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Bilateral collaboration on energy efficiency in buildings

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Introduction

This working paper aims to focus on increasing the energy efficiency of buildings through cooperative efforts between the EU and China. Energy efficiency is seen as the most effective way of improving security of energy supply, reducing carbon emissions and increasing competitiveness while realizing these energy-saving measures. The development of a large market for energy-efficient technologies and products is also seen as a by-product of policies to encourage improvements in this area. This paper is intended to complement other research within the Project on cement, white goods, lighting, and building design and construction, by focusing more generally on issues which are emerging across the specific areas of study.

The following potential areas of cooperation between the EU and China have been identified by the preliminary research:

- *Governance:* What lessons can be learned from implementation (or non-implementation) of relevant EC legislation in this area? What have been the successes and failures? What are the key blockages? What is the best way to manage the process of spreading best practice and altering consumer behaviour?

- *Knowledge transfer:* This is distinct from technology transfer, and concerns the spread and communication of best practice on issues such as building design and renovation. How can EU best practice be most effectively transferred to the Chinese buildings forums – for instance, through international seminars, or by creating networks of construction professionals (linking relevant organizations in the EU and China)?

- *Standards setting:* Given the current relatively low levels of ownership of household appliances in China, and the enormous projected growth in ownership over the coming decades, achieving high levels of efficiency in new appliances in China (and in the EU) is crucially important. How can the EU and China cooperate to set high standards in this area which would deal simultaneously with energy security and climate security concerns? What are the intellectual property rights (IPR) concerns? What about third countries in this process?

- *Research and Development:* Much of the debate in the area of energy efficiency centres on uptake of existing technologies, since the potential energy savings, even in the absence of further technological development, are so great. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicates some product areas in which further research is needed. In these areas, how can the EU and China best cooperate to bring such technologies to market?

• *Promoting trade in energy-efficient goods:* There are a number of key questions here. What is the political economy of trade in this area between the EU and China? What is the current volume of production of such goods in the EU and China, and what is the current level of trade? Who produces substitute goods with lower efficiency and would thus object to developments in this direction?

1 Economy of buildings' energy efficiency and mitigation of greenhouse gas emissions

'Climate change is becoming one of the defining facts of economic development in the 21st century. It will shape investment, technology deployment and human development around the world and no sector will be more profoundly affected than energy.'[1] The building sector accounts for nearly 40% of energy consumption in EU countries and is growing fast in China. The way in which buildings are designed and constructed today will shape the energy perspective in the next decades. Inefficient constructions will have tremendous energy and climate implications and render climate and energy security more vulnerable. Implementing carbon mitigation options in buildings is associated with a wide range of co-benefits, including social welfare benefits for low-income households, increased access to energy services, improved indoor and outdoor air quality, as well as increased comfort, health and quality of life, job creation and economic competitiveness.[2]

Buildings are characterized by an irreversible process in terms of energy consumption during the whole operational period owing to their long operational life. A house will last for at least 30–50 years before its lifespan is complete. It is widely accepted that it is cheaper and more efficient to address the energy efficiency of buildings at the construction stage as reconstruction and/or retrofitting during the operational stage will be very costly and also create social problems.

The global effort to mitigate greenhouse gas (GHG) emissions will inevitably rely on improving the energy efficiency of buildings in the coming decades.[3] Many building professionals take it for granted that high-efficiency buildings will necessarily entail a much higher building cost and are reluctant to go beyond the government's building efficiency codes. That is why high-performing buildings remain only demonstration projects in the majority of cases, in both the EU and China. However, the IPCC's Fourth Assessment Report estimates that the potential exists to cut CO_2 emissions related to energy use in buildings by 29% cost-effectively by 2020. A recently report by the WBCSD showed that green building technologies can be used to achieve significantly reductions of energy use across the life-cycle of buildings at only a 5% extra cost, instead of the commonly supposed 17%.[4] However, although most people in the building markets (developers, contractors, house owners, tenants etc.) are aware of sustainable or green buildings, only a few have ever been directly involved. Financiers and developers of buildings were considered to present the main barriers to more sustainable approaches in the building value chain.[5] In the building market the technology to achieve efficiency improvements is available in most countries, but businesses need to be supported by appropriate policies and regulations.

The UK government's Stern Review on the economics of climate change pointed out that climate change is responsible the greatest market failure the world has ever seen. Three key elements of policy are required to tackle the global challenge:

1. Carbon pricing, implemented through tax, trading or regulation.
2. Formulating policy to support innovation and the deployment of low-carbon technologies.
3. Action to remove barriers to energy efficiency, and to inform, educate and persuade individuals about what they can do to respond to climate change.[6]

These market failures are encountered in the building energy efficiency sector as well, in both the EU and China. Policy-makers need to take account of the key policies advocated in the Stern Review to address the lack of synergy and to decouple the building sector from energy and carbon-intensive growth.

Implementation of energy efficiency measures in buildings will be a substantive contribution to the mitigation of global warming mitigation in both the EU and China in the coming decades. Research by Stephen Pacala and Robert Socolow demonstrates how a suite of existing technological options could be used to reduce GHG levels to a level that is sufficient to avoid the dangerous effects of climate change.[7] GHG emissions can be broken down into manageable (though still large) 'wedges,' each of which relates to a technology set in a specific sector. According to their projections, carbon emissions can be cut by one-quarter in buildings and appliances by 2054. Wellington et al. (2007) proposed a blueprint to structure the information, to empower decision-makers to implement 'smart wedges' in the real world in dealing with climate change. The key ingredients of this blueprint are:

Technology – The scope, scale and availability of the technologies in question, as well as the risks and other impacts associated with them.
Investment – How domestic and international investors respond to the incentives created by policy; and how the combination of policy and commercial opportunity affects capital flows from the private sector and development assistance.

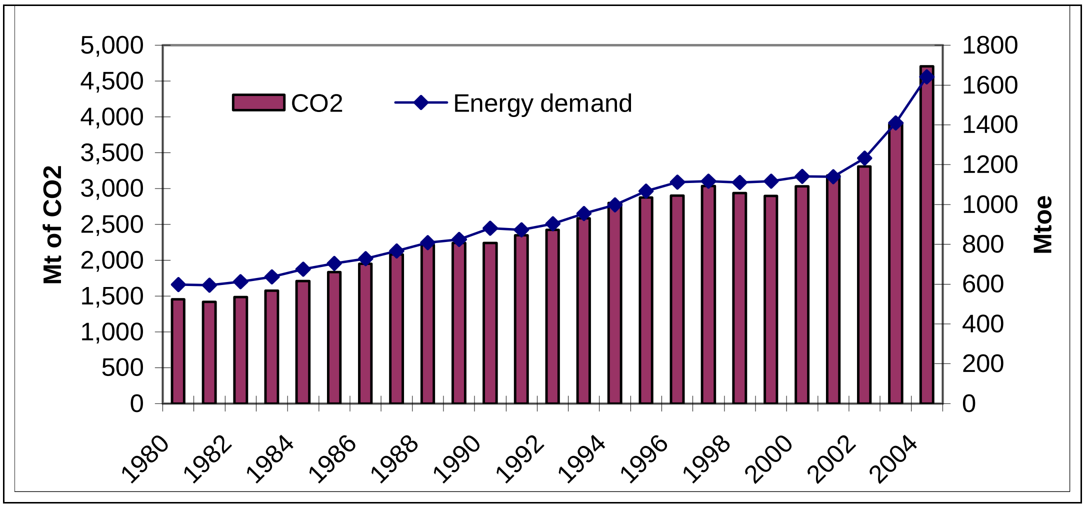
Policy – Agreements, trade conditions and other factors that affect international deployment of the technology: the successful realization of any wedge depends on understanding decision-making processes in the country or region in which it is to be implemented.

2 Overview of energy demand in China's building sector

At present, the building sector accounts for nearly 20% of final energy consumption in China, and this is very likely to increase to 35% by 2020. Energy-related CO_2 emissions in the building sector represent 18% of China's total emissions. Each year, about 12,000–14,000 million m^2 of residential buildings are constructed in China, with an investment of nearly 1,000 billion yuan – approximately 20% of China's total fixed assets investment and 8–10% of its GDP. Housing construction necessitates enormous consumption of natural and energy resource: each year it consumes 20% of China's total steel output and 17.6% of cement production.

Rapid urbanization, economic growth and rising standards of living mean that China will develop all possible means to meet energy service requirements over the next two decades. The evolution of primary energy demand and carbon dioxide emissions is plotted in Figure 1.

Figure 1: Primary energy demand and CO_2 emissions in China



Source: IEA World Energy Outlook, 2006

Energy consumption in buildings includes the energy embodied in the manufacture of building materials and in construction, and the energy used during the operational stage of buildings. However, about 85% of energy use occurs during the occupancy stage of buildings – the bulk of energy use of during the entire lifespan of buildings. Although efficient building materials, such as insulation, have more embodied energy than traditional materials, a very large amount of extra energy consumption at the manufacturing stage can be offset by energy savings during a building's first years of occupancy. Thus, from a life-cycle analysis viewpoint, energy efficiency measures ultimately allow consumers to reduce energy consumption quite considerably.

There is a broad array of accessible and cost-effective technologies and know-how that can significantly abate GHG emissions in buildings: advanced insulation materials and techniques; passive solar design, high-efficiency lighting and appliances, highly efficient ventilation and cooling systems, solar water heaters, integrated renewable systems such as roof or window PV; and double or triple glazing. Realizing these energy-saving measures requires an integrated design process involving architects, engineers, contractors and end-users.[8]

An appropriately designed institutional framework is necessary to ensure the implementation of high-efficiency building and appliance standards. It is unrealistic to expect the developers or constructors to improve efficiency performance spontaneously without any market incentive since their sole objective is to maximize profits. Consideration of building energy efficiency is often a secondary priority in the business of construction. Previous experience in developed countries show that a holistic approach should be adopted by integrating the quality of energy infrastructure, building energy efficiency and public policies to remove the barriers to implementation of energy efficiency in buildings.

General context of China's building sector – energy demand and CO_2 trends

In China, buildings have become an increasingly important energy consumption sector and energy demand in the sector is only going to increase. Table 1 provides a general picture of energy use in China's building sector in 2004.

Table 1: Final energy consumption inventory in buildings in China, 2004

		Area (million m^2)	Energy consumption
1. Residential energy use in rural areas	(Biomass included)	24,000	219 mtoe of solid energy 90 TWh of electricity
2. District heating in northern urban area		6,500	92.86 mtoe of coal/year
3. Energy use in buildings in urban area (excluding district heating in 2)	Residential electricity demand	9,500	260 TWh/year of electricity
	Commercial buildings' electricity demand	5,500	240 TWh/year of electricity
	Subtotal	15,000	500 TWh/year of electricity
Total	312 mtoe of coal and biomass and 590 TWh of electricity were consumed on site (final consumption) in China's building sector in 2004.		

Sources: Jiang, 2007. 'Current status of energy use in buildings in China', in 2007 Annual Report on China Building Energy Efficiency, Tsinghua University; China Energy Statistical Yearbook 2004.

Notes:

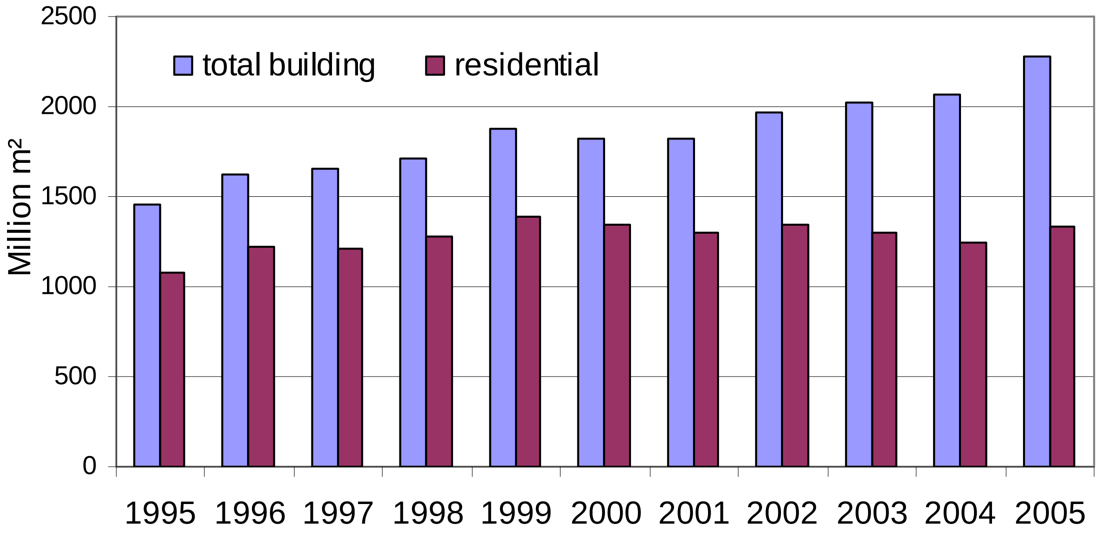
1. It is assumed that buildings use only coal and electricity as final energy source; other solid energies were ignored in these statistics.

2. IEA (2004)'s figure for biomass energy consumption (789 mtoe) is much higher than that given in the *China Energy Statistical Yearbook*. The Chinese official statistics are used here to ensure consistency of data.

Construction trends

China is engaged in a vast programme of urban development. The urbanization rate is expected to reach 55% in 2020 and 58% in 2030; the population in the urban zone is projected to increase from 460 million in 2000 to 830 million in 2030, with an average annual increase of 2%.[9] Some 300–400 million rural residents are anticipated to move into the cities during the next 20 years. The average per capita living area is expected to reach 30m^2 in the cities by 2020, approximately equivalent to that in the developed countries in 1990s. More than 2 billion m^2 of buildings are constructed each year in China – a figure higher than any other country in the world. More than half of the buildings existing in 2015 will have been built after 2000[10] and China's Ministry of Construction has estimated that around 15–20 billion m^2 of urban-zone housing will be built between 2005 and 2020 to accommodate newcomers to the cities – equivalent to the entire existing building stock in the EU-15! Figure 2 delineates the historical trend of building construction over the past ten years.

Figure 2: Floor space of constructed buildings, 1995–2005



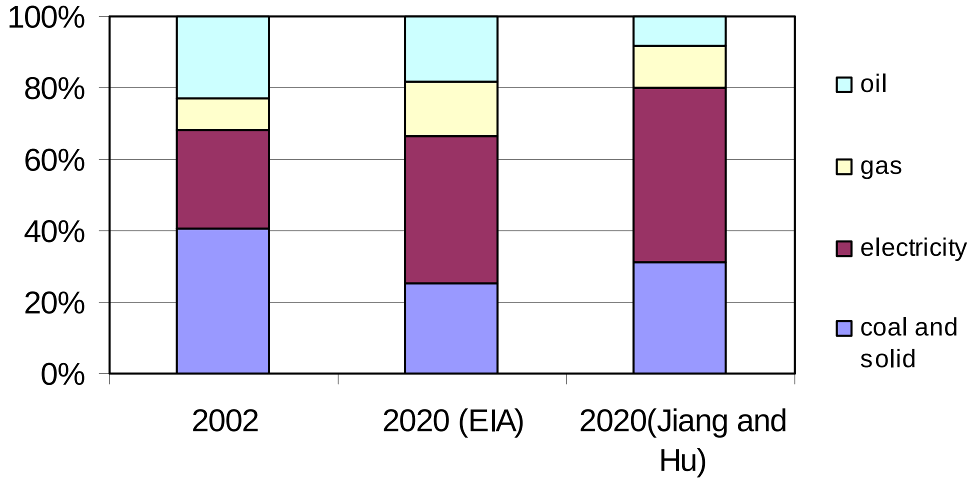
Source: SSB, 2006.

The energy demand outlook for China's building sector

Although industry remains the largest energy consumer in China, the building sector has become increasingly important as more and more people move into the cities in the wave of urbanization and interregional migration.

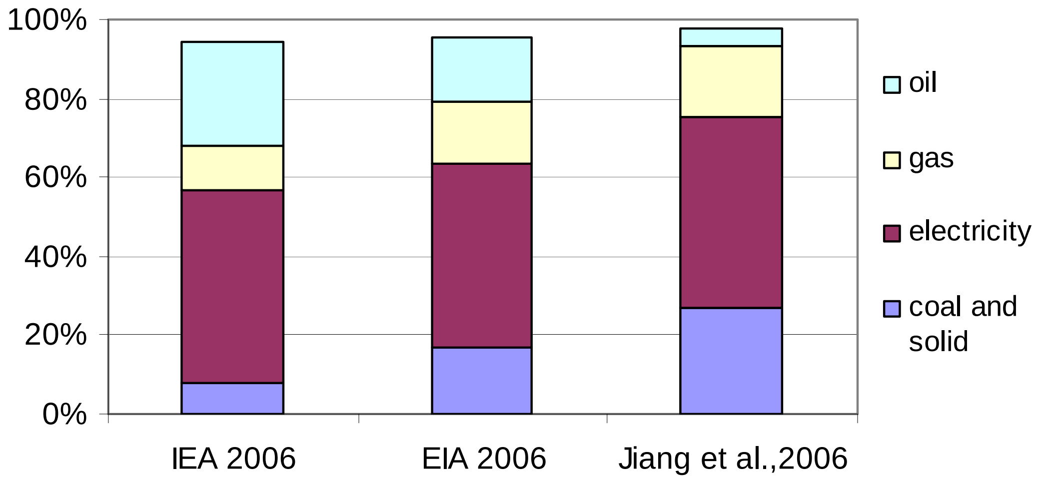
According to estimates by Jiang and Hu (2006), energy demand in buildings will amount to 347–417 mtoe in 2020 and 479–666 mtoe in 2030 under BAU scenarios: while it could be reduced to 347 mtoe and 479 ,toe respectively if efficiency policies were implemented in the building sector. The BAU scenario (Kang and Wei, 2005) suggests that energy demand would increase to 614 mtoe in 2020 but could be reduced to 343 mtoe through full implementation of building energy efficiency policies. Buildings would account for around 28% of final energy consumption in 2030 under the reference scenario, and 26.7% under the IEA's policy scenario (IEA, 2006). Energy demand in buildings would be 472 mtoe in 2015 and 617 mtoe in 2030 under the reference scenario, and 430 mtoe in 2020 and 508 mtoe in 2030 under the policy scenario. The EIA's (2006) reference case projected that China's buildings energy consumption would stand at 282 mtoe in 2015, 312 mtoe in 2020 and 401 mtoe in 2030. The urban sector will largely dominate, with a share of 73% of buildings' total energy demand. Figures 3 and 4 show the breakdown of final energy demand by energy carrier in 2004, 2020 and 2030 under two different forecast assumptions.

Figure 3: Final energy consumption breakdown in buildings, 2002 and 2020



Source: Sources: SSB 2004; IEA World Energy Outlook, 2006; EIA 2006; Jiang and Hu, 2006.

Figure 4: Final energy breakdown in buildings, 2030



Sources: SSB 2004; IEA World Energy Outlook, 2006; EIA 2006; Jiang and Hu, 2006.

Past experiences in the developed countries shows that there exists a close relationship between energy service demand (heating, air-conditioning, hot water, electric appliance etc.) and household income level. In the European countries, unitary heating consumption (KWh/m²) generally continued to decrease after 1974 with considerable improvements to the thermal performance of buildings; however, consumption for electric appliances has increased sharply over the past 30 years as a result of technology innovations and lifestyle changes. Per capita income in China is expected to increase to

US$10,000 (PPP) by 2020 (NDRC, 2004), and demand for energy services will inevitably increase in the coming decades as people's standard of living improves.

Meanwhile, the ageing population trend means significant adjustment to the structure of urban households – i.e., the number of households will increase while household size will be smaller. Empirical studies show that the energy demand per capita is much higher for small households than in large families. [11] Energy consumption in the Chinese residential sector will increase significantly as standards of living rise, household structure evolves and Western lifestyles are pursued. The improvement of living conditions and the process of urbanization process will stimulate demand for energy services such as heating and cooling in the urban building sector. Furthermore, low-income and rural residents will gradually switch to modern energy sources such as natural gas or electricity, replacing conventional biomass energy (mostly crop straw and stalk) which is still widely used in rural areas for cooking and heating.

China's CO_2 emissions could total 7,744 mt in 2015 and 10,425 mt in 2030 under the reference scenario (IEA, 2006). However, they could be cut by 15.6% through the implementation of energy efficiency measures and enhanced development of renewable and nuclear energy. Coal-fired electricity generation could have a serious impact on the environment if there is no technology breakthrough in the power sector, as electricity and heat generation plants accounted for nearly 50% of China's CO_2 emissions in 2004 – and if coal use in final consumption is taken into consideration, coal-related CO_2 emissions would amount to 3,800 mt in the same year, accounting for nearly 80% of China's total CO_2 emissions (IEA, 2006). Consequently, end-users' electricity-saving measures in buildings will guarantee a substantive contribution to China's CO_2 emission mitigation target.

Consumer-side management measures, such as energy efficiency are the most cost-effective means of energy and emission savings, and mitigating climate change related to energy-use in buildings. The full implementation of the demand-side management (DSM) policy got electricity consumption in China's building sector (both residential and commercial) may lead to a reduction of 347mt of CO_2 by 2030, and the active development of renewable energies and nuclear power for electricity production would allow a further reduction of 390mt of CO_2 during the same period, compared with the reference scenario. Overall, CO_2 emissions in the building sector could be reduced by as much as 700mt per year by 2030, almost one-half of India's anticipated total emissions in the same year. ERI (2004) projected that energy consumption in China's building sector could be reduced by 23% (422 mt) by 2020 compared with the baseline scenario by implementing key policies such as tightening energy conservation standards, introducing heating price reforms, promoting standards and labelling for appliances and scaling up energy efficiency projects.

Quite apart from climate change concerns, improvement in energy efficiency is both the most effective and the cheapest way to address key issues such as energy supply security and energy dependence risk. For the 20 billion m² of floor space in urban areas expected to be constructed in the next 15 years, policy-makers should therefore prioritize the dissemination and scaling up of energy efficiency technology. Given the magnitude and urgency of these issues, it is imperative that comprehensive energy efficiency improvement measures should be implemented by all stakeholders at both central and local levels.

3 China's current regulatory framework for energy efficiency in buildings

Major actors

In China, different public bodies are responsible for supervising building construction and management and for the formulation of energy efficiency policies. Listed below are the major authorities in charge of land-use planning, property development and energy infrastructure construction:

- Development and reform commission (energy planning, endorsement of large-scale energy and municipal infrastructure construction);
- Municipal construction commission: enforcement of building efficiency code, elaboration of building energy efficiency policies, inspection of energy efficiency designs for buildings submitted by architects and engineers);
- Municipal energy conservation bureau (subsidiary of construction commission, in charge of management of energy conservation, building materials innovation);
- Municipal security and quality inspection bureau;
- Municipal building material association (certification of building materials quality, including insulation material);
- Municipal district heating bureau (specific institution in the northern cities in charge of central heating service);
- Municipal commerce committee (management of commercial buildings in the city);
- Urban planning bureau (urban development strategy elaboration, land-use planning, issuing of land-use permit and construction permit (plot ratio is a major index in the review process[12])

- Urban housing administration, land and resource bureau (in charge of land and natural resource management, management of transactions for construction on urban land and existing housing stock)

The institutional organization of building construction and energy efficiency implementation is quite complex for Chinese cities. Interagency collaboration is often lacking in energy efficiency policy implementation for buildings.

It is interesting to note that municipal finance and tax bureaux are not directly involved in the energy efficiency implementation process for buildings; in effect, in most cities no fiscal or financial incentive is available in the building sector. Building efficiency compliance is managed through a rigid command-and-control approach. No flexible structure has been created to allow developers to exceed existing energy efficiency design standards.

Some highly energy-efficient buildings, or even zero-energy buildings, are constructed for demonstration or marketing purposes, but their design and construction fall into the high-price category that ordinary people cannot afford. As far as district heating[13] is concerned, today most municipalities (which are the landowners in urban areas) develop the energy infrastructure, including district heating networks, before official land transactions take place. Property developers pay for these services in the development right purchasing contract. Housing and public building development is subject to specific constraints with regard to construction area and density, plot ratio, contribution to local education services, etc. In areas where municipality-owned district heating services are unavailable, housing developers are obliged to develop an independent heating system, for example coal- or gas-fired boilers or water/earth source heat pumps. However, the energy efficiency requirement for buildings is separate from these terms and directly regulated by building codes. Therefore, very often the designed capacity is well above the actual requirement if the buildings were to be designed in a very efficient way. Unfortunately, most energy planning (electricity, heating) is carried out by public works engineers without any coordination with future property development actors. Thus it is quite common for heating systems in most northern cities to hardly ever operate at full capacity because of over-conservative designs based on professional experiences or assigned textbook values. This may lead to inefficient performance and entails a huge loss of energy infrastructure investment. Examples of good practice can be found in some European countries, where the energy efficiency requirement has been integrated into the overall urban planning process, and the activities of all the likely project participants are coordinated by a pilot committee such that buildings' energy performance will be taken into account right from the start, rather than after the master plan and energy infrastructure have been finalized.

Building codes

The most important energy conservation potential in the building sector is offered by reductions in space heating and cooling consumption – particularly the former. Each year, about 130 million tons of standard coal equivalent (tce) are burned just for space heating in urban residential and commercial buildings – approximately 54% of total energy consumption in buildings.[14] Major losses are caused by inappropriate design and deficiency of regulation in centralized heating systems, which commonly force consumers to open windows because of excessive overheating. Four consecutive building energy efficiency standards have been stipulated in China since the mid-1980s.

Residential buildings

China's vast geographic zones mean climatic conditions vary significantly. Space heating is the primary energy demand in buildings in the north, whereas air-conditioning consumption dominates in summer in the southern and eastern provinces.

The first residential energy conservation design standard was issued in 1986. It aimed at a 30% reduction in heating energy consumption over the consumption in typical Chinese residential buildings ('base buildings') designed in 1980–81. In 1995, the MOC (Chinese Ministry of Construction) issued a revised standard (JGJ 26–95) with an increased energy-saving goal of 50% (Lang, 2004). A significant reduction of energy consumption was achieved after the implementation of the 1995 Energy Efficiency Standard for New Residential Buildings (JGJ 26-95), but the average energy consumption for heating in an efficient house in China ($20W/m^2$)[15] is still almost twice as high as in the most efficient houses in Sweden, Denmark, the Netherlands and Finland ($11W/m^2$).

In 2001, design standard JGJ 134–2001 was approved. Its goal was to reduce electricity consumption by 50% through energy efficiency in residential buildings in both hot summer and cold winter zones.

Design standard JGJ 75–2003 came into force in 2003 for energy efficiency in residential buildings in both hot summer and warm winter zones – which covers mainly the southern provinces.

District heating exists only in the northern part of China. Design standard JGJ 26–95 regulates heating consumption in the building and district network; JGJ 134–2001 regulates electricity consumption for heating and air-conditioning, assuming the services are provided by heat-pump air-conditioners in residential buildings. In comparison, only cooling consumption in residential buildings is regulated by JGJ 75–2003, since heating is rarely necessary in the southern provinces.

Public buildings (commercial)

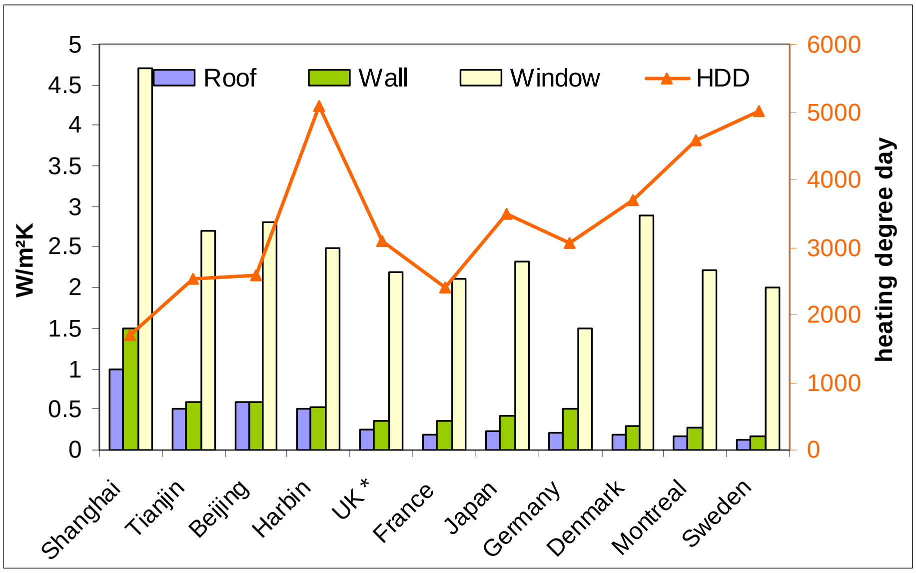
In 2005, MOC (Ministry of Commerce) and AQSIQ (China's General Administration for Quality Supervision, Inspection and Quarantine) co-issued design standard GB 50189-2005 for energy-efficient design in public buildings (administrative buildings, hospitals, schools, shopping malls, offices etc,), whereby newly constructed public buildings should cut 50% of energy compared with those that do not comply with the norm. This standard regulates the values of energy consuming services in commercial buildings: lighting, heating, air-conditioning, ventilation.

Green building evaluation standards

This national standard defines the mandatory requirements for buildings eligible to be entitled Green buildings, and introduces different assessment indicators, ranging from natural resource recycling to the energy performance of the building envelope. This standard is not mandatory but a technical reference for voluntary implementation of environmentally friendly architectural design by property developers. It came into force in 2006.

China's current thermal quality requirement for buildings is still lower than that of most developed countries, in particular the north European countries. Figure 5 compares the different building energy efficiency design codes in China and some developed countries.

Figure 5: Comparison of building thermal performance between China and other countries (W/m²K) (watts per square metre per Kelvin)



Notes:

[1] 19℃ baseline, the degree-day data of European countries are extracted from Waide 2006 [16].

[2] France will reinforce the energy performance standards in buildings by 15% in 2010 and 40% in 2020.

Sources : MOC 1996 ; p.35 ; RT 2000 ; RT 2005 ; http://www.worldenergy.org/; http://www.eere.energy.gov/; UK building regulations 2000 and in 2006 update

Energy-saving and policy priority objectives for the building sector

NDRC (2004) has set out comprehensive energy-saving objectives in the medium- and long-term energy-saving plan. Priority areas for action in the building sector during the 11th Five-Year Plan were defined in this national energy conservation plan (see Box 1).

Box 1: Buildings energy efficiency improvements scheme

Commercial and residential

–Buildings

New buildings, existing residential and public buildings

Use of centralized air conditioning, cold storage and heat storage technology

Application of renewable energy such as solar and geothermal energies in buildings

–Household electric appliances

–Lighting appliances

Source: He (2006).[17]

All new buildings must comply with energy-efficient design standards requiring a 50% reduction of energy for heating. In some major cities including Beijing and Tianjin standards requiring 65% reduction have come into force. In the next few years, standards for heat regimes must be implemented in the northern cities. In order to promote thermal retrofitting in existing buildings in conjunction with urban redevelopment programmes, 25% of existing areas are to be rehabilitated in big cities, 15% in medium-sized cities and 10% in small cities. [18] Specific policies have been put in place to encourage the adoption of high-efficiency technology such as cold-storage centralized air-conditioning and CCHP technology, central air-conditioning systems with multiple-speed pump fans, low energy-consumption windows and new building envelope materials. Solar, geothermal and other renewable energy use in buildings is to be accelerated.

The Plan also highlighted the necessity of tightening energy efficiency compliance requirements for building energy conservation and green lighting projects during the period of the 11th Five-Year Plan, for both residential and public buildings, which will accelerate institutional reform of district heating services, as well as intensify the development of energy-saving technologies and the promotion of energy-efficient products. All of these measures combined may lead to an energy saving of 50 million tons of standard coal.

Lighting consumption in buildings accounts for 13% of the national electricity consumption. The ratio of energy consumption between the CFL energy-efficient fluorescent lamps and ordinary incandescent lamps is 1:2.6. Efficient use of combined fluorescent lamps can save 70–80% of electricity consumption, and 20–30% can be saved by the use of electronic ballast instead of the traditional inductance ballast. One focus for improvement in building efficiency is public buildings: the use of high-performing light systems and diffusion of ESCOs to optimize energy management in buildings, three-colour fluorescent lamps in hotels, shopping malls, office buildings, stadiums, and efficient lighting systems is encouraged. Upgrading production lines for high-efficiency electrical lighting products, LED transportation signal lighting, lighting efficiency improvements for nocturnal illumination in cites could all together save 290 million kilowatt-hours of electricity over the 11th plan.

4 Financial, technical and institutional barriers to promoting energy efficiency in buildings

Although a wide range of energy efficiency techniques is available, buildings are still consuming more energy than necessary to provide the energy services required by the end-users. Substantial market barriers persist and need to be overcome through energy-efficiency policies and programmes. These barriers include the high costs of gathering reliable information on energy efficiency measures, lack of proper incentives between landlords who would pay for efficiency and tenants who would realize the benefits), limitations in access to financing, subsidies on energy prices, as well as the fragmentation of the building industry and the design process into many professions, trades, work stages and industries. These barriers are especially strong and diverse in the residential and commercial sectors; therefore, the obstacles can only be overcome through a diverse portfolio of policy instruments (IPCC 2007).

Technical and institutional problems

In China, energy efficiency policies are still implemented very largely by the traditional command-and-control approach. Market-oriented measures have been developed only slowly. Many building efficiency projects lack sustained financial resources since the major financial actors are rarely involved in investment in energy efficiency projects. Chinese banks typically do not have expertise in energy efficiency technologies and thus lack the ability to assess technical risks; energy efficiency investments are typically small and come with high transaction costs, and the value of energy-efficient projects is relatively poorly recognized.[19] Building efficiency policy formulation and implementation will involve semi-governmental energy efficiency supervision and inspection institutions at various local levels. However, many provinces and cities have only a limited number of such institutions. Institutional capacity-building in these areas matters significantly for guaranteeing policy implementation.

Billing and pricing barriers

Increased construction costs associated with energy-efficient buildings, combined with a dearth of available advanced technologies, give developers little incentive to comply with building codes. Compliance with energy efficiency requirements varies significantly among the different regions. Generally speaking, most new buildings comply with the building codes in large cities such as Beijing, Shanghai and Tianjin; however, in the small and medium-sized cities, implementation seems to be much more difficult because there is less technical support available, and a lack of institutional capacity.

Urban space heating has been considered a government-sponsored welfare requirement in the northeast, northern and northwestern provinces for decades. Heating consumption is billed on the basis of floor space area instead of actual consumption. Consumers are not given any price signal to conserve energy; and no economic incentive is available for housing developers to build more energy-efficient houses. Although the central government issued guidelines in 2003 urging local governments nationwide to bring in heating reforms as soon as possible, the old billing and pricing system remains almost intact. The pricing reform lags behind the government's reform schedule. More specifically, a number of energy suppliers and building constructors remain reluctant to establish individual billing and refuse to install heat meters and thermostatic valves; hence end-users are unable to regulate interior temperatures at will. In the absence of any price signal, consumers have little incentive to save energy. Many municipality-owned district heating companies have been in financial difficulties since the price paid by consumers is significantly lower than the real cost. Huge energy losses are caused by a series of maintenance and management deficiencies stemming from the current heat billing system. Moreover, the development of distributed energy systems such as small and medium-sized high- efficiency CHP faces tremendous difficulties in selling to the grid. They are in competition with suppliers of low-cost coal-fired small boilers, because of institutional barriers in grid power purchasing contracts.

5 Building materials industry in China – sectoral analysis

Cement is an essential ingredient in the production of concrete, a primary building material for the construction industry.

Buildings are the number one consumer of cement in China (per capita cement consumption is about 10 tons). Today, most new buildings are made of concrete. Buildings have become increasingly important in terms of embodied CO_2 emissions related to building materials production and transportation, and in particular the consumption of cement. Carbon dioxide is emitted in the production of clinker and intermediate products during the cement-making process (IPCC 1996). There are two major reasons for the exceptionally high demand for cement in China's building sector: 1) The limited availability of timber because of the low level of afforestation; 2) the relatively short turnover of buildings: a building lasts only 30 years in China,[20] compared with 50–70 years in the EU. The development of innovative building materials is one of the top priorities in China in terms of improving energy efficiency in this sector.

Coal accounts for 90% of all energy consumption in the cement production process in China, whereas in the EU natural gas accounts for 85%. The general future trend will be to rely on alternative forms of energy in cement production to ease the huge fossil energy shortfall in this sector.

In terms of industrial processes, cement production accounts for the most important non-energy-related source of global CO_2 emissions (IPCC 1996) – estimated at 829 mmt CO_2 in 2000, approximately 3.4% of global CO_2 emissions from fossil fuel combustion and cement production (Hanle, 2001). To reduce this level, the Chinese government has fixed targets for energy intensity in the cement industry as shown in Table 3.

Table 2: Energy consumption Index of building materials production

Material	Unit consumption	2000	2005	2010	2020
Steel	Kgoe /t	647	543	521	500
Ethylene21	Kgoe /t	606	500	464	429
Cement	Kgce/t	129	114	106	92
Plain glass	Kgce/weight case*	21	19	17	14
Architectural ceramics	Kgoe /m²	7.17	7.07	6.57	5.14

* 1 weight crate = 50 kg

Source: NDRC 2005, China medium- and long-term energy conservation plan.

Cement industry

Table 3 : Breakdown of production processes in cement industry in China (in 10^6 tons)

	2001	2002	2003	2004	2005
New dry process	71	121	199	317	460
Vertical kiln	627	659	698	779	754
Others	82	90	83	84	82
Capability	780	870	980	1180	1296

Source: China Cement Information website (http://www.chinacement.org/)

China is the biggest cement producer and consumer in the world. Cement production contributes to about 10% of China's CO_2 emissions, just behind the coal-fired power sector. Cement output reached 1.24 billion tons in 2006, accounting for 46% of global production. Of this, 624 million tons (50%) was produced by the new dry process, a much lower percentage than in the EU (90%). Cement production is a key source of CO_2 emissions, in part owing to the significant reliance on coal and petroleum coke to fuel the kilns for clinker production. In 2005, cement clinker production was 800 million tons, the process and combustion-related CO_2 emissions were equivalent to the tonnage of output of cement clinker. More than 200 tonnes of coal are consumed in cement production each year, meaning that the combustion related CO_2 emissions were about 476 million tonnes. It is projected that the ratio of the new dry process to total cement output will reach 70%. To accomplish this goal, 360 million tons of old-style cement output will need to be phased out – about 50–70 million tons each year.

Reducing demand in the building sector by innovation in materials and improvements in cement production will be a substantive contribution to reducing CO_2 emissions in China. The central government has issued guideline to gradually phase out the use of clay bricks[22] in all buildings. Demand for cement will grow continuously given the construction boom anticipated in the next few decades. It is therefore of great importance to develop alternative high-performance wall materials as a partial substitute for the huge consumption of cement in the building sector.

Window glass for buildings

Windows are one of most important energy loss pathways in buildings, responsible for nearly 50% of heat loss during the heating season in the northern cities of China.

The thermal efficiency of double glazing and low-emissivity (low-E) windows can considerably reduce energy loss. Nonetheless, such glass represents only a very small proportion of China's building materials market. In the EU, however, it is used in 85% of new constructions because of tight building regulations on the thermal performance of windows.

There is a significant surplus in production capability of low-E glass because of the slow development of demand in the building sector – about 26m m² at the end of 2006, relative to market demand of only 9m m². Moreover, China's low-E glass market is characterized as an oligopoly since it is largely dominated by three major manufacturers – Yaohua, YaoPi and Nanbo – which account for 80% of national production capability (Report on China's building material sector risk analysis 2006).

6 Energy efficiency policies in the EU building sector

Energy policies in the EU have been guided by two main priorities: energy supply security and environmental protection. Fifty per cent of the EU's energy supply is dependent on imports. On the basis of present trends, by 2030 this percentage will rise to 90% for oil and 80% for gas.[23] The EU needs to reduce greenhouse gas emissions by 8% of 1990 levels by 2012 to meet its Kyoto commitment.

Buildings are considered the key sector for energy efficiency improvements and reduction of GHG emissions, as they are the most important consumers of energy in the EU, accounting for around 40% of final energy consumed and about 725 mt per annum of consumption-related CO_2 emissions (EU-15). More than one-fifth of current energy consumption and up to 30–45 mt of CO_2 could be saved per year by 2010 by applying more ambitious standards for new and refurbishing buildings.[24] At recent peak energy price levels, approximately €270 billion could be saved every year in energy costs (Eurima 2007).[25]

European policy context

Current EU policy in the area of energy efficiency is framed by the European Commission's Action Plan for Energy Efficiency 2007–2012.[26] This Action Plan aims to control energy use in the EU, reducing it by 20% by 2020, and the target was adopted by EU heads of state or government at their European Council meeting in March 2007. This is expected to cut CO_2 emissions by 780 mt, or more than twice the level of EU reductions needed under the Kyoto Protocol by 2012 (EU, 2006). The EU expects to achieve more than €100 billion in annual fuel savings through the initiative, and the

Commission estimated potential savings in residential and commercial buildings at about 27% and 30% respectively.

Specific EC legislation deals with a number of relevant areas. Buildings Directive 2002 (EPBD, 2002) of the European Parliament and Council establishes a common methodology for calculating the integrated energy performance of buildings, which includes not just thermal characteristics but also such elements as heating and cooling installations, lighting and the orientation of the building, passive solar systems and solar protection, natural ventilation and indoor climate conditions. Despite this common methodology, each individual member state determines the minimum performance standards for buildings and thus standards vary across the EU. The directive establishes the general policy framework relating to building and energy supply system efficiencies. Again, it is the individual responsibility of each EU member state to choose measures that correspond best to its particular situation. The Directive should have been incorporated into national legislation by 4 January 2006.

The Directive also establishes systems for the energy certification of new and existing buildings and, for public buildings, requires prominent display of this certification and other relevant information. Furthermore, the Directive provides for regular inspection of boilers and central air-conditioning systems in buildings and an assessment of heating installations in which the boilers are more than 15 years old. In addition, it sets requirements for experts and inspectors for the certification of buildings, the drafting of the accompanying recommendations and the inspection of boilers and air-conditioning systems.

The Ecodesign Directive of 2005 defines principles, conditions and criteria for setting environmental requirements for energy-using appliances, but makes no direct provision for mandatory requirements for specific products. This will be done for given products via implementing measures which will apply following consultations with interested parties and an impact assessment. The Directive stipulates that the manufacturer or authorized representative or, in their absence, the importer is responsible for guaranteeing that the product complies with the relevant implementing measures, and that consumers are informed of the characteristics and environmental performance of the product, and how to minimize the environmental impact when using the product.

There is a range of EC legislation dealing with the issue of product labelling, informing consumers of energy consumption standards of products. These stem from a 1992 European Council Directive on household appliances (directive 92/75/EEC), which applies to goods such as refrigerators, freezers and their combinations; washing machines, dryers and their combinations; dishwashers; ovens; water heaters and hot-water storage appliances; lighting sources; and air-conditioning appliances. These are standardized across member states.

The European Commission adopted a Green Paper on Energy Efficiency that seeks to achieve a 20% saving in energy consumption in a cost-effective way by 2020. It is considered that half of the target could be achieved through the transposition and full implementation by the member states of the legislation already adopted (or shortly to be adopted) concerning the energy efficiency of buildings, ecodesign and energy efficiency of household appliances and energy services.[27]

Meanwhile, the European Union has also set a target to reduce CO_2 emissions by 20% and to increase use of renewable fuels to 20% by 2020. The measures could include a ban on incandescent light bulbs by 2010, forcing people to switch to fluorescent bulbs.

Buildings energy passport and label

The energy passport is the result of the 2002 EU buildings energy efficiency Directive. Countries in northern Europe have the strictest buildings energy efficiency standards in the world, given the severe winters when temperatures can fall below -20℃. As a concrete adoption of the 2002 EU Buildings Directive on energy performance of buildings, in September 2006 the Finnish government introduced a bill to parliament proposing a law requiring an energy certificate for buildings, amendments to the Land Use and Buildings Act, and an Energy Efficiency Inspection (air-conditioning systems for buildings) Act. The energy certificate will be compulsory for new buildings and a large proportion of existing ones. When a building is sold or rented out, a valid energy certificate not more than ten years old must be presented. The certificate must be displayed in a conspicuous place in public buildings and must show the energy efficiency of the building in question (with ratings from A to G – A indicating low consumption and G high consumption).

The German government published a detailed 8-point plan to achieve a 40% reduction in CO_2 emissions by 2020. It is estimated that cutting energy consumption by modernizing building thermal quality and heating systems could lead to a reduction in CO_2 emissions of 41 million tonnes. This would be the second biggest contributor to CO_2 emission mitigation in Germany, just behind the policy of continually increasing the share of renewable energy in electric power generation. In the 2004 EnEV (Energieeinsparverordnung, energy-saving regulation) related to building energy efficiency standards, maximum primary energy demand and thickness of insulation in buildings must comply with mandatory values according to the relevant building type and construction characteristics.

The German energy agency GmbH (Dena) has developed the prototype of a federally uniform energy identification document – an 'energy passport' – for existing residential buildings and had tested this in nearly 4,000 such buildings by the end of 2004. The energy passport is currently a voluntary certificate label, but an identification document for all buildings, indicating their energy performance, will become mandatory in Germany from July 2008.

The passport informs consumers about energy-saving potential and helps them compare the energy performance of different buildings. It is similar to the Finnish buildings energy label: buildings are classified according to eight or nine energy efficiency levels based on relevant indicators such as primary energy demand. The passport will be recognized as a valid document for ten years if the requirements in the EnEV 2007 can be met.

In France, the building energy performance diagnostic (DPE) came into force from May 2007. Displaying an energy label is compulsory in selling or renting all new residential buildings. Their energy performance is rated in seven grades, according to primary energy consumption in terms of KWh/year. In addition to the mandatory DPE label, a new label 'BBC', accredited by the association *Effinergie*, is awarded to houses complying with low-energy-consumption requirements from June 2007.

The French government has set an even more ambitious target of reducing the current CO_2 emissions by a factor of 4 by 2050 over the 2000 level. Various sectoral measures will be undertaken to allow a significant reduction in the relevant energy consumption in order to achieve this climate objective. For the building sector, the government establishes the objectives of improved energy performance by upgrading thermal regulations for new buildings by 15% from 2005, with further revisions every five years; the ultimate target is a 40% improvement by 2020 compared with current requirements.

Policy instruments in the EU, by country

Table 4 shows the different public policies dealing building energy efficiency in the EU-15 member states. It is notable that almost all use capital subsidies and fiscal mechanisms to encourage improvements in energy efficiency in the building sector.

Table 4: Implemented policy instruments for energy efficiency in the EU

Country	Capital subsidies	Feed-in tariffs	Certificates/ Obligations	Competitive tender	Fiscal mechanisms
Austria	x	x	h		x
Belgium	x	x	x		x
Denmark	h	x			x
Finland	x				x
France	x	x		h	x
Germany	x	x			x
Greece	x	x			x
Ireland	x			x	x
Italy	x	h	x		x
Luxemburg	x	x			
Netherlands	x	x	x		x
Portugal	x	x			x
Spain	x	x			x
Sweden	x		x		x
UK	x		x	h	x

X: mechanisms currently present

H: historical policy, now changed

Source: EEA 2006.

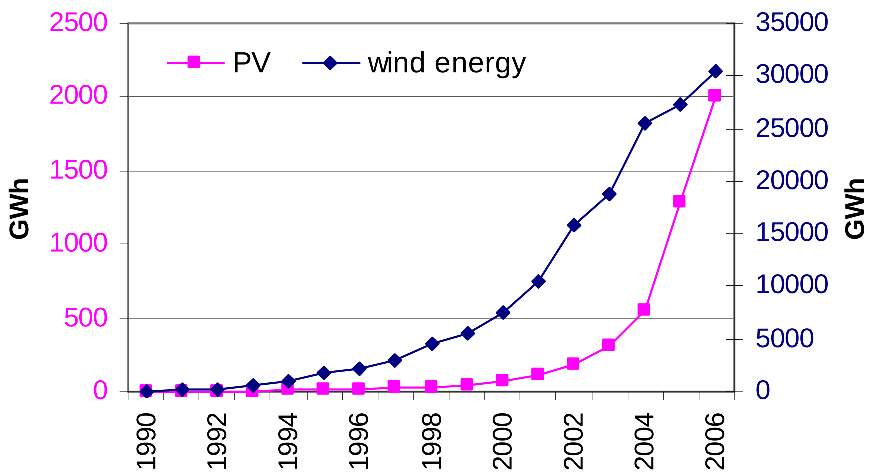
France

Energy efficiency and use of renewable energy in buildings are also encouraged by specific urban planning policies. For example, property developments that factor them in at the design stage can benefit from a plot ratio grant. Under the framework of the French national plan to combat global warming, the tax rebate of 15% from which private individuals can benefit for the purchase of efficient equipment (high-performance boilers, double-glazing, solar heating, etc.) will be raised to 40% for the use of renewable energies. Decentralized high-performance heating systems such as CHP are being promoted by guaranteeing the mandatory purchase by EDF (the French national electricity company) of electricity generated from renewables.

Germany

The German federal government initiated a 'Climate Protection Programme' for existing buildings in order to reduce carbon dioxide emissions by 5–7 million tons by 2005. The existing credit programme of the German Reconstruction Bank will be extended by five years. Germany achieved a successful development of renewables through the Erneuerbaren-Energien-Gesetz (EEG) (Renewable Energy Act). In 2006, the share of renewable energies in total electricity consumption was 12%; about 45 million tonnes of CO_2 were saved because of the EEG alone. The share of renewable energies in total electricity consumption should increase to at least 20% according to the government's projection, and should have risen to 45% by 2030.[28] Figure 6 shows the rapid development of electricity generation from renewable sources in Germany.

Figure 6: Development of electricity generation from PV and wind power in Germany since 1990



Source: Erfahrungsbericht 2007 zum Erneuerbaren-Energien-Gesetz

The promotion of photovoltaic (PV) electricity generation is a major aspect of the integration of renewables in buildings. The German government has put in place several regulatory frameworks and schemes to stimulate the development of building-integrated PV system by guaranteeing a long-term price. The installation of solar-panel systems benefited from a low-interest loan until 2000 in the programme of 100,000 roofs. In 2004, the programme was replaced by REL (Renewable Energy Law), which sets a fixed payment rate for solar electricity.[29]

Policy overview in the UK

6.1.1.1 Climate Change Bill

On 13 March 2007, a draft Climate Change Bill was published following cross-party pressure over several years, led by environmental groups. The Bill aims to put in place a framework to achieve a mandatory 60% cut in the UK's carbon emissions by 2050 (compared to 1990 levels), with an intermediate target of between 26% and 32% by 2020. The UK government also anticipates dramatic energy reductions to achieve its goal that all new housings in England will be carbon-neutral by 2016.

6.1.1.2 Climate Change Levy

Current actions aimed at achieving these targets include a Climate Change Levy on all non-domestic energy bills, typically raising them by 8–10%. The Climate Change Levy is, however, offset by corresponding reductions in Employers' National Insurance Contributions (NICs), having a net zero effect on the tax burden on UK businesses. Introduced on 1 April 1 2001, the levy applies to all 'traditional' energy sources.

6.1.1.3 Renewables Obligation

Introduced on 1 April 2002, the Renewable Obligation requires all suppliers of electricity to end- users to supply a set portion of their electricity from eligible renewable sources; a proportion that will increase each year until 2015, from a 3% requirement in 2002–03 up to 15.4% by 2015–16. The UK government announced in the 2006 Energy Review an additional target of 20% by 2020–21. The Photovoltaics Demonstration Programme (PVMDP) programme during the period 2002–06 guaranteed grants to cover 40–50% of installation costs to households, businesses and social housing groups. The PV system is also exempted from the Climate Change Levy. In addition, for each eligible megawatt hour of renewable energy generated including PV, a tradable certificate called a renewable obligation certificate (ROC) is issued by OFGEM (the Office of Gas and Electricity Markets).

6.1.1.4 The Low Carbon Building Programme[30]

The Low Carbon Building Programme (LCBP), initiated by the UK government, offers grants towards the cost of installing domestic microgeneration technologies and larger-scale distributed generation installations for public buildings and businesses, provided energy conservation standards are also met. The programme commenced on 1 April 2006, is expected to last for six years, and is managed by the Energy Saving Trust.

High-performance and green buildings

Although the existing housing stock is considered the priority for energy-saving measures in the building sector,[31] the French government has taken an ambitious energy-saving initiative for new buildings by launching the ‘PREBAT’ project, involving five different national agencies: ADEME (Agence de l'environnement et de la maîtrise de l'énergie), ANAH (Agence de l'amélioration de l'habitat), ANR (Agence nationale de la recherche), ANRU (Agence nationale de rénovation urbaine) and OSEO Anvar (Agence française de l'innovation). The PREBAT project promotes design in the new construction of buildings that achieve zero net energy output (or which generate a positive surplus of energy that can be fed into the grid infrastructure). Various new technologies will be integrated into these housing projects from the building design and site planning stage. The first demonstration projects were expected to start in 2007, and the results of research and the experimental phase will make it possible to further tighten regulatory requirements for the energy performance of buildings.

Sweden's Bo01 housing estate (the first stage of the Western Harbour redevelopment) was designed as a sustainable urban environment prototype project which is characterized by 100% renewable energy supply, increased biodiversity and a waste management system that uses waste and sewage as an energy source on site.

7 EU-China interdependency on energy-consumption appliances in buildings

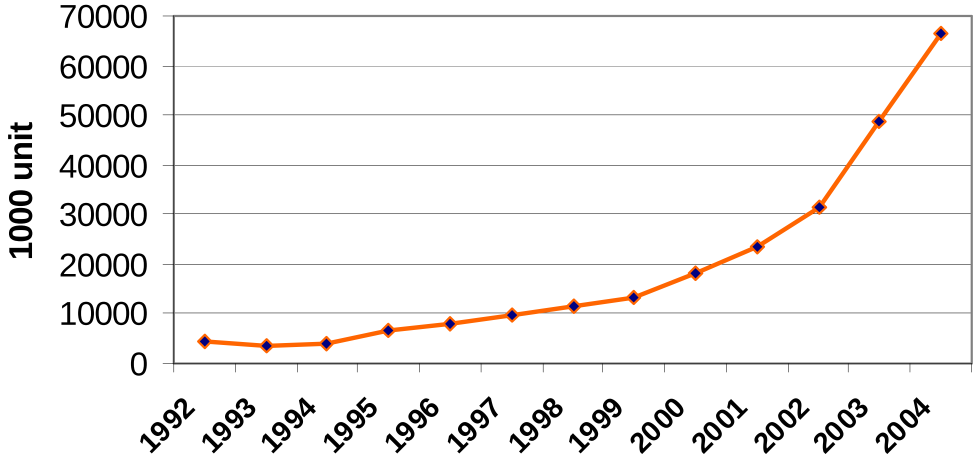
Potential for increase in air–conditioning appliances

China

Air-conditioning and other electric appliances in residential and commercial buildings account for nearly 27% of electric power consumption in China. This implies huge environmental impacts since 80% of electric power plants in China are coal-fired. Improving the energy efficiency of air-conditioning equipment therefore contributes substantially to reducing energy consumption and emission of pollutants from power plants. Air-conditioning in buildings has been increasing steadily over the past few decades, accounting for nearly 40–50% of electricity consumption in buildings. In many large cities such as Shanghai, it represents over 40% of peak load during the hottest hours in summer, presenting a serious challenge to the operational security of the electricity grid. Reducing electricity demand related to air-conditioning is regarded as the priority of demand side management (DSM) policy implementation in China's building sector.

China remains the world's largest producer and exporter of air-conditioners, manufacturing 60% of global output and accounting for just over 30% of total global exports. The annual room air-conditioner (RAC) output is plotted in Figure 7. Output grew more than forty-fold between 1992 and 2004.

Figure 7: Room air-conditioner production in China



Source: China Statistical Yearbook 2005.

From January to August 2006, China exported 23 million air-conditioners worth US$2.9 billion, a rise of about 15% in both value and volume compared to the same period in the previous year. Of these, units worth US$573 million went to the EU, representing about 82% of the EU air-conditioner market. [32] Compliance with the EU's Directive on *Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment* (also known as RoH 20060) is proving to be a major challenge for most small and many medium-sized air-conditioner manufacturers in China. In fact, exports to the EU have dropped considerably since the directive came into effect.

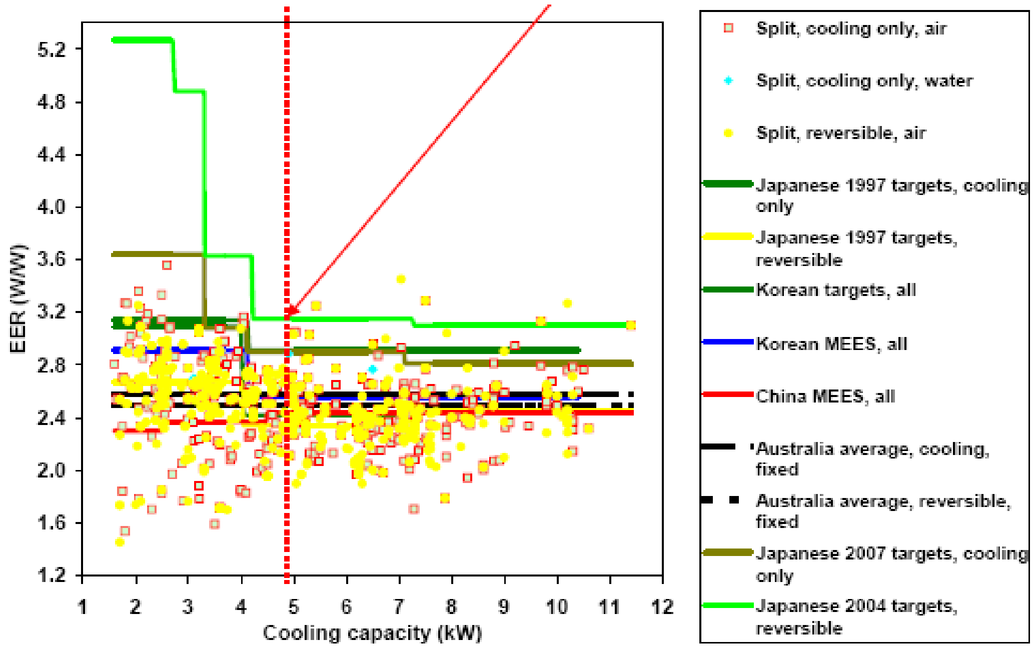
European Union

European countries were long considered an 'air-conditioner-free territory' thanks to their mild, oceanic climate. However this situation started to change in the early 1980. Figure 8 shows the constant growing trend of central air-conditioning-equipped areas in Europe over the last 25 years. Today, southern Europe, with its Mediterranean climate, accounts for most air-conditioning consumption. Of this, Italy and Spain account for nearly 50%.

The current air-conditioned area in the EU is about 1,500 million square metres. This is expected to increase to 2,500 million square metres by 2020.[33] Most air-conditioners in the EU will be imported from China despite more stringent efficiency regulations. In fact, China's National Bureau of Standardization is committed to upgrading the current energy performance codes relating to air-conditioners. It is expected that by 2009 the energy efficiency ratio (EER) of room air conditioners should increase to 2.9 for the single model and 3.2 for the split model. Most suppliers will focus their research and development on releasing more energy-efficient and environmentally friendly models. The bulk of China's output and exports of air- conditioners are produced by a handful of large, high-profile suppliers. Many of these are profiled in, including Chunlan, Galanz, Guangdong Kelon, Hisense, Sichuan Changhong, Guangdong Chigo, Jiangsu Shinco and Wuxi Little Swan. This concentration of large producers will facilitate the implementation of new energy-efficiency norms and innovation in energy-conservation technology.

The impact of EU regulations on the energy efficiency of air-conditioners will help to accelerate environmentally friendly actions by Chinese suppliers since the EU is one of their most important export destinations. Some politicians are calling for the imposition of an eco-tax on Chinese manufactured goods and electrical appliances will make European consumers bear most of the cost. Any imposition of an anti-dumping eco-tax or carbon tax on Chinese highly energy-intensive goods is likely to force the Chinese government to tighten its own environmental regulations in the manufacturing sector.

Figure 8: Energy performance of air-conditioners in the major production countries
The red arrow indicates the current Japanese standard



Key:

EER = energy efficiency ratio

MEES = mechanical energy expenditures

Appliance market potential

China is, to date, the world's largest producer of CFLs (compact fluorescent lamps). Less than 20% of energy-saving bulbs on sale in Europe are made within the European Union; more than two-thirds are imported from China.[34] In 2003, Chinese exports of CFLs to the EU were worth $210.5 million. Osram is the only EU-based manufacturer that has not built any factories in China. The demand for CFLs would increase sharply if all the EU member states would take the initiative of phasing out incandescent light bulb in the foreseeable future.[35] The EU and China should move forward together to unify the energy efficiency standard for commercial CFLs on the market and encourage consumers to choose more energy-efficient products.

Cooperation on improvements in energy efficiency in building materials

There will be strong interdependencies between the EU and China with respect to improvements in energy efficiency in building materials and bilateral trade. These are reflected in the carbon emission constraints in EU member states and China's national energy intensity reduction plan. In 2004, China exported 70.4 million ton of cement and 115 million m^2 of plate glass worldwide. Achieving the manufacture of high-efficiency, low-carbon building materials is consistent with bilateral common interests. The EU-based Lafarge, the world's biggest cement producer, has opened four local factories in China and is becoming increasingly involved in R&D to improve efficiency and reduce carbon intensity. Saint-Gobain, another EU-based building materials manufacturer (producing windows, envelope coatings, insulation etc.) has set up an international research centre in Shanghai specializing in high-performance building materials. Henkel, a German leading insulation manufacturer, is also actively involved in China's building insulation market.

Equipment and appliances

Heating reform will proceed in the building sector in all China's northern cities. Pricing reform will require all buildings to be equipped with heating meters. Building-based or individual metering will become more and more common. The market potential of heating appliances such as thermostatic valves, substations, heat meters and weather compensators is tremendous: if all new buildings require individual metering and regulation systems, more than 200 million heating meters and thermostatic control valves will be needed! Danfoss, the Denmark-based leading European heating appliance producer, has been very actively involved in China's heating system reform since the 1990s. A Tianjin-based production line was set up 10 years ago, specializing in the manufacture of heating-related appliances.

8 Key areas of EU-China collaboration in improving buildings' energy efficiency

'EU–China cooperation by energy service company'

EU and China will have many common interests in cooperating to improve building energy efficiency and encourage low-carbon technologies – in revising building codes, developing energy service companies (ESCOs), introducing innovation in finance, establishing internal carbon markets and encouraging trade in energy efficient products etc.

Three major types of ESCO contract terms can be identified:

1. Shared saving – this remains the most common ESCO contract, whereby the service supplier shares the saved energy costs with client;
2. Guaranteed saving, which is mostly used in industry;
3. Outsourcing energy management – this is especially adapted to commercial buildings but still under development in China. This may be the most important area in which EU ESCOs can intervene, on the basis of their knowledge and management experience.

The ESCO industry will play a more important role by promoting the energy performance contracting (EPC) mechanism. The 'energy management contract' has been developing very fast in many Chinese cities. Most projects of this type focus on efficiency improvements in industry and high-end commercial buildings. However, technical intervention in these projects remains limited since the major activity has been concentrated on supply-side technical improvements such as increasing efficiency in electric machinery.

Because of its local market background, ESCO services in China are often characterized by short-term contracting periods (generally less than three years), whereas 8–10-year contracts are common in developed countries. The ESCO market in most Chinese cities remains immature and under development.[36] In the longer term, ESCO contracts face a number of market barriers and unforeseeable risks such as clients' financial credibility.[37] Furthermore, many contractors are more concerned about investment payback rather than integrated energy performance improvement proposals. There are also institutional barriers to ESCO development such as the leasing regime constraint, which hinders the development of efficiency management projects.

Technical solutions proposed by ESCOs remain extremely heterogenous and lack a holistic approach. Many projects to improve energy efficiency in buildings deal only with the replacement of inefficient electric machinery; however, an integrated energy management approach is rarely transferred to the client. Some ESCOs in China are becoming, in effect, merely professional promoters of energy-efficient products, instead of energy service suppliers. From the client's perspective, the ESCO's *hard* investment (equipment, appliances) is more tangible than its *soft* investment (idea, organization, management). This results in the partial pursuit of high-performance equipment, whereas the importance of management expertise is often ignored by the contractors.

In the EU, by contrast, most ESCOs belong to energy utilities that are directly responsible for supplying energy efficiency services to their residential or commercial clients. Their expertise gives them a much stronger technical capability than Chinese ESCOs.

ESCO involvement in the building sector implies huge preliminary diagnostic work on the energy performance of buildings, including their thermal quality, lighting, high-voltage alternating current (HVAC) system efficiency and electric machinery. Nevertheless, only a few service suppliers are capable of such a comprehensive provision in the ESCO market since it requires a fairly high technical capacity.

The opening of the energy service market in China offers an unprecedented opportunity to the European energy utilities and their energy service providers' subsidiaries that are specialized in ESCO contracts for building efficiency improvements. Many well-known EU-based energy companies, including Siemens and Schneider Electronics, have entered China's ESCO market. Given the huge potential of China's energy efficiency service market, many other major energy-related industry actors from the EU, such as EDf, E-On and Powergen, can develop their ESCO service branches to take advantage of this situation and bring their technical know-how (e.g. on best-technology practice for energy efficiency) and their expertise to China's ESCO market.

Technology transfer is one of key elements of ESCO market development. Patent protection institutions should be established to protect intellectual property rights (IPRs) and make the transfer of technical know-how smoother. Market regulation and legislation are the most urgent issues to be addressed by the government if more and more EU ESCOs become involved in the Chinese market, since stakeholders are risk-averse and require guarantees for investment in the energy service sector.

Energy efficiency technology transfer in the EU and China

Renewable energy use in relevant buildings and other innovative technology for integrating renewable energies such as solar and wind power into buildings will enable residents to benefit from improved comfort while significantly reducing energy consumption. Several EU countries have been actively developing 'energy-positive' buildings to produce on-site electricity or hot water. EU industries are playing a leading role in energy supply systems, especially in heating and cooling technologies such as condensing boilers with efficiency higher than 1, and building-integrated PV systems, while China is the world's biggest producer of solar heaters. As far as the materials for building efficiency are concerned, the relationship between the European Insulation Manufacturers Association (Eurima) and the China Heat & Sound Insulation Materials Association (CHSIMA) is expected to be strengthened to support the transfer of mutual techniques and expertise with respect to innovation in insulation materials. Many Chinese enterprises show only limited assimilation of energy efficiency technology. Technology transfer comprises not only the purchase of hardware but the transfer of 'software', including technical training of personnel in the operation, maintenance and management of the technology.[38] Chinese firms spend much less money than Korean and Japanese industries on assimilation of foreign technology, including energy efficiency products. In this context, Chinese insulation industries will need to be more actively involved in technology promotion by increasing their investment in R&D through specific incentive schemes or programmes. However, China has a major advantage in learning about technological innovation. More and more of the younger generation are studying in the EU. So, armed with technological knowledge and communication skills, they will be able to contribute to the process of technology transfer and innovation on their return to China. This trend is confirmed by a recent report released by the OECD and the Chinese Ministry of Finance. Although China had long relied heavily on technology imported from abroad, since the end of the last decade significant progress has been made towards developing the country's own innovative capabilities (OECD 2007).[39] Both the EU and China will benefit from technology transfer from the former to the latter in the area of building energy efficiency: the EU is expected to see its trade deficit decrease while China can improve its energy efficiency and environmental quality.[40]

Scaling-up of low-carbon or eco-building experiences and expertise

The construction of large-scale energy-efficient and environmentally friendly buildings will do much to help disseminate the new technology and sustainable development models.

The EU and China should work together to promote eco-design architecture, which will serve as a good example for subsequent larger-scale building development.

Box 2: Highlights of Dongtan and BEDZED Eco-design projects

Dongtan: China's first sustainable and ecologically friendly city

Located on the island of Congming off Shanghai at the mouth of the Yangtze River, Dongtan is described as the world's first eco-city. Sustainable design is the key element in this project. Dongtan will produce its own energy from wind and solar power, bio-fuel and recycled city waste. Clean technologies such as hydrogen fuel cells will power public transport. The project's designer Arup, a London-based urban planning, engineering and design consultancy, has also been very active in integrating sustainable urban planning into project designs in Europe. These include the BEDZED project (Beddington Zero Energy Development) in a south London suburb, and Stratford City planning in East London. Arup's approach to integrated sustainable urban planning and design will help to create a city with lower energy consumption, one which is as close to being carbon neutral as possible within economic constraints.[a] Dongtan could generate 60% of its energy from renewable sources when the city opens in 2010, and 100% within 20 years. A recent change in China's energy law would allow Dongtan's power company to sell surplus green energy to Shanghai's grid. In addition, to reduce electricity demand, a simple meter is put in an obvious location such as a kitchen or office. Residents could track their own use – and get regular reminders by SMS and email.[41]

BEDZED Project

The project is designed to use only energy from renewable source generated on site. In addition to 777 m^2 of solar panels, tree waste fuels the development's cogeneration plant (downdraft gasifier) to provide district heating and electricity. The highly energy-efficient houses face south to take full advantage of solar gain, are triple-glazed and have high thermal insulation. The need for heating during winter can thereby be minimized. Moreover, low-impact building materials were selected from renewable or recycled sources and located within a 35-mile radius of the site to minimize the energy required for transportation.[42] PV integrated in the buildings supply one-third of electricity demand, which is 25% lower than the UK average. The remainder would normally be produced by a woodchip- fuelled combined heat and power plant (CHP), but this is not currently operational owing to financial problems experienced by the installation company.

[a] http://www.arup.com/arup/newsitem.cfm?pageid=7009.

Dongtan Eco-city will serve as a model for cities across China and the rest of the developing world. EU countries redeveloping their old cities can also find useful ideas there, in particular in low energy consumption and the carbon-neutral concept. Many European cities have approximately the right density for a combined heat and power system to work. London mayor Ken Livingstone visited Dongtan hoping to get inspiration for a huge zero-emission development programme in East London. In this context, the EU and China should further develop their collaboration on sustainability in urban planning, building and green energy infrastructure design. For instance, the large-scale use of renewable energy in electricity and heat generation in some European countries is a good example for energy planning in Chinese cities. City-wide district heating planning is a key element in energy development strategies. The success of the CHP development in Denmark (where more than 50% of electricity is generated in such CHP plants) has relied on a combination of strategic work, regulation, economic incentives, voluntary agreements with the energy sector and other actors, and local energy planning (Hammer 1999).

Dongtan has been developed by Shanghai Industry Investment Corporation (SIIC), the second biggest builder in China. Importantly, Dongtan is owned by SIIC, whereas elsewhere in China the land is owned by the state; thus a huge land transaction cost was avoided in the development of the project. Achieving a major scaling up of Dongtan's example will be a tough challenge in promoting eco-design and sustainable energy patterns in China's fast-growing cities.

However, the current energy price and tax structure make high-efficiency energy supply technology less competitive than the conventional low-efficiency technology. Although most property developers are aware of renewable energy technology options or green building design, they would not choose the most advanced technology because they are more interested in the short-term financial pay-back on their investment.

Public policies such as fiscal instruments should be tailored to support the dissemination and implementation of new or emerging low-energy-intensity or low-carbon technology in the building sector, since technology such as PV installation needs supportive public policies in the shape of tax incentives and grid purchase contract portfolios in the early stages of development before scaling-up, otherwise such installations will only be considered as part of a demonstration programme and depend solely on support from government funds. In order to encourage private initiatives with regard to low- carbon technology in buildings, relevant intellectual property protection laws and regulations should be enforced under the current juridical framework, which requires the establishment of relevant independent government agencies to strictly review and monitor implementation.

Tightening building energy efficiency regulations

In spite of the significant reduction of energy consumption in buildings achieved after the implementation of the 1995 Energy Efficiency Standard for New Residential Buildings, the average energy consumption for heating in an efficient house in China (20W/m^2) is still almost twice as high as in the most efficient houses in Sweden, Denmark, the Netherlands and Finland (11W/m^2). The national building code should be revised and updated, taking into account the state-of-the-art building energy efficiency design standards in north European countries. The European thermal quality requirements for buildings can be regarded as the benchmark for such revisions. In addition, CO_2 constraints should be integrated into energy efficiency design standards for the building sector to encourage the use of alternative heating and hot water supply systems, in particular the development of renewable energies. Heating system efficiency should also be upgraded by minimizing energy loss in the distribution network. The use of city-wide cogeneration with renewable (woodchips) and/or urban waste should be encouraged through specific policies. The Danish experience can serve as a good example of district heating efficiency improvements in China's northern cities. Therefore, energy supply infrastructure design and construction should be compulsorily integrated into energy efficiency policies for buildings and incorporated into urban development planning schemes. This needs a holistic approach, implying a strong need for interagency collaboration and sharing of sectoral information and expertise among the different public institutions.

Standardization of building materials

It is strongly recommended that professional energy audit bodies should be established in China to tackle the persisting inadequacies in energy consumption statistics and data collection. Without systematic and consistent energy statistics, it is impossible to review the real situation and make informed policy decisions.

Independent, impartial statutory agencies should be established to assess the whole process of building material manufacturing efficiency, material composition and energy intensity analysis. This information should be published systematically, and a rating system set up to alert consumers (constructors, developers or individual house builders) to materials' energy performance and relevant environmental impacts. The sectoral administration should release regular information on market survey analyses and supply energy conservation recommendations to consumers. Enterprises that manufacture low-efficiency materials should be required to upgrade their technology and improve production efficiency; production licences should be related to energy efficiency criteria.

Market incentives such as tax and fiscal benefits should be granted to ‘green manufacturers’, and public procurement procedures should also be instituted for the purchase of all appliances for public buildings

Furthermore, qualified organizations should be established to monitor assess the energy performance of all building material manufacturers. Corporate energy consumption and greenhouse gas emissions should also be factored in to criteria for enterprise taxation rates.

Integration of energy efficiency into planning strategies for urban building

The Dongtan and BEDZED projects demonstrate that an integrated approach should be adopted to address issues of sustainability in building design and construction. The quality of energy infrastructure and use of renewable energies on-site should be taken into account in the upstream stage of project development. This requires close cooperation between all the stakeholders, not only the housing developer or construction supervision authority, but also the urban planning bureau, land use administration, energy system development planner and the energy industry. This synergy is the essential power that enables all actors to move in the same direction.

Energy efficiency labelling and certification in the building sector

Besides the aforementioned mandatory energy passport in building, some EU countries have successfully introduced energy efficiency or ‘environment-friendly’ labelling schemes for buildings, and certificates based on voluntary participation. Examples are Minergie in Switzerland and the HQE label in France, which integrates energy efficiency and environmental impacts indicators into the general housing quality assessment for new housing construction projects. Moreover, the use of renewable energy is strongly encouraged in exchanges of land use, with financial or other in-kind advantages. French law stipulates that a developer can be partly exempted from land use regulations or urban planning codes or other specified technical requirements such as plot ratios[43] when high-efficiency buildings are constructed or large-scale renewable energy use is included in the property development project.

On the basis of experience in EU countries, building energy efficiency labelling and certificate institutions should be set up. The labelling approach has already been applied for several years in the white goods sector (refrigerators, air-conditioners). The next step is to extend the national administrative standardization process to the third-party assessment and certificate market. A gradual move from traditional highly centralized regulatory instruments towards market-based instruments that will give developers and constructors an incentive to build more efficient houses and significantly reduce government expenditure, leading to a self-sustaining building efficiency market.

Innovating DSM programmes in China

Electricity consumption in the building sector has been soaring as a result of the increased demand for energy services as the Chinese standards of living rise in line with the fast-growing economy. More specifically, the sharp increase in demand for air-conditioning in the building sector poses an urgent challenge in the areas of electricity supply security and environmental pollution. Many developed countries facing similar problems have resorted to demand-side management (DSM) programmes to alleviate the high electricity load. Cheng (2005) established that the greatest opportunities for DSM programmes in Chinese cities lie in improvement of building technologies.[44] However, the traditional integrated resources planning (IRP)/DSM framework is no longer able to overcome market and efficiency barriers, in particular in China. A new approach to designing and implementing DSM should be adopted by moving towards market-oriented and end-use funded schemes. DSM schemes should be combined with ESCO projects in developing, designing and financing energy efficiency projects in the building sector. In short, we recommend that the Chinese government should formulate an integrated policy framework that includes strategies to stimulate, facilitate and oversee the development of new electricity demand-side markets. Empirical studies show that energy suppliers, in particular the electricity utilities and district heating companies, could obtain sizeable benefits through DSM building efficiency enhancement programmes.

Removal of investment bottlenecks, and financial innovation in investment in energy efficiency in the building sector

Financing constitutes one of the major challenges to the deployment of low-carbon technologies in the building sector in both the EU and China, where there are significant barriers to capital formation. Technology risk, inflexible energy pricing structures, regulatory uncertainty and other obstacles keep borrowing costs for renewable energy projects relatively high (Wellington et al. 2007). In addition to these higher transaction costs, most investors in China's building sector are unfamiliar with many low-carbon technologies and therefore perceive them as risky, which increases the cost of capital.

Regulatory uncertainty, proof of technical feasibility and lack of a critical mass of intellectual capital and market demand for low-carbon products and services all conspire to keep investment flows to low-carbon technologies small, relative to the scale that is required. Many technologies are ready for large-scale and rapid deployment and therefore require different financing needs from different players in the market. Because different segments of the financial community can support different levels of risk, a range of custom-designed instruments will be required to finance the deployment of low-carbon technologies. This must derive from private initiatives, as public resources will prove insufficient to meet the financing requirements of low-carbon technologies in buildings. There needs to be cooperation between public and private financial players.[45]

Since financing has been a major barrier to the application and widespread diffusion of best practice technologies relating to the installation of high-performance or renewable energy systems such as PV, geothermal, heat and cool storage in the building sector, new ideas are required and the institutional framework needs to be modified. Commercial banks should get involved in the business of high-efficiency construction projects or the installation of renewable and innovative energy supply systems by supplying low interest loans. The Clean Development Mechanism (CDM) of the Kyoto Protocol offers an interesting financing alternative in energy efficiency improvement projects in this sector, in collaboration with the international actors. European energy and industry actors have been especially active in the implementation of CDM projects over the past 10 years. China's building sector offers great potential for mitigating CO_2 emissions through the implementation of clean technologies, and Chinese policy-makers should move more quickly to take advantage of this win-win finance mechanism. The Danish government has already initiated a CDM project feasibility assessment; several Chinese cities have been shortlisted as candidates.

The white certificate scheme implemented in several European countries could serve as a model for improving the efficiency of China's building materials and electric appliances. A nationwide CO_2 allocation for the manufacturers concerned could be formulated by the central or provincial government and implemented by the relevant local government departments. The producers of the most energy-efficient, low-carbon-content materials or appliances could be granted certificates, tradable as 'credits' on the country's financial market.

Apart from such innovative financing instruments, a carbon tax-like levy could be instituted to finance the investment gap in the dissemination of appropriate efficient technologies such as integrated PV, high-efficiency boilers, renewables and geothermal.

Reform of selection and supply practices in building construction materials

Building construction practice should be reviewed with regard to the procurement process for building materials. At present, only the project developer selects the materials, equipment and appliances; the designer (architect or engineer) cannot influence the developer to make energy-efficient choices. A third-party certification and review body should be set up; or the choice of materials and appliances should be inspected by experts in the Construction Commission during the review of the project design and when execution plans are submitted. Government procurement offers another energy- saving method for reducing domestic and commercial energy consumption in buildings. The Swedish experience of public procurement of domestic electrical appliances in the social housing sector shows that sizeable energy savings can be achieved.

Carbon market financing

Directive 2003/87/EC of the European Parliament and the Council, dated 13 October 2003, established a scheme for greenhouse gas emission allowance trading within the European Community. The objective is to promote cost-effective and economically efficient reductions of greenhouse gas emissions within the member states. The mechanism is to set a cap on emissions from certain industries by establishing an allocation first at national level (National Allocation Plan or NAP), and then at installation level.

A similar national GHG emission allowance plan is likely to be tailored in China, based on the model of the EU-ETS (Emission Trading Scheme) as a step towards a market-oriented energy efficiency programme. Under the framework of the scheme, the major energy-intensive industries, of which a large number are related to building material manufacture (cement, steel), will be restricted to a quantitative CO_2 emission cap, defined *a priori* on the basis of current business circumstances. Emission quotas can be traded openly at the national carbon exchange centre, and the price of carbon would be dependent on both supply and demand dynamics. Thus industries will be obliged to move more quickly to curb the associated GHG emissions, and by improving production efficiency and fuel combustion, will be given clearer price signals about the environmental damage caused by the production process. The drafting of such a national carbon trading plan must involve wide-ranging consultation with experts from both the EU and China, taking account of the industrial development context. The relationship between China's carbon trading exchange and the EU-ETS could even be furthered through the bridge of CDM project implementation.

Developing the national scheme will bring different government agencies together to address the issue more efficiently, including the ministries of construction, finance and environment. The underlying carbon allocation programme will be reviewed and released by the central government each year in which GHG emission allowance quotas and carbon trading conditions would be detailed. The objective of the carbon emission constraint imposed on the relevant building materials industry should be consistent with the development perspective of the building sector. The carbon trading market will be regulated by a special scrutinizing commission under the leadership of the National Development and Reform Commission (NDRC). An annual review should be conducted and published, disclosing information on all firms subject to emission quotas. Proposals for the allocation plan should be reviewed thoroughly with extensive diagnostic evaluation of sectoral and industry performance. A national carbon emissions trading market should be established to allow industries to buy or sell emission rights.

Carbon trading will induce the industry to significantly improve its efficiency, both in the production process and in energy consumption. And the market-based competition will help to eliminate the manufacturers of less efficient materials (generally small private companies).

Low-carbon building programme in China

The EU and China can collaborate in designing a national low-carbon building programme in China based on the UK model. Instead of focusing just on thermal efficiency of the building envelope, the programme will need to apply an integrated approach to combining the use of efficient appliances and the DSM scheme for electricity consumption. The programme could be funded by the government through specific taxes and industry contributions. It should cover a large range of energy-efficiency improvement programmes: R&D and dissemination of high-efficiency, low-carbon technologies; innovation in building materials, household electric appliances and other clean technologies, and greater use of renewable energy in buildings. Emission reduction objectives should be clearly established with regard to sectoral efficiency and carbon intensity. A designated trust should be created, charged with fundraising and budget administration.

In the meantime, an *EU–China energy efficiency foundation for buildings* could be created through a public–private partnership initiative. Major manufacturers of building materials and appliances (including HVAC equipment) in both the EU and China will be involved in financing the foundation to encourage new research into energy efficiency and innovation on both sides. The bilateral link between academic researchers and professionals must be strengthened in favour of low-carbon technology applications in buildings R&D, lowering transaction costs. Efforts will be mobilized within the building materials and energy sectors in both the EU and China.

Tax and fiscal instruments

Apart from government intervention and industry mobilization in energy efficiency programmes in the building sector, private consumer-side initiatives should also be encouraged through energy pricing and fiscal policies. Consumers will not be interested in energy saving without a clear price signal or other market incentive. In many EU countries, households prefer to buy more efficient energy consumption appliances and invest in insulation and the installation of efficient boilers or heating appliances in exchange for tax reductions or credits. In China, however, both central and local government revenues still rely heavily on the tax base from public and private corporations, whereas individual income tax represents only a very small part of government revenue under the current fiscal regime. Tax instruments should be integrated into building efficiency policies to encourage urban households to choose high-efficiency building materials and appliances in residential buildings.

Similarly, tax and fiscal instruments could also be introduced into the property market to induce developers and/or constructors to build more efficient houses and adopt low-carbon technology; property developers should benefit from tax reductions for more efficient buildings. In China during the 1990s, there were fiscal advantages of fixed capital investment in more effient buildings. Property taxation should be revised according to energy efficiency criteria.

Conclusion

In this paper, we have investigated the potential of energy efficiency improvements in the building sector in the EU and China. We have identified the main actors in both regions and discussed current issues of energy consumption, building materials, appliances, laws and regulations, and institutional organization. We have analysed the major barriers, both technical and institutional, to scaling up the construction of high-performance buildings and diffusing the use of energy-efficient appliances. Both the EU and China have strong incentives to collaborate on energy efficiency in buildings, given the global uncertainty around climate and energy security. The interdependent relationship between these two important political entities offers a positive perspective on mutual collaboration in tackling these concerns in the context of fossil fuel depletion and global warming.

Both the EU and China must accord buildings the highest priority in implementing energy efficiency policies, given their importance in both entities' total energy demand, although the emphasis and actions taken may differ significantly. The greatest potential for energy-saving in EU countries lies in the existing building stock, whereas in China energy efficiency in new buildings should be regarded as the priority.

The paper argues that supportive policy and regulatory frameworks are prerequisites for facilitating the scaling-up of technological innovation in the building sector. Technical, financial and institutional barriers to the large-scale application of highly efficient, low-carbon technology can be overcome by making significant changes in public policies.

Key areas of the bilateral cooperation programme between the EU and China include revising building codes; innovative technology governance for building materials; promotion and trade of energy-efficient appliances; enhancing ESCOs' service provision in the building sector; developing innovative financial and fiscal instruments (such as the CDM) to finance energy-efficient building projects; urban development governance; scaling up the design and construction of eco-buildings and green buildings; promotion of efficient heating and cooling technology; and institutional reform.

Specific tax or other financing instruments may be created within the building sector to empower industries to seek more benefits through marketing strategies for efficient, low-carbon products. A regulatory framework should be put in place in the upstream part of the supply chain. But the speculative housing market will ultimately do much to jeopardize the dissemination of energy- efficient technology. Housing developers and local governments are more concerned with land and real estate premiums than energy-efficient building, driven as they are by profit-maximizing motives to the detriment of building quality and integrated land use planning. A new regulatory framework should therefore be put in place to scrutinize all property development projects and bring the property market back to a rational level as soon as possible.

The traditional command-and-control approach exposed the inadequacy of government intervention in the management of energy-efficient building in China; it should be supplemented by a set of well-designed market-oriented instruments.

Interagency collaboration among relevant institutions should be strengthened: the ministry of construction, ministry of finance, ministry of science and technology and national bureau of standardization should all be involved in the global project. Integrated policies aimed at both upstream and downstream parts of the whole building sector chain, from the manufacture of building materials to the formulation and implementation of efficiency standards in the supply system. Integrated programmes for supply efficiency and consumption-side management can enable the building sector to significantly reduce energy demand and CO_2 emissions.

One of the major difficulties of disseminating emerging efficient technologies in the building sector stems from the inertia of actors and the poor dissemination of information through publications and institutional support. A self-sustaining building efficiency market must be created to encourage the development of new technologies. Actions should be focused on closer cooperation between the research community (universities, research organizations) and industry (building material suppliers, electrical appliance manufacturers etc.) in the EU and China. Both regions should move towards to an extensive partnership between public institutions and private actors (industry, consumers) to foster the emergence and diffusion of energy-efficient, low-carbon technologies in the building sector. An innovative institutional framework should be put in place to facilitate the spread of energy-efficient domestic appliances via tax and fiscal incentives. In this context, the EU–China collaboration project offers unprecedented opportunities for further scaling up of energy efficiency in the building sector in both regions.

Notes

[1] Wellington, F. et al. (2007). *Scaling Up: Global Technology Deployment to Stabilize Emissions.* World Resources Institute,. Washington, DC.

[2] IPCC (2007). Fourth Assessment Report, Working Group III. p. 6.

[3] IEA (2006). *World Energy Outlook*.

[4] WBSCD (2007). Energy Efficiency in Buildings: Business Realities and Opportunities.

[5] Ibid., p. 16.

[6] *Stern Review: The Economics of Climate Change* (2006), Executive Report, p. 4

[7] Pacala, Stephen and Robert Socolow (2004). 'Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies', *Science* 305 : 968–72.

[8] IPCC (2007), p. 6.

[9] Toth et al. (2003). *Regional Population Projection for China*. IIASA. Austria.

[10] World Bank (2001). *China: Opportunities to Improve Energy Efficiency in Buildings*. The World Bank, Washington

[11] For example, the US (1997) residential survey shows that the average per capita energy consumption in a 5-person household and 3-person household is 25 and 37 Mbtu respectively, while the per household member consumption is 75 Mbtu in the single-member household

[12] The plot ratio of a site is defined as the ratio of the gross floor area of a construction site area, it is generally declared by qualified planning authority based on the nature of land use. It is a key index in zoning regulation

[13] District heating in the northern cities in China represents more than 50% of energy consumption in the building sector.

[14] Jiang Y. (2005). Energy Efficiency Ways in China.

[15] This figure indicates the average building performance in most of the northern part of China. The total final consumption for heating is about 160KWh/m²a. Heating consumption in the very cold region (e.g. Harbin) is much higher.

[16] Waide, P., Guertler, P. and Smith, W. 2006. *High-rise refurbishment: the energy-efficient upgrade of multi-storey residences in the European Union*. IEA Information Paper

[17] He, B. (2006). *Recent Initiatives in Improving Energy Efficiency in China*. NDRC. A presentation given to IEA, April 2006

[18] In China, the size of a city is defined by the size of the non agricultural population in the municipal jurisdiction, cities are divided into four categories: 1. extra-large city (population >1 million) 2. large city (1 million>population>500,000) 3. medium city (500,000>population?200000) 4. small city (population<200000).

[19] Cheng, C. (2005). '*Electricity demand-side management for an energy efficient future in China: Technology options and policy priorities'*. Doctoral thesis dissertation. MIT.

[20] http://www.c-bm.com/rdzt/lianjie.asp?id=710.

[21] It is a key component of insulation materials EPS (expanded polystyrene)

[22] There is already a strict prohibition on the use of clay brick in all cities; the only exception is for construction in rural areas.

[23] European Commission, available at http://ec.europa.eu/energy/demand/index_en.htm.
[24] EU Directorate-General for Energy and Transport (2002).
http://ec.europa.eu/energy/demand/legislation/buildings_en.htm
[25] Eurima website, 2007.
[26] European Commission (2006). Action Plan for Energy Efficiency: Realising the Potential – Saving 20% by 2020. Brussels.
http://ec.europa.eu/energy/action_plan_energy_efficiency/doc/com_2006_0545_en.pdf.
[27] European Commission (2005). Green Paper on Energy Efficiency: Doing More with Less.
http://www.energie-cites.org/IMG/pdf/2005_06_green_paper_text_en.pdf. Brussels, 22.6.2005.
[28] Erfahrungsbericht 2007 zum Erneuerbaren-Energien-Gesetz (EEG).
[29] Brink, P. (2006). Assessing Innovation Dynamics Induced by Environment Policy. The Case of Photovoltaics. Institute for European Environmental Policy (IEEP), London/Brussels
[30] http://www.lowcarbonbuildings.org.uk/home/.
[31] Each year, new buildings constructed in France represent only 1% of the total building stock.
[32] China Sourcing Report: Air Conditioners: executive report.
[33] Idem.
[34] BBC News, 29 August 2007.
[35] Countries such as Australia and Cuba have officially announced they will phase out the use of incandescent light bulbs.
[36] According to Ye Wenbiao, director of Shanghai Energy Conservation Service Centre (SHECSC). It was once a government agency in charge of energy conservation management in the municipal administration, particularly in the industry sector. In 1998, the World Bank launched a series of demonstration projects to promote ESCO services in China in collaboration with other international organization such as UNIDO, in which the SHECSE was involved.
[37] This matters especially in the industry where a number of firms went bankrupt after signing an ESCO contract and the payment capacity of energy-efficient services crumbled.
[38] Cheng (2005). p.262.
[39] OECD (2007). OECD Reviews of Innovation Policy: China Synthesis Report. p. 9.
[40] Kiang, C.S. Interview at the Globe Forum in Stockholm. 2007.
[41] Wired Magazine, April 2007. Pop-Up Cities: China Builds a Bright Green Metropolis.
[42] http://en.wikipedia.org/wiki/BedZED.
[43] The plot ratio indicates the ceiling value of the construction area on a given plot of land according to the nature of land use and location. This value is critical to all property developers during their financial assessment of project plans. The value can only be adjusted in cases of exemption approved by the relevant administration.
[44] Cheng (2005). p. 250.
[45] Wellington et al. (2007). p.12.