Case Study 2

# A POLICY AND TECHNOLOGY ROADMAP FOR ENERGY EFFICIENT AIR CONDITIONERS IN CHINA

Case Study of the Summary Report:

## Policy and Technology Pathways to a Low Carbon Economy: Electric Vehicles and Energy Efficient Air Conditioners in China

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## Acronyms

| | |
|---|---|
| ADB | Asian Development Bank |
| BAU | Business as usual |
| CAS | Chinese Academy of Sciences |
| CDM | Clean Development Mechanism |
| CEACER | China Energy and $CO_2$ Emissions Report |
| CME | Carbon Market Economics |
| $CO_2$ | Carbon dioxide |
| $CO_{2\text{-}e}$ | Carbon dioxide equivalent |
| COP | Coefficient of performance |
| CSES | Centre for Strategic Economic Studies |
| ECS | Energy Conservation Scheduling |
| EER | Energy Efficiency Rating |
| EIA | United States Energy Information Administration |
| ERI | Energy Research Institute |
| EU | European Union |
| EV | Electric vehicle |
| FYP | Five Year Plan |
| GDP | Gross Domestic Product |
| GHG | Greenhouse gases |
| GW | Gigawatts |
| IEA | International Energy Agency |
| kW | Kilowatts |
| kWh | Kilowatt hours |
| LCE | Low carbon economy |
| MEPS | National Bureau of Statistics, China |
| NBSC | National Bureau of Statistics, China |
| NDRC | National Development and Reform Commission, China |
| NEA | National Energy Agency, China |
| NEC | National Energy Commission, China |
| NPC | National People's Congress, China |
| OECD | Organisation for Economic Co-operation and Development |
| PV | Photovoltaic (solar cells) |
| RAC | Room air conditioner |
| RMB | Renminbi or Chinese National Yuan |
| SGCC | State Grid Corporation of China |
| TCE | Tons of standard coal equivalent |
| TPY | Tons per year |
| US | United States |
| VAT | Value added tax |
| WTO | World Trade Organisation |

# 1. Introduction

## 1.1 Background

Air conditioners are major consumers of peak energy demand posing potentially serious energy supply constraints in the near future. Yet the sector provides opportunities for simple, low cost improvements in energy efficiency. As a major global producer and consumer of air-conditioners, significant local and global benefits will arise from the mass production of energy efficient air conditioners in China.

There are currently around 280 million room air conditioners (RACs) in China, representing a relatively small component of China's total energy demand. However, this is one of the key areas of future growth in energy demand. With estimates of 700 million units installed by 2025, the implications for future energy demand arising from air conditioners are significant. Today, the use of air conditioners is already a major factor in exacerbating peak-energy demand, which risks posing serious energy supply constraints in the near future. Air conditioners currently account for around 20% of Chinese household electricity use, represent 40% of household demand in summer and 40% of total peak demand in major Chinese cities. Energy demand from increasing usage of air conditioners will only rise further due to the effects of increasing temperatures, from the combined effects of climate change and urban consolidation, and interacting with the increased demand for cooling associated with rising household incomes. A further consideration is the expanding global market for air conditioners. Presently, the Chinese market is the biggest air conditioner market by value, with 80% of the world's RACs manufactured in China in 2009. Therefore, the importance of introducing energy efficiency improvements and the adoption of advanced technologies in air conditioners manufactured in China is high.

This report acknowledges that tackling the issue of energy efficiency relating to air conditioners needs to occur within four interconnected aspects: (i) energy efficiency standards of air conditioner units; (ii) building energy efficiency and urban planning; (iii) lifestyle expectations and demands; and (iv) rising temperatures attributed to climate change and the urban heat effect. While not neglecting any of these aspects, this report focuses on the first aspect, individual air conditioners, by developing policy and technology roadmaps through to 2030 for super energy efficient air conditioners.

The policies and technologies identified in this report for attaining improvements in the energy efficiency of air conditioners going forward to 2030 include a wide range of measures, techniques and knowledge, most of which already exists. For example, advanced heat pumps, inverters, refrigerants and hybrid solar cooling and heating systems are all well know, but best available technologies (BATs) are yet to penetrate commercial markets on a large scale. In order to accelerate the shift to super efficient air conditioners, a range of policies measures need to be adopted, including: the progressive tightening of Minimum Energy Performance Standards (MEPS); the introduction and gradual tightening of average regional energy efficiency requirements and minimum standards, as well as the weighted average performance measures for units sold; the provision of capital subsidies or additional rebates for the purchase of super efficient air conditioners; the strengthening of educational, monitoring and testing regimes; and support for the installation of smart meters to monitor and control energy use.

The most successful policy program identified for achieving low cost and effective energy efficiency gains to date is Japan’s Top Runner Program. The Top Runner program was introduced as a countermeasure to the increasing consumption of energy within the residential, commercial and transportation sectors. It has effectively improved the energy efficiency of machinery and equipment by incrementally tightening both the minimum and average energy efficiency standards of products under the system. In the first seven years of the program since its commencement in 1997, the energy efficiency of air conditioners rose by 67.8%. However, this program failed to adequately remove the presence of large numbers of low performing air conditioners from the market. Therefore, combining the Top Runner Program with Minimum Energy Performance Standards (MEPS) in 2004, resulted in a significant improvement in the average energy efficiency of air conditioners sold on the Japanese market. It remains unclear, however, that such a policy setting would be as effective or appropriate in China given its specific local circumstances.

One of the key outputs of this joint study is the drawing up of a technology and policy roadmap for energy efficient air conditioners in China. It sets out the policy parameters, technology requirements and investment levels that need to be adopted in order to maximise the contribution of the cooling industry to achieving an overall carbon emissions peak and decline around 2025-2030, given the expected growth in air conditioner usage over the next two decades. The roadmap incorporates five aspects, namely:

1. The availability of improved energy efficiency technologies and the challenges of moving industry standards toward super efficient air conditioners.
2. The cost and effectiveness of complementary policies, such as energy labelling, white certificate schemes, rebates and minimum installation and building standards.
3. The measurement of air conditioner performance with a priority on peak demand impact and the relative coefficient of performance (COP)/energy efficiency rating (EER) measure.
4. Implementation and program design considerations, such as changing consumer behaviour, stretch targets and governance arrangements.
5. Broader considerations relating to efficiencies achieved through integrated systems and connectivity to a smart grid and smart metering systems.

The conclusions of this report suggest the most effective policy and technology pathway for meeting the three main objectives of reducing total energy demand, peak demand for electricity and greenhouse gas abatement, whilst promoting a globally competitive and innovative Chinese air conditioner industry.

## 1.2 Impact of Air Conditioners on Electricity Consumption

Globally, annual sales of air conditioners are around 70 million with half this number, or 35 million, sold in the Chinese market alone. In 2010, China had over 700 million air conditioners, which equates to 106 units per 100 urban households and 12 units per 100 rural households. However, in wealthier cities and regions the average urban penetration rate is already around 200 units per 1,000 households. While these air conditioners consume around 200 TWh of electricity annually, the greatest impact upon electricity is during peak summer demand when they use up to 40% of overall electricity consumption. While air conditioners already play an important role in summer peak loading, it is anticipated that the sales and use of air conditioners will rise exponentially over the next two decades. It is this future growth in ownership of air conditioners combined with their greater usage due to higher expectations for comfort and lifestyle, that is concerning.

The consumption of energy by air conditioners and the buildings in which they operate are two sides of the one coin. Tackling appliance energy efficiency issues is difficult without considering the other equally important issues of buildings. The IPCC's AR4 report (2007, p. 59) concluded that the building sector as a whole can provide the *largest* and *cheapest* carbon emissions mitigation benefits across all the reviewed areas: around 6.5 Gt of $CO_2$e can be saved annually across the planet by spending less than US$20 extra per tonne of $CO_2$e. In 2011, the International Energy Agency (IEA) published a report *Technology Roadmap, Energy-Efficient Buildings: Heating and Cooling Equipment* outlining a detailed roadmap for improving the energy efficiency of buildings. The IEA estimated that the buildings sector had the potential of realising annual greenhouse gas emissions reductions of 2 Gigatons (Gt) by 2050 below business as usual (BAU). Similarly, McKinsey (2009) identified significant improvements in energy efficiency in the buildings and appliances sectors, especially with improvements to managing the climate control systems of residential and commercial buildings.

In terms of heating and cooling, many existing technologies and practices can be readily adopted to achieve these targets including: the adoption of energy efficient heating and cooling appliances; improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids ($CO_2$); the recovery and recycling of fluorinated gases; integrated cooling and heating with solar PV; the integrated design of commercial buildings including technologies, such as cogeneration, trigeneration and intelligent control systems, and meters that provide integrated feedback and control at the household level.

The IPCC recommends the adoption of a broad range of policies, measures and instruments: appliance standards and labelling; building codes and certification; demand-side management programmes; public sector leadership programmes, including procurement; and incentives for energy service companies (ESCOs). China has already established such a broad array of policy measures including the use of standards and certification. For instance, China's current building energy efficient certification system adopts five levels and is compulsory for all large-scale buildings or buildings reliant upon public funds for their construction.

The energy efficiency rating of buildings (BEER), the use of passive measures for heating and cooling, retrofitting and the application of appropriate materials, design, insulation and layouts, all directly influence the demand for and use of air conditioning. Despite the great potential and low cost of achieving significant energy efficiency gains in the buildings and appliances sector, Jin and Rui (2008) argue that little progress in this sector has occurred until recently.

Understanding the life cycle costs of buildings is an important way of ensuring that locked-in energy usage costs of operating the building are minimised at the design and construction stage. It is estimated that operating contributes an average 80% of total life cycle energy use and related emissions compared to around 15% for the building materials and a very small percentage for the maintenance, construction and demolition of the building.

China has introduced a broad range of building energy codes which are aimed to achieve a 50% reduction in energy use at less than a 10% cost increase compared to pre-existing buildings. However, due to a return-benefit timeframe of 5 to 10 years it is perceived as too long to be worthwhile for the original builders who are often not the building occupiers. Another constraining aspect is that Chinese buildings only stand for an average of between 25 and 30 years. In contrast, the average life expectancy of a building in Britain is 132 years and around 74 years in the United States.

## 1.3 Potential Impact 2010-2030 in China

### *Urbanisation and rising living standards*

Population growth and rapid urbanisation are major drivers of China’s growing energy consumption. The share of urban population in China’s total population has doubled from 26% in 1990 to 50% in 2008 or from 254 million to 750 million people. This is equivalent to an annual increase of over 1% of the total population or about 17 million shifting to China’s urban centres every year. The urbanisation rate will remain steady over the next twenty years growing from the present 650 million or half of the population to 850 million in 2020, before reaching 1 billion by 2025-2030 or two thirds of the total population of 1.5 billion.

The growing urban population creates massive pressures on existing infrastructure as well as demands for the construction of new housing, offices and infrastructure, all of which require building materials, construction machinery, steel, cement, chemicals, power, land and water. Between now and 2030, according to McKinsey (2009, p. 32), ‘China plans to build 50,000 new high-rise residential buildings’ to cater for this new urban population. Between 2005 and 2030, commercial and residential floor space will increase by around 2 billion square metres annually or from $42m^2$ billion to $91m^2$ billion.[1] As a result, total energy demand from urban residential buildings will more than double from 6.6 EJ in 2000 to 15.9 EJ in 2020 (McKinsey, 2009; CEACER, 2009).

Residential energy consumption now contributes to over 11% of China's total energy consumption, and is the second highest energy consumption sector following the industrial sector. And yet, there is already considerable scope for achieving energy savings by targeting urban households, whose energy consumption is three times that of rural households (Zhang Lixiao et al., 2009). The behavioural characteristics and lifestyle expectations of ordinary Chinese will play an increasingly important role in determining future energy demands and the success of energy efficiency initiatives.

In 2006, regulations were introduced requiring the halving of energy consumption levels in new buildings compared to the current levels. However, very few existing buildings and not many new buildings, especially outside major cities such as Beijing and Shanghai, meet the new energy efficiency guidelines. A green star building evaluation standard has been more successful in urban areas, especially in raising the levels of awareness about the importance of energy efficiency at the building design stage. The program has been less successful at the construction stage, but remains in its early days. Another buildings program has targeted the introduction of temperature controls for government buildings, which requires the winter heating temperature to not exceed 20°C and the summer cooling temperature is set no lower than 26°C.

Conservative estimates of growing energy demand show the building and appliances sector's contribution to total energy consumption rising from the present 17% to 25% by 2030, which would require the construction of a further eighteen 1,000 MW coal-fired power stations. This increase would result in an annual increase of 80 million tons of GHG emissions, so that by 2030 the sector produces 3.2 Gt of $CO_2$-e.

According to "China's comprehensive energy development strategy and policy" (State Council DRC, 2005), in order to reach a *xiao kang* society by 2020, energy efficiency programs should focus on promoting industrial energy conservation and energy efficiency in buildings and transport. The rising incomes, living standards and consumption patterns of these urban residents will fuel an appetite for larger residential and commercial buildings. China's *xiao kang* society sets a number of benchmark requirements, including a residential area of $35m^2$ per capita, a population of 1.47 billion, an urbanisation rate of 55.78% and total residential area of $55m^2$ billion. More critically, each household will most likely be equipped with the indispensable list of all requisite energy intensive functions and facilities, including air conditioners, PCs, plasma TVs, clothes dryer and the family car.

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[1] NBSC (2007) *China Statistics Yearbook* 建筑业房室建筑面 *zhi* [Construction area of building industry], National Bureau of Statistics China, accessed June 2009 online http://www.stats.gov.cn/tjsj/ndsj/2007/html/01537.xls

The improving quality of life experienced by a growing number of Chinese is marked by increasing levels of consumption. While the main source of energy growth is energy-intensive heavy industry, consumption-led energy demand is set to become the main driver in the future. In fact, it is already playing a significant role in absolute terms. For example, despite the current global economic downturn, Chinese consumers have shifted into over-drive on the back of a generous government stimulus program including appliance subsidies, rebates and lending programs (see Figure 1). During 2009 and 2010, the sales of consumer goods rose at levels above GDP growth. For instance, vehicle sales in 2009 and 2010 rose 42% and 32%, respectively, compared with the previous year. Sales of household appliances, such as refrigerators, washing machines and other kitchen and laundry equipment, have experienced similar growth.

**Figure 1. Financial Assistance Criteria for Promoting Super Efficient AC Units under the Social Welfare Project**

| Rated cooling capacity (W) | Highest price (RMB per total unit) | | Financial rebate (RMB per total unit) | |
|---|---|---|---|---|
| | EER 1 | EER 2 | EER 1 | EER 2 |
| Rated cooling capacity ≤28 000 | 4000 | 3500 | 500 | 300 |
| 2800<CC≤4500 | 5000 | 4000 | 550 | 350 |
| 4500<CC≤7100 | 8500 | 7500 | 650 | 450 |
| 7100<CC≤14000 | 12000 | 11000 | 850 | 650 |

Note: The home appliance subsidy and financial assistance programs were withdrawn in June 2011.

In addition to national subsidy and rebate programs, several provincial and municipal governments commenced their own stimulus orientated energy efficiency programs. For example, Shanghai commenced a residential subsidy program of RMB400 to RMB1,000 for the purchase of energy-efficient home appliances. For example, an energy efficient Haier air conditioner costing RMB3, 499 would receive a RMB700 rebate. During 2009, around 340,000 energy-saving air-conditioners were sold in Shanghai alone and increased the market share of energy efficient units to 54% from 17% in 2008. Local authorities claimed this was equivalent to reducing power consumption by 42 million kWh.

A more ambitious program was implemented in Beijing, where subsidies for the retail sector were available for refurbishing and upgrading old air conditioner systems and components (see Figure 2).

**Figure 2. Subsidised Retail Sector Energy Conservation Projects in Beijing Municipality**

| Project | Description | Subsidy |
|---|---|---|
| Air conditioner system | Refurbish and upgrade air conditioning system ducting, insulation, pumps, water regulator, fans and variable frequency control to more energy efficiency model. | Central air conditioner equipment replacement to not exceed RMB 800 per ton; central air conditioning system refurbishment to not exceed RMB 150 per ton. |

Source: Beijing Municipality Bureau of Commerce, 2010.

In defiance of the literature arguing that the Chinese are conservative and discretionary consumers, an increasing proportion of sales are being funded by debt. In the first three quarters of 2009, household credit card use increased 40% and car loans rose 25%. By 2009, China had 175.2 million operating credit cards or seven times as many as in 2003 and 30% more than in 2008 (Financial Times, 2010).[2] There was a significant shift in lending in 2009 towards households when their share of lending increased from 15% in the first quarter to 60% by the third quarter (Naughton, 2009c). The resilient growth in retail sales data in 2009 and 2010 highlighted how private consumption rebounded from the confidence impact of the global slowdown.

A combination of factors are behind the growing consumption levels in China, including rising household salaries, growing consumer confidence, greater access to credit and critically the recent government stimulus measures such as rebates and tax reductions. Interestingly, household savings rates have come down markedly in China from 26% in 2004 to 12% in 2009. Such a shift defies the accepted economic argument that savings will remain high until the current social reforms covering health, wages, education, social security and pensions, are fully implemented (Credit Suisse, 2010). During the same period, household income of the lowest 20% has risen by 50%, while the top 10% has grown 255% to around RMB34,000 per month. In comparison, the United States savings rate is around 4-6% and consumption levels are five times higher than in China. Such levels correlate with GDP per capita figures and per capita annual incomes of US$2,775 in the city and US$840 in the countryside. However, as the Chinese rapidly scale up the wealth ladder, the gap in consumer spending between the two nations is expected to narrow. While offering a boon for retail outlets and manufacturers, the implications for energy and resource use as well as carbon emissions will become an increasingly challenging problem.

## 1.4 Energy Efficiency Policies for Air Conditioners

Since 2001, the Chinese government has introduced a comprehensive range of policy measures aimed at increasing the sale and manufacture of energy efficient household appliances, especially air conditioners. New energy efficient regulations, standards, codes, labelling systems, plans, pilot

[2] The same report cited credit card penetration rates of 0.13 per capita in China, compared with 0.99 in the UK and 2.06 in the US.

projects, incentive schemes, tax rebates, targets, and procurement policies have been introduced in an attempt to reduce the expected growth in energy consumption.

In response to the collapse of export markets following the global financial crisis in 2008 and 2009, the Chinese government introduced a wide range of fiscal incentives, tax rebates and subsidy programs to promote the commercialisation and sale of energy efficient air conditioners. While the initial aim of the programs was to stimulate the domestic economy, the broader objective of the subsidy program was to increase the market share of high energy efficient air conditioners from around 5% to 30% by 2012, whilst encouraging domestic manufacturing innovation in energy efficiency.

In 2009, the Ministry of Finance allocated RMB2 billion in funds to provide a 10% rebate on the purchase of new energy efficient air conditioners and other household appliances. In addition, export rebates for air conditioners were increased to 15-17% to assist local manufacturers and exporters to cope with the rapid decline in export orders of around 40-60% in 2009. In total, 4290 air conditioner models produced by 27 companies were eligible for the rebate and subsidy ranging from RMB500-850 for units meeting Grade 1 standards and RMB300-650 for Grade 2 units.

Cities have also introduced their own programs to encourage the domestic consumption of energy efficient appliances. For example, in 2009 Hangzhou, Shanghai and Beijing commenced offering an additional RMB350 rebate or 10% of the retail price on old air conditioners when a new efficient one is purchased. Officials estimated that the subsidy programs resulted in a RMB100 billion boost in sales of air conditioners with energy savings of 75 billion KWh and $CO_2$ abatement of 75 million tons.[3]

As a result of the government's subsidy program introduced in mid-2009, one of China's largest air conditioner manufacturers and exporters, Gree Electric, actually ceased the production of lower grade energy efficient air conditioners (Lu Jie, 2009). Other leading manufacturers also suggested they would phase out lower grade air conditioner manufacturing. Many of the major retail outlets have also stopped selling air conditioners below Grade 3.

In response to the subsidy program, two of China's largest air conditioner manufacturers, Changhong Electric and Hai'er have ceased production of some models that were below Grade 2 standards, so that around 90% of the two companies' range of products meets Grade 2 and above. Overseas air conditioner manufacturers, such as LG, Fujitsu and Daikin, responded to the energy efficiency challenge by increasing their exports to China and Chinese local production of high energy efficiency units.

[3] Shanghai Daily, 1 June 2009.

# 2. Potential for Improving Air Conditioner Energy Efficiency

## 2.1 Measuring the Predicted Performance of RACs

Two key calculations are used as a standard for measuring the energy efficiency of an air conditioner unit, the Coefficient of Performance (COP) and the Energy Efficiency Rating (EER).

The COP refers to the ratio of volume of heat or cooling output of an air conditioner measured in kW to the input of electricity measured in kW to achieve the output. Hence, an improvement in energy efficiency results in a higher COP and the higher the COP of an air conditioner, the greater is its the energy performance.

In contrast to the COP, the Energy Efficiency Ratio (EER) of an air conditioner is the ratio of output cooling (typically measured in Btu/hr) to input electrical power (in Watts) under fixed climatic conditions. The expected overall performance using the Seasonal Energy Efficiency Ratio (SEER) adopts the same unit of measurement as EER (Btu/W/hr), but the calculation incorporates weighted variables depending upon the climatic conditions in a given location, and should more closely represent actual conditions of use (see Figure 3). Therefore, while the COP provides a stable measure of cooling and heating power divided by electricity use, the EER and SEER are averaged over a period of time, which are several hours for EER and a full year under typical climatic conditions for SEER. As a result, SEER is typical viewed as a more accurate and scientific reflection of the actual energy efficiency and operating performance of the air conditioning unit.

**Figure 3: Seasonal Cooling Requirements for Temperature and Duration in China**[4]

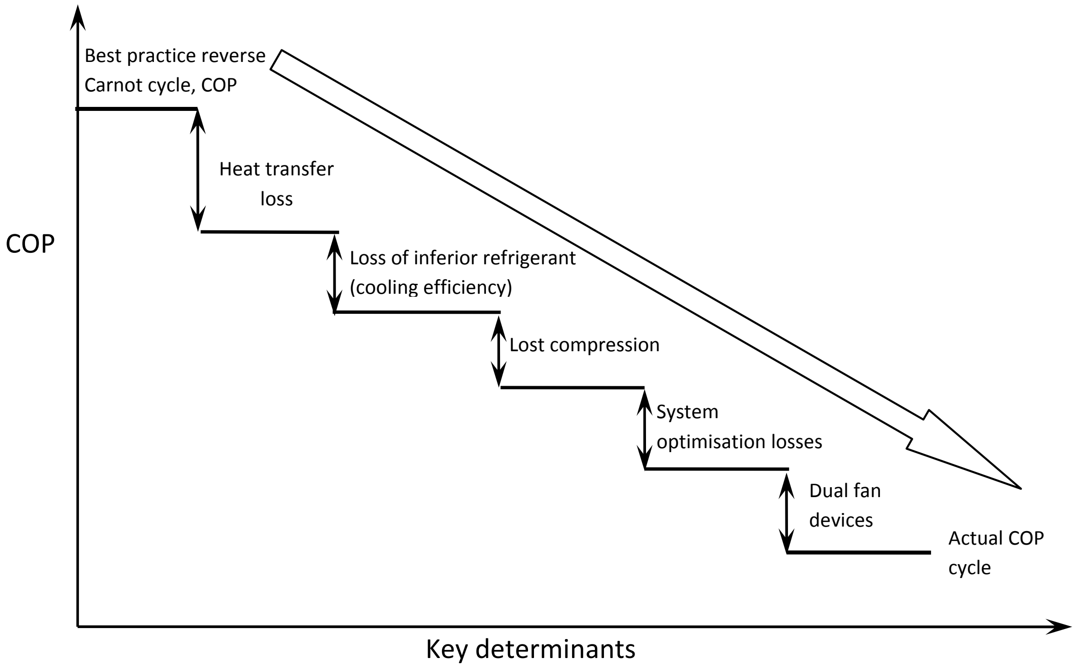
| **Temp °C** | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hours** | 54 | 96 | 97 | 113 | 98 | 96 | 110 | 107 | 105 | 94 | 76 | 61 | 22 | 5 | 2 | 1136 |

However, the purpose of identifying super efficient air conditioners requires a comparable unit of measurement of the energy efficiency of air conditioner throughout the world. The Coefficient of Performance (COP) for air conditioners in heating and cooling mode is used as the basis of determining the energy efficiency of an air conditioner. The discussion in this paper of the COP of air conditioners does not attempt to deal with the various refinements of the COP to take into account differences in seasonal variations of one region. Nor is there any discussion of the testing conditions to arrive at the COP measure. However, it needs to be recognised that over time, improved methods of measuring the energy performance of air conditioners will be important in encouraging the development of energy efficient air conditioners.

[4] According to National Standard for RACs, GB 21455-2008.

For room air conditioners, refrigeration systems and other chilling units, the energy efficiency of its actual operation can be clearly illustrated by contrasting it with the best practice reverse Carnot cycle method to the actual energy efficiency through a descending COP ladder as shown in Figure 4.

**Figure 4. Steps for Declining Energy Efficiency and a Lower COP for RACs**




Source: Kang Yanbing, Energy Research Institute (ERI).

Figure 4 illustrates the process of improving the energy efficiency and reducing the COP of room air conditioner units beyond the best practice reverse Carnot cycle. The energy efficiency ladder highlights how the COP of RAC units can be substantially improved by adopting new technologies which eliminate heating, cooling and compression losses. Such losses shall be gradually reduced and even eliminated, thereby substantially reducing the energy efficiency gap between best practice reverse Carnot cycle and the actual COP cycle of RACs.

## 2.2 Performance and Standards: International Approaches

The typical approach adopted by countries aimed at reducing energy consumption from air conditioners is to introduce mandatory minimum energy performance standards (MEPS). MEPS are designed to improve the efficiency of air conditioners by prohibiting the sale of air conditioners that do not reach a minimum standard. The effectiveness of MEPS in reducing energy consumption depends on the proportion of sub-MEPS air conditioners that would have been sold in the market in the absence of a MEP standard. If the market is ahead of the MEP standard, the application of the MEPS will not have the effect of reducing electricity consumption from air conditioners. In these circumstances the MEPS will be following the market rather than leading the market.

### 2.2.1 Minimum efficiency performance standards

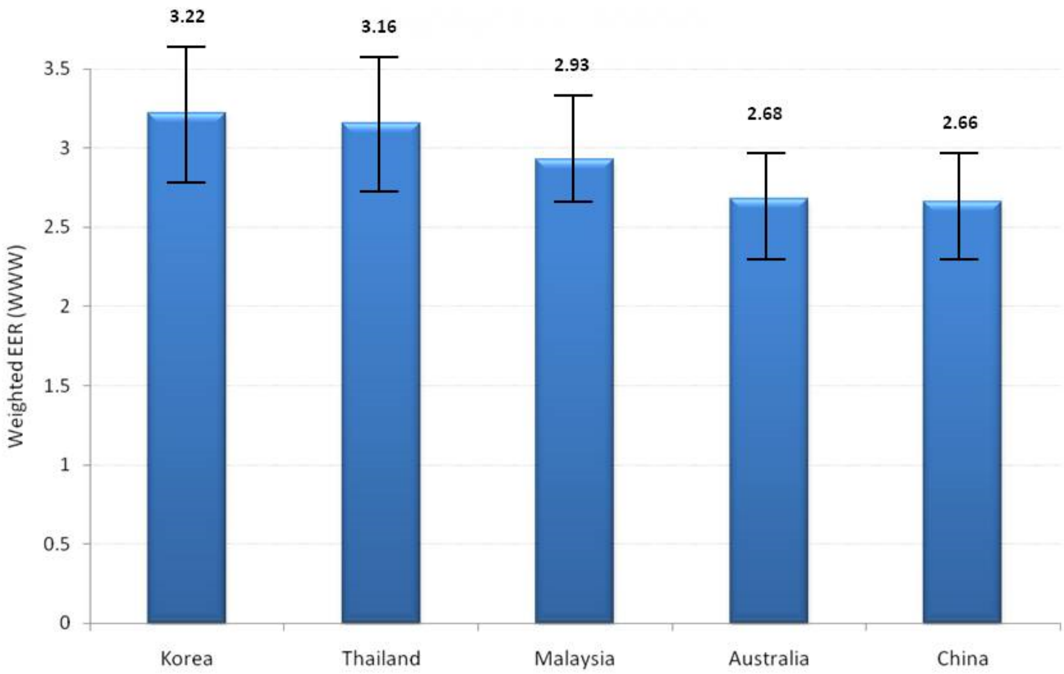
A number of countries have introduced Minimum Efficiency Performance Standards (MEPS) supplemented by complementary policies. MEPS are the primary vehicle in Australia, China, Korea and the USA to drive improvements in the energy efficiency of air conditioners. In these countries, different MEPS are set for different types of air conditioners and different sizes. The standards set are specific to the size and type of the air conditioner. For example, there are specific MEPS for 1.5 kW heat pumps and 1.5 kW evaporative air conditioning units.

The objective of the MEPS is to ensure that all air conditioners sold in the respective markets do not fall below a given energy efficiency standard. The impact of the MEPS standard compared with business as usual (BAU) on the energy efficiency of air conditioners depends on the level of the MEPS, the average efficiency level of air conditioners prior to the setting of the MEPS and the level of the energy efficiency of air conditioners that would have been sold in the respective markets in the absence of the MEPS.

In comparing differences in MEPS between countries, it is important to ensure that there is comparability in the units used to define the standard. In China and Australia for example the MEPS is set for the Coefficient of Performance (COP) or the Energy Efficiency Ratio (EER) for air conditioners, and this is the ratio of kW of heat or cooling produced from a kW of electricity. The higher the COP or the EER, the better is the energy performance of the air conditioner.

It is difficult to obtain comparative data on the energy efficiency ratios of air conditioners between countries. A comprehensive review of the air conditioner market in five Asian countries by Danish Energy Management (DEM, 2004) highlighted this point. According to the DEM findings, Korea had the highest indicative sales-weighted EER amongst five countries of 3.22 (Figure 5). The study concluded that for RAC cooling only units, the higher EER outcome in Korea was due to the country’s stringent MEPS levels.

**Figure 5. Country Comparison of EER for Air Conditioners**




Source: DEM, 2004, p. 13.

The energy efficiency standards of the USA for air conditioners are expressed in different units to the countries shown in Figure 5. The Seasonal Efficiency Energy Efficiency Ratio (SEER) is the measure that is used to set minimum efficiency standards for air conditioners in the USA. The SEER is the ratio of British thermal units (Btu) in a typical cooling season to electricity used expressed in watt-hours. The higher the SEER, the more efficient is the air conditioning system. As the USA measure is not comparable to the COP, it is necessary to convert USA data to an equivalent COP measure. When SEER is adjusted to a COP measure, the minimum energy efficiency standard in the USA is below Korea.

### *China*

The MEPS standard that came into force in China on 1 June 2010 sets the EER for a single-packaged room air conditioner (cooling) at 2.9 and a split system with watt capacity equal to or less than 4,500 watts at 3.2 (Figure 18). This increased the MEPS from the 2004 level from 2.3 and 2.6 respectively (Figure 6). In addition to the MEPS for the final air conditioner unit, China has a range of standards for the key air conditioner components such as the IPLV, heat pumps and new smart appliance technologies (Figures 7 and 8).

The dominant product on the market are the split air conditioners with a cooling capacity smaller than 4500 watts, which is higher than the EU standard, whereas the standard in the USA and Canada only trails the requirements of Japan and South Korea (Lin & Rosenquist, 2006). The comparable standard in Japan ranged between 3.65 and 5.27 and in South Korea the standard was 3.37.

As the average EER of air conditioners sold in 2008 in China was 2.8 when the EER was 2.6 it is problematic whether the new Chinese MEPS will lead to a significant increase in the average value of EER for air conditioners sold in the market in 2009 and beyond. At this stage it has not been possible to obtain data on the proportion of small split air conditioners sold in China that were below 2.6 (EER applicable in 2008).

**Figure 6. Room Air Conditioner EER Index, 2004**

| Type | Rated Cooling capacity(CC)/W | EER (W/W) | | | | |
|---|---|---|---|---|---|---|
| | | 5 (Limit) | 4 | 3 | 2 | 1 |
| Integrated system | | 2.30 | 2.50 | 2.70 | 2.90 | 3.10 |
| Split system | CC≤4 500 | 2.60 | 2.80 | 3.00 | 3.20 | 3.40 |
| | 4500<CC≤7100 | 2.50 | 2.70 | 2.90 | 3.10 | 3.30 |
| | 7100<CC≤14 000 | 2.40 | 2.60 | 2.80 | 3.00 | 3.20 |

Note: This standard applies to units with a cooling capacity of 14,000 W.

**Figure 7. Current Standards for the Air Conditioner Industry**

| Item no. | Title | Status | Implementation |
|---|---|---|---|
| **20078062-T-604** | Device specifications for energy efficiency controls for central water system ACs | Recommended | **2009** |
| **20080969-T-333** | Water evaporative cooling AC units | Recommended | **2009** |
| **20081655-T-604** | Air-sourced heat pumped water heated AC units for commercial and industrial use | Recommended | **2010** |
| **20081656-T-604** | Super low temperature heat pump AC unit using digital variant refrigerant flow (vrf) for commercial and industrial use | Recommended | **2010** |
| **20091125-T-333** | Metering, charging and time-of-use device for household central air conditioners | Recommended | **2011** |

**Figure 8. China's Energy Efficiency Standards on Air Conditioner Components**

| **Standard GB 21454-2008** | |
|---|---|
| The minimum allowable values of the IPLV and energy efficiency grades for multiple split system air conditioner (heat pump) units. | |
| Program Type: | Mandatory Minimum Energy Performance Standard |
| Product: | Multi-connected AC (Heat Pump) |
| Description: | Applies to multiple split system air conditioning (heat pump) unit of T1 climate type. Does NOT apply to double or multiple cooling circulations system units. This standard specifies the IPLV (C), evaluating values of energy conservation, decision method of the energy efficiency grades, test methods and inspection rules of the multi-connected air-condition (heat pump) unit. |
| Year Promulgated: | 18 Feb 2008 |
| Implementation: | 1 September 2008 |
| Implementing Agency: | NDRC (National Development and Reform Commission), and AQSIQ (State General Administration of Quality Supervision, Inspection and Quarantine) |

| **Standard GB 21455-2008** | |
|---|---|
| The minimum allowable values of the energy efficiency and energy efficiency grades for variable speed room air conditioners. | |
| Program Type: | Mandatory Minimum Energy Performance Standard |
| Product: | RACs (Variable Speed) |
| Description: | Applies to air-cooling condenser, completely closed type with variable electric motor-compressor type AC, whose cooling capacity is below 14000W and climate type is T1. Does NOT apply to portable, fixed speed or multi-connected types of ACs. |
| Year Promulgated: | 18 Feb 2008 |
| Implementation: | 1 September 2008 |
| Implementing Agency: | NDRC (National Development and Reform Commission), and AQSIQ (State General Administration of Quality Supervision, Inspection and Quarantine) |

### *Japan*

Figure 5 does not include the energy performance of Japanese air conditioners (possibly because they would have been off the scale). Japan is generally regarded as the global market leader of high efficiency air conditioners. Figure 9 sets out the changes in the COP for Japanese room air conditioners in the 2.8 kW class over the period 1997 to 2005. This data is not strictly comparable with the data in Figure 5 as the data in Figure 8 includes all air conditioner classes. Nevertheless it is significant that the weighted average COP for air conditioners sold in Japan in the 2.8 kW class is greater than 5 – well above the weighted average of air conditioners sold in Korea.

Japan’s Top Runner provides an insight into how policies can be developed to stimulate the demand for high efficiency air conditioners.

A review of the Top Runner Program on The Energy Conservation Centre of Japan’s website (METI, 2009) provides a succinct outline of the program:

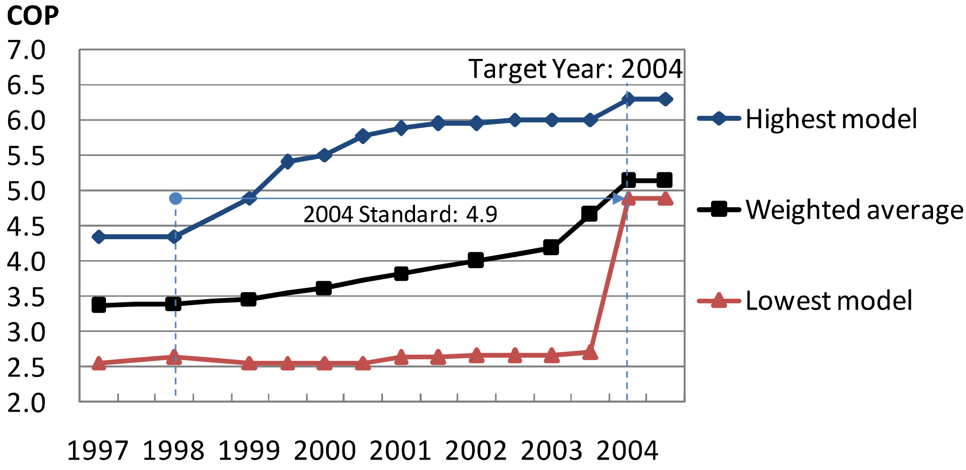
> *The Top Runner Program uses, as a base value, the value of the product with the highest energy consumption efficiency on the market at the time of the standard establishment process and sets standard values by considering potential technological improvements added as efficiency improvements. Naturally, target standard values are extremely high. For achievement evaluation, manufacturers can achieve target values by exceeding target values by weighted average values using shipment volume, the same as the average standard value system. The implication of using weighted average values is the same as the average standard value system, that is, the system is meant to give manufacturers incentives for developing more energy-efficient equipment.*

Japan’s Top Runner Program is designed to encourage the rapid uptake of the most energy efficient products on the market.

The Top Runner policy does not impose a minimum efficiency performance standard for each air conditioners sold on the Japanese market. Instead manufacturers of air conditioners are expected to meet a standard based on average weighted performance of air conditioners sold by the manufacturer in the target year. This flexibility allows manufacturers to sell a wide range of air conditioners. It also means that manufacturers have a strong incentive to develop and market high efficiency air conditioners.

Figures 9 and 10 clearly illustrate the marked shift in energy efficiency performance following the introduction of the program.

**Figure 9. Comparative COP for Air Conditioners Models, Japan, 1997-2005**

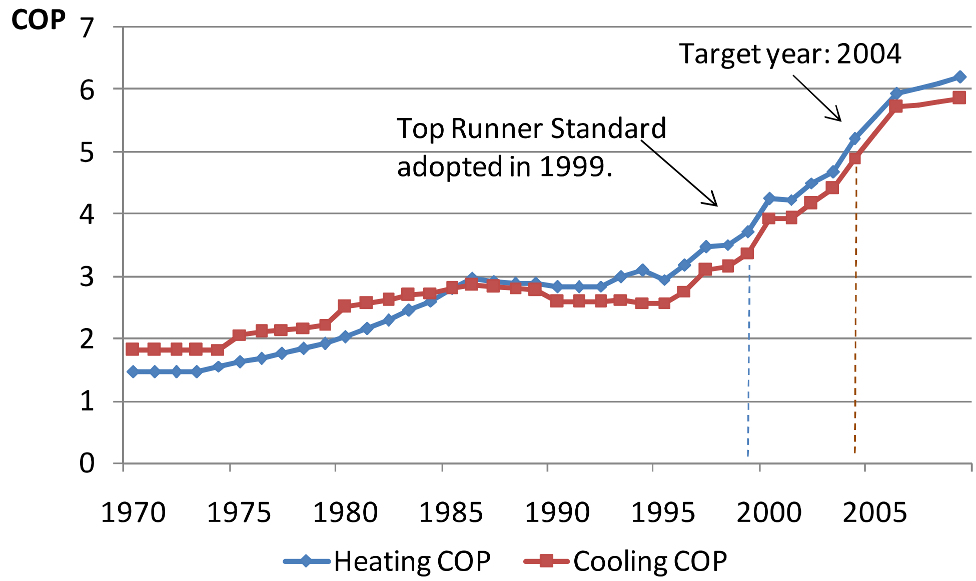



Source: Kimura Osamu, 2010.

Figure 10 provides information on the COP for air conditioners sold in Japan over the years 1970 to 2005. According to the IEA (2009), the coefficient of performance (COP) of an air conditioner's heat-pump improved from about 4.3 in 1997 to around 6.6 in 2006, with some COPs reaching 9.0 (IEA, 2009). The program achieved an impressive 67.8% improvement in energy efficiency between its introduction in 1997 and 2004. Similar energy conservation targets were met for a range of household appliances, such as refrigerators, PCs, VCRs and TVs.

Figures 10 and 11 highlight both the strengths and weaknesses of the Top Runner Program in steadily raising the average COP, yet failing to remove poorly efficient units. For instance, the COP of heat pump air conditioners on the Japanese market increased from around 4.3 in 1997 to around 6.3 in 2005, whilst the lowest model stagnated just above 2.5 until the introduction of the 4.9 minimum COP standard in 2004. The average EER for air conditioners sold in the Japanese market in 2005 was 5.27 and 6.32 in 2010.

**Figure 10. COP for Air Conditioners in Japan, 1970-2005**




Source: Kimura Osamu, 2010.

The cumulative impact of the Top Runner Program is shown in Figure 11, which charts the dramatic decline in energy usage levels for air conditioning in Japan. While air conditioner penetration rates and hours of usage increased between 1995 and 2007, actual total energy usage declined by 42%.

**Figure 11. Japanese Room Air Conditioner Energy Usage Levels, 1995-2007, kWh**

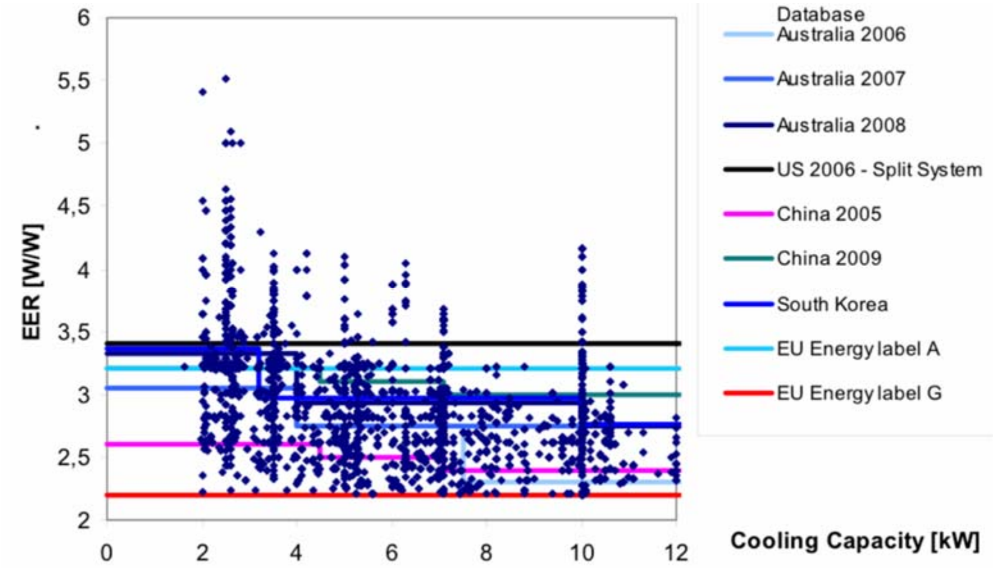
| | 1995 | 2000 | 2002 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| Cooling function | 412 | 262 | 262 | 237 | 227 | 217 | 213 |
| Heating function | 1080 | 755 | 755 | 708 | 692 | 665 | 652 |

Source: Japanese Energy Efficiency Centre, 2007.
Note: Data are for a split system wall mounted 2.8kW energy efficient model.

### *Europe*

A study of the best available products on the European air conditioner market (Michel et al., 2011a) noted the COP (heating) and the average EER was around 5.63 (cooling function). In contrast, in 2008 the average COP was around 3.4 for air conditioners sold in the EU27 and the average EER was around 3.23. These efficiency levels are similar to Korean levels and do not challenge Japan’s position as the leader in energy efficiency of air conditioners.

**Figure 12. Comparison of BAT and Weighted Average of Air Conditioners Sold in EU27**




Source: Riviere, P, Adnot, J, Grignon-Masse, L et al., 2008 cited in Michel, A, Bush, E, Nipkow, J et al. 2011b, p. 11.

It is interesting to note that there is a significant gap between the energy efficiency levels of best available technology (BAT) in Europe for air conditioners and the weighted average EER and COP of air conditioners sold in the EU. A comparison of BAT and the energy efficiency levels of air-cooled split air conditioners according to different size units sold in the EU27 are set out in Figure 12. It also includes the MEPS for various countries (including Australia, the US, China and South Korea), and highlights how many of the units would not have been allowed to have been sold in these markets.

### *Australia and New Zealand*

The Australian and New Zealand Government are considering an increase in the MEPS standard for air conditioners of around 10% in 2011. The current MEPS for a range of air conditioners in Australia are set out in Figure 13, which provides the context of the proposed increase in MEPS for air conditioners in Australia.

**Figure 13. MEPS Proposal for Air Conditioners in Australia**

| AC Category | MEPS 2010 (BAU) | MEPS2010 + 10% | Proposal A | Proposal A1 | Proposal B | Proposal C |
|---|---|---|---|---|---|---|
| *Date Implemented* | *Current (Apr 2010/11)* | *Oct 2011* | *Oct 2011* | *Oct 2011* | *Oct 2012* | *Oct 2014* |
| Non-ducted Split <4kW | 3.33 | 3.66 | 3.6 | 3.66 | 3.7 | 4.0 |
| Non-ducted Split 4kW to <10kW | 2.93 | 3.22 | Slope | 3.22 | Slope | Slope |
| Non-ducted unitary <10kW | 2.84 | 3.12 | 3.1 | 3.1 | 3.2 | 3.5 |
| Non-ducted unitary 10kW to 19kW | 2.75 | 3.03 | 3.1 | 3.1 | 3.2 | 3.5 |
| Ducted <10kW | 2.75 | 3.03 | 3.1 | 3.1 | 3.2 | 3.5 |
| Non-ducted split 10kW to 19kW | 2.75 | 3.03 | 3.1 | 3.1 | 3.2 | 3.5 |
| Ducted 10kW to 19kW | 2.75 | 3.03 | 3.1 | 3.1 | 3.2 | 3.5 |
| All 19kW to 39kW | 3.05 | 3.35 | 3.1 | 3.1 | 3.2 | 3.5 |
| All >39kW | 2.75 | 3.03 | 3.1 | 2.9 | 3.2 | 3.5 |
| Average % efficiency above MEPS2010 | | 10% | 12% | 10% | 15% | 25% |

Source: EnergyConsult, 2010.

## *Summary*

In terms of an industry-wide policy, Japan's Top Runner program provided the clearest direction for the air conditioner sector to achieve a rapid transition to higher efficiency air conditioners.

Generally when governments decide to increase MEPS for air conditioners or any other product they are taken after due consideration of the views of a wide range of stakeholders. It is also likely that a national government will need to take into account the views of local governments before increasing MEPs. In some cases like Australia, the decision to increase the MEPS for air conditioners is a joint decision of a number of different state governments, as well as with the New Zealand government. Similarly, a European Union decision to increase MEPS requires the agreement of member countries when changing MEPS for any particular product.

The need to work with stakeholders and governments at various levels generally means that the response lag to changing efficiency standards in the market and the implementation lag is likely to be long. It also generally means that the MEPS will be below what could be achieved. The lowest common denominator problem is always a difficult issue to deal with in any forum that requires collective agreement amongst a wide cross section of views.

# 3. Challenges of Moving to Super Efficient Air Conditioners

## 3.1 Key Barriers

The major challenges of moving to the widespread adoption of super efficient air conditioners are: (i) the development of super efficient air conditioner technology (technology barriers); (ii) ensuring the cost effectiveness of air conditioners (market barriers); (iii) the implementation of policy measures to encourage the installation of super efficient air conditioners (policy barriers); and (iv) the provision of quality information to buyers of energy efficient super efficient air conditioners (knowledge barrier). With the exception of the last point, this section will discuss the first three barriers in more detail. The technology and policy considerations are then explored in more detail later in this section.

According to a comparative analysis of existing energy efficiency standards across the globe, China's air conditioning energy efficiency can still be improved. The main ***technical barriers*** for achieving improvements in the energy efficiency of air conditioning units remains limited by manufacturing capacity and access to technology. In addition, energy efficiency improvements confront the theoretical constraints of the basic principle of thermodynamics and heat transfer. Despite these caveats, there remains an ongoing gap between the theoretical limit of energy efficiency and existing levels of energy efficiency in appliances. As such, there still remains much room for improvement. For example, significant improvements in the energy efficiency of air conditioners can be adopted from developments in systems engineering, the heat exchangers, compressors, motors, types of refrigeration and control systems (see Figure 14).

**Figure 14. China's Key National Energy Efficient Technologies during the 11th Five Year Plan**

| Energy efficiency technology list | Smart control system for central AC | Energy efficient adjustable speed inverter technology |
|---|---|---|
| Scope | AC cooling system | Current technology |
| Main technological content | Dynamic control to achieve targeted energy efficiency | Using a variety of models including fuzzy control, neural networks, expert systems and self-optimization |
| Typical project investment | RMB 2.26 million | Medium voltage frequency converter for a water pump station costs about RMB 0.6 million |
| Penetration rate during the 11th FYP | 30% | Industry ratio achieved around 30% |
| Energy savings | 20% | Improve motor efficiency by reducing network charges and reducing electricity losses |

There are several ***market barriers*** to the penetration of energy efficient air conditioners, including:

- Price sensitivity of the appliance market.
- Few financial incentives for manufacturers to invest in energy efficiency.
- Lack of financial incentives and mechanisms to promote energy efficient products in the market.

- Remaining uncertainty for manufacturers about the market demand of high efficiency models especially given the tendency of governments to adjust policy support.
- Lack of resources amongst small-scale manufacturers for developing and marketing energy efficient products.

The key market barrier refers to the financial misalignment or split incentives between those who make the decision on energy efficient investments and the final users who purchase the units and pay the energy bill. This is often referred to as the principle-agent problem because the end-users are excluded from the purchase decision when air conditioners are selected. Also, due to split-incentive issues, the purchasers are often not motivated to consider life-time costs and, hence, energy efficiency. For example, these economic considerations relate to the difference in purchase price of highly super efficient air conditioners and the potential change of costs to manufacturers that would be required to shift production from low to high efficient air conditioners. Raising MEPS to remove least efficient appliances is one approach, but there remains an economic need to balance the regulatory and market drivers promoting energy efficient air conditioners. Therefore, governments have introduced a range of additional or complementary schemes to promote energy efficient appliances, such as air conditioners. However, as this section of the report reveals, several challenges remain, and unless they are effectively resolved, then improvements in performance and energy efficiency shall remain slow.

The downward trend in air conditioner prices and the greater affordability of energy efficient units has been met with rising consumer awareness of energy conservation and thus sales of units, which were previously classified as top-end. The mass production of more energy efficient units has further brought down their prices, which has reduced the initial high purchase price of such units which acted as a financial barrier. Despite the positive improvements in overcoming the market barriers to the manufacture and purchase of energy efficient air conditioners, problems remain.

In addition to the technical and market barriers, there remain several key ***policy barriers*** to the widespread penetration of super energy efficient air conditioners, including:

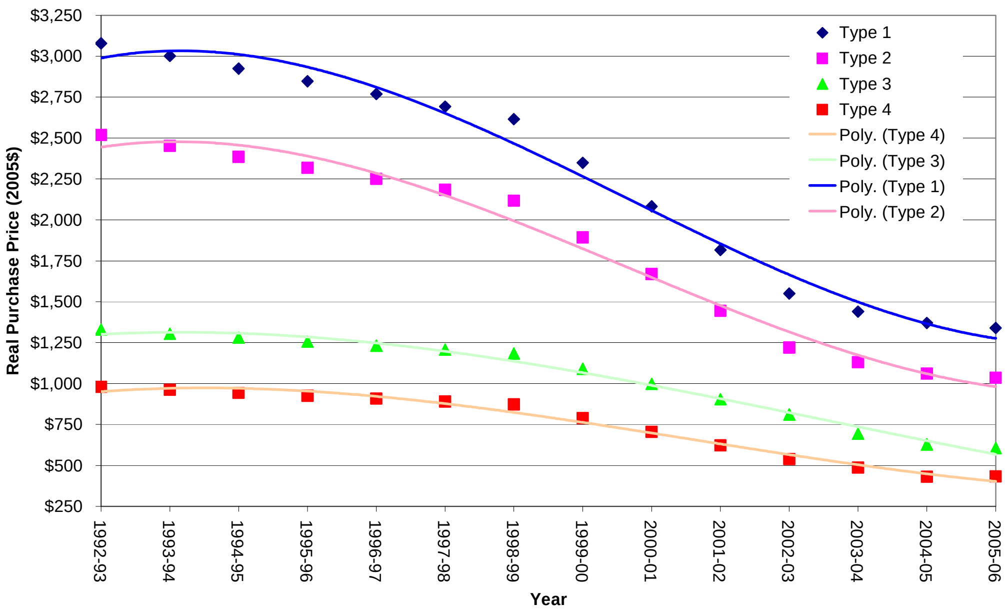
- Lack of institutional capacity, particularly at national level, to implement EE programs in the end-use sector.
- Energy efficient technologies is not given due consideration at the fiscal policy level.
- Lax, if any, Minimum Energy Performance for most end-use equipment.
- Pricing of electricity below costs and poor recovery of electricity bills.
- The challenge of needing to constantly strengthen the energy efficiency standards.
- A lack of policies to promote technical R&D and industrialisation of energy efficient air conditioners.
- Lack of policies supporting the commercialisation of energy-saving air conditioners from research to application.
- Potential intellectual property rights issues that could slow the transformation to highly efficient air conditioners.

## 3.2 Energy Efficiency and Purchase Cost

There is a general presumption that the more efficient air conditioners, are also the more expensive ones. An analysis by the EEEC (2009) of the relationship between purchase price and appliance efficiency, however, did not reveal that "efficiency is related to cost". Instead, the EEEC report for the Australian Government argued that consumers remain energy efficient literate poor in terms of their air conditioner purchasing decisions. Research from the International Energy Agency (Ellis et al., 2007) supported this finding, concurring that there remains little evidence of a relationship between price and efficiency, or improving energy efficiency, and the rising cost of air conditioners. Instead, it found that the retail prices of units have been steadily reducing, whilst becoming increasingly efficient. This has been evident in China as well, where the average price for an inverter air conditioner declined from RMB4,022 in 2009 to RMB3,659 in early 2010.

In addition to the studies that demonstrate there is no correlation between energy efficiency and the purchase price of an appliance, international data shows that improvement in the energy efficiency of air conditioners over the years 1992 to 2005, was achieved without a rise in the purchase price of air conditioners. In fact, they fell sharply over this period (Figure 15).

**Figure 15. MEPS for Air conditioners in Australia, 1992 to 2005**




Source: EEEC, 2009, p. 52.

There are a number of observations arising from the data in Figure 15. Firstly, the real purchase price of air conditioners has dropped sharply over the 14 years to 2005. Secondly, the real price has dropped for all types of air conditioners. Finally, there are some signs that the rate of decline in air conditioners began to plateau in 2005.

## 3.3 Ability of Industry to Respond

Discussions with representatives of a major air conditioner manufacturer in China on the capacity to manufacture air conditioners with a higher COP than levels prevailing in 2010, indicated that manufacturers would not face substantial hurdles in meeting higher MEPS. However, without higher domestic and international MEPS, there does not appear to be a strong incentive for manufacturers in China to shift to producing super efficient air conditioners except to capture a small segment of the advanced performance segment of the market. In these circumstances, it would appear that manufacturers are unlikely to be motivated to produce super efficient air conditioners. In contrast, according to an insightful interview with Daikin's CEO Inoue Noriyuki (JARN, 2009), the company set up a strategic joint venture partnership with the Chinese air conditioner manufacturer Gree, which is based in Zhuhai. The partnership aimed to produce more energy efficient air conditioners, because according to CEO Inoue, if Daikin didn't share the necessary inverter technology and production knowledge, then the Chinese companies would have gained these abilities anyway. They would either partner with another air conditioner company or develop the technologies themselves. The catalyst for the shift in approach to IP resulted from the tightening of China's COP standards, which would make it difficult to meet a COP = 3.0 without the use of inverters.

Given that air conditioner producers in Japan are already manufacturing air conditioners with a COP in excess of 7, and that there is no evidence that increasing the COP of air conditioners necessarily results in higher prices, serious consideration needs to be given to implementing an incentive structure that will encourage the manufacture and consumption of high efficiency air conditioners.

## 3.4 Cost and Effectiveness of Complementary Policies

Many of the existing technologies and technical breakthroughs described in this report are already understood, but are yet to be included in large scale commercial production. Therefore, it is likely that future energy efficiency improvements in air conditioning units adopting BAT are likely to be more gradual. The key requirement at present is reducing the barriers and costs to the widespread deployment of these technologies throughout the cooling and heating sector to ensure they are more competitive. However, such an approach needs to be strategic and coordinated to ensure that the range of policy measures adopt and complement market mechanisms and remain effective in achieving their outcomes.

### 3.4.1 Labelling

All of the countries involved in setting MEPS for air conditioners place labels on air conditioners sold on domestic markets. One of the main objectives of air conditioner labels is to provide information on the relative energy use of various types of air conditioners sold in retail outlets.

The key elements of an energy efficiency labelling system for encouraging the purchase of more energy efficient air conditioners are:

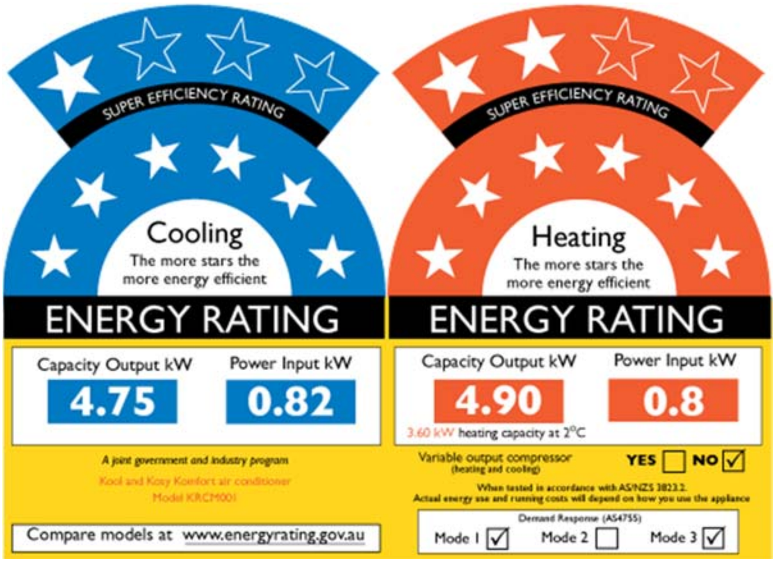
- Relevance to purchaser
- Comprehensible to buyer
- Buyer is aware of label
- Information on label likely to impact on buyers decision making

The labels of a number of countries are considered in the light of the above criteria.

### *Australia*

Australia has one of the most sophisticated labelling systems for air conditioners in the world. An important feature of the energy efficiency labels for air conditioners in Australia in 2011 is that part of the labelling system applies to super efficient air conditioners.

**Figure 16. Air Conditioner Label Australia**




It is mandatory for air conditioners sold in Australia to include an energy efficiency label in the format illustrated in Figure 16.

The information contained in the label is relevant to purchasers of air conditioners. In particular, the volume of output from the electricity used is set out for the air conditioner in cooling and heating mode. The label is built on a six-star rating system for standard air conditioners. Six stars signify that the air conditioner has the highest rating. The label also has provision for a super efficiency rating in cooling and heating mode.

Australians are well aware of the star rating system, as this is a common feature of ranking the energy efficiency of electric appliances. This means that most buyers of air conditioners in Australia would recognise that the more stars equates to a higher efficiency. The introduction of a star rating for super efficient air conditioners is a relatively new feature and may not be readily understood by buyers. There may be some confusion during the early period of this new labelling feature.

However, the additional stars highlight the ongoing problem of adjusting to stars to tightening MEPS and improving COPS of air conditioner units. For example, a unit sold in 2001 may have been granted 5 stars, yet by 2011 would only receive 2 stars. As such, the rating system needs to be updated with relevant information in retail outlets and through communication from staff.

The provision of information on output and input levels in heating and cooling mode is not the most comprehensible way of presenting energy efficiency information. The energy efficiency ratio (EER) or the coefficient of performance (COP) is a simpler way of presenting energy efficiency information.

Most Australian buyers of air conditioners would be aware of energy efficiency label and five stars. Discerning buyers are likely to examine the label in detail whereas less informed buyers are more likely to listen to the shopping assistant on the benefits of purchasing one air conditioner over another. In the absence of an incentive system that encourages the purchase of more efficient conditioners, shop assistants will focus on selling air conditioners to customers that yield the best return to the assistant or the retailer.

The impact of the energy efficiency label on the buyer will depend on a range of factors. These factors range from the broader attitude of the community to energy efficiency to individual preferences of the customer. In respect to the broader approach towards energy efficiency, there appears to be wide discrepancies between countries.

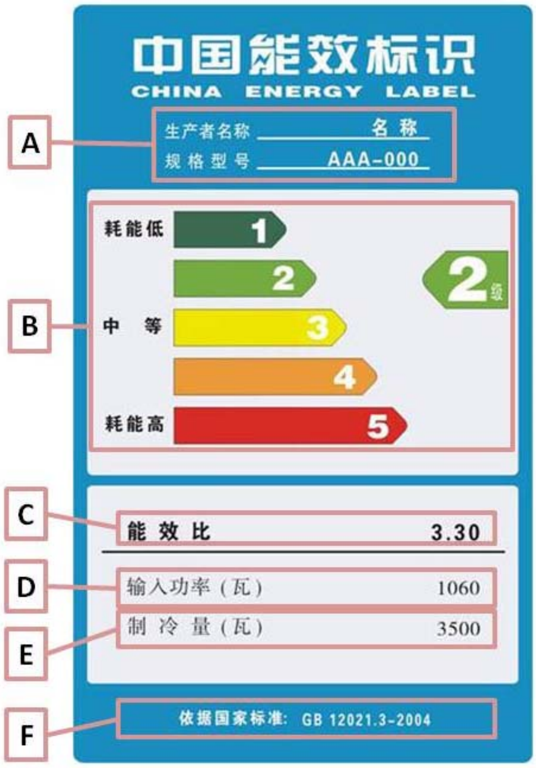
Financially conscious buyers will be interested in considering the dollar value of energy savings from different air conditioners compared with the purchase price. On the other hand, energy conscious consumers are more likely to focus on the energy saving and greenhouse gas abatement of different types of air conditioners. The Australian label does not provide information on the estimated annual energy costs or energy savings of using different types of air conditioners.

### *China*

In 2004, the NDRC introduced the first labelling laws for China. China's mandatory energy information label has been in place since March 2005 and was adapted from the EU system (Figure 17). The label includes five grades of efficiency from highest at Grade 1 (fully meeting the minimum standard) to lowest at Grade 5 (rated at 55% of the minimum standard). Air conditioner units were required to be labelled and graded upon entry to the market according to five colour coded levels ranging from: Grade 1 energy efficiency rating above 3.4 EER Grade 2 for above 3.2; Grade 3 for above 3.0; Grade 4 for above 2.8; and Grade 5 for above 2.6.

The Chinese National Institute of Standardization (CNIS) manages the labelling program. The labelling program has been quite successful during the government's subsidy and rebate program which commenced in 2009. Rebates and subsidies were only available for the highest efficiency model air conditioners which raised both the public's awareness and the manufacturers' interest in improving the energy efficiency of their units.

**Figure 17. Air Conditioner Label China**




- **A** Manufacturer's name and model
- **B** 5-grade efficiency rating system according to compliance with MEPS (55-100%)
- **C** MEPS
- **D** Energy consumption rate (watts)
- **E** Average cooling capacity (watts)
- **F** Applicable national standard

One of the weaknesses of the programs remains the manufacturers' ability to self-report the energy consumption of each model. The current auditing and testing regime remains limited by the resources of the responsible authority, the State Administration of Quality, Supervision, Inspection, and Quarantine. In response, the CNIS set up the China Energy Label Center to improve monitoring and testing regimes. Small sample testing in 2006 of labelling compliance, however, found that 91% of air conditioners actually met the published grade. This increased to 100% compliance in 2007 (Zhou Nan, 2008c).

In 2009, the government introduced a further tightening of labelling standards (see Figure 18) to raise the minimum allowable value to EER 3.0, so that products of fourth and fifth grades will be eliminated. When the new standard was implemented, the cost of manufacturing air conditioners was estimated to increase by around 15% and the price of air conditioners to increase by about 10% in 2010. These increases were, however, offset by the rebate and subsidy programs for energy efficient appliances.

Following the national implementation of the new energy efficiency standards in 2010 (Figure 18), ERI estimated that the new standards would result in annual savings of 200 million kWh of electricity and 130,000 tons of $CO_2$ emissions. By 2016, these figures are expected to rise to more than 650 million kWh of electricity and nearly 50 million tons of $CO_2$ emissions.

**Figure 18. Minimum Energy Efficiency Ratios (EER) for Air Conditioners, 2009**

| Category | Rated cooling capacity (CC) (W) | EER (W/W) |
|---|---|---|
| Single package system | | 2.90 |
| Split system | CC≤4500 | 3.20 |
| | 4500<CC≤7100 | 3.10 |
| | 7100<CC≤1400 | 3.00 |

Source: Lin and Rosenquist, 2008, p. 1091.

## *Japan*

The energy efficiency label for air conditioners in Japan incorporates a 5-star rating system and provides information on comparative performance of the air conditioner at the time in which the energy performance standard was implemented. For instance, if an air conditioner on the Japanese market received 5 stars, there would be information on the label to indicate how the brand related to the "top runner" product on the market. If the air conditioner had the same energy efficiency performance as the top runner product, the label would show 100%.

**Figure 19. Air Conditioner Label Japan**


**A** Fiscal year when the 5-star multistage rating criteria is set
**B** Displays non-CFC status if applicable
**C** 5 star efficiency rating system
**D** Energy saving labelling program, compliance rate and average annual energy consumption.
**E** Manufacturer's name and model
**F** Expected annual electricity cost

The label on an air conditioner on the Japanese market (Figure 19) also includes an estimate of the annual volume of kilowatt hours (kWh) used for heating and cooling. The inclusion of data on energy consumption enables the buyer to simply compare the energy use of different brands and types of air conditioners.

Japanese buyers have been accustomed to evaluating the energy performance of air conditioners for many years. The Top Runner program has resulted in a rapid improvement in the energy performance of air conditioners over the past decade. The 5-star label is easily recognisable, consumers can assess how the product compares with the performance of the Top Runner air conditioner that was used to determine the performance standards for air conditioners.

The estimated level of energy consumption of different air conditioners on the market enables consumers to readily understand the differences in energy consumption between air conditioners, and to easily calculate differences in the running costs of different air conditioners.

This overcomes the problems of rising MEPS and the inability to adjust the star system due to the provision of stock from various years in most retail outlets.

It is likely that most Japanese buyers would be aware of the energy efficiency label. Labels have been included on air conditioners in Japan since 2006. A unique feature of the Japanese energy efficient policies is that "a public invitation is made to each home appliance retail shop, each shop that actively offers information and promotes sales is selected as an 'Outlets that Excel at Promoting Energy-Efficient Products' and the results of the public invitation are announced".[5] The recognition of retailers that promote energy efficient products is likely to provide an effective means to inform consumers where to locate energy efficient air conditioners.

The impact of the Japanese energy efficiency label is likely to have a significant impact on buyer decision-making. The buyer is provided with simplified information that indicates the rating of the product and how it compares with the Top Runner product. Most importantly, it includes an estimate of annual energy consumption that enables simple comparisons on energy use to be made between products.

### *Korea*

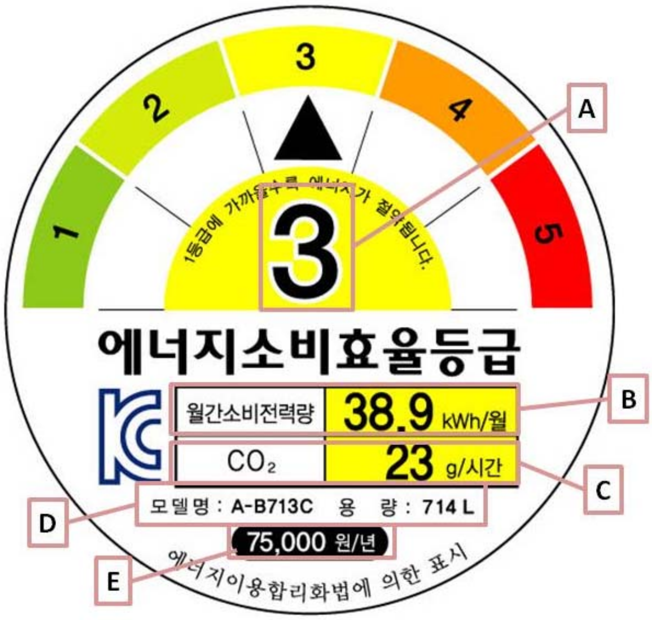
The energy efficiency label on air conditioners in Korea includes 5 energy efficiency grades. Grade 1 is the highest level of energy efficiency and Grade 5 the lowest. Grade 1 products are generally 30-40% more efficient than Grade 5 products. The COP of the air conditioner is also shown on the energy efficiency label (see Figure 20). A unique feature of the Korean energy efficiency label is the inclusion of data on $CO_2$ emissions. The volume of $CO_2$ per hour of use is also included on the label. The inclusion of $CO_2$ emission data (1Wh = 0.425g of $CO_2$) commenced from July 2009 and was reported as a world first for product labelling. Data on energy expenses (1kWh = 160Won) was

[5] Top Runner 2010, p. 25.

added from 1 July 2010 and will enable consumers to easily compare the electricity cost of air conditioner usage amongst different brands and types of units.

In 2011, the energy efficiency label is planned to include data on the estimated energy expense per year of using an air conditioner.

**Figure 20. Energy Efficiency Label Korea**




| | |
|---|---|
| **A** | Energy efficiency rating scale |
| **B** | Annual energy consumption |
| **C** | Annual $CO_2$ emissions |
| **D** | Model and capacity |
| **E** | Annual running electricity costs |

The comparative style of the Korean energy efficiency label has existed since 2004 and the energy efficiency label for air conditioners has been in existence since the mid 1990s. Korean buyers appear to be reasonably energy conscious due to concerted advertising campaigns by the government and the Korea Energy Management Corporation (KEMCO), which includes in its mandate the objective of fostering projects to reduce energy consumption and greenhouse gas emissions. KEMCO also plays an important monitoring and reviewing role to ensure policies, programs and regulations are effective.

The inclusion of information on the estimated cost of energy use enables consumers to make direct comparisons of the running costs of one type of air conditioner with another. Data on estimated hourly $CO_2$ emissions is very helpful information for the environmentally conscious consumer. It is likely that most Korean buyers would be aware of the energy efficiency label due to the long period of its application.

### *USA*

The USA energy star label for electrical appliances was first established in 1991. The energy star is a voluntary label that can only be included on air conditioners performing above a given efficiency level. In 2011 the energy star label on room air conditioners signifies that the air conditioner is at least 10% more efficient than regular room air conditioners.

It is likely that most USA buyers would be aware of the energy star label. While the existence of the energy star is likely to encourage consumers to purchase an energy star air conditioner in preference to a conditioner that does not have an energy star label, it does not give any influence on a decision to purchase high efficiency air conditioners. The energy star label does not included information on the relative efficiency performance of air conditioners, the different COP for air conditioners, the annual energy consumption of air conditioners nor the greenhouse gas emissions resulting from the use of air conditioners.

### 3.4.2 Energy performance labels in the future

Purchase price is a critical factor to consumers and operating cost has been shown to be of minimal influence in purchasing decisions of household appliances. Labelling programs have been an important first step in raising the awareness of energy efficiency in household appliances, but the Australian system highlights the potential problems of providing too much technical information, which is likely to confuse consumers and remain onerous for manufacturers and retailers to communicate.

Based upon discussions with sales assistants in retail outlets in both Australia and China as well as with manufacturers, it was found that the level of understanding of the value of energy efficiency and the labels was particularly low in Australia and significantly strong in China. A noticeable shift in awareness of the labelling system and energy efficiency occurred in China when the government's rebate for high efficiency units was introduced. At the same time, manufacturers and retailers offered staff training and product development sessions to improve their understanding of not just the rebate system but the efficiency of units. Another noticeable difference in China was the expectation that installation was included in the price of the unit. Whereas in Australia, installation costs were often excluded and could in fact exceed the actual cost of the original unit. This is not just important in highlighting the real cost of the product and the reduced benefits of a lower retail price, but has significant benefits for ensuring the efficient installation, fitting and orientation of on-site air conditioner units. In addition, the integrated role of the manufacturer in installing the appliance ensured that there would not be the same shifting responsibilities and blame that are evident in Australia due to complaints post-installation, such as leakage, noise levels and inefficient operation.

#### *Relevant information*

The evidence of poor consumer consciousness of both energy efficiency and the life cycle energy costs of air conditioners reveals the need for improved systems of labelling (Ellis, Harrington & Meier, 2007; EnergyConsult, 2010). Moreover, it is apparent that retailers are also ineffective in communicating the benefits of higher efficiency units to consumers due largely to the larger profit margins of inefficient appliances.

With the increasing concern about climate change and the desire of many countries to encourage an improvement in the energy performance of air conditioners, it is reasonable to expect a shift towards energy efficiency that contains information on the relative energy efficiency performance and greenhouse gas emissions of different air conditioners.

Over the next few years, it is likely that if a country has the objective of reducing energy consumption and greenhouse gas emissions from the use of air conditioners, information should be provided on labels that enable buyers to differentiate the energy performance of air conditioners. In 2011, Japan and Korea provide the most relevant data on energy use and greenhouse gas emissions on their energy efficiency labels. It is likely that other countries energy efficiency labels will include this type of information in the future.

### *Comprehensible to buyer*

Although more information on energy use and greenhouse gas emissions is likely to be included in the future a 5-stage energy efficiency ranking system is expected to be maintained in most of the abovementioned countries. This provides a headline energy efficiency ranking system that makes it easy and quick for buyers to identify the most efficient air conditioners on the respective markets. This information is likely to be important to consumers who do not have the time to assess the energy efficiency of different air conditioners in detail. Countries may consider imposing a super efficiency-ranking overlay on energy efficiency labels along the lines of that of Australia.

### *Buyer awareness of label*

There is a case for government giving consideration to promoting the importance of energy efficiency labels. This could be an information program sponsored directly by governments or an indirect program such as the Japanese retail awards program that encourages retailers to become known as retail stores that encourage the purchase of energy efficient products.

### *Impact on decision making*

Improvements in consumer awareness of the energy efficiency label and the greater the understanding of the information on the label, the greater the likelihood consumers shall take into account the energy efficiency of product at the time of purchase. However, it is increasingly clear how important the role of the retailer and the sales assistant is in making the final decision on air conditioners. Therefore, the introduction of a rebate or subsidy program that also benefits retailers through higher sales figures could be accompanied by education programs to raise their level of understanding.

Consumer friendly information continues to remain a weak link in the broad efforts to improve the energy efficiency of air conditioners in many markets. This section has highlighted the critical failing of labelling programs, whereby consumers continue to lack the ability to understand the provision of increasingly technical information. As such, their low awareness of energy efficiency reduces their likelihood of making optimal decisions regarding the most efficient and lowest cost unit over a particular period. At the same time, the labelling schemes have played an important role in accelerating the market share of energy efficient appliances especially when combined with government rebates and subsidy programs or MEPS and targeted maximum weighted average efficiency, such as Japan's Top Runner program.

### 3.4.3 White certificate schemes

A number of countries use white certificate schemes as an instrument to provide an incentive to purchase energy efficient products. The UK was one of the first countries to introduce a white certificate scheme. Two states in Australia (New South Wales and Victoria) have adopted this approach.

A white certificate scheme is a certificate market created by a government to encourage the purchase of energy efficient products. The basis of a white certificate scheme is that buyers have the choice of purchasing more energy efficient products available in the market and that these products are not generally purchased by consumers. It is assumed that energy efficient products would be purchased if a financial incentive were made available to purchases of designated energy efficient products. The implication is that the cost of energy efficient products is higher than standard products on the market.

The creation of a white certificate scheme is typically based on the following:

- A target to reduce energy consumption and/or greenhouse gas emissions by encouraging the purchase of energy efficient products.
- Certification of products that are eligible to participate in the white certificate scheme.
- Estimation of the amount of energy saved or reduction in greenhouse gas emissions that would flow from the purchase of energy efficient products.
- Creation of white certificates following the purchase of certified energy efficient products.
- A requirement that electricity retailers purchase a given quantity of white certificates or pay a shortfall penalty.
- Competition between white certificate providers/sellers to provide electricity retailers with the requisite white certificates.

The supply of white certificates is determined by the number of certified products and the estimated number of certificates created by each product. The higher the expected price of the white certificates, the greater the supply. The economic theory underpinning white certificate schemes is that there will be sufficient certified products to facilitate a supply of white certificates at a price that is below the cost of the certificate short-fall penalty. A diversified supply of certified products provides the greatest prospect of competition amongst white certificate suppliers and reassurance that competition between certificate creators will lead to low cost energy reduction.

Of fundamental importance to the success of a white certificate scheme in reducing energy consumption, is that action to purchase a white certificate leads to a reduction in energy consumption ‘beyond business as usual’. The strict application of the principle of ‘beyond business as usual’ is a necessary condition to the success of any white certificate scheme. If the purchase of white certificates does not lead to a reduction in energy consumption ‘beyond business as usual’, then the scheme is a waste of resources because the scheme imposes additional costs without reducing energy consumption.

A second condition of the success of a white certificate scheme to achieve the objective of reducing energy consumptions is the development and application of rigorous energy reduction measurement. It is important that the measurement of energy reduction is credible and will withstand close scrutiny.

It is extremely important to develop rules to ensure that certified products actually fulfil their intended function. A number of schemes have failed badly on this criterion. The problem is particularly important in the case of products with a low upfront cost. Certified products with a low upfront cost in some cases were purchased and never installed. Compact fluorescent light globes (CFLs) are probably the worst example. For instance, in one Australian state, the value of gaining white certificates was significantly higher than the cost of the globes. As the globes did not have to be installed prior to payment, a ‘green shoe’ brigade developed that was able to make a profit from creating and selling NSW Greenhouse Gas Abatement Certificates (NGACs) without installing a globe. Rorts of this kind undermine the credibility of white certificate schemes and great care needs to be taken to avoid problems of this kind.

Introducing a mandatory requirement on electricity retailers to purchase white certificate schemes requires complex accreditation and arbitrary judgements on relative energy efficiency gains from purchasing accredited products. The experience in Australia of these schemes indicates there are difficulties in avoiding loopholes and there is a tendency to encourage the purchase of low cost items such as energy efficient light globes. In the case of light globes, it is very difficult to determine that the purchase would not have taken place in the absence of the white certificate scheme. This means the energy efficiency level may not go beyond business as usual.

To the extent the policy boosts demand for super efficient air conditioners on the domestic market, a spin off for export markets is that manufacturers of super efficient air conditioners would achieve economies of scale and be able to export at highly competitive costs, which could in turn boost further innovation.

The scheme needs to be implemented carefully as super efficient air conditioners will compete with other energy efficient products for the creation of white certificates. There is a potential problem that the value of the certificates will not be sufficient to increase the sale of super efficient air conditioners or the price could affect alternative technologies that offer greater energy savings. Also, international experience shows that the time and complexity of demonstrating proof of purchase and installation may not warrant consumers applying for the white certificates.

### *White certificate schemes: Australian experience*

The experience in New South Wales and Victoria shows that low cost products such as CFLs and low flow showerheads have dominated certificate creation. This is consistent with the view that white certificate schemes tend to encourage the purchase of products with low upfront cost. Further, the outcome suggests that the method of calculating energy savings from CFL's and low flow showerheads leads to greater financial rewards to certificate creators than products with a higher upfront cost. There is also the ever-present concern that the sale of white certificates will not result in additional energy savings. This would arise if in the absence of white certificates, buyers would have purchased CFLs. In these circumstances, the principle of 'additionality' would be compromised.

A separate problem for existing white certificate schemes relates to the monitoring of the installation of low cost certified products. In an endeavour to reduce the supervision costs of products with a low up front purchase cost, regulators find it innately difficult to put in place arrangements that ensure that products like CFLs are even actually installed. This was a very serious problem with the NSW Greenhouse Gas Abatement Scheme (GGAS) and was recognized by the International Energy Association in 2009.

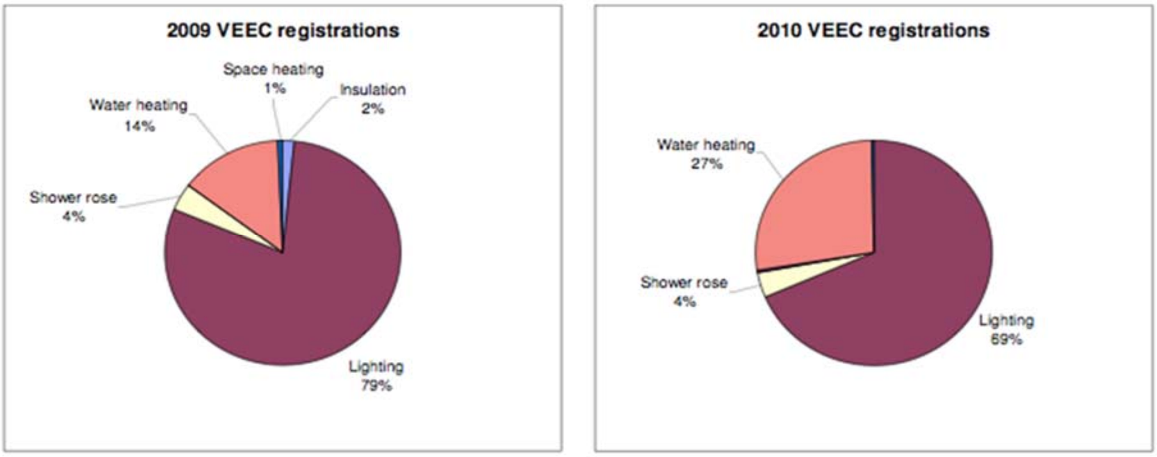
The IEA Demand Side Management Newsletter noted that in NSW "in early 2006, the Scheme Administrator for GGAS became concerned that the CFLs and showerheads obtained by households through giveaway schemes may not actually be installed".[6]

While the Victorian Government in Australia avoided the problem of giveaways with CFLs there are strong doubts that in 2009 and 2010, CFL's met the criterion of additionality. CFLs were readily available in the market, the Australian Government had announced that standard incandescent globes were to be effectively banned in Australia and the reduction in the costs of CFL's had already increased their attractiveness to buyers. In these circumstances it is a delusion to believe that all of the CFLs used to create white certificates in Victoria would have resulted in energy savings 'beyond business as usual'.

[6] IEA, DSM Spotlight, January 2009.

Data sourced from the Essential Services Commission in Victoria highlights the dominance of CFLs in certificate creation. In 2009, lighting accounted for 79% of white certificates created. Although there was a decline in the proportion of white certificates created from lighting in Victoria in 2010, lighting still accounted for 69% of total certificates created. Figure 21 shows the percentage of white certificates in Victoria (Victorian Energy Efficiency Certificates – VEECs) created from various sources in 2009 and 2010.

**Figure 21. Victorian Energy Efficiency Certificates, 2009 to 2010**




Source: Victorian Essential Services Commission, 2011.

In summary, the lessons from the Australian experience with white certificate schemes are:

- It is critically important to ensure that the methods used to estimate energy savings from certified products are comparable with each other.
- The inclusion of low cost products such as CFLs has the potential to undermine the credibility of the scheme and crowd out products with high upfront costs such as air conditioners.
- Good governance of the scheme is critical to the success of all white certificate schemes.
- The principle of additionality needs to be strictly applied to all certified products to ensure that claimed energy savings represent actual energy savings.

### 3.4.4 Product rebates

The rationale of providing rebates to reduce the purchase cost of energy efficient appliances is to overcome market failures. Market failures can be classified as behavioural failures and the presence of externalities. The objective is to provide a rebate that is sufficient to encourage buyers to purchase products whose use is to reduce energy consumption and greenhouse gas emissions.

An important distinction between a product rebate and a white certificate scheme is that the former reduces the price of selected products directly by a set amount, whereas a white certificate scheme reduces the cost of certified products by an amount that is uncertain and dependent on the price of white certificates. As previously noted, white certificate schemes have generally favoured low cost products and have done little to stimulate investment in energy efficient air conditioners.

While the cost of white certificates is mostly borne by electricity consumers, the cost of rebates are generally financed as part of a government budget allocation.

The value and the method of determining the rebate for an efficient product are fundamental to determining the success of any scheme. In the case of electrical appliances, it is important to set a rebate level that encourages an increase in the consumption of selected products without creating an unexpected surge in demand that can present severe market distortions and create political liabilities. For example, the rebates provided for insulation in homes in Australia created a massive surge in demand and a market breakdown. The sale of insulations batts jumped sharply, and unqualified and inept installers flooded the market. This led to numerous cases of ineffective insulation and breaches of safety provisions. Reporting of the large number of failures created enormous pressure on the Australian Government and ultimately led to the abandonment of the scheme.

One of the lessons of the experience of home insulation in Australia is that policy makers need a better understanding of the impact of a new rebate on demand to avoid a market calamity. In this context it is important to appreciate that markets are very efficient in responding to marginal changes in market conditions, but are ill equipped to adjust to large structural changes.

In determining the size of a rebate for air conditioning it is necessary to recognise that the cost of putting an air conditioner in a home is the equipment cost and the installation cost. Further, the quality of the installation is a significant factor in determining the energy performance of the air conditioner. Therefore, there are significant benefits for including installation in the purchase price, with a clear relationship between the producer, retailer and installer to reduce the risk of blame transfer, whilst encouraging the likelihood of appropriately selected units and effective installation.

### *Determining the value of the rebate*

On the basis that the objective of providing a rebate for purchasing an efficient air conditioner is to reduce energy consumption, an economic approach should be taken in determining the rebate value on the basis of the value of energy saved. This requires an estimate of the amount of energy saved over the life of the unit and a price to estimate the value of energy saved. In the context of a policy designed to achieve a target reduction in greenhouse emissions, the price used for energy could include an implicit cost for carbon reduction. The present value of the energy savings from an energy efficient air conditioner could be set as the value of the rebate.

An illustrative example to estimate the value of a rebate for two different air conditioners is set out below.

***Assumptions***

- MEP standard air conditioner uses 1,000 kWh of electricity per annum.
- Energy efficient air conditioner A uses 300 kWh of electricity per annum.
- Energy efficient air conditioner B uses 500 kWh of electricity per annum.
- The average life of both air conditioners is 10 years.
- The average wholesale price of electricity per kWh to cover long-term investment in generation, transmission and distribution, including a $25 carbon price per tonne, is 7c/kWh.
- The greenhouse gas intensity of electricity generation is equal to 1.
- The discount rate to calculate the value of electricity saved is zero.
- The value of the rebates for energy efficient air conditioner A and B are calculated using the formula:

  (Bench Mark Air Conditioner annual kWh – Energy Efficient Air Conditioner annual kWh) x Average Life of Energy Efficient Air Conditioner x Average Wholesale Price of Electricity including Carbon Price
- The specific calculations for Energy Efficient Air Conditioner A and B are:

  A - 300 x 10 x 0.07 = $210
  
  B – 500 x 10 x 0.07 = $350

## *Effectiveness of product rebates*

The effectiveness of a product rebate scheme in achieving reductions in energy consumption and greenhouse gas emissions is heavily dependent on the structure of the scheme. If the value of the rebate was determined along the principles outlined in Subsection 2.6.1, it would be a cost effective measure in reducing electricity generation and cutting greenhouse emissions at a cost equal to the carbon price. The wholesale price of electricity is the relevant price for determining whether to invest in electricity generation, and a market price of carbon is a reflection of the cost of reducing greenhouse gas emissions in the broader carbon market.

The effectiveness of a product rebate in switching demand from standard air conditioners to higher efficiency air conditioners will depend on the price elasticity of demand of the highly efficient air conditioner. An assessment of the potential market response of buyers to a rebate system is a critical element of policy decision making. If such an assessment is not undertaken and the rebate is too high, there is a grave risk that there will be a surge in demand for air conditioners and severe disruptions in the market for air conditioners. A very high rebate could also lead to the displacement of existing air conditioners, as well as a switch from standard air conditioners to highly efficient air conditioners. In these circumstances, there would be increased pressure on installers and a significant risk of installers taking short cuts in installing new air conditioners, potentially compromising the energy efficiency of the newly installed air conditioner.

The provision of a high rebate also runs the risk of a stop/start policy. As rebates are generally financed from government budget sources, a surge in demand could place pressure on scarce budget resources and lead to a political reaction to cut back on the subsidy. The pressure placed on Australian Government budget of the solar photovoltaic cells (PVs) rebate is a clear case of budget pressure leading to the abolition of a rebate. Under immense pressure to maintain support for solar PVs, the Australian Government replaced the rebate with the introduction of a Renewable Energy Certificate (REC) multiplier for solar PVs under the mandatory renewable energy target. This highlights how important it is to have a clear understanding of the impact of a product subsidy. The pressure decision to replace the solar rebate with the REC multiplier was a major reason why there is a surplus of RECs in 2010 and an important factor why investment in large scale renewable energy has been stifled.

### 3.4.5 Feebates

Feebates are a particular form of rebates that are finance rebates for highly efficient products from standard air conditioners. The apparent advantages of a Feebate are twofold. Firstly, Feebates remove the pressure on government budget general revenue to finance the rebate as they have the potential to be revenue neutral. Secondly, buyers of standard air conditioners finance rebates to buyers of high efficient air conditioners

The issues to be considered in determining the value of the Feebate are generally the same as they are for a conventional rebate system. Policy makers need to be clear on their policy objectives. If the Feebate is part of a range of policies to reduce greenhouse gas emissions, then the Feebate paid to buyers of highly efficient air conditioners should be based on the same principles as outlined in the previous section. Knowledge on the price elasticity of demand between different air conditioners is an essential requirement for determining the value of the revenue raising penalty on the standard air conditioner and the rebate paid for highly efficient air conditioners.

There are potentially significant equity issues when considering a Feebate. The purchasers of standard air conditioners face higher costs under a Feebate than the free market price. This means they pay a higher upfront cost, as well as pay for higher energy bills compared with buyers of highly efficient air conditioners. In order to assess the equity impact of a Feebate, it is necessary to have quality statistical information on the buyers of standard air conditioners and the price differences between air conditioners on the market.

A Feebate for highly efficient air conditioners has the potential to significantly change the composition of air conditioners purchased in the market. The greater the difference between the level of energy efficiency of a standard air conditioner and highly efficient air conditioners available on the market, the greater the impact of the Feebate in encouraging the purchase of energy efficient air conditioners.

Behavioural economists (such as Ariely, 2010) suggest that consumers place greater value on avoiding losses than making financial gains. Eliert and others (2010) argue that "psychological factors are a more powerful motivating factor than rewards. One potential implication of this for Feebates is that the 'stick', if clearly communicated to the customer, will provide more motivation than a 'carrot' alone".

### 3.4.6 Monitoring and testing

Governments commonly neglect the monitoring and enforcement of mandatory requirements. Yet this is a critical area of policy implementation. Unless the performance of air conditioners in the field is consistent with the stated performance measures, energy efficiency policies will fail. The matching of the claimed performance of an air conditioner with the actual performance is a necessary condition for an effective MEPS or any other performance standard.

In China, Lin and Fridley (2007) found that many of the technical staff assessing energy efficiency standards are trained in health and safety rather than monitoring and verifying appliance performances. The NDRC and the AQSIQ[7] are responsible for undertaking inspections for energy efficiency labelling and compliance with energy efficiency standards. Typically, the agencies publically announce inspections prior to a campaign. The performance measures of local officials now include energy efficiency targets. More work is required in monitoring the success and progress of energy efficiency programs so that further adjustments can be made.

EU testing results revealed air conditioner units were substantially below reported standards. If there is a concern in international markets that the specified standard of an air conditioner does not reflect the actual performance of a product, this will have an adverse effect on exports. Greater synchronisation towards global testing and labelling standards could streamline processing and bring down the cost of energy efficient air conditioner units. Risks remain with greater global standards on energy efficiency testing and standards, because to achieve global agreement, a high-degree of trade-offs and consensus is involved, which ends up reducing the efficiency gains, resulting in ineffective and unsubstantial agreements.

There is unlikely to be any resistance from companies that have high standards of quality control. Instead, resistance is likely to come from firms that are struggling to keep up with mandatory standards.

[7] Administration of Quality Supervision, Inspection and Quarantine, China.

### 3.4.7 Installation and maintenance

In addition to developing sound and effective policies to promote the sale of energy efficient air conditioners, it is important that regulations are put in place to ensure that these units are correctly installed and maintained. Such regulations are necessary to ensure that installed air conditioners perform in accordance with the EER of the air conditioners. A recent study (Sachs et al., 2008) of the energy performance of air conditioners operating in the field in the USA covered the following areas:

- Refrigerant charge errors
- Refrigerant leakage over time
- Air handler impact on over-sizing (indirect)
- Ductwork and accessories external static pressure
- Cabinet air leakage
- Air filter rack and tight door
- Call for service (other)

All of these issues are important and require close attention, as it is the performance of air conditioners after they are installed that determine whether the purported energy savings are achieved or not. A study by Neme, Proctor and Nadel (Sachs et al., 2008) in the USA found that improved installation practices could reduce heating, ventilation and air conditioning (HVAC) energy use in existing buildings by 24% and 35% in new buildings. If the goal is to achieve optimal performance of installed air conditioners, it is essential that effective regulations are established, monitored and *enforced*.

## 3.5 Energy Efficient Air Conditioners: Smart Appliances, Smart Grids and Smart Meters

Before analysing the potential application of Smart Appliances, Smart Grids and Smart Meters it is helpful to have a clear understanding of meaning of “smart” in the context of an electricity grid. The USA has had considerable experience in the research and development of smart grid technology. The US Department of Energy provides a helpful list of definitions relating to smart grids as follows.

A Smart Grid is an electricity grid that is:
**Intelligent** – capable of sensing system overloads and rerouting power to prevent or minimize a potential outage; of working autonomously when conditions require resolution faster than humans can respond...and cooperatively in aligning the goals of utilities, consumers and regulators
**Efficient** – capable of meeting increased consumer demand without adding infrastructure
**Accommodating** – accepting energy from virtually any fuel source including solar and wind as easily and transparently as coal and natural gas; capable of integrating any and all better ideas and technologies – energy storage technologies, for example – as they are market-proven and ready to come online
**Motivating** – enabling real-time communication between the consumer and utility so consumers can tailor their energy consumption based on individual preferences, like price and/or environmental concerns
**Opportunistic** – creating new opportunities and markets by means of its ability to capitalize on plug-and-play innovation wherever and whenever appropriate
**Quality-focused** – capable of delivering the power quality necessary – free of sags, spikes, disturbances and interruptions – to power our increasingly digital economy and the data centers, computers and electronics necessary to make it run
**Resilient** – increasingly resistant to attack and natural disasters as it becomes more decentralized and reinforced with Smart Grid security protocols
**"Green"** – slowing the advance of global climate change and offering a genuine path toward significant environmental improvement.

Source: US Department of Energy (2011, p. 21).

In the context of air conditioner use and the impact on electricity demand, the key elements are: the capability of sensing system overloads and rerouting power without human intervention; the capability of meeting increased consumer demand without adding infrastructure; and enabling real-time communication between consumers and utilities.

A major issue with the expected increase in the installation of air conditioners in China is the associated increase in peak demand for electricity. While improvements in energy efficiency will reduce the demand for energy from air conditioners, the anticipated growth in electricity demand during peak periods is likely to be a problem that will need to be dealt with by Smart Meters as well as a Smart Grid.

Smart Meters in the USA are technically referred to as Advanced Metering. According to the USA Federal Energy Regulatory Commission (2010, p. 6) advanced meters are:

> *…meters that measure and record usage data at hourly intervals or more frequently, and provide usage data to both consumers and energy companies at least once daily. Data are used for billing and other purposes. Advanced meters include basic hourly interval meters, meters with one-way communication, and real-time meters with built-in two-way communication capable of recording and transmitting instantaneous data.*

The combination of a Smart Grid and Smart Metering provides an opportunity for consumers and utilities to develop approaches that simultaneously reduce electricity bills to consumers and reduce peak electricity demand. The existence of a Smart Electricity system would enable utilities to reduce peak electricity demand by setting high electricity prices during peak demand and low prices during off-peak hours. This is known as time-of-use pricing and is starting to emerge in a number of countries, including Australia. The effectiveness of time-of-use pricing depends on the time-of-use price levels and willingness of consumers to trade space comfort in buildings for a reduction in the electricity costs.

Work undertaken by the American Council for an Energy Efficient Economy (ACEEE) suggests that utilities, while embracing the technology of smart meters, generally do not have programs to provide direct feedback to electricity consumers. The work by the ACEEE (Ehrhardt-Martinez, Donnelly & Laitner, 2010, p. 13) on advanced meters and other feedback mechanisms to electricity consumers found that:

> *Using the advanced metering systems to connect to in-home appliances wasn't selected by any utility. This analysis indicates that even those utilities that are deploying advanced meters are not currently using them to provide either indirect, or direct, feedback to households. In fact, FERC report makes it painfully obvious that even demand response is low on the list of priorities, and energy efficiency is completely absent from the list. Advanced metering initiatives are being driven by utility operational issues instead of concerns regarding in-home energy management.*

The fact that demand response management is low on the list of priorities for electricity utilities in the USA, indicates that a great deal of work is required before smart metering becomes a significant force for reducing peak electricity demand. Electricity consumers will need to change from being passive electricity consumers to active consumers that understand the opportunities and implications of their consumption under a time-of-use tariff system.

In the absence of an effective time-of-use electricity pricing system, a combination of a Smart Grid and Smart Meters provides an opportunity for utilities to control peak demand for electricity without causing electricity outages. With smart chips embedded in air conditioners, it would be possible for utilities to reduce peak demand from air conditioners by either controlling temperature settings on air conditioners or switching air conditioners on and off remotely. This could be implemented through a pure system of administration without time-of-use pricing or could become a negotiated voluntary contract which authorises utilities to reduce the power used by air conditioners during peak demand periods.

The outcomes of initial studies of the "effectiveness" of smart metering programs should provide a useful lesson in the predicted rolling out of smart chips, which can offer households and even utility companies the ability to remotely control air conditioner settings and operations.

## 3.6 2050 COP Target

In considering the appropriateness of setting a COP target of 9 for air conditioners installed in 2050 it is relevant to consider the state of the air conditioning market in 2011. As noted in Subsection 2.2.1 of this report, the average COP for air conditioners sold in EU27 for cooling was 3.23 and 3.4 for heating. An increase of in excess of 170% in the average COP for air conditioners by 2050 seems to be a stretch target. However, the COP of 9 by 2050 needs to be considered in the context of the best available technology and energy performance of air conditioners currently sold in Japan and the COP for air conditioners available on the market in 2010.

The average COP for small air conditioners sold in Japanese market in 2006 was greater than 5 – a substantially higher level than the average COP for air conditioners sold elsewhere, especially in the EU, the US and Australia. By 2008 the average COP of small air conditioners sold in Japan was 6.6.

As there were a number of air conditioners in the Japanese market in 2008 achieving a COP of 7.0 or higher in 2008, the improvement in technology over the next 40 years to achieve an average COP of 9.0 is relatively modest. This suggests that the major issue associated with achieving average COP for air conditioners in the EU27 by 2050 is not the rate of technological progress, but the cost effectiveness of high efficiency air conditioners and government policy measures. It is also possible that technological change will be greater than the IEA's conservative Blue Map scenario suggests and the average COP for air conditioners on the market could be in excess of 9.0 by 2025. An assessment of the scope for further improvements in the energy efficiency of air conditioners is needed to indicate the likelihood of improvement in technology leading to a COP that is greater than 9.0.

The IEA's *Technology Roadmap – Energy-Efficient Buildings: Heating and Coolin*g (2011) provides a useful starting point for considering the COP of a super efficient air conditioner. Under the IEA's Blue Map scenario for heat pumps, the weighted average COP for air conditioners in 2050 should reach 9 for cooling and heating. An air conditioner with of a COP of 9 in the year 2050 is regarded as an "ultra efficient" air conditioner. Under this scenario, the annual amount of energy related greenhouse gas emissions compared with a business as usual scenario, is reduced by 50% in 2050 if the building sector installs super efficient heat pump systems for cooling, as well as for space heating and hot water systems.

The narrow energy efficiency gap between the best performing air conditioners in the Japanese market and the IEA's 2050 target under the Blue Map scenario suggests that there is great scope for increasing the MEPS of air conditioners in most markets. The restraints on significantly increasing MEPS in countries like China and Australia are not technological, but rather are due to economic and policy making considerations.

# 4. The Scope for Improving Technology and Increasing MEPS

## 4.1 Introduction

Improving the energy efficiency of RAC systems by means of technical improvements offers significance gains (Figure 22). The following section provides an overview of relevant technological developments pertaining to air conditioning with a detailed discussion of heat pump technologies (Figure 23).

## 4.2 Technologies for Improving RAC Energy Efficiency

There are several technological approaches for improving the energy efficiency of room air conditioners (RACs) as follows:

1. Raising the evaporation temperature and reducing the condensation temperature.
   At the design stage of manufacturer, a higher evaporation temperature and lower condensing temperature should be selected for default operation.
2. Using efficient compressors, such as variable speed compressors, both to better meet the user's comfort, whist achieving significant energy savings.
   Efficient compressors can achieve additional energy savings of 10-20% or more. In addition, if a permanent magnetic brushless DC motor is used for the compressor motor, then even higher levels of energy saving can be achieved. By adopting these measures, material usage is also reduced. For example, copper is only 21% of the traditional DC motor and steel consumption is around 37% without significantly affecting the unit's operations. By significantly reducing the consumption of materials, the unit's size and weight can be reduced.
3. Improve the heat transfer capacity of the heat exchanger.
   This can be achieved in several ways: firstly, by increasing the fan's heat exchange area of heat transfer; secondly, by improving the fans air flow heat exchanger; thirdly, using an integrated control system for the refrigerant to maximize the flow of refrigerant in the heat exchanger and therefore increase the thermal efficiency; fourthly, use the most appropriate tubing so that when the refrigerant evaporates it maximizes the area of heat exchanger; and finally, using new brass and hydro-aluminium foil ribbing to increase fluid disturbance and increasing the coefficient of heat transfer.
4. Alternative refrigerants should be used to reduce the environmental impact of air conditioner usage.
   Refrigerant losses are credited with causing 10-20% of human greenhouse gas emissions. Therefore, alternative and natural refrigerants need to be increasingly used to reduce the greenhouse warming potential of the gases, whilst continuing to research how emerging technologies can utilize new refrigerants, such as $CO_2$, to effectively work with the compressor and heat exchanger because of the need for higher compression levels.

**Figure 22. Technologies for Improving the Energy Efficiency of RAC Units**

| Energy efficiency technology | Impact | Principle |
|---|---|---|
| Heat pumps | See Section 4.2.1 | |
| Efficient heat exchange technology | Losses attributed to differences in heat transfer | Enhancing ducting and external heat transfer coefficient; optimise refrigerant distribution; and increase the heat exchange coefficient. |
| Alternative refrigerants | Losses due to inappropriate refrigerant | The efficiency of the refrigerant shall improve as a result of the use of advanced coolant control systems and greater alignment of the circuit designs with the characteristics of the coolant (R410A). These changes can improve the thermodynamic proprieties of the refrigerants and improve the characteristics of heat transfer and flow. |
| Compressor technology | Compressor losses | Improve the efficiency of the motor; use frequency conversion technology to optimise the structure of the compressor and thereby reducing compression losses. |
| Fan technology | Fan power | Improve motor efficiency; use frequency conversion technology to optimise uniformity and reduce fan power. |
| System optimisation | System optimisation losses | Optimise system pairing, recycling the expansion work, effectively using the cycling method to improve overall energy efficiency. |

### 4.2.1 Heat pumps

The discussion in this section focuses on improving the energy efficient performance of heat pump air conditioning systems (Figure 23). Split system inverter heat pumps are the most efficient form of air conditioning available on the world market in 2011. The IEA's (2011) *Energy-efficient Buildings* Blue Map scenario concludes that the installation of high performance heat pump air conditioning systems are expected to be a dominant factor in reducing the energy consumption of air conditioning over the next 40 years. The IEA relies heavily on the development and installation of heat pump technology to achieve the targeted reduction of 2 gigatons of $CO_2$ emissions by 2050.

The IEA found that the use of energy efficient heat pump technology for space and water heating as well as cooling "account for 63% of the heating and cooling technology savings" (p. 21). The expectation of this extraordinary contribution to the reduction in greenhouse gas emissions from energy efficiency heat pumps emphasises the importance of focussing on policies that lead to the adoption of energy efficient technologies in appliances. The IEA acknowledge the energy efficiency gains achieved by heat pumps in recent years has improved the COP of the most efficient RACs from 6 to 7, but there remains further gains to be achieved. The IEA sets a relatively modest COP target of 9 for heat pumps in 2050. Given that there are reports from Japan that some heat pumps already have a COP of 8, it is reasonable to expect that a COP in excess of 9 for heat pumps could be achieved well before 2050 and more likely by 2025.

**Figure 23. Water Heat Pump Technical Breakthroughs**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| **COP** | | 9 | ? |
| **Technical Breakthroughs** | High-efficiency coolant circuit design technology | Advanced coolant control technology | Development of new coolants |
| | High-efficiency matrix converter | Further size reduction using surface tension | Next-generation sensor-less PM motors |
| | Exhaust heat recovery | Micro-channel type heat exchangers | High-density heat accumulation and latent heat accumulation |
| | Load forecast control | Power recovery compressors with integrated expanders | Water-coolant double-bundle hot water supply systems |
| | Integrated hybrid solar heat panels | Solar heat pressure reduction boiling panel evaporators | Heat recovery from waste water |

Source: The Japan Society of Mechanical Engineers, 2009.

While the gap between the most efficient air conditioner on the market in 2010 and the IEA's target COP for 2050 is relatively small, there is considerable scope for improving the energy performance of heat pumps over the next 40 years. The potential to reduce electricity use of heat pump air conditioners in future is likely to be the result of improvements in various technologies, including the development of heat pumps to combine space conditioning with water heating and the development of hybrid heat pump systems that draw on renewable distributive energy sources and rely less on electricity from the grid. A report released by the Japan Society of Mechanical Engineers (JSME, 2009) point out that the future development of heat pump systems will be determined by a range of technical developments pertaining to compressors, refrigerant, waste heat recovery technology, recovery of coolant expansion energy, heat exchanges, motor systems and hybrid technologies and systems.

### 4.2.2 Alternatives and innovations

In addition to the prospect of developing hybrid air conditioners there is scope for expanding the production of gas sourced air conditioners. If coal fired electricity generation continues to dominate electricity generation in China and Australia, consideration needs to be given to encouraging the use of gas fired air conditioners. Gas has a substantially lower greenhouse gas footprint than coal. This means that if gas driven air conditioners can operate at similar levels of efficiency to electric driven air conditioners, a switch to gas air conditioners would result in a significant reduction in greenhouse gas emission. In addition, a switch to gas would assist in reducing the peak electricity demand problem caused by the use of air conditioners.

In 2011, gas driven air conditioners make up a minute section of the market. Detailed research into the potential of gas air conditioners needs to be undertaken. The research should examine the technical restraints of developing gas driven air conditioners, cost factors associated with using gas as the energy source for air conditioners and the resource restraints of using gas as a significant energy source for air conditioners in the future.

There is also the potential of using fuel cells to provide heating and cooling of buildings in the future. At this stage fuel cells are a relatively expensive technology, but may be an important technology in the future. For example, an Australian company Ceramic Fuels Cells are well on the way to developing a commercially competitive combined heat and power generator. Ceramic Fuel Cells believe they will be able to significantly lower the costs of manufacture over the next decade and make fuel cells an economically attractive alternative to conventional heating and power. Given the potential of fuel cells to reduce the demand for grid electricity and that fuel cells can use a wide range of energy sources, improved policy support to accelerate the commercial scale production of fuel cell units should be given a high priority in the future. In addition, further research is required into the potential efficiency gains from combined heating and cooling technological applications in fuel cells. Such a development would facilitate the potential deployment of distributed small-scale trigeneration units.

The use of decompressed-boiling solar panel evaporators combined with butane refrigerant heat pumps should result in energy efficiency improvements of around 80% on current solar heating hybrid systems.

## 4.3 Summary

In order for China to reduce the rapidly rising energy use arising from the increased ownership and usage of air conditioners, whilst ensuring the domestic manufacturers strengthen their global competitive advantage, this report has recommended a range of priority technological advancements, policy measures and investments that need to be implemented with an emphasis on constantly updating and strengthening energy efficiency standards for air conditioners, whilst strengthening energy efficient air conditioner technologies and product R&D, demonstration and promotion.

In summary the key technologies that need to be prioritised in the coming decade include the following:

- Efficient heat transfer technology (threaded piping, to strengthen enhanced-fin heat exchanger technology).
- Paired processes and technologies for DC speed compressors.
- High-efficiency powered devices (IGBT, intelligent power modules, etc.).
- DC speed drive technology (for air conditioning compressors and fans).
- Optimised throttling device technology.
- Research into the external characteristics of the cooling cycle and refrigeration cycle control technology.
- Efficient heat transfer technology (micro- and small-tubing heat transfer pipe technology).

- Efficient fan technology (highly efficient axial flow fans, tube current fans, centrifugal fans, etc.).
- Uniform and efficient refrigerant heat exchange technology.
- Optimised automatic AC unit control technology.
- Alternative refrigerant technologies.

# 5. Policy Roadmap for Promoting Energy Efficient Air Conditioners in China

China needs to constantly update and strengthen energy efficiency standards for air conditioners in three key areas:

- Constantly update and strengthen the mandatory minimum energy performance standards and promote energy-saving air conditioning technologies.
- Encourage, using incentive programs, local governments and industry to exceed national energy efficiency standards.
- Improve the inspection, monitoring and reporting of standards and measuring for air conditioning energy consumption.

In addition, policies need to be implemented which aim to strengthen energy efficient air conditioner technology and product R&D, demonstration and promotion in two key ways:

- Urgently formulate the research guidelines "Guidance for the development of an energy efficient air conditioner industry in China".
- Strengthen support for the development, demonstration and industrialisation of key air conditioner energy saving technological innovation.

## 5.1 Adopting Energy Efficient Policies for China

China could adopt a combination of MEPS with the key features of Japan's Top Runner program, such as the market leader policy. This approach is most likely to encourage rapid innovation of energy efficient RACs. Any adoption would need to be in line with local Chinese conditions. For example, a mix of voluntary and mandatory elements would require reviewing, as would the adopted method for the value system (minimum standard, average standard or maximum standard) for determining the energy consumption efficiency standards. The maximum standard has been utilised as part of the Top Runner program in Japan (see discussion earlier in the report).

A market leader policy would provide a strong incentive to manufacture super efficient air conditioners in China. Moreover, as manufacturers are likely to produce air conditioners with a range of energy performance levels, they can target world markets with a wide range of product requirements. However, there may be some resistance from manufacturers because they will be required to provide data on the value of sales of different types of air conditioners sold on the domestic Chinese market.

China's new EER standards for RACs, effective from 2009, are at the forefront of energy efficiency standards for air conditioners. In fact, the new requirement for RAC units (split system 4500 Watts) is actually higher than the European Union's A label, and is just behind Japanese and South Korean

requirements (Lin & Rosenquist, 2006). In terms of window air conditioners, the 2009 Chinese standard is above other international comparisons with a minimum EER of 2.9, compared to 2.88 in South Korea, 2.87 in the US and 2.85 in Japan (Lin & Rosenquist, 2006).
Consideration should be given to increasing the EER of air conditioners beyond the levels currently proposed. A substantial increase in the MEPS could be achieved over the next decade. A leading manufacturer in China, Gree, has indicated that they are capable of manufacturing air conditioners with a substantially higher EER on a large scale. Figure 24 presents one possible scenario for a technologically realistic stretch of the EER standards that could be achieved in China over the next three Five Year Plans (FYP) from 2011 to 2025.

**Figure 24: Proposed Extension of the EER Standards in China, 2011-2025**

| | |
|---|---|
| 12th FYP, 2011-2015 | 5.5 EER |
| 13th FYP, 2016-2020 | 7.0 EER |
| 14th FYP, 2021-2025 | 8.0 EER |

Source: CSES and ERI.

The proposal in Figure 24 is an extension of China's current MEPS standard for RACs. The proposed EER represents a substantial increase on the existing EER. The listed EERs are considered realistic stretch targets based on the capability of major manufacturers in China. Technology is available to commercially produce air conditioners with an EER of greater than 7.0 in 2009 in Japan. Also GREE have indicated that they have the capability of producing an air conditioner with an EER of 6.5 with little additional cost. With expected technology improvements, an EER of 8.0 is achievable by the end of the 14th FYP.

According to modelling undertaken by the Energy Research Institute, they estimate that the average EER for RACs will more than double between 2010 and 2030 from 3.29 to 6.37 (see Figure 25). The next twenty years of technical progress will be more modest because many of the components will have reached their optimum efficiency. Most of the benefits obtained during the next two decades will come from the use of heat pumps and efficiencies in the heat exchange. By 2050, the average rated EER will rise to 7.72, whilst the maximum limit of the EER will reach 9.22 with the SEER at 10.55. These assumptions are based on achieving an overall optimised efficiency of the air conditioner system at 98%.

The energy efficiency benefits depicted in Figure 25 will result in an incremental increase in the average EER of air conditioners sold on the domestic market. The impact on energy consumed by households will be affected by the size of the replacement market and the extent to which the MEPS EER exceeds the lowest performing air conditioner on the market. It is also important to consider whether improved energy efficiency is likely to increase the use of air conditioners because of lower running costs. Any consideration of the impact on exports will depend on the EER standards of importing countries and the price of air conditioners produced in competing countries.

**Figure 25. Development Forecast for Efficiency Levels of RAC Units in China, 2010-2050**

| Year | Condensation temp/°C | Evaporation temp/°C | Heat transfer coefficient | Cooling efficiency | Compressor efficiency | Optimised system efficiency | Fan losses | Rated EER | EER Max. | SEER | Max. SEER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 45.00 | 6.00 | 1.00 | 0.738 | 0.720 | 0.950 | 0.910 | 3.29 | 5.28 | 4.49 | 7.22 |
| 2015 | 43.03 | 10.38 | 1.50 | 0.768 | 0.770 | 0.958 | 0.921 | 4.53 | 6.67 | 6.20 | 9.11 |
| 2020 | 42.38 | 11.82 | 1.83 | 0.771 | 0.803 | 0.964 | 0.928 | 5.16 | 7.18 | 7.06 | 9.82 |
| 2025 | 42.06 | 12.55 | 2.07 | 0.830 | 0.827 | 0.968 | 0.934 | 6.01 | 8.03 | 8.21 | 10.98 |
| 2030 | 41.86 | 12.99 | 2.27 | 0.833 | 0.847 | 0.971 | 0.938 | 6.37 | 8.25 | 8.70 | 11.28 |
| 2035 | 41.73 | 13.29 | 2.43 | 0.835 | 0.863 | 0.974 | 0.942 | 6.65 | 8.41 | 9.10 | 11.49 |
| 2040 | 41.63 | 13.51 | 2.57 | 0.890 | 0.877 | 0.976 | 0.945 | 7.33 | 9.07 | 10.03 | 12.39 |
| 2045 | 41.56 | 13.67 | 2.69 | 0.890 | 0.889 | 0.978 | 0.948 | 7.54 | 9.15 | 10.31 | 12.51 |
| 2050 | 41.50 | 13.80 | 2.80 | 0.890 | 0.900 | 0.980 | 0.950 | 7.72 | 9.22 | 10.55 | 12.60 |

Note 1: Losses attributed to fan power consumption are incurred by the decline in the energy efficiency of the RAC, rather than efficiency of the fan.
Note 2: EER refers to the theoretical limit of the reverse Carnot cycle whilst taking into account the difference in refrigeration temperature efficiency to determine the EER, which represents the actual upper limit of energy efficiency the RAC unit may reach. SEER refers to the extreme limit of the actual EER corresponding to the upper limit of the SEER.
Source: Kang Yanbing, Energy Research Institute, NDRC.

The tightening of MEPS is unlikely to produce significant innovation, as all manufacturers would be required to meet the standards which by definition do not refer to super efficient air conditioner. Innovation may arise, however, with alternative technologies due to the increasing demands on energy efficiency and expected increasing cost of electricity. Implementation considerations or barriers may include equity or pricing concerns, as well as support for industry restructuring. Further analysis of the impact of the increased standards on the cost to consumers vis-à-vis purchase price and operation costs is necessary. Due to the size of the Chinese market, economies of scale may mean only small increases in the cost of production. However, imposing stretch targets on manufacturers may lead to rationalisation of the air conditioning industry in China and the closure of older or smaller manufacturers or their relocation to secondary markets. This may lead to resistance to change and protectionism from some local governments.

In order for additional gains to be made in the energy efficiency performance of air conditioners, a further RMB3.57 billion of investment in research and development is required for advancing the technical components of RACs. Figure 26 provides a timeline and cost estimates for a range of key R&D investments for RAC units. During the current 12$^{th}$ Five Year Plan, RMB820 million in investments is required to achieve the gains as described in Figure 26. Half of this investment will go towards research into efficient heat transfer technologies and the compression technology of RACs.

The highest cost of R&D investments for RAC components between 2016 and 2050 is the RMB900 billion for the development of alternative refrigerant technologies. Soft technologies, including the digitisation of the design and control system as well as for developing an integrated system, will require the greatest investment commitments of over RMB1 billion from 2031 to 2050 alone.

**Figure 26. Technological Measures, Investment and Time Line for Improving the Energy Efficiency of RAC Units**

| | **R&D investments** | **Forecasted investment, million RMB** |
|---|---|---|
| **2011-2015** | Efficient heat transfer technology (threaded piping, strengthen the highly efficient finned heat exchange technology) | 250 |
| | Speed control of DC compression processing technology | 200 |
| | High performance motor drives & devices (IGBT: intelligent power module chip) | 100 |
| | DC speed drive technology (for air conditioners and fans) | 60 |
| | Optimised throttling drive technology | 60 |
| | Research into the external characteristics of the cooling cycle and refrigeration cycle control technology. | 150 |
| **2016-2020** | Efficient heat transfer technology (micro- & small-tubing heat transfer pipe technology) | 150 |
| | Efficient fan technology (highly efficient axial flow fans, tube current fans, centrifugal fans, etc.) | 80 |
| | Uniform and efficient refrigerant heat exchange technology | 50 |
| | Optimised automatic AC unit control technology | 70 |
| | Alternative refrigerant technologies | 200 |
| **2021-2030** | Alternative refrigerant technologies | 200 |
| | Optimised and optimised control techniques for system piping and the refrigeration cycle | 200 |
| | Digital design techniques for the refrigeration technology | 250 |
| **2031-2040** | Alternative refrigerant technologies | 300 |
| | Optimise the design and control of the refrigeration cycle | 250 |
| | Decompression heat recovery capacity | 400 |
| **2041-2050** | Developing and promoting integrated technologies | 600 |
| **2011-2050** | Total required investment | 3,570 |

Source: Kang Yanbing, Energy Research Institute, NDRC.

## 5.2 Summary

During the 11th Five Year Plan, China set an ambitious target of reducing its energy intensity of GDP by 20%. It came very close to meeting this target and has since strengthened its national targets for energy efficiency during the 12th and 13th Five Year Plan periods with a 40-45% reduction by 2020 on 2005 levels. If China is to meet this targeted reduction, it will need to continue finding significant savings in the energy use of air conditioners. Air conditioners remain an energy intensive appliance, which is increasingly popular in households as the country's economic and social conditions continue to rise. Therefore, it is important that China prioritises policy measures which accelerate the technological development and commercialisation of super efficient air conditioners, in order to meet the national energy reduction targets and contribute to sustainable economic and social development.

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