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Overcoming barriers to implementation of carbon reduction strategies in large commercial buildings in China

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ABSTRACT

With an economic growth in GDP of around 10% per annum in recent years, energy consumption in the building sector in China now accounts for 25% of the total energy use in the whole nation. In large buildings in Beijing and Shanghai the consumption rate, at approximately 190 kWh/m^2 per annum, is around five times the energy use in residential buildings in those cities. Addressing this ever increasing energy consumption and the consequential green house gas (GHG) emissions must be a priority to achieve low carbon sustainability in China.

As part of the Kyoto Protocol the Clean Development Mechanism (CDM) has been used to assist in the finance of GHG reduction projects in developing countries in the context of low carbon sustainable development. However, hitherto the majority of CDM projects of an energy related nature have focussed almost exclusively on renewable energy projects or those which enhance the efficiency of industrial processes. To date the opportunities for using the CDM approach in reducing emissions in large buildings have been largely overlooked in China and other countries. Part of the reason is the lack of an adequate established baseline methodology against which the impact of any proposed CDM project can be judged. This paper explores the barriers to the implementation of carbon reduction strategies in large commercial buildings using China as a particular example.

1. Introduction

In 2007, China's primary energy consumption was 2,655.83 million tonnes of standard coal equivalent (or 21,618 TWh) and since 2000 the energy consumption has been rising at 8.98% per annum [1], Overall the per capita emissions at tonnes per person per annum are still well below those in the developed world as shown in Table 1 but significantly above those of a comparable country, India.

Currently the Chinese Government is trying to improve the average wealth of its citizens through increased urbanisation which in turn is encouraging additional energy growth and carbon emissions. In recent years, nearly half the increase in carbon emissions in China have been associated with production of goods for export [4], but nevertheless it is the building sector which still accounts for significant carbon emissions.

In recent years, China has issued three important policies relating to climate change:

i) The eleventh five-year plan [5],
ii) China's national climate change programme [6],
iii New legislation relating to energy use in buildings which was enacted on 1st October 2008 [7] although this is in very general terms with little in the way of specifics.

These policies complement two laws and standards as follows:

i) The renewable energy law [8],
ii) The energy conservation law of China [9],
iii) The specification of six separate energy saving standards applicable to the building sector since 1995 of which one is relevant to commercial buildings: The Public Buildings Energy-efficient Design Standards GB50189-2005 which came into force on July 1st 2005 [10].

With such instruments now in place, the Chinese government is paying more attention towards energy saving and GHG emission reduction within the building sector as part of its national sustainable development strategy. However, the 1998 Law is now over 10 years old and was formulated before the Kyoto Protocol and the associated Clean Development Mechanism came into force.

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Table 1
GHG emissions of selected countries in 2005 [2,3].

Country	Population (Million)	Total Emission (Million tonnes CO_2 equivalent)	Emission per capita (Tonnes CO_2 equivalent)
India	1,100	1,164	1.1
China	1,300	5,323	4.1
France	64	553	8.6
UK	61	657	10.8
Russia	141	1696	12.0
Germany	82	1,001	12.2
USA	301	5,982	19.9

The latest standard (GB50189-2005) requires that all new and refurbished public/commercial buildings reach the 50%-saving goal in energy use compared to the benchmark of energy use in similar buildings built in the 1980s. Despite these measures, it is thus interesting to note that not one CDM scheme falling into the category of energy savings in the large building sector has been considered in China. This paper attempts to explore where such opportunities to enhance energy saving activities through the implementation of CDM projects might exist in the future.

Approximately 25% of all the energy consumed in China is associated with the building sector and currently amounts to around 4800 TWh per annum [1,11] which is associated with an annual emission of over 1 billion tonnes of CO_2 equivalent [12]. However these figures mask a wide variation in consumption between rural and urban areas and between residential and commercial properties [11]. With a continued high growth in energy consumption in recent years which is expected to continue in the next decade, the consumption in the building sector will continue to play an important role in China's long-term sustainable development strategy [11].

2. Energy use and CO_2 emissions in large commercial buildings in Beijing and Shanghai

Beijing and Shanghai are the two biggest cities in China, with populations of 17 million and 18 million respectively. Not only do they have the largest number of commercial buildings but also the highest growth rate in this sector and are thus good examples to explore opportunities for energy conservation and carbon reduction.

According the Shanghai Statistical Year Book 2008 [13], the total area of building stock in Shanghai in 2007 was 749 million m^2 of which the non-residential building area accounted for 294 million m^2 or 37% of the total area. However, this sector consumed abound 70% of total energy in whole building stock in Shanghai. Corresponding data from Beijing [14] indicates a total building area of around 543 million m^2 in 2006, of which the non-residential area comprised 232 million m^2 or 43% and accounted for 72% of total energy consumption of all buildings in Beijing. In both cities, the non-residential sector has a separate sub-sector of large commercial buildings which are the main focus of the research reported in this paper. Such buildings are defined as having an area of over 20,000 m^2 and the specific energy consumption (i.e. the energy consumption per square metre) in such large buildings is much higher than the average consumption level in non-residential buildings (Fig. 1).

Nine large commercial buildings which included office buildings, shopping malls and hotels were selected as the research examples for analysing the energy performance over a 12 month period. Five of the buildings were in Beijing, the remainder in Shanghai. In Beijing the average consumption was 173 kWh/m^2 per annum or nearly six times the consumption rate in residential buildings (at 30 kWh/m^2 per annum, Fig. 1 [12,14]). In Shanghai, the corresponding figures were 132 kWh/m^2 per annum and 32 kWh/m^2 respectively [12,13]. If other energy sources such as the use of natural gas for cooking both in Shanghai and Beijing, and the centralised hot water use for heating in winter in Beijing are included, the average total energy use in large commercial buildings will be higher. Qiu [11] noted that the total energy consumption was in the range of 70 ~ 300 kWh/m^2 per annum in large commercial buildings in Beijing and Shanghai (Fig. 2).

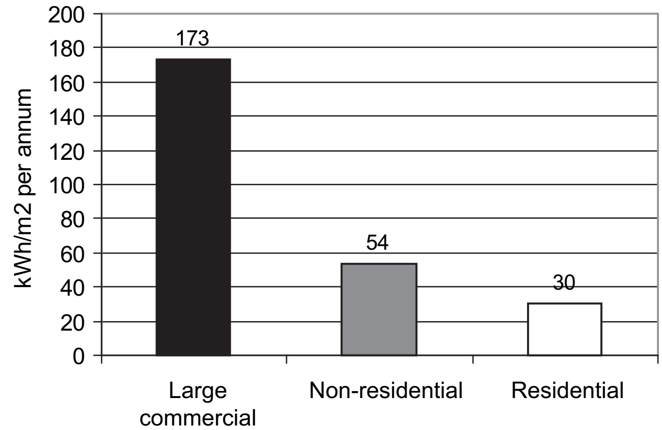

Fig. 1. Electricity use per m^2 in Beijing's building sector in 2006 (derived from [12,14] and [15]).

Jiang and Tovey [16] using data from the National Development and Reform Commission of China [17] noted that the CO_2 emissions factors for electricity generation were 1.030 CO_2e/kWh and 0.905 CO_2e/kWh for the Beijing and Shanghai electricity grids respectively. Using these factors leads to a total average CO_2 emission in large commercial buildings of approximately 178 kg CO_2/m^2 per annum in Beijing and 119 kg CO_2/m^2 per annum in Shanghai.

3. CDM development in China

The Kyoto Protocol [18] was designed to mitigate climate change through collaboration between developed countries (i.e. Annex I countries) and developing countries (i.e. non-Annex I countries). It entered into force on 16th February in 2005 following ratification

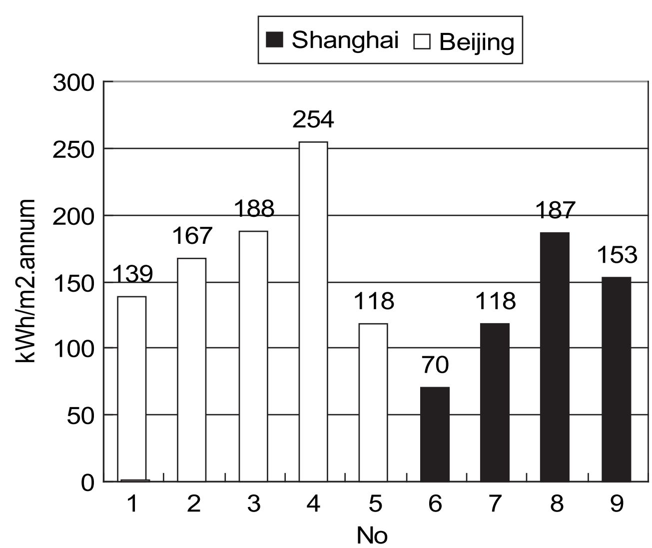

Fig. 2. Electricity consumption in sample buildings in 2006 [12,16].

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by 177 states. The Clean Development Mechanism (CDM) is one of mechanisms of the Kyoto Protocol which allows Annex 1 countries to partly meet their GHG emission commitments by investing in GHG reduction projects in non-Annex 1 countries and thereby claim the reduction against their own obligations. This can be effective for Annex 1 countries as implementing low carbon technologies in developing countries can be a more cost-effective mechanism to promote overall carbon reduction. Certified Emission Reductions (CERs) which are credited by the CDM Executive Board (EB) for approved schemes can be bought and sold between Annex I and non-Annex I parties. In this way low carbon strategies can be promoted in developing countries.

China, as a non-Annexe 1 country was an early signatory of the Kyoto Protocol and by 17th July 2009, had hosted the largest number of CDM projects (712 in total) as shown in Fig. 3a and at the same time had also generated the largest number of CERs in the world [19]. By 2012 it is expected that China will generate over 44% of the CERs in the world with India providing 16%, and Brazil providing 10% as shown in Fig. 3b [20] Most of China's CDM projects are associated with energy efficiency, CH_4 reduction, mine/coal gas collection, and renewable energy. There are none in the area of building efficiency, which as indicated above, should be a focus for carbon reduction [19].

As a mechanism which aims to promote carbon reduction and encourage sustainable development in developing countries through a cost-effective carbon trading approach, it has been strongly supported by the Chinese Government and has expanded quickly [21,22]. There are, however, missed opportunities in the large building sector and this is partly because of the lack of effective approved methodologies for such projects, but the cumulative carbon reductions from such actions could be significant and experience gained in Beijing and Shanghai of such projects could be replicated with good effect in other large cities in China and elsewhere.

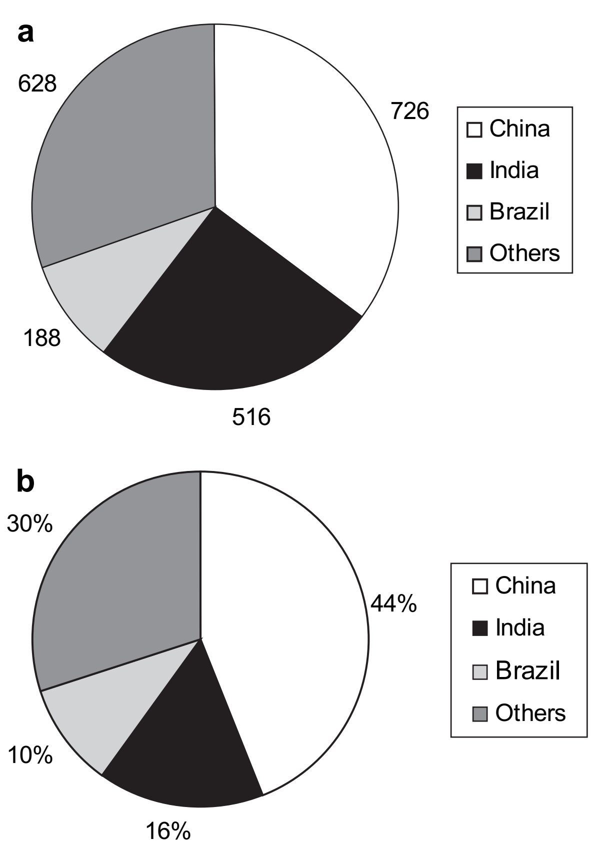

Fig. 3. Extent of CDM projects a) number hosted by key countries [19]. b) projected number of CERs generated by country by 2012 [20].

4. A review of the requirements of CDM projects and the impacts on the building sector

4.1. Introduction

According to the Kyoto Protocol the key requirements that any proposed CDM projects should meet are:

1. They should assist non-Annex I Parties (i.e. Developing Countries) in achieving sustainable development and should also assist Annex I Parties in achieving compliance with their commitments to the Protocol [23].
2. They must demonstrate additionality i.e. any GHG reductions must be in addition to those that would have occurred in the absence of the registered CDM project activity [23].
3. They must be assessed against an approved methodology and at present (July 2009) though there are 124 such approved methodologies [24] very few relate to buildings, and in all the cases that do they miss several critical aspects of importance for carbon reduction.

To proceed, any potential CDM project which meets the above criteria must be registered as a legal CDM project activity. A relevant Project Design Documentation (PDD) must be produced and this must specify the essential technical and organisational aspects of the project activity as well as adopting an approved baseline methodology. This approved methodology must also address the issues of monitoring and demonstrate how the additionality aspects of the project will be assessed as described in the Appendix B of the CDM modalities and procedures [23].

CDM projects fall into two categories, those which are relatively large and classified as normal projects and those which are classed as Small Scale (SS) for which the documentation requirements are less onerous. There are different criteria used to ascertain whether a project falls into the SS category: the relevant one for large commercial buildings being Type (ii) eligibility, i.e. having an energy demand of less than 60 GWh per annum [25]. Of the nine existing large buildings in China whose energy demand was monitored over a year, the building with the highest demand recorded an electricity consumption of 18.008 GWh which represented over 80% of the total energy use, and the overall the consumption was thus well below the threshold. Any large single building is thus likely to be eligible and fall under the Project Category (AMS-II.E)–"Energy efficiency and fuel switching measures for buildings". However, where many buildings share the same heating or energy system the eligibility as a small scale CDM (SSC) project may no longer be true. This would apply to buildings linked by large city wide district heating systems.

Despite having a large number of CDM projects overall, China has none in the large building sector despite the significant potential that exists. By 22nd June 2009, out of 1681 approved CDM projects worldwide covering all sectors, there were just five such projects worldwide (or 0.3%) which could be classified as energy efficiency improvements in the building sector and which had been registered by CDM EB. The Republic of Moldova has hosted two of the projects, India has two projects with a further one under review and South Africa has one project. One project in this sector proposed for implementation in Brazil has been rejected [19].

Facing continually increasing energy prices and stricter national and local environmental protection policies and laws, stakeholders, energy managers in large commercial buildings in China are paying more attention to the energy conservation and are exploring technical energy efficiency improvements such as improving insulation, utilizing low energy lighting systems, and using appliances with "green" logo, etc. They have identified the following as measures for improving energy efficiency:

i) Effective energy management system, including optimal operation procedures and arrangement of equipments, etc.
ii) Improved insulation through the refurbishment of external wall and roof insulation, and replacement of windows with double glazing, etc.
iii Efficient heating, ventilation, lighting and air-conditioning systems, and appliances, and
iv) Behavioural change of the occupants.

However, several barriers are preventing the adoption of the full potential of these measures including investment barriers, technological barriers, infrastructure barriers and institutional and management barriers, etc. Of these, the investment barrier is a significant and it is here that the CDM could potentially provide an effective approach in overcoming these barriers.

Though even the largest building would be classed as a small scale scheme, the potential emissions savings in any one building may still be relatively small compared to other CDM projects and anecdotal evidence suggests that such schemes individually may be of little interest to potential investors unless there was an aggregation of many buildings under the same scheme or the simultaneous deployment of multiple energy saving technologies. Such aggregation will incur further management barriers as the necessary data collection for baseline determination and the subsequent monitoring schemes would be more complex and costly to implement and would hinder effective carbon reduction with adequate financial support from CDM.

4.2. Current CDM approved methodologies relevant to the building sector

Of the 45 methodologies so far approved for small scale projects (to June 2009) only one is currently directly relevant to the large building sector, i.e. methodology AMS-II.E "Energy Efficiency and Fuel Switching Measures for Buildings" [26]. This methodology has been revised several times with the current (December 2008) version being number 10 and is aimed primarily at energy efficiency through technical means in a single building, such as a commercial, institutional or residential buildings, or groups of similar buildings, such as a school, district or university.

As part of the methodology there is provision for improved energy management, but this aspect does not presently figure in its own right even though savings of 50% (or more) can be achieved by effective adaptive energy management alone as is demonstrated below.

In the addition to approved methodology (AMS-II.E), other methodologies may be relevant for small scale projects associated with buildings such as AMS-I.C ("Thermal energy production with or without electricity ") which is primarily concerned with renewable energy technologies, AMS-I.D ("Grid connected renewable electricity generation"), and AMS-III.B ("Switching Fossil Fuels"). All of the four successful projects relating to buildings have included one or more of these other methodologies within their assessments. There are two further current methodologies which are potentially relevant for building projects: i) AMS-II.C ("Demand-side energy efficiency activities for specific technologies") which encourages the adoption of energy efficient appliances including ballasts, refrigerators etc, and ii) AMS-II.J ("Demand-side activities for efficient lighting technologies").

All methodologies have a requirement to establish a baseline of emissions associated with the project in the absence of any CDM involvement. However, the monitoring aspects relate almost exclusively to assessing the potential savings from technical changes whether they are from the installation of more efficient equipment, fuel switching or installation of renewable energy systems. There are limited references to energy savings where energy management is the primary focus although AMS-II.J does include a small element of social engagement and surveying. The concentration on technical solutions and lack of proper recognition of the role effective management can play within the CDM is causing a barrier to further effective reduction in carbon and related emissions.

Technical solutions whether by the installation of more energy efficient equipment or renewable energy systems may not reach the full predicted potential of energy and carbon reduction and there have been many examples where so called low energy buildings have not performed as well as expected. This information was confirmed in interviews made as part of the research for this paper and will be reported more fully elsewhere [12]. On the other hand with good management a building which is good technically can see its energy consumption reduced significantly as demonstrated by Tovey and Turner [27].

Fig. 4 shows a plot of energy consumption against external temperature from a low energy building at the University of East Anglia which was completed in 2003 and won the low Energy Building of the year award in 2005. The building, as new, and operated in accordance with the original specifications, demonstrated an energy consumption shown by line heat loss rate line A–B. However with careful record keeping and adaptive management over the first months of occupancy where, in response to the collected data, the timing and mode of operation of the heating and heat recovery system were changed, a significant saving in energy requirement was demonstrated as shown by line C–D. This improved operation was achieved by the end of the second year of operation and represents solely an achievement from improved management. Noteworthy is the fact that the gradient of the heat loss rate line is only 43% of that previously confirming a saving of 57%.

Good energy management can be a cost-effective approach which can reduce energy consumption and CO_2 emissions. However, it does require that personnel with the necessary technical competence and management skills are given the correct level of responsibility in operating buildings. If savings as large as 50% as demonstrated above can be achieved largely by non technical measures, there is scope for substantial savings in emissions and this is something which has been overlooked so far in CDM projects. However, to achieve the benefits new approved methodologies need to be explored which will be acceptable to the CDM Executive Board.

Projects which involve changes to management regimes to achieve reductions in emissions will not be without initial cost. As a minimum, there will be a requirement for the employment of staff with the necessary high degree of technical competence in energy management, something which is rarely present in most managers responsible for the energy performance of buildings. In addition, in most cases, there will be requirement for investment in more sophisticated monitoring equipment. These different aspects will impose a financial barrier which without incentives are not likely to proceed, and these will be "additionality" aspects which are relevant to the project and will need to be addressed. If a CDM project is approved by the Executive Board because of enhanced energy management with minimal expenditure on technical equipment, then good management will continue to improve the energy performance and achieve a better outcome during the project life cycle.

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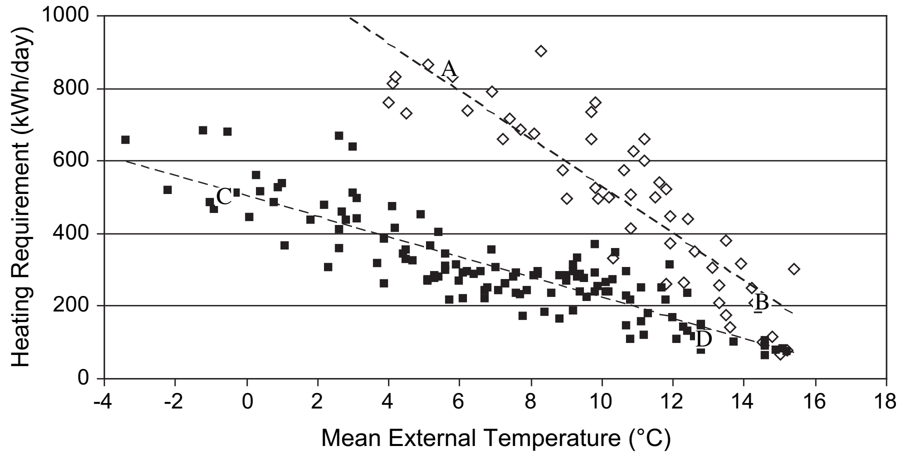

Fig. 4. Energy demand of low energy building after construction (line A–B) and after adaptive management (line C–D). The energy consumption at any temperature was reduced by 57% [27].

A requirement of all CDM projects is that the relevant approved methodologies produce "real, measurable, and long-term" emission reductions through the adopted technologies. For building sector projects the focus on technology is a significant barrier and more attention needs to be paid on actual performance which may arise as much from changed management practices as technology itself. There are no adequate approved CDM methodologies to address this issue even though there can be significant financial barriers ranging from the data monitoring, collection and analysis which can be complex and costly to require highly skilled staff to ensure the optimum performance. As was noted above, energy conservation and carbon reduction which are solely management based can result in significant savings. The remainder of this paper addresses this situation and explores a sound and reasonable CDM baseline methodology which is combined with both technology and management aspects and based on the intrinsic and functional energy performance to energy-efficiency project activities in large commercial buildings in China.

4.3. Energy management issue arising in CDM projects in buildings

For large commercial buildings in Beijing and Shanghai, carbon reduction opportunities will normally arise from improvements in the technical way energy is used and also how its use is managed. Measures to reduce energy consumption can be separated into two categories:

i) *Intrinsic energy use* – i.e. the energy requirements to sustain a comfortable thermal and visual environment for activities to take place. To a large extent, the intrinsic energy requirements will be independent of the actives taking place. Thus a similar thermal environment will be required for buildings in which the primary function is for laboratory work, office work or for meeting space. In some situations e.g. in a sport hall or warehouse, the internal temperature requirements may be different and these difference will affect energy consumption. It is this intrinsic energy that will normally be under the direct control of the energy management company in large commercial buildings.

ii) *Functional energy use* which is consumed as a result of activities in the building. Frequently, the building management company will have little control of these activities in the subareas of let space in a large commercial building. Thus in the same physical space, the energy used in an office full of computers will be much higher than that of the same space used as a meeting area.

There will be some interactive aspects between functional and intrinsic energy use which may act as a barrier to implementation of CDM projects. There is often also a lack of interaction between the management responsible for the two different aspects. Thus in Beijing the company managing the overall energy for heating often charge tenants a fixed rate based on floor area even though the actual amount of heat supplied will vary from month to month. There is thus little incentive on the part of tenants to adopt sensible energy saving strategies such as adjusting the thermostats instead of opening windows as there will be no financial benefit for them. Equally, if a tenant changes the appliances under his/her control to low energy devices which would reduce carbon emissions this will mean that there will be less incidental heat gain and this will increase the space heating requirements of the building complex as a whole and at the same time increase the carbon emissions in winter. On the other hand, a reduction in the incidental gains will reduce the cooling load in summer and potentially increase the carbon savings during that period. Under current CDM business procedures, the Project Participants could be the building management companies or Joint Ventures of investors. However, herein lies a potential problem. In general, the management companies will not have much direct control over the functional energy use in the spaces controlled by the tenants even though such energy consumption could be significant, and in some cases be larger than that controllable by the management company itself. The tenants of commercial premises cannot themselves be Project Participants and it will be necessary for the management companies to engage in effective dialogue with them as it is only the latter who can effectively influence the behaviour of the staff in their employ to reduce energy consumption.

Effective energy management can identify the contribution of both intrinsic and functional energy uses to overall carbon emissions. Turner [28] presented an example of the relative contributions in the low energy building referred to in Fig. 4. She demonstrated that, in the actual low energy building as built, intrinsic energy requirements amounted to only 34% of the total operational energy requirements over the predicted 60 year life span of the building with the remainder (i.e. 66% coming from functional energy use). On the other hand had the building been built to conventional standards, the same absolute amount of functional energy use would now represent just 32% of total lifetime operational energy requirements with 68% associated with

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the intrinsic energy requirements. These figures demonstrate how critical it is to engage all relevant stakeholders in any project under a overall energy management strategy, not just those in control of the overall intrinsic energy requirements.

Current CDM methodologies concentrate on technical improvements and little direct weight is given to savings arising solely from better management itself. Yet, the implementation of enhanced management will incur costs such as the employment of highly qualified energy managers and these costs present a barrier to implementation of effective carbon reduction strategies. In the case of buildings there is a clear need to move towards a performance based approach to the allocation of Certified Emission Reduction Certificates as opposed to the present allocation based initially on expected savings. Several large commercial buildings in Beijing and Shanghai would implement such measures, but the resources to employ energy managers of sufficient calibre are not available. Equally important and necessary is the need of a rethink of the responsibility and interaction of those responsible for the intrinsic energy and those responsible for functional energy use within the building. This rethink should take place under an integrated energy management scheme based on performance based methodologies.

4.4. Requirements of CDM projects for large commercial buildings

All CDM projects require the determination of a baseline emission against which any future savings are judged. Such savings can generate Certified Emission Reduction (CER). Certificates which are tradable and can provide a financial driver to encourage the implementation of projects which may not otherwise have materialised. To ensure the additionality criteria a met, two requirements need to be met when identifying the valid baseline scenario [26]. These requirements are:

a) The baseline against which the project is judged must be a realistic and credible alternative to that proposed. Possible ways in which this baseline might be specified include:
   - The emissions arising from an equivalent reference project which is being undertaken but without the financial support that a CDM project would receive. Both the proposed project and the reference project should provide same outputs or service. These criteria are largely relevant for new projects.
   - The emissions arising if the current situation continued – i.e. this would potentially cover existing buildings.

b) The baseline calculations should take due account of the latest local laws and regulations. In the case of new buildings in China this would imply the Public Building Standard GB50189-2005 [10] and the relevant local byelaws in Shanghai and Beijing. In addition there is a local law in both Shanghai and Beijing which stipulates a mandatory requirement for the use of natural gas for cooking and in boilers in those cities. In this respect opportunities for fuel switching as a means to reduce carbon emissions are more limited.

All energy-efficiency measures and activities including effective energy management which decrease the specific energy consumption (i.e. the energy requirements for a unit of output) can be treated as potential CDM project activities. Specific energy consumption parameters such as the energy consumption per unit floor area or the consumption per employee etc would be relevant measures.

All five successful CDM projects in the building sector area have related to existing buildings and have achieved approval by the implementation of technical measures such as renewable energy installation and/or enhanced standards to the intrinsic energy performance of buildings through better insulation and performance of relevant equipment.

Different approaches to baseline determination will be needed in cases where a holistic approach to carbon reduction is proposed including technical, managerial measures and behavioural change. The approach for the baseline determination will depend on whether the proposed project involves the refurbishment and updating of an existing building or the construction of a new building as outline below:

1) For existing large commercial buildings, the determination of the baseline emissions will need to separate the intrinsic and functional energy uses within a building. For functional energy use, a sufficiently long baseline monitoring period such a year may be adequate as long as external influences can be identified e.g. day of week, season of the year. Such monitoring would address that energy used primarily by the tenants in the building. The intrinsic energy use, particularly for heating and cooling requirements, this is highly dependent on climatic conditions and in the determination of the baseline emissions, normalisation of consumption data to represent average local climate conditions is important. It appears that such normalisation is rarely done in buildings in China and is thus something which must be addressed before an adequate baseline can be determined.
2) For new buildings, the intrinsic energy consumption baseline should be determined according to the heating and cooling requirements of a building of identical size but specified by the insulation levels specified in the relevant building standards and climatically normalised to the latest long-term average climatic data. For functional energy use an estimate should be made according to typical consumption data per unit floor area in comparable buildings used for similar purposes.

For projects involving technological developments, CERs are awarded according to expected performance over the project lifetime. Review opportunities exist to check the actual performance and the relevance of the baseline after a period of years. However, while this might be a valid approach for many schemes such as renewable energy and industrial energy efficiency projects it is questionable whether this is the correct approach for buildings where energy management itself plays an important part. It would appear that such a project should be based as much on actual performance as on projections of likely technical outcome. In other words CERs should be awarded on demonstrated performance at the end of each accounting period. Such an approach would encourage innovative approaches to energy management such as the one demonstrated in Fig. 4. It would also encourage effective dialogue between those responsible for the functional energy use and those who control the intrinsic energy demand to ensure that a holistic strategy to carbon reduction is implemented. In addition this would encourage, through the use of rewards, performance improvements achieved through strategies such as awareness raising.

A performance based approach to approved methodologies would be more appropriate. Such an approach would focus primarily on actual performance whether it arises from technological improvement or from better management. Table 2 summarises the key approaches to carbon reduction in buildings together with comments on the status of current approved methodologies.

There are several benefits which would arise from the development of performance based approved methodologies for CDM projects applicable to large commercial buildings. Such performance based methodologies issuing CERs retrospectively on actual performance would:

Table 2
Potential of CDM projects to large commercial buildings in China if current barriers are removed.

Item	Standards appropriate to defining the baseline scenario	Measures in project activity which will reduce carbon emissions	Relationship to existing approved methodologies
Technical Measures to improve thermal performance of insulation of building fabric including windows	Standard building methods. For older existing buildings insulation standards (i.e. *U*-values) may not reach current standards. For new buildings would have a baseline set at prevailing standard.	Enhanced insulation standards above those specified in baseline.	Covered partly by AMS-II.E but role of management and actual performance as part of procedure is weak.
Technical Measures to improve efficiency of heating, ventilation, and air-conditioning systems. Also including fuel switching	Existing Standard conventional plant.	Latest state of the art efficient devices for heating and cooling including facilities for heat recovery which may include natural ventilation, but in many cases will not. Includes also replacement of fossil fuel energy devices with heat pumps etc.	Covered partly by AMS-II.E and AMS-III.B but role of management and actual performance as part of procedure is weak.
Installation of Renewable Energy	Hot water and electricity provided by conventional means.	Installation of solar thermal, solar photovoltaic, wind, biomass devices.	Covered partly largely by AMS-II.E and AMS-1.D, but role of management and performance could be enhanced.
Building Services: Lighting, Hot Water, Lifts etc	Current technology e.g. tungsten filament lights, old fluorescent lamps with magnetic chokes etc.	Latest low energy devices such as Compact fluorescent or LED lights. High efficiency fluorescent tubes with smart control. High efficiency motors for lifts.	Covered partly by AMS-II.C, AMS-II.E and AMS-II.J but role of management and actual performance as part of procedure is weak.
Energy management	No energy management, or at very basic level.	Effective energy management using enhanced analysis and control together with implementation of adaptive energy management strategies.	Not covered in CDM approved methodologies apart from in a very peripheral way.
Changes to behavioural patterns of occupants of buildings	Energy consumption based on current practices of occupants of buildings.	A more pro-active approach to energy conservation and carbon reduction promoted through awareness raising, "Green" Champions etc. Implementation of such measures will cost money.	Not covered in any CDM project and it would need a change of philosophy from predictive savings to retrospective performance based savings to be relevant under CDM. Costs would be incurred by management for additional monitoring and employment of suitable staff. Tovey and Turner [27] indicated that potential savings in this area could be large, however more research is needed to ensure continued engagement in such approaches. Using an approach based on performance would overcome any uncertainty with respective to whether savings in one year are actually maintained thereafter.
Non Building Service appliances such as computers, office and other equipment classed under functional energy uses by tenants.	May not be recognised as a CDM project except in exceptional cases as such equipment in commercial buildings will normally have a life span of a few years and replacement will take place automatically anyway and it would be difficult, if not impossible to prove additionality over a project lifetime. Actions to enhance energy performance here may save energy and carbon emissions in areas controlled by tenants. However such actions will also reduce internal heat gains and increase winter time heating loads and thus carbon emissions by the space heating system which is under the control of the management company and thereby reduce potential carbon savings. On the other hand in summer cooling loads would be reduced and such actions by the tenants would be additive in terms of carbon savings. A careful dialogue between the management companies and the tenants on a holistic basis is thus needed. However, tenants of large commercial buildings will not normally be Project Participants and this creates a barrier to effective carbon reduction.		

1. allow technological based projects as present, but would give additional benefits if the participants achieve greater reductions that projected,
2. encourage continual development of management practices to ensure the best performance is achieve,
3. recognise that significant savings can be made in some situations from effective adaptive management alone as witnessed by the example in Fig. 4,
4. simplify the assessment of savings in cases where there are a combination of several technologies are involved by reducing costs of data monitoring, and in which individually it might be difficult to ascertain the true savings as interactive issues between the different technologies may occur (for example architectural design might enhance solar gain in winter reducing heating loads but at the same time increase cooling loads in summer),
5. address issues where there may be interactive issues from different technologies such as where architectural design might enhance solar gain in winter reducing heating loads but at the same time increase cooling loads in summer,
6. provide a holistic approach to address issues where actions by tenants to reduce electricity consumption and incidental gains may have adverse effects on the overall carbon reduction emissions under the control of the management company,
7. encourage innovative ideas towards carbon reduction through awareness raising by tenants and their staff,
8. provide a framework for dialogue between management companies and tenants which could result in additional reductions in carbon emissions.

If electricity is the only source of energy consumed in a building as is the case for many large commercial buildings in Shanghai then Liu and Lu [29] suggest that the total baseline emissions (E_o) in a building are given by:

$$E_o = e_o \cdot \epsilon_L \quad (1)$$

where e_0 is the baseline electricity consumption and ϵ_L is the local overall emission factor for electricity supply.

Electricity supplied to Beijing comes from the North China Grid for which the latest (2008) emission factor as noted above is 1.03 kg CO_2e/kWh compared to 0.90 kg CO_2e/kWh for the East China Grid serving Shanghai.However, as noted above it is important when defining the baseline consumption to separate previous consumption into the intrinsic and functional energy use and that the former should be adequately normalised for average climate conditions. In the case of a building in Shanghai where heating is provided electrically, equation (1) should be modified for the relevant baseline period denoted by the subscript "o" during the heating season to:

$$E_o = \left(i_{ho}\frac{T_{AH}}{T_{oH}} + i_{no} + f_o\right)\cdot\epsilon_L \quad (2)$$

Where i_{ho} is the intrinsic electricity use for space heating; i_{no} is the intrinsic electricity use for services (e.g. lifts etc); f_o is the functional energy use; T_{oH} and T_{AH} represents the climate condition parameters (such as degree-days) for the baseline heating period, and the recent long-term average respectively.

A similar equation would be relevant for the summer season when cooling is required. For simplicity, let

$$H_o = i_{ho}\frac{T_{AH}}{T_{oH}} + i_{no} + f_o \quad (3)$$

and let C_o be the equivalent term during the cooling period. The total annual emissions will be:

$$(H_0 + C_0)\epsilon_L \quad (4)$$

In practice it may be difficult to separate all the components i_{ho}, i_{no},and f_o. For CDM projects which aim to reduce heating/cooling energy requirements whether by technical measures or through improved management/awareness raising, this will not matter as all that is needed is the sum of the terms i_{no} and f_o, and it is then relatively easy to separate these parameters from i_{ho} by plotting historic data used for baselines purposes against a suitable climate parameter as shown in Jiang and Tovey [16] (2009).

Using the same method, the emissions following implementation of a CDM project emissions (E_i) may be estimated from the new equivalent electricity consumption parameters H_i and C_i where the subscript "i" refers to values during the ith year after implementation of the project.

Over a period of n years the savings in emissions (S) would be:

$$S = \sum_{i=1}^{n}(H_i + C_i)\epsilon_{Li} - (H_0+C_0)\sum_{i=1}^{n}\epsilon_{Li} \quad (5)$$

It should be noted that this performance based approach allows for varying emissions factors for the local electricity grid, allows for additional potential savings (or otherwise) to be achieved through good effective management and provides a more robust methods to track largely technological enhancements through CDM projects.

The above approach will give an indication of savings, but there is scope for a more enhanced methodology to correctly reflect all the possible measures outlined in Table 2. The aim of this paper has been to emphasize the need for a performance based approach and these more advanced ideas will be covered in Jiang [12] and subsequently published elsewhere. Important in these enhancements will be the extension of the relationships to cover multiple fuels, not just electricity, and allow further subdivision and exploration of the interactions between the different energy uses in a large commercial building as discussed above.

5. Conclusions

The Clean Development Mechanism is a method whereby developing countries can be assisted in their economic development but at the same time minimise the impacts this will have on carbon dioxide emissions and consequential climate change. The building sector accounts for significant emissions amounting to over 25% of total emissions in the case of China and yet not one CDM project covering buildings has been implemented in China, and worldwide the uptake has been low, just 5 projects in total or 0.3% of the total.

A reason for the low take up such projects in the building sector has been the restrictions that current methodologies place on projects and the limited scope for energy management to be effectively incorporated into projects. Large commercial buildings in China have been shown to consume energy at a significantly higher rate than in other buildings and there is a need to remove the barriers which currently limit the scope of CDM projects in this sector.

It is important to recognise that in such large buildings those responsible for the overall management of the buildings will not control the activities within the spaces let to tenants, and conversely the tenants will often have little incentive to reduce the energy consumption for services such as heating and cooling if these are charged at a flat rate based on area alone. It is also important to separate out the intrinsic energy uses in a large commercial building which are primarily the responsibility of the management company and the functional energy use which will be under the control of the tenants.

It is recognised that the actions of the management company and the tenants will be interactive and in some case will work in opposite directions with regard to climate change mitigation actions and a new methodology is proposed to overcome the current barriers. Within this methodology an outline is given as to how variations in climatic data could be incorporated to provide a more robust approach. A performance based methodology will achieve this more readily than the current technology based approaches. Methodologies based on performance will give true recognition by rewarding effective management and encourage continual improvement by awarding all CERs retrospectively based on actual performance. Such an approach will encourage innovation in management and provide incentives for awareness raising initiatives. Furthermore such an approach will give energy management the recognition it deserves and will encourage identification of malfunction of equipment at an early stage which in itself could save significant amounts of carbon emissions.

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