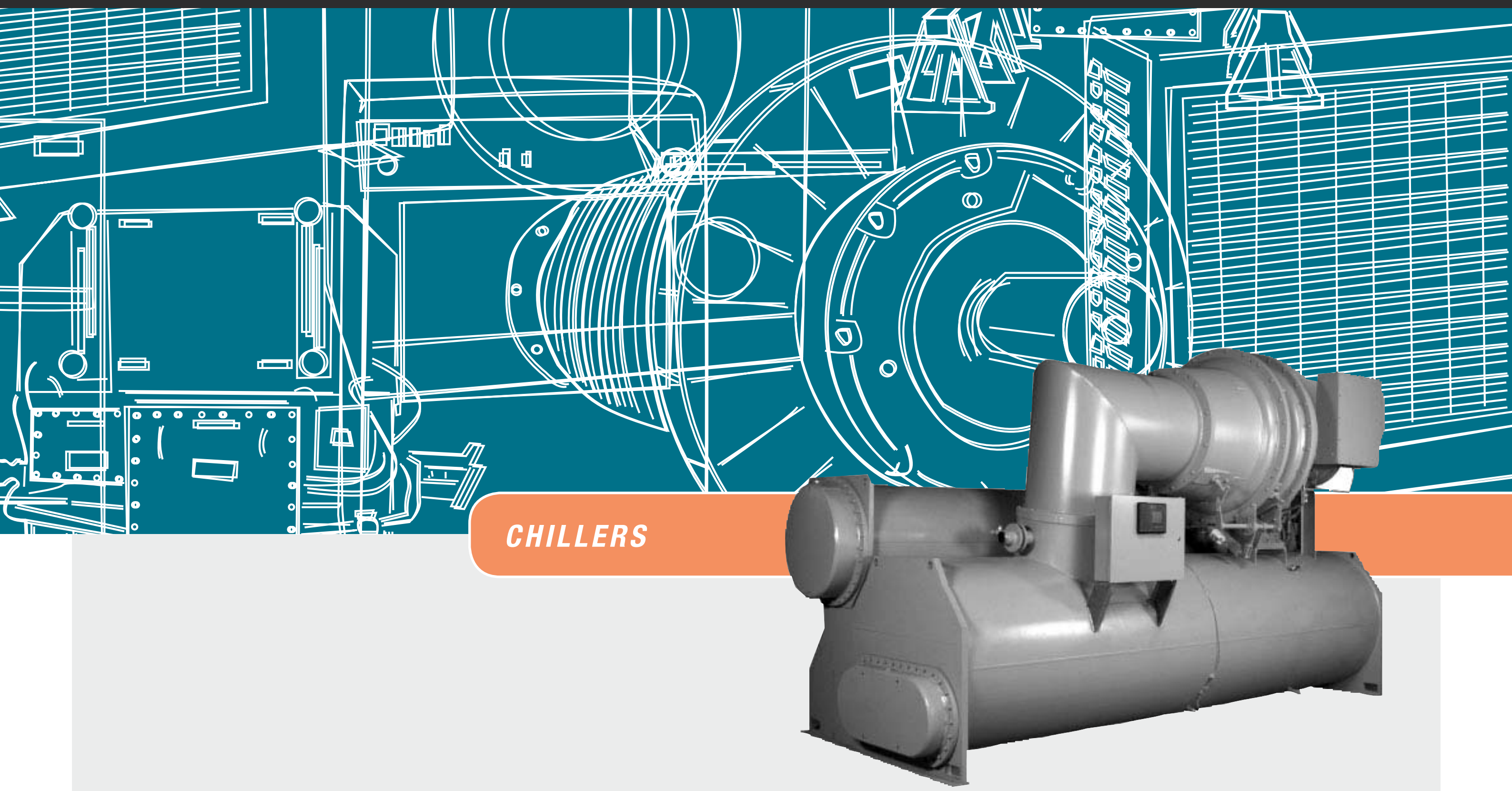
Report No: 2004/15

NATIONAL APPLIANCE AND EQUIPMENT ENERGY EFFICIENCY PROGRAM

Minimum Energy Performance Standards



CHILLERS

PREPARED FOR

THE AUSTRALIAN GREENHOUSE OFFICE UNDER
THE NATIONAL APPLIANCE & EQUIPMENT ENERGY
EFFICIENCY PROGRAM

Minimum Energy Performance Standards - Chillers

Commercial chillers are usually made with four types of compressors: reciprocating, scroll, screw and centrifugal compressors. They range in output capacity from under 100 kW to over 2000 kW. The vast majority of chillers sold in Australia are imported, with the Australian air conditioning water chiller market estimated between AUD$60M – $70M.

Chillers are generally used in large commercial buildings to provide chilled-water for space cooling equipment. They are the typically the largest energy using space conditioning equipment in a commercial building. Commercial water chillers were among a group of products identified in 2003 for possible efficiency regulation. Energy consumption from chillers in 2003 is estimated at 1,909 GWh. Minimum Energy Performance Standards (MEPS) and energy labelling regulations already apply to smaller air conditioners used in the commercial and residential sectors.

Preliminary research of the Australian market shows that chillers being sold in Australia are generally of lower efficiency than the USA and other countries where regulation applies. The range of efficiency for commercial chillers on the Australian market is wide and, based on international comparisons, there is scope for improvements to energy efficiency.

INTERNATIONAL HARMONISATION

In the USA, Canada and Chinese Taipei (Taiwan) MEPS programs are implemented for commercial chillers. Canada and Chinese Taipei apply the MEPS to the equipment sold in that country. The USA requires a minimum efficiency of chillers in their building code, ASHRAE 90.1-1999. In addition, the Eurovent Certification Programmes covers chillers in Europe, where products are certified and energy performance information is provided. In Australia, most suppliers source their product from those supplying the USA market, although some smaller sized chillers are assembled in Australia.

Internationally, Canada, the USA and Chinese Taipei MEPS levels are almost identical, with the USA and Canada levels in place from 2004 and Chinese Taipei matching these levels in 2005. All MEPS levels are testing in accordance with Air-Conditioning and Refrigeration Institute (ARI) Standard 550/590 -2003 *Water Chilling Packages using the Vapour Compression Cycle*, or equivalent conditions.

Australia does not currently have a standard that relates to this type of equipment though creating such a testing standard is a simple task of copying ARI 550/590, which operates as a de facto international test standard in this field. The adoption of this new standard can be managed by Standards Australia International.

STAKEHOLDER COMMENT

NAEEEC invites comments from any interested person or organisation on the measures proposed in this study. Comments should be directed to energy.rating@greenhouse.gov.au by 31 December 2004. Information sessions for industry participants can be arranged during the comment period if requested.

Electronic copies of profiles and full reports released for public discussion can be obtained from www.energyrating.gov.au

Cover photo courtesy of Trane

The benefit of testing chillers to ARI 550/590 should make for ease of compliance for Australian suppliers as this is the methodology used by the major world suppliers.

Australia proposes to adopt the USA/Canada MEPS as the basis for the regulatory program, as this is international best regulatory practice.

NAEEEC PLAN

NAEEEC proposes to introduce minimum energy performance (MEPS) regulations for chillers.

The key components of these regulations will be as follows:

1. That a MEPS for chillers be implemented to ensure that the worst performing chillers are removed from the Australian market.
2. The MEPS will apply to factory-designed and prefabricated vapour-compression chillers that have a cooling capacity of less than 7000 kW (2000 tons) with water condenser and less than 700 kW (200 tons) with air condenser. These packaged water chillers are intended for application in air-conditioning systems for buildings.
3. The testing method for chillers should be based on the ARI 550/590 - 2003 Standard for Water Chilling Packages using the Vapour Compression Cycle.
4. The MEPS levels be based on section 6.2.1 of ASHRAE 90.1-2001 SI edition. This will become a Part 2 of the new Australian and New Zealand test standard.
5. The MEPS be introduced in October 2007 (three years after the North American levels and two years after Chinese Taipei).
6. The compliance and check testing of chillers for MEPS is integrated with USA certification programs and USA/ Canadian regulators. Test facilities in Australia are encouraged and will be supported by Australian regulators.

The recommended MEPS are shown in Table 1.

TABLE 1: RECOMMENDED MEPS LEVELS FOR CHILLERS

Vapour Compression Chillers	Capacity (kWR)	Min COP	Min IPLV
Air cooled, with Condenser	All Capacities	2.80	3.05
Air Cooled, without Condenser	All Capacities	3.10	3.45
Water cooled, Reciprocating	All Capacities	4.20	5.05
Water Cooled (Rotary Screw and Scroll)	< 528 kW	4.45	5.20
	>528 kW and < 1055 kW	4.90	5.60
	>1055 kW	5.50	6.15
Water Cooled, Centrifugal	< 528 kW	5.00	5.25
	> 528 kW and <1055 kW	5.55	5.90
	> 1055 kW	6.10	6.40

A high efficiency level is usually provided in the Australian Standard as a tool for use by suppliers to identify and market those chillers that exceed the minimum standard. The proposed high efficiency levels for COP are shown in Table 2, which are approximately 15% higher than the proposed MEPS levels. These high efficiency levels will be examined once the ASHREA 90.1 standard is revised in 2007, when the US say is likely to propose new minimum energy performance levels for chillers.

TABLE 2: RECOMMENDED HIGH EFFICIENCY LEVELS FOR CHILLERS

Vapour Compression Chillers	Capacity (kWR)	Min COP
Air cooled, with Condenser	All Capacities	3.20
Air Cooled, without Condenser	All Capacities	3.60
Water cooled, Reciprocating	All Capacities	4.85
Water Cooled (Rotary Screw and Scroll)	< 528 kW	5.10
	>528 kW and <1055 kW	5.65
	>1055 kW	6.35
Water Cooled, Centrifugal	< 528 kW	5.75
	> 528 kW and <1055 kW	6.40
	> 1055 kW	7.00

Table 3 shows the timetable for implementation of MEPS and labelling. The regulatory (Part 2 Standard) will be published at least 12 months in advance of the date in which the MEPS come into force, in order to provide industry with sufficient time to make the necessary purchasing decisions.

TABLE 3: TIMETABLE FOR IMPLEMENTATION OF PROPOSED MEPS

October 2004	Government publication of MEPS Proposals for Chillers
December 2004	Industry response to recommendations
January 2005 - October 2005	Consultation on Draft Standard(s) by Standards Australia
October 2005	Publication of Draft Standard by Standards Australia
April 2006 or October 2006	Publication of Final Standard by Standards Australia
2006	Regulatory Impact Statement undertaken
October 2007	Introduce MEPS

IMPACT OF MEPS

Since the MEPS criteria apply only to new products entering the market, it will be a number of years before these measures impact on the stock of existing products. By 2012, the proposed MEPS criteria is estimated to reduce annual energy consumption by 300 GWh, and by 2020 the annual savings will total approximately 710 GWh. This is equivalent to reducing annual greenhouse emissions by 266 kt CO_2-e and 560 kt CO_2-e respectively. The total cumulative savings in emissions by these dates are approximately 0.95 Mt CO_2-e and 4.5 Mt CO_2-e.

NAEEEC MEMBERS

The Commonwealth, New Zealand, and all State and Territory governments are part of NAEEEC. Representatives are senior officials from various government agencies and statutory authorities or persons appointed to represent those bodies.

The *Australian Greenhouse Office (AGO)* is the Australian Government agency responsible for monitoring the National Greenhouse Strategy in cooperation with State and Territory Governments and with the support of local government, industry and the community. The AGO chairs NAEEEC and other members provide support for its activities.

The NSW *Ministry of Energy and Utilities* (incorporated within the Department of Energy, Utilities and Sustainability since 1 January 2004) provides policy advice to the NSW Government and operates a regulatory framework aimed at facilitating environmentally responsible appliance and equipment energy use. The Ministry is represented on the Energy Efficiency and Greenhouse Working Group, through which the appliance and equipment related elements of the National Greenhouse Strategy are being progressed.

The NSW *Sustainable Energy Development Authority* was established in February 1996 with a mission to reduce the level of greenhouse emissions in New South Wales by investing in the commercialisation and use of sustainable energy technologies.

The *Office of the Chief Electrical Inspector* is the Victorian technical regulator responsible for electrical safety and equipment efficiency. Its mission is to ensure the safety of electricity supply and use throughout the State. The corporate vision of the Office is to demonstrate national leadership in electrical safety matters and to improve the superior electrical safety record in Victoria. The Office's strategic focus is to ensure a high level of compliance is sustained by industry with equipment efficiency labelling and associated regulations.

The *Sustainable Energy Authority* was established in 2000 by the Victorian Government to provide a focus for sustainable energy in Victoria. The Authority's objective is to accelerate progress towards a sustainable energy future by bringing together the best available knowledge and expertise to stimulate innovation and provide Victorians with greater choice in how they can take action to significantly improve energy sustainability.

The *Electrical Safety Office*, Department of Industrial Relations, is the Queensland technical regulator responsible for electrical safety and appliance and equipment energy efficiency. The office ensures compliance with electrical safety and efficiency regulations throughout Queensland.

The *Department of Energy* is the lead agency with regard to sustainable development within the Queensland energy sector and is involved in a range of activities that reflect the importance of a sustainable approach. These activities involve developing and evaluating policies and initiatives through flexible and responsible decision making that allows economic, environmental and social outcomes from the energy sector to be maximised.

The Western Australian electricity regulator *Energy Safety* (a Division of the Department of Consumer and Employment Protection) is responsible for the technical and safety regulation of the electrical industry in WA. This includes the safety of consumers' electrical installations and appliances and the auditing of appliances and equipment to check compliance with energy efficiency and prescribed safety requirements.

The Western Australian *Sustainable Energy Development Office* promotes more efficient energy use and increased use of renewable energy to help reduce greenhouse gas emissions and increase jobs in related industries.

The *Office of the Technical Regulator* seeks to ensure the coordinated development and implementation of policies and regulatory responsibilities for the safe, efficient and responsible provision and use of energy for the benefit of the South Australian community.

The Tasmanian Government's interest is managed by the Department of Infrastructure, Energy and Resources' *Office of Energy, Planning and Conservation (OEPC)*. The OEPC provides policy advice on energy related matters including energy efficiency. Its web site is www.dier.tas.gov.au/energy/indext.html.

Electricity Standards and Safety is the technical regulator responsible for electrical safety throughout Tasmania. Regulatory responsibilities include electrical licensing, appliance approval and equipment energy efficiency.

The Australian Capital Territory's interest is managed by the *Energy Policy Unit, Economic Management Branch*, Department of Treasury. The primary function of this Unit is to provide the ACT Government with advice on National and Territory energy related matters including energy efficiency.

The *Department of Infrastructure, Planning and Environment* is responsible for the administration of regulations in the Northern Territory regarding various aspects of safety, performance and licensing for goods and services including electrical appliances.

The *Energy Efficiency and Conservation Authority (EECA)* is the principal body responsible for delivering New Zealand's National Energy Efficiency and Conservation Strategy (NEECS). EECA's function is to encourage, promote and support energy efficiency, energy conservation and the use of renewable energy sources.

Analysis of the Potential Policy Option:

Commercial Building Air Conditioning Chillers (Vapour Compression)

Prepared for

The Australian Greenhouse Office: National Appliance & Equipment Energy Efficiency Program

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EnergyConsult PTY LTD

655 Jacksons Track
Jindivick, Victoria 3818
Australia
ABN: 18 090 579 365
Tel: +613 5628 5449
Fax: +613 9923 6175
Email: info@energyconsult.com.au

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Introduction

The purpose of this report is to provide an analysis of the policy options, primarily their suitability for Minimum Energy Efficiency Standards (MEPS), for the new product types identified in the National Appliance & Equipment Energy Efficiency Program from 2003.

Scope

This report focuses on chillers for commercial air conditioning. Although chillers can be used for industrial purposes, they are not considered suitable for a MEPS program, as no overseas country applies MEPS and the overall system efficiency gains outweigh the equipment efficiency gains. In addition, industrial chiller systems are designed for varying conditions and test standards do not easily represent these constantly variable operating environments. An industrial chiller is a refrigeration system that cools water, oil, or some other fluid to provide a constant stream of coolant for cold storage (including cool rooms), manufacturing and laboratory processes. The uses and applications for industrial chillers are varied and include: food processing and storage, process cooling, plastic moulding, solvent coolers, milk coolers, aerospace production, medical facilities etc.

Background of Air Conditioner Efficiency Regulation

The National Appliance and Equipment Energy Efficiency Program (NAEEEP) is part of the National Greenhouse Strategy and targets the energy efficiency of consumer appliances, industrial and commercial equipment. The main tools of the Program are mandatory energy efficiency labelling and minimum energy performance standards, and voluntary measures including endorsement labelling, training and support to promote the best available products. Mandatory minimum energy efficiency performance standards (MEPS) are needed to overcome the market failure regarding whole-of-life costs and to meet the objectives of both increasing energy efficiency and reducing greenhouse gas emissions.

National product regulation can only be justified where the benefits outweigh the costs to the community; where the costs of improving efficiency is outweighed by the energy savings made over the lifetime of the product. To date, the cooling cycle of all three phase air conditioners and single phase (domestic) air conditioners are regulated for MEPS and energy labelling.

Package Air Conditioners

Since 1 October 2001, three phase air conditioners with a cooling capacity of up to 65kW manufactured in or imported into Australia must comply with Minimum Energy Performance (MEPS) requirements which are set out in AS 3823.2-2001. MEPS covers three phase non-ducted or ducted room air conditioners of the vapour compression type of up to 65kW cooling (commercial or residential). It covers only those units with a single compressor with a single indoor control such as single packaged units, packaged ducted units, double and triple split systems and single split systems. It does not cover multi-split systems, portable systems without an exhaust duct or evaporative coolers. Manufacturers can choose to label three phase air conditioners, but this is not mandatory.

Packaged Air conditioning MEPS introduced in 2001 are projected to save 14.6 Mt CO_2e from 2000 to 2015 and save the community $400 million (NPV - 10% discount). The benefits exceed costs by 6:1. These MEPS levels are due to increase in 2007.

Single Phase Air Conditioners

From 1 October 2004, all single phase air conditioners manufactured in or imported into Australia must comply with Minimum Energy Performance (MEPS) requirements which are set out in AS/NZS 3823.2-2003. MEPS covers single phase non-ducted or ducted room air conditioners of the vapour compression type (commercial or residential) within the scope of AS/NZS 3823.1.1 or AS/NZS 3823.1.2. These MEPS levels are also due to increase in 2007, however MEPS for some specific product classes, such as split type air conditioner under 7.5kW, may be implemented in 2006 rather than 2007. This will be subject to a separate announcement.

Product Description

Introduction

Chillers produce water that is used by building space cooling equipment and many industrial processes. Chillers remove heat from a circulating cold water loop and discharge that heat to the outside air through a cooling tower.

Chillers are generally used in large commercial buildings to provide chilled-water. The chiller is usually located on the roof or behind the building. It cools water to between 4.4 and 7.2°C. This chilled water is then piped throughout the building and connected to air handlers as needed. The cooling tower creates a stream of lower-temperature water that runs through a heat exchanger and cools the hot coils from the chiller.

The chiller is part of a system that is called "applied" air conditioning, where the system is usually specified by the building designer/engineer. This is compared to unitary (all-in-one) systems where the air conditioners are "packaged" and cool air is ducted around the building.

The product type (Chillers – commercial air conditioning systems) are further defined as follows

- Factory assembled vapour compression unit designed to cool water or brine using an evaporator, with an integral remote condenser and controls
- Cooling only
- Includes components such as motor, compressor, evaporator, economiser, condenser, receiver, water connections and passes, control panel, purge equipment, fastenings and couplings, refrigerant charge oil and pump if included
- Types of compressors are reciprocating, screw, scroll and centrifugal
- Heat is rejected process is via air cooled (with integral condenser), condenserless (remote air cooled condenser) and water cooled.

Commercial air conditioning chillers are primarily used to provide cooling for occupied commercial properties such as office buildings and retail centres.

Compressor Types

Commercial chillers are usually made with 4 types of compressors, as follows:

Reciprocating/Scroll

- Market for reciprocating and scroll chillers is estimated at 350 units pa which represents a decrease of 8% from 2001
- Most common in the < 530 kWR market
- Has dominated market for many years due to their lower capital cost and ability to cover large ranges of capacity
- Scroll compressors appear to be more reliable than reciprocating chillers
- Reciprocating compressors usually requires more refrigerant than other compressor types and are not as energy efficient

Screw

- Increasingly popular amongst designers because of low maintenance requirements, low vibration and noise levels
- Used predominantly in the 530 - 1055 kWR cooling capacity range
- Market growth expected at the expense of reciprocating chillers due to energy efficiency, accurate control and reduced noise levels

Centrifugal

- Usually only used in capacity requirements above 1055 kWR, with small market requirement in the 530 to 1055 kWR range
- Used in larger installations
- Number sold varies dramatically year by year due to the variation in development of large building projects

Australian Market Characteristics

In research undertaken by the UK's Building Research and Information Association (BSRIA) the world air conditioning market was estimated to be in the vicinity of AUD$50 billion. Approximately 10% of this market value has been attributed to air conditioning water chillers. With the Australian air conditioning water chiller market estimated between AUD$60M – $70M, this represents around 2% of the total world market and is considered modest compared to the room and unitary air conditioning market of over AU$800M (Infomark 2004).

There is little or no published data on the energy performance characteristics Australian chillers. Therefore, information in this section is primarily derived from personnel interviews with major suppliers of chillers.

Current Installed Base and Sales

There are no Australian Bureau of Statistics data on the installed number of commercial chillers in Australia. In addition, the data contained in other studies (Burbank 2002, AGO 1999) of the commercial market do not appear to detail the number of installed chillers. To estimate the number of installed chillers, interviews were conducted with key organisations (Interviews 2004) from the representatives of the Air Conditioning and Refrigeration Equipment Manufacturers Association of Australia (AREMA). From these interviews, it is estimated that there are some 6,000 to 7,000 chillers of varying technology types, efficiencies and refrigerants currently installed in Australian commercial buildings, entertainment complexes and retails facilities. Approximately half of these chillers are believed to be air cooled.

Major Suppliers of Chillers

Based on AREMA supplied information, around 85-90% of chillers supplied in the past 2 years are from only three (3) major suppliers – Trane, Carrier and McQuay. These companies are predominately USA owned. A second tier market is in place and consists of companies such as York, Fluid Chillers, PowerPax, Airwell, Cooline, Matsu, MTA, Pendry and Daikin. It would appear that the only three Australian manufacturers are in this group and they focus on the lower capacity market (< 300 kWr). These companies combined would supply less than 15% of the water chillers to the commercial sector. Many of these companies provide the air handing units and controls.

Chiller Capacity Range

The capacity range of chillers available in today's Australian market can be as small as 10kW up to 4,000 kW in cooling capacity. In large installations it is not unusual to have multiple chillers, with different capacities and different compressor types.

Figure 1 - Chiller Sales by Type & Range

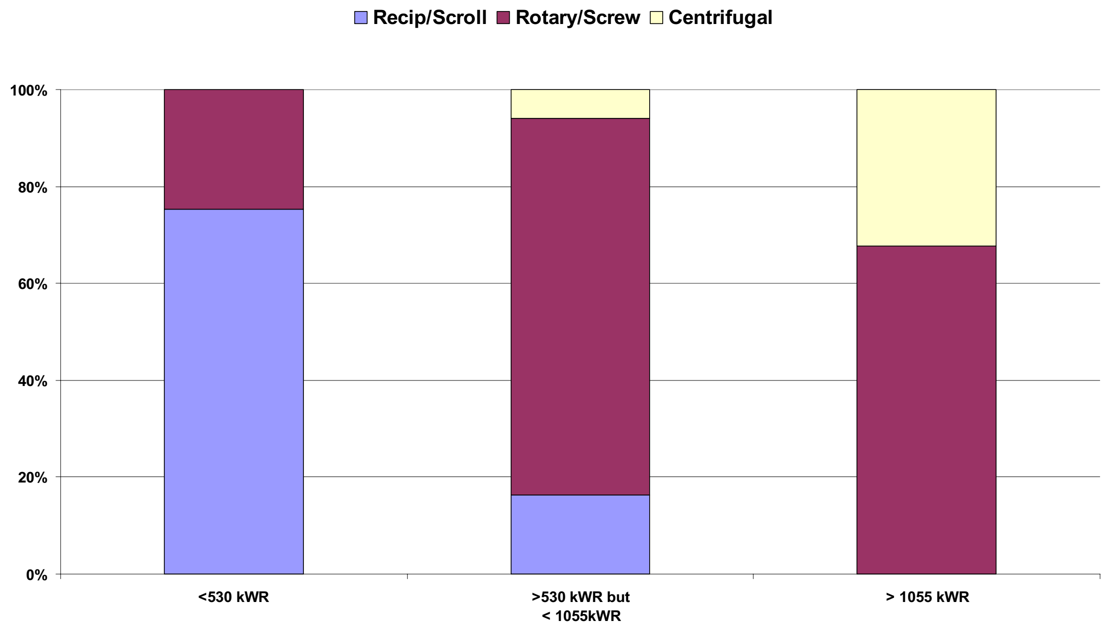


Figure 1 shows the range of sales by type of chiller. Applications with cooling requirements below 250 kW are mainly dominated by scroll compressors, with other applications up to 1,000 kW using a mixture of helical rotary (screw) and reciprocating compressors. Cooling capacity requirements above 1,000 kW is usually managed by the use of screw and centrifugal compressors.

Sales Trends

Chiller sales vary from year to year and correlate closely with building industry activity. The chiller market has reduced from its last peak (1998) with a range of influencing factors that include: economic downturn; oversupply of commercial office space; outbreak of SARS, global conflicts and uncertainty of both Australian and US economies. Overall the market has stayed consistent with sales volume estimated between 600 and 800 units per annum. Off these sales, it is estimated that around 40% are for replacement of existing equipment. This is not expected to experience any significant increase or decline over the next five years. Hence there is a relative static total market. .

There has been a trend towards greater installations of air cooled chillers over the past decade and it is estimated that these chillers represent 66% of chiller market, mainly influenced by increased regulations surrounding cooling towers, waste water management, chemical treatment costs and escalating maintenance costs.

Expected Chiller Service Life

Service life is based around the time in which a particular system or component remains in its original service application. Estimated service life of new equipment can be obtained from manufactures. For consistency the datum for chiller service life has traditionally been based on ASHRAE "Estimates of Service Life" where chiller life is between 20 to 23 years.

The changes in design, design standards, manufacturing standards, materials and components has raised a re-estimate amongst industry that believes air cooled chillers now have a life of 10 to 15 years, with water cooled chillers between 10 and 20 years.

This modified approach to service life expectancy significantly alters economic chiller analysis when considering replacements or new installations.

Range of Chiller Efficiencies

Chiller efficiency is measured as Coefficient of Performance (COP). COP is defined as "the ratio of the rate of heat removal to the rate of energy input". This measurement is usually quoted at Full Load capacity of the chiller or at Part Load conditions. The development of the Integrated Part Load Value (IPLV) when assessing the performance and efficiency of chillers is significant especially considering that operation is usually at 'off design(99%)' rather than 'design conditions (1%)' for a majority of its operating time.

It would appear that a majority of chillers now benchmark their ratings, capacity and efficiency, against current international test procedures and standards. The main driver for this process has been the need to assure consistent treatment for ratings of similar products by the industry in general. A majority of chiller equipment is benchmarked against ASHRAE Standard 90.1 which is a "proxy" MEPS for Chillers in the USA.

In Australia, based on the interviews with major suppliers, the estimated average efficiency for Australian chillers are shown in Table 1.

Table 1: Chiller Efficiency in Australia (estimated)

Chiller Type	Capacity (kWR)	Estimated COP of Australian Units (COP)
Air cooled, with Condenser	All Capacities	Not available
Air Cooled, without Condenser	All Capacities	2.3
Water cooled, Reciprocating	All Capacities	3.7
Water Cooled (Rotary Screw and Scroll)	< 528 kW	4.2
	>528 kW and < 1055 kW	4.6
	>1055 kW	5
Water Cooled, Centrifugal	< 528 kW	NA
	> 528 kW and <1055 kW	5.1
	> 1055 kW	5.5
	> 1055 (300)	5.5

Chiller Cost versus Efficiency

For chillers between 500 and 1000 kW, the additional cost for choosing a high efficiency unit over standard efficiency is between 6% and 15%. This is estimated based on the results of interviews with industry representatives. Due to the commercial confidentiality of such data and the sensitivity of sales data of the three key suppliers, it is not possible to obtain a sample of efficiency vs sales data from usual sources. On the basis of overseas markets, particularly Canada and the USA, studies have found cost effective efficiency improvements are achievable.

In Canada (NRCan 2003) a benefit-cost analysis was undertaken to determine the economic attractiveness of improving the energy efficiency of packaged water chillers. The net present value, calculated by subtracting the present value of the incremental costs from the present value of the incremental savings over the life of the product is chosen as the indicator of economic attractiveness. The base case analysis used a 7 percent social discount rate, as prescribed by Treasury Board Secretariat of Canada. The NRCan market study revealed that most chillers already meet the proposed efficiency levels. Only two categories were analysed in greater detail because there were a significant number of units that are below the proposed efficiency levels. These categories were:

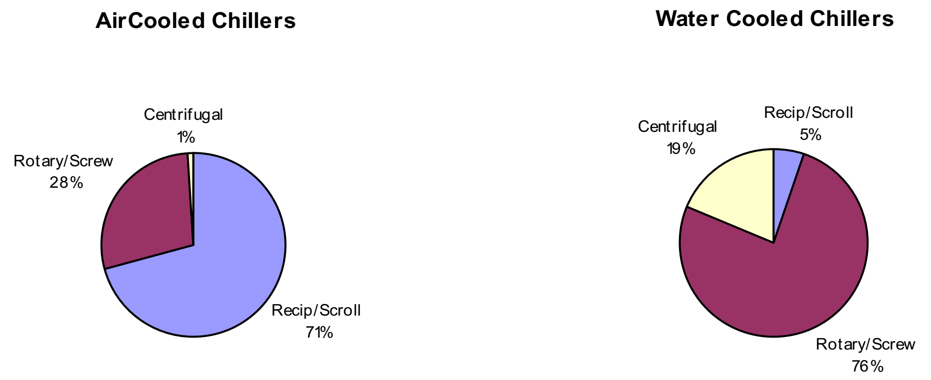
- air-cooled with condenser, less than 528 kW (150 tons)
- water-cooled centrifugal, greater than 1055 kW (300 tons)

For air-cooled units of less than 528 kW, the net financial result was slightly negative if the proposed levels were implemented. Since most equipment in this category meets the proposed minimums, NRCan decided to go ahead and adopt the proposed minimum level. For centrifugal chillers of more than 300 tons, the analysis shows a significant economic benefit in adopting the proposed minimum.

Heat Rejection Method

Preliminary research has indicated that the market is currently dominated by air cooled chillers, accounting for 66% of the volume in 2002. Air cooled use is expected to increase to some 70% of the market by 2005. The estimated market share of chillers by cooling type is shown in Figure 2.

Figure 2 – Sales of chillers by Heat Rejection and Compressor Type



Water cooled chillers are more expensive to install and maintain. Increasing regulatory requirements and including those regarding waste water are also placing downward pressure on the sales of water cooled chillers.

Refrigerants

Suppliers currently offer a small range of refrigerants based on chiller type, capacity and regulatory requirements. Current refrigerants available for use include:

- Reciprocating (Open drive) – R22, R134a, R401A, R409A, R410A, R413A
- Centrifugal & Screw – R22, R134a, R123, R410A
- Accessible semi-hermetic (includes reciprocating & scroll) – R22, R123, R134a, R401B, R404A, R407C, R409B, R410A, R507

Refrigerants have a COP (Coefficient of Performance) efficiency rating that is dependant on chiller type and variables such as operating set-points, condensing and evaporator pressure, and heat rejection method.

Testing Standards

Vapour compression chiller sets are covered by a range of regulations and standards. These include materials and construction standards, test standards and performance standards. Currently in Australia these chillers are only governed by construction and materials standards, however most major manufacturers rate their product based on their country of origin.

Internationally, manufacturers of chillers have participated in the testing and certification of their products by using standards such as Air-Conditoning and Refrigeration institute (ARI) who represent the North American suppliers and Eurovent, who represent the European air conditioning, ventilating and refrigeration manufacturers.

The purpose of these rating or "certification programmes" is to create a common set of criteria for rating products. Through specification of certified products, the engineer's tasks are made easier, since there is no need for carrying out detailed comparison and performance qualification testing. Consultants, specifiers and users can select products with the assurance that the catalogue data is accurate.

The two dominant organisations promoting certification programs are:

- ARI (Air-Conditioning & Refrigeration Institute) is a trade institute that represents the manufacturers more than 90% of North America's HVACR companies.
- Eurovent – used as a common voluntary certification program in Europe, but open to all manufacturers,

Eurovent and ARI provide similar testing criteria for performance rating with only minor differences with little comparative impact on testing results.

The dominant certification program for chillers imported into Australia is "ARI 550/590 - 2003 Standard for Water Chilling Packages using the Vapour Compression cycle". All ARI standards are available for download for free from the ARI web site (http://www.ari.org/std/standards.html).

In Australia, the use of the ARI standard ARI 550/590 – 2003 as the testing standard for performance measurement of Chillers would require the adoption be Standards Australia International and the creation of a new standard. Alternatively, the ARI standard may be utilised within a Memorandum of Understanding (MOU) framework agreement between SAI and ARI (see http://www.ari.org/pr/2004/07-04-MOU1.html, where an agreement has been made with the Korea Refrigeration and Air-Conditioning Assessment Center.

There are no longer any certified testing facilities in Australia for air conditioning chillers, however most suppliers ensure their product is rated to the ARI test conditions when sourcing products. The provision of rating information in accordance with the ARI 550/590 is not envisaged to be an issue by the industry representatives contacted for this research report. It will be unlikely that an Australian test facility be established due to the high costs of establishment and low volume of product requiring testing. If Australia adopts the ARI standard, units tested in the USA to this standard would be applicable in Australia. For compliance testing, it is likely that models will be tested in the USA or country of origin, to the ARI standard and reported in Australia.

Table 2: Standard Rating Conditions ARI 550/590-1998

Chiller Type	Water-Cooled	Evaporative-Cooled	Air-Cooled
Condenser Water			
Entering	29.4 Deg C		
Flow Rate	0.054 L/s per kW		
Condenser Fouling Factor Allowance			
Water-side	.000044 m^2 Deg C/W		
Air-side		0	0
Entering Air			
Dry Bulb			35.0 Deg C
Wet Bulb		23.9 Deg C	
Evaporator Water			
Leaving	6.7 Deg C		
Flow Rate	.043 L/s per kW		
Evaporator Fouling Factor Allowance			
Water-side	.000018 m2 Deg C/W		
Condenser-less			
	Water or Evaporative Cooled		Air Cooled
Saturated Discharge	40.6 Deg C		51.7 Deg C
Liquid Refrigerant	36.7 Deg C		40.6 Deg C
Barometric Pressure – 101 kPa			

The vast majority of Chillers sold in Australia are sourced from USA based suppliers and specified with ARI based standards. The ARI standard is hence the most relevant to Australia.

Review of International Approaches

USA

The regulatory framework for the US programs consists of the National Energy Policy and Conservation Act (NEPCA) of 1978 (and subsequent amendments), which requires comparative labelling for household appliances and packaging disclosure panels for certain classes of lighting; the National Appliance Energy Conservation Act (NAECA) of 1987 (and subsequent amendments), which requires MEPS for a range of household appliances; and the Energy Policy and Conservation Act (EPCAct) of 1992, which extended MEPS and labelling to certain classes of non-household products. This legislation requires the US Department of Energy (DOE) to set MEPS for a wide range of named products, plus any other products that consume more than a specified amount of energy.

While the USA has equipment based MEPS for many products under the Energy Policy Act of 1992, the efficiency of air conditioning chillers is regulated as part of State building codes. The ASHRAE Standard 90.1 (Energy Standard for Buildings Except for Low Rise Residential Buildings) specifies the test standards and MEPS levels for chillers and this standard then forms the technical basis for the all State building codes.

Testing Standard

The ASHRAE Standard 90.1 was approved by the ASHRAE and IESNA boards in 1993 and is intended to promote the application of cost-effective design practices and technologies that minimise energy consumption without sacrificing either the comfort or productivity of the occupants. This standard references ARI 550/590. The test conditions are shown in the earlier section in Table 2.

The test method applies to factory-made vapour compression refrigeration Water-Chilling Packages including one or more hermetic or open drive compressors. These Water-Chilling Packages include:

- Water-Cooled, Air-Cooled, or Evaporatively-Cooled Condensers,
- Air-Cooled or Water-Cooled Heat Reclaim Condensers,
- Packages supplied without a Condenser.

MEPS Levels

The Energy Policy and Conservation Act of 1992 (EPCAct 92) requires state and local governments to update their commercial building energy efficiency codes to be at least as stringent as ASHRAE Standard 90.1-1999 by 2004. To meet this requirement, almost all States have adopted ASHRAE 90.1-1999 and many have gone further and adopted ASHRAE 90.1-2001, including California, Oregon, Texas, Florida, New Jersey, New York, Maine, Georgia, Pennsylvania and Ohio (http://www.energycodes.gov/). The chiller efficiency levels for ASHRAE 90.1-1999 and 90.1-2001 are however the same.

Table 3 summarises the requirements for Chillers in ASHRAE Standard 90.1-1999, which is scheduled for mandatory adoption from July 2004.

Table 3: ASHRAE 90.1-1999&2001 Chiller Performance Standards

Vapour Compression Chillers	Capacity (kWR)	Min COP	Min IPLV
Air cooled, with Condenser	All Capacities	2.80	3.05
Air Cooled, without Condenser	All Capacities	3.10	3.45
Water cooled, Reciprocating	All Capacities	4.20	5.05
Water Cooled (Rotary Screw and Scroll)	< 528 kW	4.45	5.20
	>528 kW and < 1055 kW	4.90	5.60
	>1055 kW	5.50	6.15
Water Cooled, Centrifugal	< 528 kW	5.00	5.25
	> 528 kW and <1055 kW	5.55	5.90
	> 1055 kW	6.10	6.40
	> 1055 kW	6.10	6.40

Canada

The Canadian economy is the eighth largest in the world (measured in US dollars at market exchange rates) after the US, Japan, Germany, the UK, France, China and Italy. It is highly integrated with the US economy, which absorbs over 85% of its exports. The Energy Efficiency Act passed in 1992 provides for the making and enforcement of regulations concerning minimum energy performance standards (MEPS) for energy-using products, as well as the labelling of energy-using products and the collection of data.

Canada has a MEPS program that covers air and water sourced heat pumps, commercial air conditioning chillers and dehumidifiers. A voluntary comparative labelling program for heat pumps also exists.

In 2003, Canada proposed MEPS for chillers that are intended for application in the air conditioning of buildings. Products to be covered include vapour-compression chillers with a capacity less than 7 000kW with water condenser or less than 700kW with air condenser and absorption chillers up to 5 600kW. Energy efficiency was defined as COP and the Integrated Part Load Value (IPLV) for various size and technology combinations. The MEPS is set for implementation in October 2004 and will operate under the standard CSA-C743-02. This testing standard is equivalent to the American standard of ARI 550/590.

Testing Standard

The scope of Canadian Chiller Test Standard CSA-C743-02 is similar to ARI 550/590, and applies to:

- factory-designed and prefabricated absorption or vapour-compression refrigeration chillers equipped with centrifugal or rotary screw and positive displacement (reciprocating or scroll) compressors. The Standard applies to chillers having a cooling capacity under 5600 kW (1590 tons) and intended for application in air-conditioning systems for buildings.

- absorption chillers, single-effect indirect-fired by steam or hot water; double-effect, both indirect and direct-fired; and multiple-effect and multi-loop cycle absorption chiller/heater units. Water is the refrigerant and lithium bromide is the absorbent. It may also be used for rating gas-fired absorption chillers at the discretion of the user.
- hermetic and external-drive centrifugal or rotary-screw chillers with continuous capacity modulation, whether driven by an electric motor, steam turbine, or another prime mover, such as an internal combustion engine.
- hermetic and external-drive positive displacement (reciprocating or scroll) compressor equipped chillers, with either self-contained or remote condensers.
- positive displacement compressor heat reclaim chillers.

The Canadian Standard does not apply to

- absorption chillers with air-cooled condensers;
- liquid chillers for use with liquids other than water; and
- centrifugal or rotary screw heat reclaim chillers.

There are no labelling standards associated with air conditioning water chillers.

MEPS Levels

The MEPS levels are shown in Table 4. These MEPS are listed in CSA-C743-02, Section 6.

Table 4: Canada Minimum COP and IPLV of Packaged Water Chilling Packages

Type	Capacity Range, kW (tons)	COP	IPLV
Vapour Compression			
-- air-cooled with condenser	< 528 (150)	2.80	3.05
	>= 528 (150)	2.80	3.05
-- air-cooled without condenser	all	3.10	3.45
-- water-cooled, reciprocating	all	4.20	5.05
-- water-cooled, rotary screw, scroll	< 528 (150)	4.45	5.20
	>= 528 (150) and <= 1055 (300)	4.90	5.60
	>1055 (300)	5.50	6.15
-- water-cooled, centrifugal	< 528 (150)	5.00	5.25
	>= 528 (150) and <= 1055 (300)	5.55	5.90
	> 1055 (300)	6.10	6.40
Absorption			
-- single-effect absorption, air-cooled	all	0.60	N/A
-- single-effect absorption, water-cooled	all	0.70	N/A
-- double-effect absorption, indirect-fired	all	1.00	1.05
-- double-effect absorption, direct-fired	all	1.00	1.00

Chinese Taipei

The Energy Commission in the Ministry of Economic Affairs (MOEA) has developed MEPS for a number of products. In most cases the energy tests are detailed in Chinese National Standards (CNS) of Chinese Taipei, and the MEPS requirements are published by MOEA. The Bureau of Commodity Inspection and Quarantine is also involved in the implementation of the program.

Chinese Taipei introduced MEPS for commercial air conditioning chillers in January 2003. There are no regulations for the other chiller categories.

Testing Standard

Test standards are established in CNS 12575 for volumetric-type compressors (screw, scroll, piston, etc) and in CNS 12812 for centrifugal-type compressors. These standards reference test standards, ARI 550/590 and the Japanese Industrial Standard (JIS), as follows:

- B8613 - Chiller standard for displacement type motor compressor, evaporator, condenser, etc., and which have a cooling capacity of 420 kW; and
- B8621 - Centrifugal water chillers to be used for cooling or heating water having not less than 348.8 kW in refrigerating capacity

MEPS Levels

The MEPS for commercial air conditioning chillers required different units to attain varying MEPS levels dependent upon the chiller type and capacity. The MEPS level for water cooled type volumetric compressors will increase in 2005.

The current MEPS levels are shown in Table 5.

Table 5 - Chinese Taipei MEPS for Commercial Air Conditioning Chillers

Chiller Type	Min COP 2003	Min COP 2005
Water Cooled Type, Volumetric Compressors		
Cooling Capacity < 150 RT	4.07	4.45
Cooling Capacity ≥ 150 RT< 500 RT	4.19	4.90
Cooling Capacity ≥ 500 RT	4.65	5.50
Water Cooled Type, Centrifugal Compressors		
Cooling Capacity < 150 RT	5.0	5.0
Cooling Capacity ≥ 150 RT, < 300 RT	5.55	5.55
Cooling Capacity ≥ 300 RT	6.10	6.10
Air Cooled Type, All	**2.79**	**2.79**

Note: Volumetric compressors are screw, scroll and reciprocating

Summary

The USA, Canada and Chinese Taipei all test chillers to ARI 550/590 or the equivalent. The MEPS levels of the USA and Canada are the most stringent international standards, with Chinese Taipei coming into line with these standards in 2005. The USA and Canadian MEPS is specified in terms of minimum Coefficient of Performance (COP) and Integrated Part Load Value (IPLV), while the Chinese Taipei is applied to the COP only. The USA uses a building code (ASHRAE Standard 90.1) to enforce the MEPS for chillers and has had standards in place since 1993. The USA requires state and local governments to update their commercial building energy efficiency codes to be at least as stringent as ASHRAE Standard 90.1-1999 by 2004, however some States have already done so. The Canadian and Chinese Taipei MEPS are applied to equipment sold in that country.

Preliminary Views of Stakeholders

Interviews were undertaken via phone with several key industry stakeholders to assess the impact of any regulatory or voluntary measures relating to chillers and efficiency. These individuals are listed in the Reference section of this report.

The diversity of stakeholders was an important measure to avoid polarising answers to organisations or interests that are influenced by items such as brand, refrigerant type, technology and market dominance. This report contains much of the input from the industry stakeholders; however the following points are a summary of the more specific comments regarding the objective of this report:

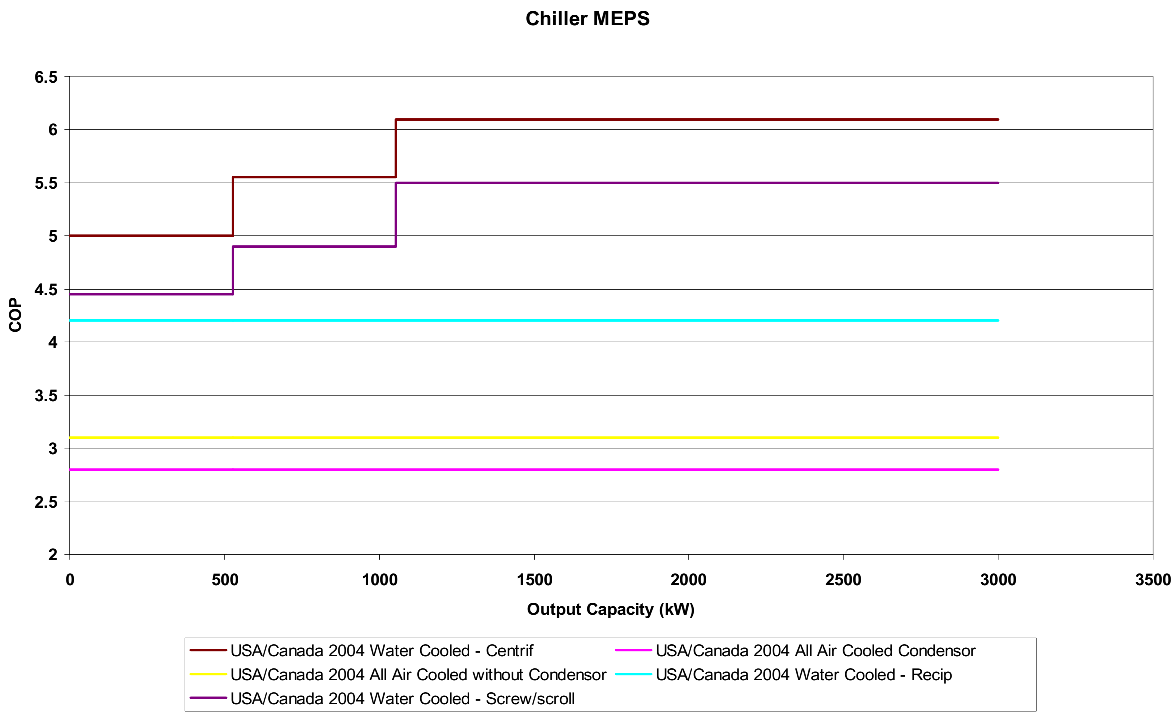
- Mandatory MEPS should be implemented for Australia
    - It was widely commented that voluntary programs can be effective in raising awareness for energy efficiency issues. However, it was generally felt that without code and legislative reinforcement there was no ongoing incentive to maintain compliance, especially from what is considered the "bottom end" of the chiller market place.
- Australia should follow the ARI measurement and certification procedure
    - As most of the chillers sourced for Australia are either imported from USA companies or based on USA test conditions, the ARI test method is the most applicable to Australia.
- Australia needs to verify the efficiency and performance data if a MEPS is applied
    - Any form of efficiency measure needs to be verifiable and enforced. Organisations such as ARI and Eurovent depend on being able to physically test chillers on test rigs to be able to maintain certification of those products. With Australia no longer operating a chiller test rig, and ARI and Eurovent not operational in this country, formalised testing of chillers is not possible.
- Energy labelling of chillers is not an appropriate or effective efficiency measure.
    - This was largely believed to be difficult or impossible to administer with chillers operating at varying capacities and efficiencies at different conditions. A certification scheme adopted from the ARI would be more appropriate.

Recommended MEPS

MEPS Levels

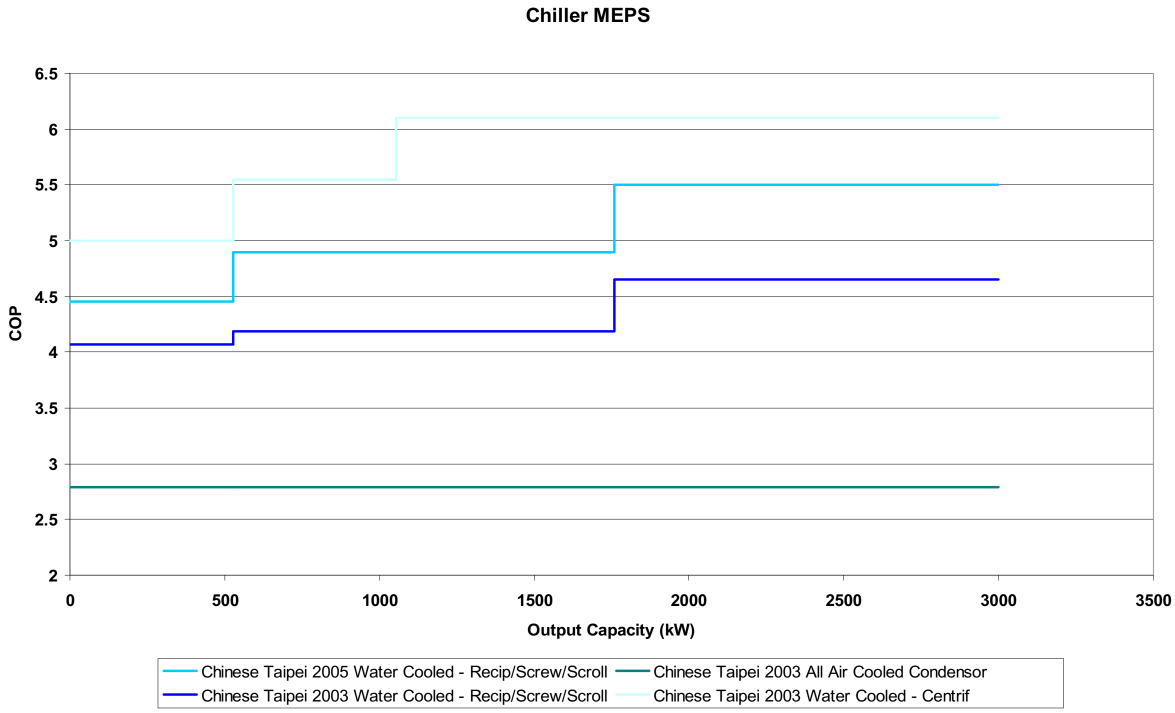
The Australian MEPS levels are to be based on international regulatory best practice. The MEPS levels in place in the USA and Canada are shown in Figure 3. These are the most stringent international MEPS levels for chillers.

Figure 3: Chiller MEPS Levels – USA/Canada 2004



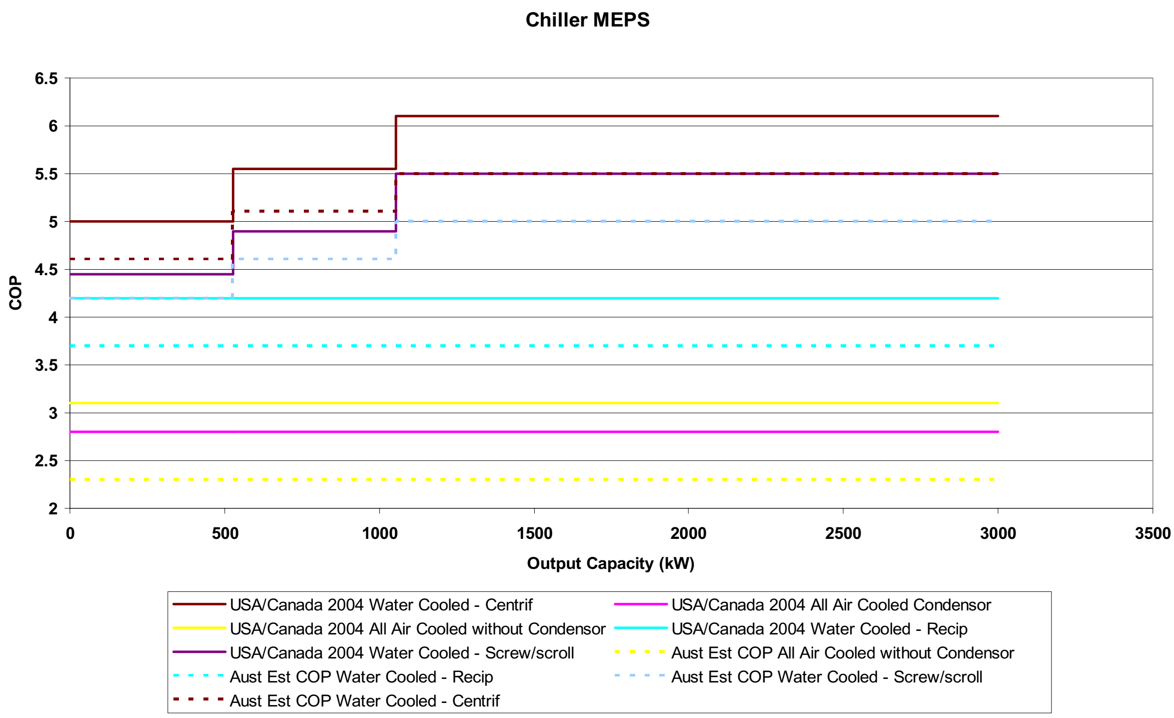
The Chinese Taipei chiller MEPS levels are shown in Figure 4. By 2005, their MEPS levels will be the same as the USA and Canada 2004 levels.

Figure 4: Chiller MEPS Levels –Chinese Taipei 2003 & 2005



The average efficiency of chillers in Australia appears to be lower than those in the USA and Canada, as shown in Figure 5 Cost effective efficiency levels for MEPS have been determined in the USA and Canada for chillers and will be implemented by July 2004 and October 2004 respectively.

Figure 5: Chiller MEPS USA/Canada compared to Estimated Australia Levels



As Australia suppliers source product that is typically rated under the USA/Canadian test method and now these countries have introduced the most stringent international MEPS levels, it is proposed to match the USA and Canada MEPS levels for chillers in Australia. Table 6 shows the proposed MEPS levels for Australia.

Table 6: Proposed Australian Chiller MEPS Levels

Vapour Compression Chillers	Capacity (kWR)	Min COP	Min IPLV
Air cooled, with Condenser	All Capacities	2.80	3.05
Air Cooled, without Condenser	All Capacities	3.10	3.45
Water cooled, Reciprocating	All Capacities	4.20	5.05
Water Cooled (Rotary Screw and Scroll)	< 528 kW	4.45	5.20
	>528 kW and < 1055 kW	4.90	5.60
	>1055 kW	5.50	6.15
Water Cooled, Centrifugal	< 528 kW	5.00	5.25
	> 528 kW and <1055 kW	5.55	5.90
	> 1055 kW	6.10	6.40
	> 1055 kW	6.10	6.40

Like the USA and Canada, the proposed minimum MEPS level applies to both the COP and the Integrated Part Load Value (IPLV).

Based on the USA, Canada and Chinese Taipei requirements, and as the market for Australian chillers is generally specified with the ARI and ASHREA standards, the Australian MEPS levels will ensure our product matches world best regulatory practice.

The USA will shortly issue a revised ASHRAE 90.1-2004 which will all the addenda issued since 1999 and revised code format. Over the period 2004 to 2006 ASHRAE will revised 90.1 and issue a new ASHRAE Standard 90.1-2007. At this stage, the MEPS levels for chillers in the new ASHRAE 90.1-2007 are not known, but these levels could be introduced into the Australian Standard as the "High Efficiency" levels, similar to the levels specified for "Class A" Efficiency of air conditioners in the AS 3823.2. This will be reviewed with the appropriate standards committee as required.

In the interim, the proposed high efficiency levels for COP are shown in Table 7, which are approximately 15% higher than the proposed MEPS levels. These high efficiency levels will be examined once the ASHREA 90.1 standard is revised in 2007, when it is likely that new minimum energy performance levels will be proposed for chillers.

Table 7: Recommended High Efficiency levels for Chillers

Vapour Compression Chillers	Capacity (kWR)	Min COP
Air cooled, with Condenser	All Capacities	3.20
Air Cooled, without Condenser	All Capacities	3.60
Water cooled, Reciprocating	All Capacities	4.85
Water Cooled (Rotary Screw and Scroll)	< 528 kW	5.10
	>528 kW and < 1055 kW	5.65
	>1055 kW	6.35
Water Cooled, Centrifugal	< 528 kW	5.75
	> 528 kW and <1055 kW	6.40
	> 1055 kW	7.00
	> 1055 kW	7.00

MEPS Implementation Issues

Testing Standard

The implementation of a MEPS for chillers will require the adoption of a new method of test under Standards Australia. A new standards committee may need to be formed to enable the adoption of the ARI standard ARI 550/590 – 2003. Alternatively, this standard will be managed by the existing committees. As the ARI standard is a proven model used by most of the international suppliers, there will not be significant issues in adopting this standard in Australia.

Verification of MEPS Compliance

Verification and testing of chillers for a MEPS program will be difficult in Australia as there is currently no testing facility. In addition, chillers are generally not available "off the shelf" like other equipment; they are specified by purchasers and usually imported as single units into Australia. The options available are:

- Establishment of an independent testing laboratory. This will require considerable resources and a commitment by Australian regulators to test a number of chillers on a regular basis. Expressions of interest in establishing a testing facility would be considered by the Australian regulators. This approach has been used successfully to encourage testing facilities for three phase electric motors. Once a chiller has been "landed" in Australia, the unit can be tested locally. In consultation with the chiller supplier and the purchaser, the of the chiller can be made available for testing.

- Use of overseas testing laboratories to test the chillers in the country of origin before they are shipped to Australia. Several testing facilities exist in the USA and collaboration with the ARI is highly likely. The Australian government collaborates with various USA government agencies via the Australian/US Climate Partnership and has close working relationships with the Californian Energy Commission. These international relationships will be used to verify the MEPS claims of Australian suppliers of chillers where they are sourced in the USA.

- Use of the ARI database for verification of the MEPS compliance. The ARI provide a publicly available database of certified chillers for both 50hz and 60hz electricity supply systems. This database will be used to verify the chiller complies with MEPS.

Building Code of Australia

In Australia typically applies MEPS to the equipment being sold. The Australian Building Code Board is proposing to change the Building Code of Australia (BCA) to include energy efficiency measures as part of the building code for office buildings. This building code will incorporate specifications of chiller energy performance; however the draft code is not currently published. The draft code for provisions for multi-residential buildings is published and contains specifications for chiller performance where the chiller is greater than 125kWr. The minimum requirement is 3.1 COP and 4.2 IPLV, and it is considered that these specifications will be utilised for office buildings (Class 5 buildings in the BCA). These minimum requirements are less then the proposed MEPS levels and would only apply to all new buildings constructed. Hence the replacement chiller market will not be covered by the BCA energy efficiency measures and the proposed BCA measures are not matching international best regulatory practice. The MEPS will be more effective if applied to the equipment being imported and sold in Australia. After consultation on the proposed chiller MEPS is finalised, the ABCB may consider the use of these levels in further BCA efficiency proposals.

Impact of MEPS

In collecting data for the market analysis, assumptions were made regarding market trends, mix of product type and the potential efficiencies of new products. These assumptions are based on actual data collected and historical references to chiller performance levels.

The analysis for GHG reduction impact has been based on two scenarios and associated assumptions. These scenarios are and assumptions are contained in Appendix A.

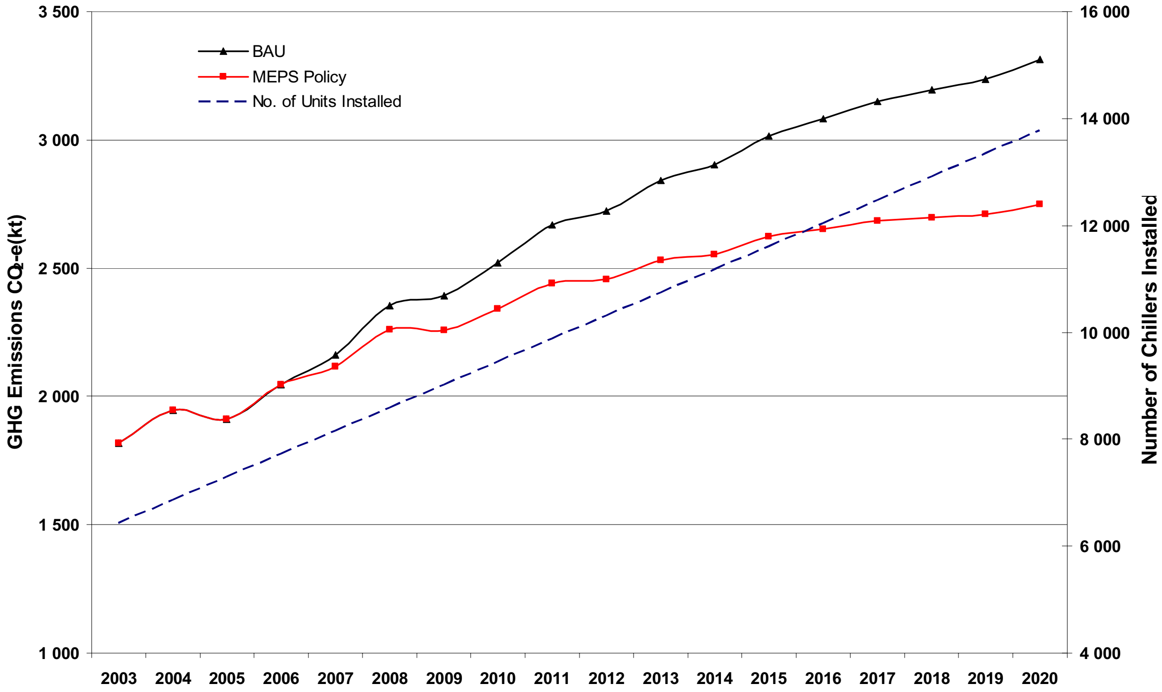
These scenarios are:

1. Business As Usual (BAU) – An existing baseline that is based on estimated installed base levels of chillers being replaced or additions to this base using current efficiencies

2. MEPS Policy – New additions and replacement chillers are predominantly sold at efficiencies that are comparable with ASHRAE 90.1 from 2007.

Figure 6 shows the overall GHG impacts of the proposed MEPS. It is estimated to provide an overall reduction of an estimated 8% of total baseline emissions in the period 2007 to 2012, totalling approximately 1.0 Mt CO^2e. The estimated annual emission reduction in 2016 is 430 kt CO_2-e, which is comparable to the impact of the 2001 MEPS for three phase packaged air conditioners, of 530 kt CO_2-e pa after 9 years of implementation. The proposed MEPS levels provide an estimated $50M of discounted (at 15%) energy cost savings by 2016.

Figure 6 – Estimated GHG emissions – BAU vs. MEPS Policy



Recommendations

The analysis in this report concludes that a MEPS level for chillers is warranted and that the levels match the USA and Canada, which is international best practice. There is a range of efficiency levels for chillers sold in Australia and it is consider that chillers that meet the proposed MEPS levels should be available, especially as the USA, Canada and Chinese Taipei have introduced MEPS levels equivalent to the proposed Australian levels.

The proposed MEPS levels are shown in Table 6. The testing method for chillers should be based on the ARI 550/590 - 2003 Standard for Water Chilling Packages using the Vapour Compression Cycle. It is proposed to adopt this standard as an Australian Standard and prepare a Part 2 Standard which is based on section 6.2.1 of ASHRAE 90.1-2001 SI edition.

The MEPS will apply to factory-designed and prefabricated vapour-compression chillers that have a cooling capacity of less than 7000 kW (2000 tons) with water condenser and less than 700 kW (200 tons) with air condenser. These packaged water chillers are intended for application in air-conditioning systems for buildings.

Testing of the units initially in Australia will most likely not be possible, due to the lack of an Australian testing facility. Suppliers however, will be able to test their products in the country of origin to the ARI standard, as this is the common international standard, and hence certify that the product is tested to the AS standard.

Check testing of the units being sold in Australia for compliance can be undertaken in overseas testing facilities to the ARI 550/590-2003 standard, or by checking the ARI certification is in accordance with ARI requirements.

A timetable for implementing the major elements of these recommendations is shown in Table 8, including the various stages of consultation with industry and other stakeholders. A twelve to eighteen month period has been included between the final publication date of the Australian Standards documents and the first implementation date.

Table 8: Proposed Implementation Plan for Recommendations

Item		Date(s)
1.	Initial interviews with industry	April 2003 (completed)
2.	Government publication of MEPS Proposals for Chillers	October 2004
3.	Industry response to recommendations	December 2004
4.	Consultation on Draft Standard by Standards Australia	January 2005 - October 2005
5.	Publication of Draft Standard by Standards Australia	October 2005
6.	Publication of Final Standard by Standards Australia	April - October 2006
7.	Regulatory Impact Statement undertaken	2005
8.	Introduce MEPS	October 2007

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ARI 550/590-2003. Air-Conditioning and Refrigeration Institute, ARI Standard 550/590, 2003 *Water Chilling Packages using the Vapour Compression Cycle.* (http://www.ari.org/std/ individual/550.590-2003.pdf).

ASHREA 90.1 – 2001. American Society of Heating, Refrigerating and Air-Conditioning Engineers(ASHREA) *Standard 90.1 – 2001 Energy Standard for Buildings Except Low-Rise Residential Buildings.* AHREA 2004

BSRIA Study "The Australian Air Conditioning Study" (Summary Only), January 2002

Eurovent Certification Programme, (www.eurovent-certification.com)

Interviews – 2004 various, including

- Simon Ho (Trane Australia), representing AREMA
- Warwick Barnes, Systems Consultant, Air Solutions International
- John Shewan, Managing Director, Airwell Australia
- Brian McDonald, Managing Director, Fluid Chillers Australia
- Ian Stewart, Managing Director, McQuay Australia
- Kate McDonald, Editor, Climate Control News

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NRCan 2003, Office of Energy Efficiency Natural Resources Canada, *Proposed Regulations for Packaged Water Chillers, Bulletin – February 2003.* http://oee.nrcan.gc.ca/regulations/packaged_water_chillers.cfm.

Appendix A: Data and Assumptions

Weighted Average Marginal electricity coefficients (kg CO2-e/kWh) from GWA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Australia Avg	0.929	0.929	0.925	0.953	0.953	0.878	0.886	0.885	0.913	0.882	0.886	0.896	0.875

BAU Option - Correction for replacement units

No. of existing units to be replaced	288
Estimated average COP of existing units	3.23
Annual kWh Consumption of existing units	85 230 644
CO2-e Emissions in Tonnes	81 236
Estimated average COP of replacement units	3.22
Annual kWh Consumption of replacement units	87 528 477
CO2-e Emissions in Tonnes	83 426
Net reduction in CO2-e emissions	2190
Net reduction in kWh Consumption	2 297 833

ASHRAE 90.1 Correction for replacement units

No. of existing units to be replaced	288
Estimated average COP of existing units	3.23
Annual kWh Consumption of existing units	85 230 644
CO2-e Emissions in Tonnes	81 236
Estimated average COP of replacement units	4.19
Annual kWh Consumption of replacement units	67 223 839
CO2-e Emissions in Tonnes	59 546
Net reduction in CO2-e emissions	- 21 690
Net reduction in kWh Consumption	-18 006 805

Input Factors for COP

	Installed Base		Current Non 90.1		ASHRAE 90.1	
	Water Cool	Air Cool	Water Cool	Air Cool	Water Cool	Air Cool
Recip/Scroll	3.70	2.50	3.70	2.60	4.20	3.45
Rotary/Screw	4.50	2.50	5.00	2.75	5.20	4.45
Centrifugal	4.70	0.00	5.55	0.00	6.10	0.00

Other Factors

Installed base	6000	units
Annual Chiller sales	720	units
Installed base electricity coefficient	0.953	kg CO2-e (2003 base year for calculation)
Average run hours per unit	2000	per annum
Average installed capacity		
Recip/Scroll	450	kW refrigeration capacity
Rotary/Screw	500	kW refrigeration capacity
Centrifugal	700	kW refrigeration capacity

Assessed Installed Base

Market Size in # of Units: 6000

Type	Units	%	Sub-type	Units	%	Average installed capacity in kWR	Total Installed Base Capacity in kWR	Estimated Average COP	kW used per annum	Hours run per annum	kWH's per annum	CO2 Equivelant Emissions in Tonnes
Air-Cooled	2400	40%	Recip/Scroll	2280	95%	450	1 026 000	2.50	410 400	2000	820 800 000	847 370
			Rotary/Screw	120	5%	500	60 000	2.50	24 000	2000	48 000 000	49 554
			Centrifugal	0	0%	700	-	0.00	-	2000	-	-
Total Results Line							2 864 400	3.23	887 819		1 775 638 413	1 833 117
Water-Cooled	3600	60%	Recip/Scroll	2880	80%	450	1 296 000	3.70	350 270	2000	700 540 541	723 218
			Rotary/Screw	108	3%	500	54 000	4.50	12 000	2000	24 000 000	24 777
			Centrifugal	612	17%	700	428 400	4.70	91 149	2000	182 297 872	188 199

Replacement Units - Current Efficiencies

Total Annual Unit Sales: 720

Percentage of total annual sales as replacement units: 40%

Market Size in # of Units: 288

Cooling type	Units	Share	Compressor	Units	Share	Average installed capacity in kWR	Total Installed Base Capacity in kWR	Estimated Average COP	kW used per annum	Hours run per annum	kWH's per annum	CO2 Equivelant Emissions in Tonnes
Air-Cooled	190	66%	Recip/Scroll	135	71%	450	60 731	2.60	23 358	2000	46 715 815	48 228
			Rotary/Screw	55	29%	500	27 562	2.75	10 022	2000	20 044 800	20 694
			Centrifugal	0	0%	700	-	0.00	-	2000	-	-
Total Results Line							140 728	3.22	43 764		87 528 477	90 362
Water-Cooled	98	34%	Recip/Scroll	5	5%	450	2 203	3.70	595	2000	1 190 919	1 229
			Rotary/Screw	74	76%	500	37 210	5.00	7 442	2000	14 883 840	15 366
			Centrifugal	19	19%	700	13 023	5.55	2 347	2000	4 693 103	4 845

Additional Units - Current Efficiencies

Percentage of total annual sales as replacement units: 60%

Market Size in # of Units: 432

Cooling type	Units	Share	Compressor	Units	Share	Average installed capacity in kWR	Total Installed Base Capacity in kWR	Estimated Average COP	kW used per annum	Hours run per annum	kWH's per annum	CO2 Equivelant Emissions in Tonnes
Air-Cooled	285	66%	Recip/Scroll	202	71%	450	91 096	2.60	35 037	2000	70 073 723	72 342
			Rotary/Screw	83	29%	500	41 342	2.75	15 034	2000	30 067 200	31 040
			Centrifugal	0	0%	700	-	0.00	-	2000	-	-
Total Results Line							211 092	3.22	65 646		131 292 716	135 543
Water-Cooled	147	34%	Recip/Scroll	7	5%	450	3 305	3.70	893	2000	1 786 378	1 844
			Rotary/Screw	112	76%	500	55 814	5.00	11 163	2000	22 325 760	23 048
			Centrifugal	28	19%	700	19 535	5.55	3 520	2000	7 039 654	7 268

Replacement Units - ASHRAE 90.1 Efficiencies

Total Annual Unit Sales: 720

Percentage of total annual sales as replacement units: 40%

Market Size in # of Units: 288

- Air-Cooled: 190 (66%)
- Water-Cooled: 98 (34%)

Cooling	Type	Units	%	Average installed capacity in kWR	Total Installed Base Capacity in kWR	Estimated Average COP	kW used per annum	Hours run per annum	kWH's per annum	CO2 Equivelant Emissions in Tonnes
Air-Cooled	Recip/Scroll	135	71%	450	60 731	3.45	17 603	2000	35 206 122	35 572
Air-Cooled	Rotary/Screw	55	29%	500	27 562	4.45	6 194	2000	12 387 236	12 516
Air-Cooled	Centrifugal	0	0%	700	-	0.00	-	2000	-	-
Total Results Line					140 728	4.19	33 612		67 223 839	67 923
Water-Cooled	Recip/Scroll	5	5%	450	2 203	4.20	525	2000	1 049 143	1 060
Water-Cooled	Rotary/Screw	74	76%	500	37 210	5.20	7 156	2000	14 311 385	14 460
Water-Cooled	Centrifugal	19	19%	700	13 023	6.10	2 135	2000	4 269 954	4 314

Additional Units - ASHRAE 90.1 Efficiencies

Percentage of total annual sales as replacement units: 60%

Market Size in # of Units: 432

- Air-Cooled: 285 (66%)
- Water-Cooled: 147 (34%)

Cooling	Type	Units	%	Average installed capacity in kWR	Total Installed Base Capacity in kWR	Estimated Average COP	kW used per annum	Hours run per annum	kWH's per annum	CO2 Equivelant Emissions in Tonnes
Air-Cooled	Recip/Scroll	202	71%	450	91 096	3.45	26 405	2000	52 809 183	53 358
Air-Cooled	Rotary/Screw	83	29%	500	41 342	4.45	9 290	2000	18 580 854	18 774
Air-Cooled	Centrifugal	0	0%	700	-	0.00	-	2000	-	-
Total Results Line					211 092	4.19	50 418		100 835 759	101 884
Water-Cooled	Recip/Scroll	7	5%	450	3 305	4.20	787	2000	1 573 714	1 590
Water-Cooled	Rotary/Screw	112	76%	500	55 814	5.20	10 734	2000	21 467 077	21 690
Water-Cooled	Centrifugal	28	19%	700	19 535	6.10	3 202	2000	6 404 931	6 471

GHG Emissions

BAU		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Old Installed Base		6 000	6 432	6 864	7 296	7 728	8 160	8 592	9 024	9 456	9 888	10 320	10 752	11 184	11 616	12 048	12 480	12 912	13 344
GHG Emission Factor	kgCO2e/kWh	0.953	0.953	0.878	0.886	0.885	0.913	0.882	0.886	0.896	0.875	0.875	0.859	0.859	0.845	0.834	0.817	0.800	0.793
Annual kWh Consumption	kWh	1 775 638 413	1 909 228 962	2 042 819 510	2 176 410 059	2 310 000 608	2 443 591 156	2 577 181 705	2 710 772 254	2 844 362 802	2 977 953 351	3 111 543 900	3 245 134 449	3 378 724 997	3 512 315 546	3 645 906 095	3 779 496 643	3 913 087 192	4 046 677 741
Annual GHG Emissions	*Tonnes CO2e*	1 692 422	1 819 153	1 793 460	1 927 849	2 044 068	2 231 020	2 273 665	2 401 924	2 547 957	2 607 091	2 724 007	2 787 702	2 901 672	2 969 575	3 039 579	3 086 326	3 130 118	3 207 695
Additional New Units		432	432	432	432	432	432	432	432	432	432	432	432	432	432	432	432	432	432
GHG Emission Factor	kgCO2e/kWh	0.953	0.953	0.878	0.886	0.885	0.913	0.882	0.886	0.896	0.875	0.875	0.859	0.859	0.845	0.834	0.817	0.800	0.793
Annual kWh Consumption	kWh	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716	131 292 716
Annual GHG Emissions	*Tonnes CO2e*	125 140	125 098	115 266	116 298	116 178	119 871	115 830	116 334	117 611	114 942	114 940	112 786	112 755	111 005	109 458	107 213	105 022	104 072
Replacement Units		288	288	288	288	288	288	288	288	288	288	288	288	288	288	288	288	288	288
GHG Emission Factor	kgCO2e/kWh	0.953	0.953	0.878	0.886	0.885	0.913	0.882	0.886	0.896	0.875	0.875	0.859	0.859	0.845	0.834	0.817	0.800	0.793
Annual kWh Consumption	kWh	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833	2 297 833
Annual GHG Emissions	*Tonnes CO2e*	2 190	2 189	2 017	2 035	2 033	2 098	2 027	2 036	2 058	2 012	2 012	1 974	1 973	1 943	1 916	1 876	1 838	1 821
New Installed Base		6 432	6 864	7 296	7 728	8 160	8 592	9 024	9 456	9 888	10 320	10 752	11 184	11 616	12 048	12 480	12 912	13 344	13 776
Annual kWh Consumption	*kWh*	1 909 228 962	2 042 819 510	2 176 410 059	2 310 000 608	2 443 591 156	2 577 181 705	2 710 772 254	2 844 362 802	2 977 953 351	3 111 543 900	3 245 134 449	3 378 724 997	3 512 315 546	3 645 906 095	3 779 496 643	3 913 087 192	4 046 677 741	4 180 268 289
Annual GHG Emissions	*Tonnes CO2e*	1 819 751	1 946 441	1 910 743	2 046 183	2 162 280	2 352 990	2 391 522	2 520 294	2 667 626	2 724 045	2 840 959	2 902 462	3 016 401	3 082 523	3 150 953	3 195 416	3 236 979	3 313 589
					16 864 939														

MEPS Option		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Old Installed Base		6 000	6 432	6 864	7 296	7 728	8 160	8 592	9 024	9 456	9 888	10 320	10 752	11 184	11 616	12 048	12 480	12 912	13 344
GHG Emission Factor	kgCO2e/kWh	0.953	0.953	0.878	0.886	0.885	0.913	0.882	0.886	0.896	0.875	0.875	0.859	0.859	0.845	0.834	0.817	0.800	0.793
Annual kWh Consumption	kWh	1 775 638 413	1 909 228 962	2 042 819 510	2 176 410 059	2 310 000 608	2 392 829 562	2 475 658 516	2 558 487 471	2 641 316 425	2 724 145 379	2 806 974 334	2 889 803 288	2 972 632 242	3 055 461 197	3 138 290 151	3 221 119 105	3 303 948 060	3 386 777 014
Annual GHG Emissions	*Tonnes CO2e*	1 692 422	1 819 153	1 793 460	1 927 849	2 044 068	2 184 674	2 184 098	2 266 989	2 366 069	2 384 892	2 457 371	2 482 458	2 552 917	2 583 316	2 616 381	2 630 357	2 642 862	2 684 609
Additional New Units		432	432	432	432	432	432	432	432	432	432	432	432	432	432	432	432	432	432
GHG Emission Factor	kgCO2e/kWh	0.953	0.953	0.878	0.886	0.885	0.913	0.882	0.886	0.896	0.875	0.875	0.859	0.859	0.845	0.834	0.817	0.800	0.793
Annual kWh Consumption	kWh	131 292 716	131 292 716	131 292 716	131 292 716	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759	100 835 759
Annual GHG Emissions	*Tonnes CO2e*	125 140	125 098	115 266	116 298	89 227	92 064	88 960	89 347	90 328	88 278	88 277	86 622	86 598	85 254	84 066	82 342	80 660	79 930
Replacement Units		288	288	288	288	288	288	288	288	288	288	288	288	288	288	288	288	288	288
GHG Emission Factor	kgCO2e/kWh	0.953	0.953	0.878	0.886	0.885	0.913	0.882	0.886	0.896	0.875	0.875	0.859	0.859	0.845	0.834	0.817	0.800	0.793
Annual kWh Consumption	kWh	2 297 833	2 297 833	2 297 833	2 297 833	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805	-18 006 805
Annual GHG Emissions	*Tonnes CO2e*	2 190	2 189	2 017	2 035	-15 934	-16 440	-15 886	-15 955	-16 130	-15 764	-15 764	-15 469	-15 464	-15 224	-15 012	-14 704	-14 404	-14 274
New Installed Base		6 432	6 864	7 296	7 728	8 160	8 592	9 024	9 456	9 888	10 320	10 752	11 184	11 616	12 048	12 480	12 912	13 344	13 776
Annual kWh Consumption	kWh	1 909 228 962	2 042 819 510	2 176 410 059	2 310 000 608	2 392 829 562	2 475 658 516	2 558 487 471	2 641 316 425	2 724 145 379	2 806 974 334	2 889 803 288	2 972 632 242	3 055 461 197	3 138 290 151	3 221 119 105	3 303 948 060	3 386 777 014	3 469 605 968
Annual GHG Emissions	*Tonnes CO2e*	1 819 751	1 946 441	1 910 743	2 046 183	2 117 362	2 260 298	2 257 172	2 340 381	2 440 267	2 457 405	2 529 884	2 553 612	2 624 051	2 653 346	2 685 435	2 697 995	2 709 117	2 750 265
					15 919 068														
GHG Difference P.A.		0	0	0	0	44 918	92 692	134 350	179 913	227 359	266 640	311 075	348 850	392 350	429 177	465 517	497 421	527 861	563 323
Cumulative		0	0	0	0	44 918	137 609	271 959	451 872	679 231	945 871	1 256 946	1 605 796	1 998 146	2 427 323	2 892 840	3 390 261	3 918 122	4 481 446
GWH saving pa	MWh	0	0	0	0	50 762	101 523	152 285	203 046	253 808	304 570	355 331	406 093	456 854	507 616	558 378	609 139	659 901	710 662
Cumulative	*MWh*	0	0	0	0	50 762	152 285	304 570	507 616	761 424	1 065 993	1 421 325	1 827 417	2 284 272	2 791 888	3 350 265	3 959 404	4 619 305	5 329 967
$ saving pa	$ real	0	0	0	0	5 076 159	10 152 319	15 228 478	20 304 638	25 380 797	30 456 957	35 533 116	40 609 275	45 685 435	50 761 594	55 837 754	60 913 913	65 990 073	71 066 232
Cumulative	*$ real*	0	0	0	0	5 076 159	15 228 478	30 456 957	50 761 594	76 142 392	106 599 348	142 132 464	182 741 740	228 427 175	279 188 769	335 026 523	395 940 436	461 930 509	532 996 741