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Co-benefits of CDM projects and policy implications

Abstract

This paper aims to study the co-benefits of clean development mechanism (CDM) projects, and further to discuss the policy of its implications. It has been found that many energy-related climate change mitigation (CCM) activities, including CDM projects, are able to produce a significant amount of co-benefits, while the policy implications have been limited. Through co-benefits assessment of Chinese CDM projects, it can be concluded that: (1) there are uncertainties relating to co-benefits assessment; (2) co-benefits assessment can be only applied to energy related projects (ERPs) and not to HFC23 decomposition projects; (3) hydropower and wind power projects are the largest contributors to co-benefits. Considering average capacity, projects concerning energy switch from coal to natural gas, coal mine methane recovery and biogas recovery are also important; and (4) the distribution of co-benefits in China are uneven. Through a discussion about policy implications of co-benefits, this paper suggest that co-benefits should neither be involved into current international CCM negotiation, nor used to ensure projects' contribution to sustainable development. However, co-benefits analysis can indicate synergies or optimised trade-offs between CCM and protecting local environment, which is valuable for decision-making in developing countries, especially for local governments.

Keywords: clean development mechanism, co-benefits, policy implications.

JEL Classification: Q53, 54, 56.

Introduction

The clean development mechanism (CDM) allows emission reduction (or emission removal) projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO₂ equivalence (CO₂e). These CERs can be traded and sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol (United Nations, 1998). CDM has gained a great deal of interest worldwide, since it provides the only platform to date for simultaneously engaging industrialised and developing countries in climate change mitigation (CCM) and, along with emission trading, plays an important role in motivating private sector to reduce emissions (Hepburn, 2007). By the end of August 2010, over 4200 candidate projects had been proposed in the CDM pipeline, aggregately representing over 2.9 billion tonnes of CERs by the end of 2012, and over 2300 of these candidates have been registered, annually delivering more than 300 million tonnes of CERs (UNFCCC, 2010a).

A debate about CDM concentrated on examining whether or not CDM projects assist developing countries in promoting sustainable development (SD) (Dechezleprêtre et al., 2009; Kolshus et al., 2001; Sutter and Parreño, 2007). Critical questions regarding this debate include how the scope of SD as well as impacts in the scope is defined, and how the impacts in the scope are assessed. SD is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987). However, the United Nations Framework Convention on

Climate Change (UNFCCC) has not developed any methodologies for safeguarding SD, which is left to a host country as its prerogative (UNFCCC, 2002). In addition, there will probably never be an uncontroversial definition applicable to all projects, given the differences in policy priorities in different countries (Disch, 2010; Nussbaumer, 2009).

Before 2001, a number of forward-looking studies concluded that CDM projects would make 'potential', 'theoretical' or 'possible' contributions to SD in host countries. However, these studies were subject to an obvious lack of empirical evidence, as it was too early for sufficient data to be available (Olsen, 2007). Since 2001, researchers have used a number of approaches to study CDM projects in terms of their impacts on SD in developing countries (Jack and Kinney, 2010; Kolshus et al., 2001; Nemet et al., 2010; Olsen, 2007; Sutter, 2003). To address a comprehensive scope of SD, some studies, (e.g., Kolshus et al., 2001; Sutter and Parreño, 2007; Olsen and Fenhann; and Heuberger et al., 2007), adopted qualitative or semi-quantitative method such as checklist and meta-CDM. However, these approaches failed to define an overall sustainability scope in well-measurable terms, and thus their policy implications were limited in the way that, for example, making a choice among different combinations of development and environmental policies (Heuberger et al., 2007; Sun et al., 2010b).

One way to quantify sustainability is to assess the co-impacts, or 'ancillary impacts', which refers to various economic, environmental and social impacts apart from greenhouse gases (GHG) reduction, simultaneously caused by CCM activities (Aunan et al., 2006; Aunan et al., 2004; Cao et al., 2008; Disch, 2010; Haines et al., 2006; Vennemo et al.,

2006). Although co-impacts may be negative, e.g., the loss of cultural heritage or biodiversity resulting from a hydropower project, most studies to date have often referred to it as ‘co-benefits’, reflecting the major concern about positive effects. For about twenty years, many studies have tried to quantify co-benefits of CCM policies and activities, in which the effects associated with air quality and resulting values for public health are the most important part (Ayres and Walter, 1991; Jack and Kinney, 2010; Mirasgedis and Diakoulaki, 1997). A general conclusion by these studies is that CCM projects, especially those energy-related ones, are able to deliver a large amount of co-benefits, especially mortality avoidance and other health benefits resulting from the reduction of air pollutants (Haines et al., 2006; Rive and Aunan, 2010; Vennemo et al., 2006). Among others, two comprehensive reviews of previous studies of co-benefits are Bell et al. (2008) and Nemet et al. (2010). Bell et al. (2008) mainly focused on the techniques commonly used in assessing various co-impacts, and their current application in industrialised and developing countries; and Nemet et al. (2010) addressed the significance of co-benefits in terms of their policy implications.

Aims and organisations. On the basis of existing efforts, this paper aims to study the co-benefits of CDM projects, and further to discuss the policy implications of the co-benefits. To this aim, this study concentrates on Chinese CDM projects, and preferably in the cooperation with Sweden, since China so far has been the largest host country of CDM

worldwide (UNFCCC, 2010b). Major data of these projects are derived from their project design documents (PDDs), which are considered as the appropriate source (discussed later). The method and coefficients used in this paper are obtained from existing studies, and the strengths and weaknesses of the method are addressed in a literature review. By assessing co-benefits, this paper will stress the characteristics of co-benefits regarding project categories and locations. The policy implications will be discussed based on the findings, namely to address the question that in what way should co-benefits be taken into account.

The paper begins by providing a review of co-benefits studies in China, and the assessment methods are discussed in relation to CDM projects. Next, the co-benefits of Chinese CDM projects are assessed, namely including reductions in SO₂, particle matters (PM) and NO_x, and relating avoided deaths and crop losses. Then, policy implications of the co-benefits are discussed through answers to several questions. Finally, a short summary is made to conclude the paper.

1. Review of studies of co-benefits in China

To collect existing studies, several search engines, such as Google Scholar, Science Direct, Wiley and Springer Link, were searched into with keywords such as co-benefits, ancillary benefits, climate change and SD. There are 14 studies specifically focused on China (Table 1), while much more were carried out in industrialised countries.

Table 1. Studies of co-benefits in China

Study	Region	Activity	Pollutants (apart from GHG)	Endpoints
Bottom-up				
Aunan et al. (2004)	Shanxi	6 mitigation techniques	PM ₁₀	Mortality (LYL), OPV, ERV, HA, WDL, ARS, CRS, AA
Cao et al. (2008)	China	15 techniques of power generation	PM, SO ₂ , NO _x	33 industrial sectors
Mesti et al. (2005)	Taiyuan (Shanxi)	6 cleaner production projects	PM ₁₀	Mortality, OPV, ERV, HA, WDL, ARS, CRS, AA
Vennemo et al. (2006)	China	CDM potential	TSP, SO ₂	Mortality, a number of health related and other impacts (assessed integrately)
Rive & Aunan (2010)	China	1754 ‘active’ CDM projects	PM _{2.5} , SO ₂ , NO _x	Mortality (from PM), Crop loss (from NO _x)
Top-down				
Aunan et al. (2007)	Guangzhou and the rest of China	Carbon tax	PM ₁₀ , SO ₂	Mortality, OPV, ERV, HA, WDL, ARS, CRS, AA
Cao et al. (2008)	China	Output tax, fuel tax, carbon tax and sectoral mixed policies	PM, SO ₂ , NO _x	33 industrial sectors
Garbaccio et al. (2000)	China	Carbon Tax	PM ₁₀ , SO ₂	Mortality, RHA, ERV, RAD, LRI, AA, CB, RS, CD
Gielen et al. (2001)	Shanghai	Energy policy, local environmental policy and sustainability policy	SO ₂ , NO _x	SO ₂ , NO _x
Kan et al. (2004)	Shanghai	Energy efficiency improvement, natural gas expansion, environmental target and carbon emission control scenarios	PM ₁₀	Mortality, CB, RHA, CHA, OPV, AB, AA
Pan et al. (2007)	Beijing	Clean energy consumption & industry structure transformation scenario, energy efficiency programme, and Green transportation programme	PM ₁₀ , SO ₂	Mortality, CB, RHA, CHA, OPV, ERV, COPD

Table 1(cont.). Studies of co-benefits in China

Wang & Smith (1999)	China (power and household sector)	Least-cost energy efficiency, and least-cost fuel substitution	PM ₁₀	Mortality and morbidity
Wang & Mauzerall (2006)	Zaozhuang (Shandong)	Best available end-of-pipe controls scenario, and advanced coal gasification technologies scenario	PM (PM ₁₀ , or PM _{2.5})	Mortality, CB, AB, CHA, RHA, RAD, AA
Zhang et al. (2010)	Taiyuan	Use of natural gas & coal-bed methane scenario, district heating scenario and National Grade II attainment scenario	PM ₁₀ (PM _{2.5} is transferred into PM ₁₀)	Mortality, HA, CB

Notes: AA – asthma attacks, AB – acute bronchitis, ARS – acute respiratory symptoms, CB – chronic bronchitis, CD – chest discomfort, CHA – cardiovascular hospital admission, COPD – chronic obstructive pulmonary disease, CRS – chronic respiratory symptoms, ERV – emergency room visit, HA – hospital admissions, LRI – lower respiratory infection, LYL – life years lost, OPV – outpatient visits, RAD – restricted activity days, RHA – respiratory hospital admissions, RS – respiratory symptoms, WDL – work day loss. Note that Cao et al. (2008) combined both top-down and bottom-up models in their study, which appears twice in Table 1.

Generally speaking, these studies differ about:

- ◆ the type of CCM activities (e.g., programmes, policies and projects);
- ◆ the place where the activities occurred or would occur;
- ◆ the pollutants included, e.g., particle matters (PM), SO₂ and NO_x;
- ◆ the approach used to calculate the amount of air pollutants; and
- ◆ the co-benefits (endpoints) included in the final valuation.

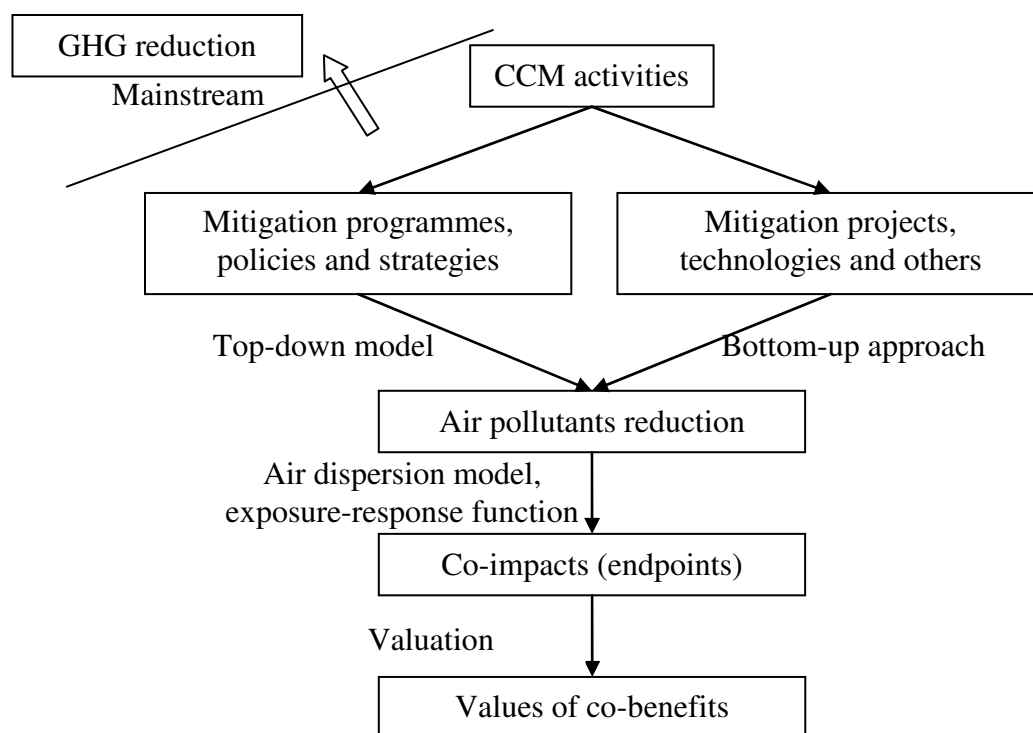


Fig. 1. The conceptual model of assessing co-benefits

Summarising from these studies, a conceptual model of assessing co-benefits is shown in Figure 1. For a concrete mitigation project, such as CDM, bottom-up approach is more suitable for estimating air pollutants reduction, since technical details and site-specific situations can be reflected in the approach. However, when the focus switches from a single project to a number of projects, Vennemo et al. (2006) calculated the average pollutants coefficients for the projects under study, namely how much PM and SO₂ would be simultaneously

reduced when one tonne of CO₂ reduction is achieved. Their approach provides an effective way to comprehensively assess co-benefits of a large number of CDM projects, while the heterogeneity of projects in different categories or regions was not considered. Rive & Aunan (2010) improved this by calculating coefficients for every project category in every region, and thus useful for a more profound analysis of CDM projects.

The next step is to estimate the physical amount of co-impacts corresponding to the reduced air pollut-

ants, and pollutants dispersion models and exposure-response functions are often used in this process (Figure 1). To date, a great number of co-impacts (endpoints) have been studied, and the mostly concerned impacts include mortality and several respiratory diseases resulting from changes in air quality (Table 1). In addition, other measurable impacts may also be considered, e.g., crop loss from NO_x avoidance, forest growth, corrosion of materials, and wear & tear of buildings and cultural heritage (Rive and Aunan, 2010; Vennemo et al., 2006). Given the research efforts in the last 20 years, the current knowledge available for quantifying health-related co-benefits are adequate and appropriate for comparing various energy-related CCM activities (Bell et al., 2008).

The following step is to value the co-impacts in account (Figure 1). Some studies chose to provide measurements of co-impacts using their original terms, while others suggested that it is advantageous to add an explicit monetary valuation of endpoints, which can be easily used by decision-makers (Aunan et al., 2004; Bell et al., 2008). Nevertheless, most studies agreed that, in all categories of co-benefits, the largest proportion comes from the avoidance of mortality, although valuation of lives is often controversial (Bell et al., 2008; Campbell-Lendrum and Corvalán, 2007; Mirasgedis and Diakoulaki, 1997). In addition, current studies on values of lives normally come from industrialized countries, and this would cause the problem known as transferability because measurements of those values often depend on many detailed parameters, such as income, education, age and traditions, which vary greatly with location and time (Clinch and Healy, 2001; Mirasgedis and Diakoulaki, 1997; Vennemo et al., 2006). The earliest work carried out in China was probably after 2001, and not much more has been done since then (Wang and Mauzerall, 2006). To deal with this situation, Vennemo et al. (2006) suggested that people's lives should remain unvalued, while other co-benefits were monetised.

In general, the number of studies on co-benefits in developing countries is still limited, and some inputs rely on the work in industrialised countries. Studies have shown that energy-related CCM activities are able to produce substantial amounts of co-benefits, especially reductions in air pollutants and relating impacts (Aunan et al., 2007; Aunan et al., 2004; Bell et al., 2008; Burtraw et al., 2003; Cao et al., 2008; Ekins, 1996). However, since existing measurements do not reflect the full range of illness relating to air pollution, results are usually subject to underestimation (Aunan et al., 2006; Bell et al., 2008). Compared with U.S. and European studies, Chinese epidemiological studies often report lower coefficients in exposure-response functions (Aunan and Pan, 2004; Kan et al., 2004; Wang and Mauzerall, 2006), while the overall magnitude of co-benefits is especially large (Jack and Kinney, 2010; Mestl et al., 2005). The reasons relate to different levels of air pollutants, local population and age distribution (Kan et al., 2004). It is also found that policy implication of co-benefits has been limited to date, owing to: (1) the uncertainty in reductions that would be produced by CCM activities; (2) current institutional barriers both scientifically and politically; and (3) the measurement and valuation of co-benefits (Jack and Kinney, 2010; Nemet et al., 2010). Compared with other CCM activities, the uncertainties and barriers regarding CDM are largely reduced, partly due to the transparent and consistent baseline and monitoring methodologies and strict implementation of the methodologies (Sun et al., 2010a). Hence, the next Section will assess the co-benefits of Chinese CDM projects, and relevant policy implications of co-benefits will be discussed later.

2. Co-benefits of Chinese CDM projects

In this Section, Chinese CDM projects in the cooperation with Sweden will be studied to investigate the stringency of co-benefits assessment. Only registered projects were used here due to data availability, and the major data source of these project is the UNFCCC's CDM database (UNFCCC, 2010a).

Table 2. CDM projects in the cooperation between China and Sweden

Region* \ Category	Biogas recovery	Biomass	Coal mine methane recovery	HFC23 decomposition	Hydro-power	Natural gas	Waste gas and/or heat recovery	Wind power	Sum
Number of projects	1	1	1	2	89	1	12	21	128
Central					47	1	6		54
East		1		2	1			2	6
Hainan							1		1
North	1		1				4	6	12
North East					2			6	8
North West					9		1	7	17
South					30				30
									54

Table 2 (cont.). CDM projects in the cooperation between China and Sweden

Region* \ Category	Biogas recovery	Biomass	Coal mine methane recovery	HFC23 decomposition	Hydropower	Natural gas	Waste gas and/or heat recovery	Wind power	Sum
Total annual CERs (tCO ₂ e)	66393	123055	3016714	18848681	7803677	858165	1520631	2566762	34804078
Central					4384899	858165	532632		5775696
East		123 055		18848681	43603			588865	19604204
Hainan							38400		38400
North	66393		3016714				922014	744985	4750106
North East					126101			554623	680724
North West					1440287		27585	678289	2146161
South					1808787				1808787

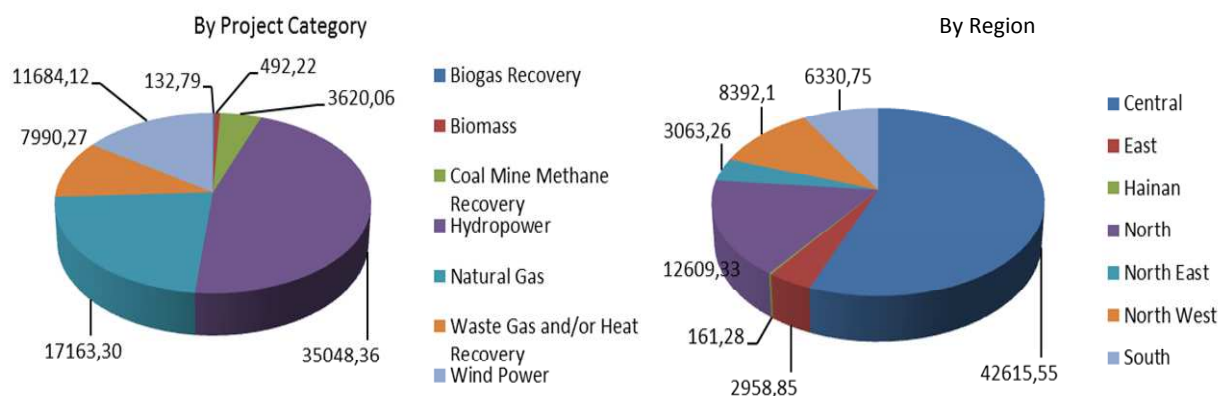
Sources: UNFCCC (2010a). CDM Project Database, <http://cdm.unfccc.int/Projects/projsearch.html>, accessed on August 1, 2009.

By July 31, 2010, there had been 128 Chinese CDM projects concerning Swedish investment, and these projects consist of eight types of activities, namely biogas recovery, biomass, coal mine methane recovery, HFC23 decomposition, hydropower, natural gas, waste gas and/or heat recovery and wind power (Table 2). These categories are obtained from the CDM database (UNFCCC, 2010a), while the category 'energy industries' is further divided into sub-groups by energy type. The 128 projects are also placed into 7 location groups according to Chinese national power grid.

In order to have the CERs accredited, a CDM project must qualify through a rigorous public registration process, where its additionality is assessed following relevant baseline and monitoring methodologies. The additionality, indicating that the project activity would not have occurred in the absence of CDM, is calculated on the basis of real, measurable

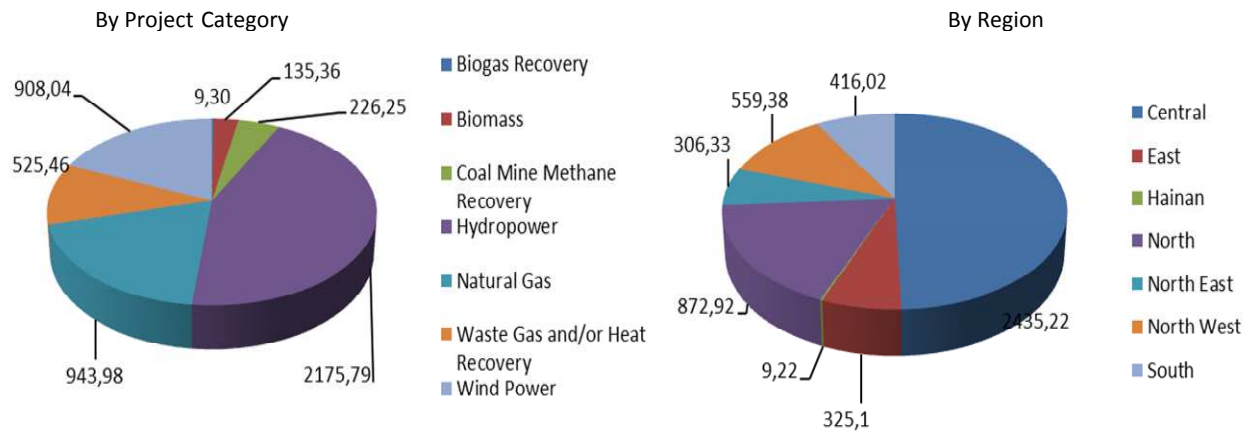
and verifiable reductions and associated financial costs. Given the availability and reliability, PDDs are the main data sources of most studies, as they are in this paper. Any CDM investment in China is required to contain an environmental impact assessment (EIA) and the stakeholders' comment evaluation (SCE) in its PDD, which, however, are argued as being too loose to secure the sustainability of CDM projects (Disch, 2010; Sun et al., 2010b).

To measure co-benefits of those CDM projects, this paper adopts the approach developed by Vennemo et al. (2006) and Rive & Aunan (2010). More specifically, this study takes the coefficients for various types of pollutants, avoided deaths and avoided crop loss from Rive & Aunan (2010), while follows the suggestion by Vennemo et al. (2006), by not monetising people's lives. Figure 2 (a-e) shows the results of co-benefits produced by the 128 CDM projects in the cooperation between China and Sweden.



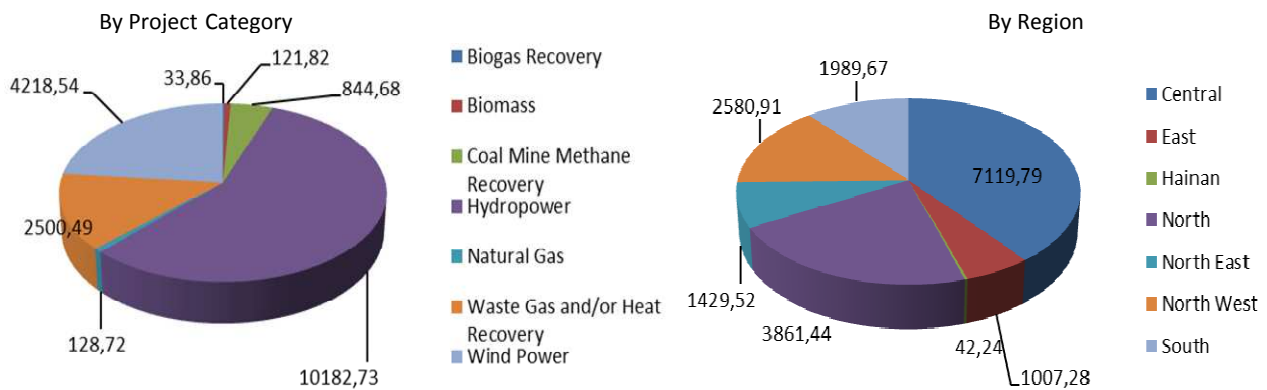
Notes: Total: 76131,11; 1000 tonne.

Fig. 2(a). Annual co-benefits of Chinese CDM projects in the cooperation with Sweden (reduction in SO₂)



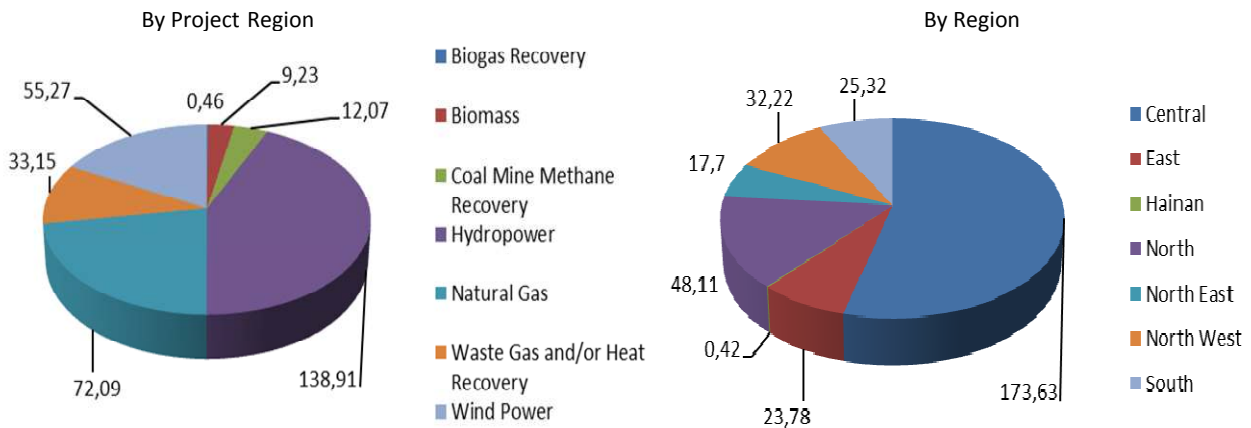
Notes: Total: 4924,18; 1000 tonne.

Fig. 2(b). Annual co-benefits of Chinese CDM projects in the cooperation with Sweden (reduction in PM)



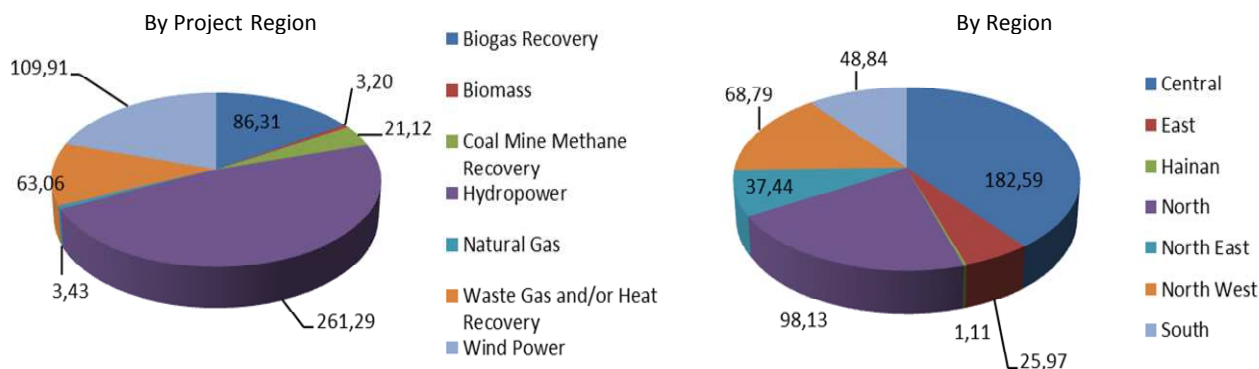
Notes: Total: 18030,85; 1000 tonne.

Fig. 2(c). Annual co-benefits of Chinese CDM projects in the cooperation with Sweden (reduction in NO_x)



Notes: Total: 321,18; lives.

Fig. 2(d). Annual co-benefits of Chinese CDM projects in the cooperation with Sweden (avoided deaths from PM reduction)



Notes: Total: 462,87; 1 million RMB. Rive and Aunan (2010) used the exchange rate in 2005 to calculate the coefficients for co-benefits, resulting from which the values for co-benefits above may be overestimated compared with current terms.

Fig. 2(e). Annual co-benefits of Chinese CDM projects in the cooperation with Sweden (avoided crop loss from NO_x reduction)

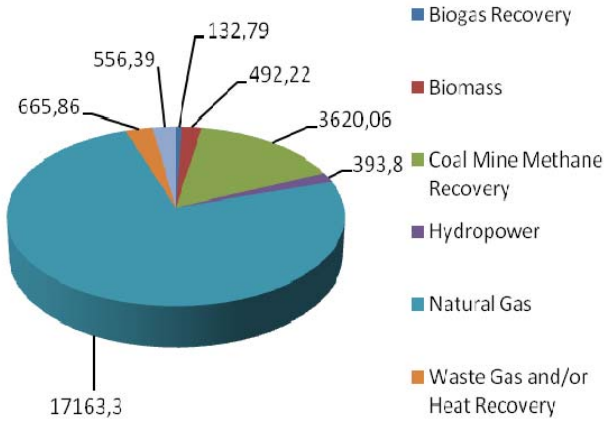
‘These projects in general show huge potentials in producing co-benefits, such as thousands of tonnes of SO₂, PM and NO_x will be mitigated, hundreds of lives will be saved and huge amounts of crop loss can be avoided, compared to the business-as-usual situation. Looking into the results, several findings are summarised below:

- ◆ It is noted that uncertainties were involved in the above assessment, which can be generally divided into measurement of CERs and calculation of coefficients for various co-benefits. For measurement of CERs, monitoring reports that verify the operation of a CDM project can provide more reliable figures than PDDs. However, PDDs would be the best choice for ex-ante assessments, due to their reasonability and stringency mentioned above. Calculation of coefficients is even more complicated and relies on a number of interrelated techniques (see Section 1). A good application of these techniques calls for knowledge in several fields, such as energy engineering, geology, epidemiology, statistics and environmental economics. This study took the outcomes of previous studies and supposed that the uncertainties involved in the outcomes had been considered. In addition, discussion about measurement of co-benefits can also be found in, for example, Aunan et al. (2006) and Bell et al. (2008).
- ◆ The calculation of co-benefits is based on the fact that a project is going to offset a certain amount of energy, which would otherwise be generated in the business-as-usual situation. Since the project generates power in a ‘cleaner’ way than business-as-usual, a number of air pollutants as well as other damages resulting from these pollutants could be avoided. Within the eight categories of CDM projects, the evaluation

can be applied to the seven categories of energy-related projects (ERPs) and not to HFC23 decomposition projects. The reason is that no electricity generation or energy conservation is produced by HFC23 decomposition projects and hence no air pollutant reductions, avoided mortality or other co-benefits can be further expected from it.

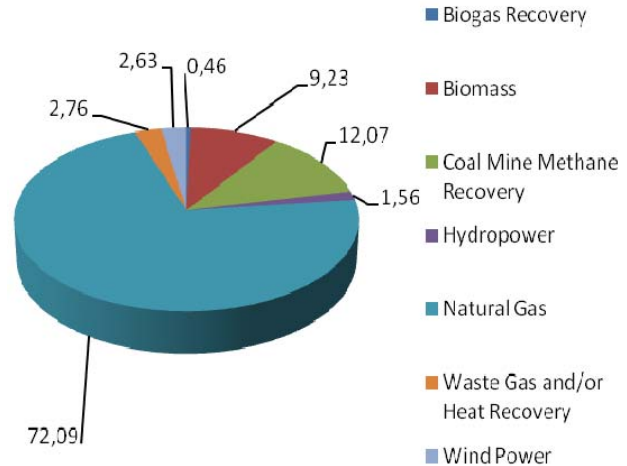
- ◆ The amount of co-benefits is proportionate to the amount of CERs, and the largest contribution to co-benefits is made by the largest categories in terms of CERs, i.e. hydropower and wind power projects (Figure 2). Considering average capacity of co-benefits production (Figure 3), projects concerning energy switch from coal to natural gas have the largest potential, and this is followed by coal mine methane recovery projects. Regarding PM reduction, the category of natural gas still represents the greatest potential and coal mine methane projects take the second place again. Corresponding to the PM reduction, these two categories are also the two largest contributors to avoided deaths. For NO_x reduction, coal mine methane recovery projects become the greatest efforts, while they are overtaken by biogas recovery projects in terms of avoidance of crop loss.

The regional distribution of co-benefits is uneven (Figure 2), and this reflects the fact of uneven distribution of CDM projects. However, the development of CDM projects depends on a number of complicated issues, e.g., natural environmental resource, local industries, infrastructure and institutional capacity. For instance, over 80% (77/89) hydropower projects are located in the central and south part of China, where there is an abundant amount of water resource; and wind power projects are mostly found in the northern regions (19/21).



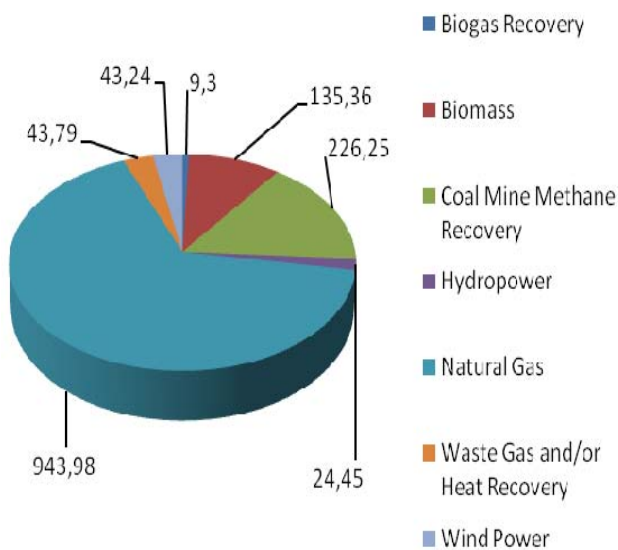
Note: Unit: 1000 tonne.

Fig. 3(a). Average co-benefits per project (reduction in SO₂)



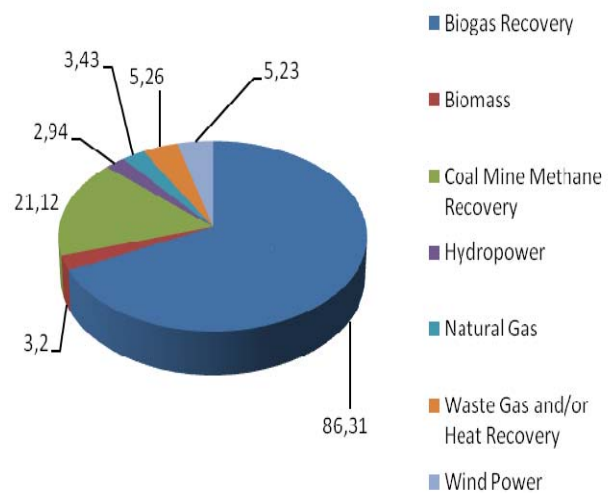
Notes: Unit: lives.

Fig. 3(d). Average co-benefits per project (avoided deaths from PM reduction)



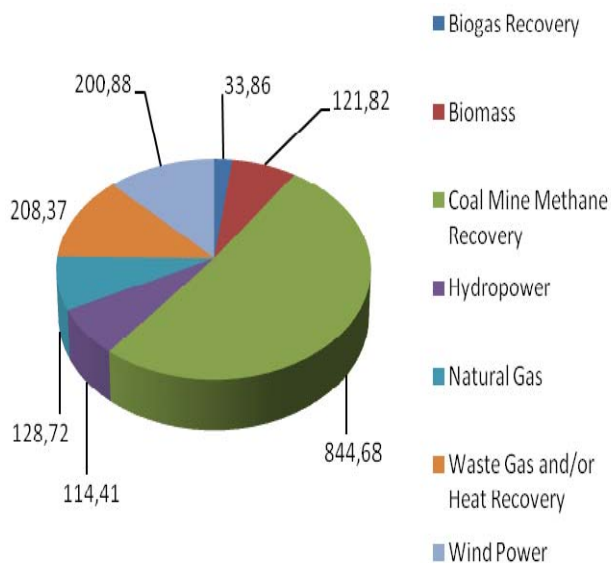
Notes: Unit: 1000 tonne.

Fig. 3(b). Average co-benefits per project (reduction in PM)



Notes: Unit: 1 million RMB.

Fig. 3(e). Average co-benefits per project (avoided crop loss from NO_x reduction)



Notes: Unit: 1000 tonne.

Fig. 3(c). Average co-benefits per project (reduction in NO_x)

3. Policy implication of co-benefits

This Section will discuss the policy implications of co-benefits, namely to address the question that in what way should co-benefits be taken into account. This paper discusses this question from three aspects, which are: (1) should co-benefits be involved into the current international CCM negotiation regarding CDM? (2) should co-benefits be used to ensure projects' contribution to SD? and (3) What policy implications could co-benefits be concerned?

3.1. Should co-benefits be involved into the current international CCM negotiation regarding CDM? The suggested answer is no. Although with uncertainties, existing studies have similarly pointed out that a huge amount of co-benefits are able to be simultaneously produced by various of CCM activities, including CDM projects, and suggested that these co-benefits could be incorporated to justify the

huge costs of CCM activities (Ekins, 1996; Mestl et al., 2005; Pittel and Rübbelke, 2008; Plambeck et al., 1997). Pittel & Rübbelke (2008) further used Game Theory to study what would happen if co-benefits of climate policies were involved into international negotiation, and their conclusion was that the likelihood for industrialised and developing countries to participate in international joint CCM actions would be increased. A critical precondition to these analyses is that reduction activities would be possible to equivalently develop in industrialised and developing countries, and equivalently delivering co-benefits; or in other words, both industrialised countries and developing countries will choose to deliver reductions by themselves or to wait for efforts from the others. However, the real question for industrialised countries should be 'to choose the most cost-effective way to achieve their reduction commitment', rather than 'to do or not to do', while for developing countries, the strategy has not been clear enough, but very close to 'how much will be reduced'. Different from GHG, most co-benefits are local and short-lived, and thus difficult to correspond to primary GHG benefits, which is global and long-lived (IPCC, 1996). When values for co-benefits is taken into account, an industrialised country will decide whether it would be worth to purchase reduction accredits, since reduction in its domestic emissions would be largely offset by co-benefits; and developing countries may consider how much more reduction credits could they offer, and at what price can they offer. Moreover, different countries may define the scope of co-impacts based on their own needs, and thus the final values of co-impacts may be manipulated. For example, when China tries to address climate change in order to avoid crop loss, Sweden can argue that, for example, they will get more crop yield from global warming. In this case, the co-benefits become completely incomparable between different countries. Even if the scope of co-benefits is confined to air pollutants and various health-related impacts, the incorporation of co-benefits into an overall assessment still turns to be difficult. All changes will have to be mixed and handled on the global market, causing unpredictable significant changes. Very likely, such changes may threaten the cohesion of the current international cooperative system (Nemet et al., 2010; Pittel and Rübbelke, 2008). Right now, there is just too long distance away from that point.

3.2. Should co-benefits be used to ensure projects' contribution to SD, a requirement for CDM? The answer is probably no. There has been an argument on whether co-benefits should be used to ensure projects' contribution to SD, a requirement for CDM (Aunan et al., 2006). However, SD by defini-

tion is a multi-dimensional concept, and has different meanings in different contexts. Current studies on co-benefits have mainly considered changes in air-pollutants and relating health-related and other quantifiable impacts, while many other important issues regarding SD are intrinsically difficult to quantify and have been seldom involved, such as technology transfer, employment generation and poverty alleviation (Olsen, 2007; Sirohi, 2007; Sutter and Parreño, 2007). A real example is HFC23 decomposition projects, which did not produce any co-benefits in the above assessment. However, Peterson (2008) suggested that technology transfer is mainly found in HFC23 decomposition and thermal efficiency projects. Even confined to ERPs, co-benefits may also create misleading information if the values would be used to ensure its contribution to SD. Given that a project's co-benefits are relating to the amount of its CERs (see the assessment above), for the same category of projects in the same region, the conclusion turns to be – the larger amount of CERs a projects can produce, the greater contribution to SD it will make. Certainly, this outcome is debatable. Therefore, since SD represents a far more complicated meaning than co-benefits, it is probably wrong to use co-benefits to ensure CDM's contribution to SD, even for ERPs.

3.3. What policy implications could co-benefits be concerned? In China, the policy focus is often on acidification and other environmental problems resulting from pollutants such SO₂, NO_x and PM, rather than GHG, and this was also the main issue in Sweden 30 years ago. Actions aiming at reducing air pollutants can also achieve GHG reductions as co-benefits in many cases (Gielen and Changhong, 2001; Morgenstern et al., 2004). Given the possibility to achieve dual targets through the same effort, decision-making would benefit from co-benefits assessments that can indicate synergies or optimised trade-offs between CCM and protecting local environment (Campbell-Lendrum and Corvalán, 2007). Especially for local governments, who do not always have a sufficient financial budget on different environmental actions, the analysis of co-benefits would provide them valuable information. For example, Chinese renewable energy projects, e.g., hydropower and wind power projects, in general are important for not only helping the country to reduce GHG emissions, but also significantly reducing air pollutants as well as delivering other relating co-benefits. Therefore, these projects should be further encouraged to help China address climate change and improve ambient environment. In addition, projects concerning energy switch from coal to natural gas are especially good at reducing SO₂ and PM, coal mine methane recovery projects have the large-

est potential in mitigating NO_x, and biogas recovery projects have the large effects on avoiding crop loss. All these outcomes are helpful in future local and regional policy-making, no matter the primary target is to address CCM, to promote CDM, or to improve local environment.

Conclusions

This study reviews existing studies on co-benefits in China, evaluates the co-benefits of Chinese CDM projects in the cooperation with Sweden, and further discusses the policy implications of the co-benefits. Through the review, it has been found that studies have generally agreed on that many energy-related CCM activities, including CDM projects, are able to produce a significant amount of co-benefits, while the policy implications of co-benefits have been limited to date. Then, through co-benefits assessment of Chinese CDM projects, it can be concluded that: (1) there

are uncertainties relating to co-benefits assessment; (2) co-benefits assessment can be only applied to ERPs and not to HFC23 decomposition projects; (3) hydropower and wind power projects are the largest contributors to co-benefits, and considering average capacity, projects concerning energy switch from coal to natural gas, coal mine methane recovery and biogas recovery are also important; and (4) the distribution of co-benefits in China are uneven. Through the discussion about policy implications of co-benefits, this paper suggest that co-benefits should neither be involved into current international CCM negotiation, nor used to ensure projects' contribution to SD. However, co-benefits analysis can indicate synergies or optimised trade-offs between CCM and protecting local environment, which is valuable for decision-making in developing countries, especially for local governments.

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