of hydrofluorocarbon (HFC) compounds (23% R32, 25% R125, and 52% R134a). It has no chlorine content, no ozone depletion potential, and only a modest direct global warming potential. In addition to slight capacity losses, R407C requires a greater cooling surface area compared to R22, but the mass flow rate of the gas is much the same.

R407F — *ODP = 0, GWP = 1824.*

This refrigerant blend (30% HFC-32, 30% HFC-125, 40% HFC-134a) serves as a non-ozone depleting replacement for R22 in low- and medium-temperature commercial refrigeration applications such as supermarket freezer cases, display cases, reach-in coolers, transport refrigeration, and ice machines.

Requires polyol ester compressor lubricant. This blend has a lower mass flow and this may cause a problem with oil return, especially if the suction pipe work has already got a lower flow rate. Check flow rates to ensure that oil is returned.

R427A — *ODP = 0, GWP = 1828.*

This refrigerant blend (15% R-32, 25% R-125, 10% R-143a, and 50% R-134a) offers comparable capacity to R22 and nearly identical operating pressures and can be used with minimal need for modification to the existing R22 installation. It can be used to retrofit low-temperature refrigeration equipment and air conditioning installations. It requires polyester (POE) lubricants but is tolerant of high levels of alkylbenzene or mineral oils of up to 10%.

R428A — ODP = 0, GWP = 3607.

This is a HFC blend retrofit solution used for low-temperature applications and flooded evaporator systems where temperature glide makes other options unfeasible. It has a glide of 0.8°C and needs a significant mass flow increase when compared to R22. A change of thermostatic expansion valve is recommended.

R434A — ODP = 0, GWP = 3245.

This is a retrofit solution used for medium-temperature applications and flooded evaporator systems where temperature glide makes other options unfeasible. It has a glide of 1.5°C and needs a significant mass flow increase when compared to R22. A change of thermostatic expansion valve is recommended.

R438A — *ODP = 0, GWP = 1890.*

This refrigerant blend (44.2% HFC-134a, 8.5% HFC-32, 45% HFC-125, 0.6% Isopentane, 1.7% N Butane) has an A1 safety classification (non-flammable and low toxicity) and is suitable for residential and commercial air conditioning, and medium and low-temperature refrigeration systems. It is not recommended for use in centrifugal compressor systems or for chillers with flooded evaporators. For use in semi-flooded systems with low-pressure receivers, refer to manufacturer guidelines.

It can be suitable with mineral oils, AB, and POE. This blend has a lower mass flow and this may cause a problem with oil return, especially if the suction pipe work has already got a lower flow rate. Check flow rates to ensure that oil is returned.

Change of refrigerant classification

R22 is classified as an A1 refrigerant. All of the above listed retrofit refrigerants are also classified A1 (low-toxic and non-flammable).

To retrofit equipment to an alternative refrigerant with an A2, A2L or A3 classification a significant conversion process is required. In most cases this is not a recommended or cost-effective strategy. For a comprehensive list of the standards, regulations, and procedures that need to be applied when converting systems to use a different (flammable) refrigerant classification, refer to AIRAH's *Flammable Refrigerant Safety Guide.*

Appendix C Long-term refrigerant options

Most of the retrofit refrigerants listed in appendix B feature a high GWP and are likely to be the subject of future HFC phase-down legislation. This presents a risk in that retrofitted equipment may face similar HFC scarcity in the future, similar to the HCFC scarcity now.

All air conditioning and refrigeration applications are unique; operating at different temperatures and pressures and having individual requirements and technical characteristics. There is no single refrigerant solution that can be applied across all applications. It is judicious to investigate low GPW refrigerant options when upgrading equipment to reduce the risk of exposure to future HFC phase down.

With ongoing international focus on greenhouse gas emission reduction, future restrictions in the use of HFC are being considered. The global industry of refrigerant manufacturers are developing lower GWP options for many applications. HFC-407F (GWP 2107) and HFC-407A are now available to use in place of the higher GWP refrigerant HFC-404A (GWP 3922). HFC-32 (GWP 675) is now being used in applications previously dominated by HFC-410A. New generations of unsaturated HFCs, known as HFOs, have now been developed which have very low GWPs (HFO1234yf has a GWP of 4). An exceptional amount of information regarding HFC use is available in the report *A study into HFC consumption in Australia*.

Natural refrigerants such as Ammonia, Hydrocarbons and Carbon Dioxide and being employed in more varied applications due to their comparatively negligible effect on the environment.

Long term refrigerant alternatives should be evaluated compared to currently available refrigerant options:

- Up front capital cost of equipment
- Ongoing cost and long term availability of refrigerant
- Energy efficiency across expected operating parameters
- Life cycle comparison
- Environmental impact - Zero ODP and Low GWP
- Safety requirements – for transport, storage facilities, in use in plantrooms, flammability, toxicology.