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

Summary Report to the

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This report is dedicated to the memory of David Fewchuk. David played a key role in this project report and its earlier version. His sudden death in Shanghai in September 2010 following our joint conference with the Energy Research Institute in Beijing was a shock to us all. David's constant flow of ideas, grounded realism and ceaseless enthusiasm for new ideas and technologies will be sadly missed on both sides of this project.

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About ERI

The Energy Research Institute (ERI) is China's leading energy researcher, playing a key role in shaping and informing the government's energy and climate change policies. For the past 15 years, ERI has been engaged in modelling the Chinese economy and its relationship to projected greenhouse gas (GHG) emissions with a particular focus on the potential of a low carbon economy in decoupling the relationship between economic development and increasing levels of carbon emissions.

About CSES

The Centre for Strategic Economic Studies (CSES) was established in 1993, and over time has developed a reputation for producing high quality research outputs in applied economics, with a focus on the processes of economic, technological, environmental and social change in the contemporary world. It seeks to understand the causes and consequences of these processes, and the appropriate policy responses for different situations in the Asia Pacific region.

EXECUTIVE SUMMARY

As the world struggles to find a way of controlling greenhouse gas (GHG) emissions so as to hold global warming to no more than 2° C relative to pre-industrial temperatures, the key role of China is widely recognised. Not only is China now the world's largest emitter of GHG emissions from energy use, with those emissions continuing to grow rapidly, but it is also committed to a comprehensive range of policy measures and ambitious targets aimed at reducing energy intensity, slowing emissions growth and rebalancing its economic structure. These policies and targets are widely recognised as being at the leading edge of global initiatives. Given the scale of China's energy use and emissions the successful implementation of these measures, and the achievement of the targets, is of immense importance to China and the world.

Since 2009, the *Centre for Strategic Economic Studies*, Victoria University, and the *Energy Research Institute*, National Development and Reform Commission, China, have collaborated on research to guide the effective implementation of policies to reduce China's energy use and emissions. Placed within the broader context of collaborative research on policy implementation issues concerning the reduction of China's energy use and emissions, this report summarises the outcome of that ongoing collaboration in two areas: the move to low carbon motor vehicles and super-efficient air-conditioners.

BACKGROUND AND CONTEXT TO THE CURRENT STUDY

In spite of the many other challenges that it faces, China is vigorously pursuing the emerging opportunities presented by a carbon constrained future through a shift towards a low carbon economy. China is attempting to accelerate the transition from carbon intensive growth, as well as to strengthen and consolidate its competitive advantages through innovation, science and technology, and research and development in new energy developments. In 2009, Premier Wen Jiabao promised to "make China a country of innovation" with science and technology leading development. However, it remains unclear whether the current pace of adjustment in policy and technology is sufficient to meet current and future challenges. Serious analysis of the effects of current policies and of the options for effective new policies is urgently needed.

While the nature and scale of China's economy is often associated with negative environmental impacts, significant positive opportunities exist in the nation's massive domestic market and highly skilled and low-cost production sectors, especially in bringing new innovative products and clean technologies to market through mass production. China provides the world with a unique opportunity in terms of economies of scale in clean technologies and products. The scale of China's domestic market and access to international markets will ensure that if China can manufacture low-cost highly energy efficient products, then not only will they capture a significant share of the global market but they will also force producers in other countries to adopt advanced, clean tech approaches. Both of these effects would generate significant global energy savings and lower carbon emissions.

This report is one part of an attempt to understand better the economic, political and technological processes driving and impeding the implementation of energy efficient and low carbon technologies and processes in China. By locating the key constraints on the implementation of new policies and instruments, the best ways of introducing emission-reducing technologies can be identified. These issues are examined through the identification of practical low carbon policies and technologies in two industries which are critical to the future growth of energy demand and emissions in China: motor vehicles (see Case Study 1) and air conditioners (see Case Study 2).

New energy motor vehicles

China's burgeoning motor vehicle industry is moving from strength to strength on the domestic front. These changes are revolutionary in terms of scale, design, innovation and future potential, but also perhaps in terms of the challenges that they raise. In 2009, China emerged as the world's largest manufacturer and market for motor vehicles. At the same time, China is not only launching itself on the international market with a new generation of low cost vehicles, but it is also targeting the cutting edge of innovation with a strong commitment to new energy vehicles. It is increasingly clear that decisions made by China's consumers and vehicle manufacturers will play a critical role in shaping the future development of the global auto industry.

Technology roadmaps for electric and hybrid passenger vehicles

Following an extensive review of alternative technologies for low carbon passenger vehicles by ERI, fully electric and hybrid electric vehicles have been prioritised for the future of the motor vehicle industry in China. This has been reinforced through the issuance of a range of policy initiatives by the Chinese Government including the draft 12th Five-Year Plan for the auto industry, the 'Energy Saving and New Energy Vehicle Development Plan (2011-2020)' and the 2010 pilot government subsidy program for new energy vehicles. The Chinese government is dedicated to the development of the motor vehicle industry as a pillar of the domestic economy and as a global leader by 2020. At the same time, it is strongly supporting new-energy vehicle production with an interest in indigenous innovation rather than a heavy reliance upon foreign companies. The goal is to make China the world's largest new-energy vehicle country whilst reducing energy use, improving energy security, reducing carbon emissions and tackling urban air pollution.

Successfully improving the performance and cost of the batteries used in electric vehicles, so that they are competitive with vehicles using traditional internal combustion engines, is the prime technological challenge in the development of electric vehicles. This has been recognised by the motor vehicle industry around the world, and large scale development programs have been introduced in the USA, Europe, Japan, South Korea and elsewhere to develop new battery technology, particularly based on lithium-ion and other advanced materials. Currently the technological leaders in this area are Japan and South Korea, followed by the USA with China rapidly improving its standing.

In the first stage of this study, ERI and CSES jointly developed a framework for a technology roadmap for electric vehicles aligned with the Chinese Government's successive five-year plans. ERI has devoted significant resources to articulating the specific technology requirements for this within five-year periods to 2030 based on a review of similar roadmaps such as those of the IEA (2009), the European Commission (2009) and the Fraunhofer Institute (2010), in consultation with a range of technology experts in China and elsewhere. A summary of this roadmap is provided in Figure 1 below.

Figure 1. Electric Vehicle Technology Roadmap, Summary

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030
EV development targets					
Total EV (1,000)	Few	1250	8,000	50,000	94,000
EV market (1,000)	Few	250	800	5000	
EV technological progress					
Highest speed (km/h)	85	120	140		
Distance (km)	112	130	200	350	400
Mileage (kWh/100km)	16-18	13-14.3	10	8	
EV battery technology					
EV power density (Wh/kg; Wh/L)	90-125 Wh/kg	150 Wh/kg; 150 Wh/L	225 Wh/kg; 200 Wh/L	500 Wh/kg; 460 Wh/L	700 Wh/kg
Battery power capacity (kWh)	16kWh	24 kWh	40-48 kWh	80-93 kWh	112-124 kWh
Battery recharge limit	1000 times	1500 times (5.4 years)	3000 times	3800 times (13 years)	Integrated super battery capacity
Battery cost $/kWh	$750	$375	$107	$75	$30
Battery charging station technology and roll-out					
Battery charging station development plan (State Grid & Southern Grid)	325 stations with 18,700 charging points	Additional 4325 stations with 24,800 charging points	Additional 10,000 stations with 30,000 charging points		
Battery charging station system and roll-out schedule	Commence construction of standard charging using recharge points & battery swap method. Based mainly in residential districts and the car parks of vehicle fleets.	Standardised charging using recharge points & battery swap method. Located at airports, train stations, hospitals, shopping centres, petrol stations.	Standard recharging leads supported by rapid charge and battery swapping.	Complete integration of an electric charging network. Arrival of solar charging stations. Advanced vehicle-to-grid (V2G) technology improves utilisation rate. Trials of mobile charging.	Complete integration of an electric charging network. Solar charging stations hold 5-10% of market share. Mobile charging network in operation.

Source: ERI, 2010.

While the work in 2011 has focused mainly on the policy issues involved in implementing this technology roadmap, and hence on the policy roadmap, this technology map needs to be continually updated to take account of new information (e.g. IEA 2010).

Policy roadmap for low carbon motor vehicles in China

In Stage 1 CSES undertook an initial review the policy options available to influence the development of new battery and other advanced vehicle technologies and to accelerate the uptake of electric vehicles. These include the introduction of strengthened emission standards for new and existing vehicles, the use of taxes and subsidies for petrol and alternative fuels, differential price subsides such as 'feebates' for new vehicles, differential registration fees, government purchasing polices and infrastructure support. A range of Government programs are available to support the development of new technology including direct grants, industry-university collaboration and tax incentives. Further analysis of these programs and options is an important feature of this Stage 2 report.

One of the important constraints on policy is the desire of the Chinese Government not to overly restrict the ability of Chinese consumers to purchase motor vehicles as they are able to afford them. This is likely to limit, for instance, the use of taxes and subsidies for alternative fuels. Policies that reduce the use of vehicles, such as congestion charges and licence restrictions, may therefore play a more important part. The current report has jointly developed an initial policy roadmap and timetable to support the timely uptake of electric vehicles over the period to 2030, given the likely course for the improvement in performance and the price of battery and other technologies over this period.

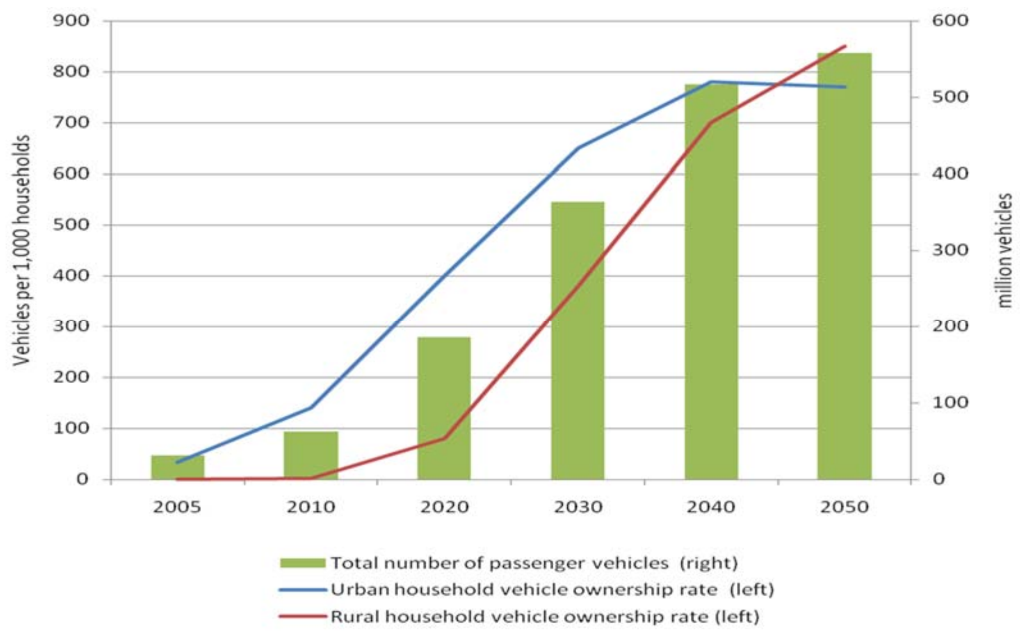
The broader transport policy context of the policy roadmap

The technology and policy roadmaps cannot be seen in isolation, but must be set within the broader context of transport policy, and indeed economic development policy, if the objectives are to be achieved. Some of the many additional questions and challenges that need to be addressed are the following: How will the government prioritise different options for reducing carbon emissions against a background of a rapidly expanding transport sector? What source of energy is going to power the cars of tomorrow and where is the fuel coming from? What strategic investment decisions is the industry making in terms of the domestic and international markets? While the existing challenge for many Chinese cities is tackling their increasingly congested roads, how are urban planners responding to the expected tripling of vehicles to 360 million vehicles by 2030? Given the importance of each of these issues, what role does energy efficiency and technological innovation play?

These complex issues cannot be addressed in this project alone, but what is essential is that the technology and policy roadmaps are clearly set in the context of them, and of the potential answers to them. For example, the projections for motor vehicle ownership contained in the path-breaking CEACER 2009 analysis prepared by ERI and other groups are summarised in Figure 2 below. Clearly the pace of growth in motor vehicle ownership, and the types of vehicles purchased, will have a major influence on technology paths and on the achievement of scale economies for many producers. But such a rapid expansion in vehicle numbers in China – to over

300 million vehicles by 2030 and 500 million by 2050 – will have massive economic, social and planning implications for China. This aspect of the analysis in this report thus attempts to ensure that the implementation of the Government's preferred policy and technology roadmaps takes adequate account of these broader implications.

Figure 2. Projections for Motor Vehicle Ownership under a Low Carbon Scenario to 2050

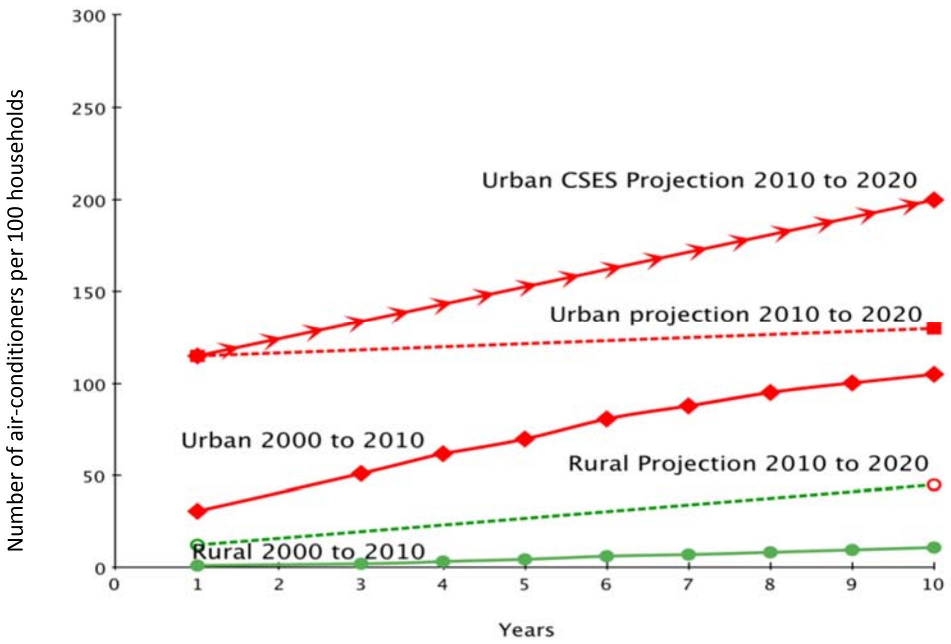


Source: CEACER, 2009.

Energy efficient air conditioners

Much of China's current growth in energy demand is driven by the building sector's demand for energy-intensive production of steel, cement and glass. However, in the coming decades it is expected to be driven by consumption-led energy demand trying to keep these same buildings cool. China is both the world's largest market for and manufacturer of air conditioners, with more than 110 million units produced in 2010, representing around 80% of global production. While China's 300 million residential air conditioners represent a relatively small component of the nation's total energy use, they already constitute a leading area of growth in energy demand. With clear signals of rising household penetration rates (see Figure 3) and estimates of already over 700 million units installed in the foreseeable future, the implications for future energy demand 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 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, arising from the combined effects of climate change and urban consolidation, interacting with the increased demand for cooling associated with rising household incomes.

Figure 3. Past and Future Air Conditioner Penetration Rates, 2000-2020



Source: NBSC, 2009; CEACER, 2009; CSES, 2010.

In acknowledging the energy implications of air conditioners, the central government has introduced a comprehensive range of policy measures aimed at improving the manufacture and sale of energy efficient air conditioners. New energy efficient regulations, standards, codes, labelling systems, plans, pilot projects, incentive schemes, tax rebates, targets, and procurement policies have been introduced in an attempt to reduce the expected growth in energy consumption.

The most effective policy and technology options available to both government and industry for achieving energy efficiency improvements in air conditioners have been reviewed through our joint ERI and CSES studies. We found that most countries have adopted mandatory energy performance standards (MEPS) for air conditioners, including Australia, Canada, China, Japan, Korea, Mexico and the USA. The most effective approach was Japan's industry-wide Top Runner Program, which sets a coefficient of performance (COP) for the manufacturers of air conditioners and is driven by a market leader component. The required COP is a weighted average of air conditioners sold by all manufacturers and is advanced by the most energy efficient unit on the market. Accordingly, during the first seven years of the program the energy efficiency of air conditioners improved 67.8%.[1]

In 2010, however, Japan's Central Research Institute of Electric Power Industry argued that cost effective improvements in the energy efficiency of air conditioners are *virtually exhausted*. And yet, this project report argues that minimal technology and cost barriers remain for achieving ongoing energy efficiency improvements. This joint ERI-CSES study also found that additional technologies and policy tools are readily available for achieving significant energy savings with high efficiency air conditioners in China. However, key challenges remain in terms of accessing new technologies and sharing intellectual property rights and the monitoring, testing and enforcement of compliance standards in the production, installation and maintenance of air conditioners. In addition, this report highlights several areas requiring further attention, including improved coordination in setting energy efficiency standards, especially in: the approach and timing of implementation; greater alignment between consumer behaviour and national smart metering policies; monitoring the efficiency and operation of units; and a broader consideration of the application of emerging heating, cooling and power generation technologies including integrated systems such as gas heat pumps, geothermal and fuel cells.

Technology and policy roadmap for super efficient air-conditioners

Based upon this knowledge, this report seeks to identify for air-conditioners the most effective series of policy steps for achieving accelerated technological innovation, production and sales of super energy efficient units in the Chinese context.

One of the key outputs of this joint study is a technology and policy road map for energy efficient air conditioners in China. It has set out the policy parameters and 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. Thus the roadmap needs to cover many aspects, including:

- The availability of improved energy efficiency technologies and the challenges of moving industry standards toward super efficient air conditioners;
- The cost and effectiveness of complementary policies, such as energy labelling, white certificate schemes, rebates and minimum installation and building standards;
- The measurement of air conditioner performance with a priority on peak demand impact and the relative COP/EER measure;
- Implementation and program design considerations, such as changing consumer behaviour, stretch targets and governance arrangements; and

[1] In order to continue to achieve energy efficiency gains, Japan has recently replaced the COP with an annual performance factor (APF) system to better reflect actual unit usage.

- Broader considerations relating to efficiencies achieved through integrated systems and connectivity to a smart grid and smart metering systems.

OVERVIEW OF RESEARCH RESULTS

Case Study 1: High Fuel Efficiency Motor Vehicles[2]

The Chinese Government, through a number of major policy announcements over recent years, has decided that a principal initiative that it will undertake to lower greenhouse gases and address greater fuel security for passenger vehicles is to promote the greater development and uptake of electric vehicles. Accordingly, this report concentrates on what the central and sub-national Governments have done in China to promote the development of electric vehicles, and describes and discusses a technological roadmap and set of policy instruments to achieve this end.

The report provides background on both the rapid rise in the number of motor vehicles in China during the past decade, and the corresponding rapid growth in the output of the domestic automotive production industry. It describes how national, regional and municipal governments within China have promoted the growth of the industry through joint ventures among foreign automotive manufacturers, domestic manufacturers and government, and more recently have encouraged the development of automotive technology, such as electric cars. The government has introduced policies and programs to address pollution, congestion, fuel costs and climate change associated with motor vehicle use, and these are described in terms of their impact on the industry and consumers.

Although established in automotive component export markets for some time, the Chinese motor vehicle industry is poised to make a serious attempt to become a global presence in the automotive trade. As the Japanese and Korean examples illustrate, this is necessarily a long-term program which will require Chinese manufacturers to meet environmental, safety and engineering and other standards in developed economies, as well as the quality and other expectations of consumers. Therefore, manufacturers will increasingly need to adopt world's best practice manufacturing and supply chain management techniques and invest in the innovation necessary to achieve this, either within their own organisations or in collaboration with private and public technology organisations.

The challenges faced by the Chinese Government in reducing carbon emissions from transport are illustrated in the study by comparing growth in the Chinese passenger vehicle fleet with that in Australia as an example of an advanced economy. The anticipated strong growth in the number of cars in China highlights why the Chinese Government is giving priority to the

[2] At http://www.vises.org.au/documents/2011_CSES&ERI_Roadmap_Elec_Vehicles_Report.pdf

development of electric and hybrid diesel vehicles as it seeks to reduce vehicle energy use and emissions.

There are a range of policies that can be adopted to encourage low carbon transport suggested in this report including stronger emissions standards for vehicles, fuel taxes, vehicle purchase taxes, support for infrastructure for electric vehicles and encouragement of alternative transport modes. One such program, that has already been implemented in a number of European countries and is gaining wider attention, is the so-called "feebate" scheme, which provides rebates for vehicles with emissions lower than a benchmark rate and fees for vehicles exceeding the benchmark rate. The feebate is described and analysed in some detail, and should be considered as a supplement to the setting of stronger emission standards.

The concern about carbon emissions from transport has prompted governments and other bodies to develop roadmaps setting out goals and timelines for achieving lower emission vehicles. These are reviewed and illustrated using the UK Consensus Technology Roadmap.

In conjunction with this work, the Energy Research Institute has developed a technology roadmap for the introduction of electric vehicles in China, along with a roadmap for the introduction of associated charging infrastructure and a range of policies and programs to implement the roadmap. The latest versions of these roadmaps are summarised in Figures 25 and 26 of the Case Study 1 report. The analysis found that the success of electric vehicles in penetrating the market will be dependent upon three key factors: advances in battery technology; the widespread deployment of charging facilities; and pricing parity between electric vehicles and conventional vehicles. Each of these issues is discussed to provide a picture of how China intends to develop policies to advance electric vehicle technology and deployment so that they make up a significant proportion of the Chinese motor vehicle fleet within twenty years.

The policy roadmap (Figure 26) shows the proposed coordinated development out to 2030 of five factors seen as critical: the strategic national framework, R&D policy, a wide range of support policies to encourage the development of key technologies and the market take-up of electric vehicles, the introduction of comprehensive standards for all elements of electric vehicles and of the key policies necessary to establish an adequate vehicle charging infrastructure. The Appendix to Case Study 1 provides a review of fuel efficiency and emission standards in various countries.

Case Study 2: A Policy and Technology Roadmap for Energy Efficient Air Conditioners in China[3]

This report finds that, if it is to achieve its energy efficiency goals, China needs to constantly update and strengthen energy efficiency standards for air conditioners in three key areas:

[3] At http://www.vises.org.au/documents/2011_CSES&ERI_Roadmap_AirCon_Report.pdf

- Constantly update and strengthen the mandatory minimum energy performance standards (MEPS) 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.

In strengthening standards it is suggested that China could adopt a combination of stronger MEPS standards together 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 room air conditioners (RACs). Any adoption would need to be in line with local Chinese conditions. For example, a mix of voluntary and mandatory elements would require regular review, 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, as discussed in the body of 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. 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.

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 in the Case Study 2 report 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 from 2011 to 2025, leading to an EER of 8.0 by 2021-25.

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 in the Case Study 2 report). 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 in the Case Study 2 report 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.

The tightening of MEPS alone 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 conditioners. 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, substantial further investment in research and development (estimated at RMB3.6 billion) is required for advancing the technical components of RACs. Figure 26 of the Case Study 2 report provides a timeline and cost estimates for a range of key R&D investments for RAC units. During the current 12th 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.

THE BROADER CONTEXT OF POLICIES TO REDUCE ENERGY USE AND EMISSIONS

As noted earlier, this report is one part of an attempt to understand better the economic, political and technological processes driving and impeding the implementation of energy efficient and low carbon technologies and processes in China. In these two case studies these issues are examined through the identification of practical low carbon policies and technologies in two industries which are critical to the future growth of energy demand and emissions: motor vehicles and air conditioners. But many other issues remain of critical importance, and three which are matters for ongoing collaboration are noted briefly here.

The level of emissions from energy use in a given country can be analysed in terms of three effects: (i) the structure of GDP, in terms of the relative importance of high and low energy intensity industries within the economy (*the structure effect*); (ii) the level of energy use per unit of value added within individual industries (*the energy intensity effect*); and (iii) the level of emissions per unit of energy use (*the emissions intensity effect*). In the 11th and 12th Five Year Plans the Chinese Government has committed to major action in each of these three areas: to rebalance the economy to a less energy-intensive structure, to introduce new technologies and practices to reduce energy intensity within particular industries and to reduce the carbon intensity of energy production.

Progress is necessary in each of the three areas, and if progress in one stalls the demands on the other two areas to achieve a given aggregate target will be so much the greater. It is planned that the ongoing collaboration between CSES and ERI will have projects in each of these three areas, subject to the availability of funding and other resources.

Economic structure and energy use

A critical component of tackling the dual problems of China's rising energy use and carbon emissions is rebalancing the economic structure. In 2005 the Chinese Government recognised the need to adjust China's development model to one that is 'socially and environmentally sustainable' and that contributes to maintaining a 'harmonious society', and in the process to change China's economic structure. Among the key goals of the 11th Five Year Plan (2006-10) were programs

- to increase innovation within all sectors, including industry, and shift the pattern of activity from low value added output based on low labour costs towards higher value added activities based on knowledge; and
- to change the structure of growth towards the service sector, and accelerate the growth of particular service sectors that directly contribute to individual welfare.

These have been reiterated as goals of the 12th Five Year Plan (2011-15), but achieving these goals has proven very difficult. This has been the case even as the domestic rationale for achieving significant rebalancing – pollution, inadequate support for people's basic needs and the economic risks of overheating and unbalanced growth – has become more urgent and as international pressure for real progress on restructuring has intensified.

China has made only limited progress over the past decade in shifting the pattern of industrial activity from low value added output based on low labour costs towards higher value added activities based on knowledge, although the matters considered in Case Study reports 1 and 2 can be seen as part of that attempt. China has made virtually no overall progress since 2005 in shifting the structure of growth from industrial to service sectors, in part because of the nature of the stimulus package and the recovery from the global financial crisis. Achieving structural change in these two dimensions remains critical to achieving China's economic, environment and social goals, and the policy implementation issues are both very difficult and of high importance.

The energy intensity of individual industries

By contrast, China has made substantial progress in reducing energy use in particular industries, and the work in relation to energy efficient vehicles and air-conditioners described in the two case study reports is a case in point. But in these areas it will continue face major challenges in terms of identifying, testing and proving up such technologies, and hence effective collaborations with other countries are likely to be of value.

Australia has many promising clean technologies and aspires to be a global leader in some of them, but has only a limited market in which those technologies can be trialled and applied, and limited access to capital. China has a great thirst for such technologies, a massive market in which they can be pilot-tested at realistic scale and good access to capital and to government support in developing and applying clean technologies.

It is possible that, as an extension of the current joint work, ERI and CSES could collaborate, including with relevant experts in China and Australia, to identify clean technologies, including advanced energy technologies, which could be the subject of collaboration between Chinese and Australian firms, and to help to facilitate such collaboration. Such technologies might be pilot-tested in China on a joint venture basis, as part of that country's push into the low-carbon economy, and then taken to world markets on a collaborative basis. This would provide China with access to valuable new technologies from Australia. But it would also give Australian firms an opportunity to access the largest and most rapidly growing clean tech market in the world, and use this as a base from which to enter other world markets.

Given the powerful role of government in China and the scale and dynamism of its push into clean technologies, this could be an important opportunity. It could focus on technologies from small and medium sized firms and agencies, and not address those (such as carbon capture and storage) that already involve multi-national programs and large firms. It could also give much attention to 'soft' technologies, involving services, systems and management processes, where Australia has much to offer.

Reducing the emissions intensity of energy use – the role of natural gas

Natural gas has been identified as playing an important part as the transition fuel for reducing demand from coal, whilst providing a cleaner form of energy. In 2010, natural gas contributed 4% to China's primary energy demand compared to 71% for coal. However, by 2015 the share of gas is expected to double to 8% with coal reduced to 61%. Almost half of this gas is anticipated to be imported, mostly as shipped LNG. Recent developments – the increasing urgency of reducing energy use and emissions at home and increased global supplies of conventional and non-conventional natural gas – has led us to propose the consideration of a much more rapid rise in gas use, rising perhaps to more than 400 bcm or about 10% of energy use by 2020.

Many questions arise about such a potential rapid expansion of gas use in China. What applications (such as residential and commercial, power generation or industrial uses) would support natural gas use of the order of 400 bcm by 2020? In what regions would such a level of gas be used, and what would be the pipeline and distribution requirements? What are the key technologies in each application that might support this level of gas use? Is such a level of gas supply likely to be realised in China from a viable mix of domestic production and imports, and at an acceptable price in terms of domestic fuel substitution? Will growing use of natural gas support or hinder the growth of renewable energy sources in China? More generally, what are the policy changes required to facilitate a rapid increase in natural gas use and will the benefits justify incurring the costs involved? These issues are also seen as appropriate ones for ongoing cooperation between ERI and CSES, given ERI's (and NDRC's) key role in the relevant policy issues and Australia's experience in the production, distribution and use of natural gas, including the development and regulation of gas markets.