



Government initiatives

An innovative system for promoting cleaner production: mandatory cleaner production audits in China



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ABSTRACT

Many studies have shown that positive and negative incentives can greatly promote cooperation in public goods games. The best policy for turning a population of defectors into a population of cooperators is to provide the “carrot” first and the “stick” later. Cleaner production (CP) is a new preventive environmental strategy, and its promotion is also an example of a public goods game. Voluntary participation and other positive incentives have been widely used to encourage industries to implement CP worldwide. However, taking into consideration specific industry characteristics and new environmental management requirements in China, the Chinese Cleaner Production Promotion Law proposes use of mandatory cleaner production audits (as compared to voluntary cleaner production initiatives) as innovative measures for advancing CP. This paper provides a general overview of this innovative system, explaining how the mandatory audit system was established and promoted in various policies, regulations, and national plans, and analyzing the design of the system. The paper also summarizes implementation results of the mandatory cleaner production audit system, based on annual surveys conducted in all provinces of China between 2008 and 2011. The Chinese experience can be used as a reference case by other developing countries similar to China.

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1. Introduction

It is well known that environmental issues provide an example of public goods games (Hardin, 1968; Hauert and Szabó, 2003; Ostrom, 1990). Collective efforts to protect a group's interests (e.g., by protecting the environment) present individuals with the temptation to defect, i.e., to take advantage of the public good without contributing to it, known as the free-rider effect (Hauert et al., 2002). In such social dilemmas, the pursuit of individual interests conflicts with the maximization of social welfare (Michael et al., 2009). Game theory has been considered the most appropriate method for studying conflict and cooperation in the provision of public goods (Archetti and Scheuring, 2012; Hardin, 1968; Ostrom, 1990). Cooperation and defection are the two strategies that are usually at the heart of every social dilemma (Dawes, 1980; Perc and Szolnoki, 2010), including public goods games. While cooperative individuals contribute to collective welfare at personal

cost, defectors choose not to (Perc and Szolnoki, 2010). Many studies have shown that positive and negative incentives can greatly promote cooperation in public goods games (Hilbe and Sigmund, 2010; Olson, 1965; Ostrom and Walker, 2003). The best policy for turning a population of defectors into a population of cooperators is to use positive incentives, followed at a later point by negative incentives, i.e., providing the “carrot” first and the “stick” later (Hilbe and Sigmund, 2010).

Cleaner production (CP) is a new preventive environmental strategy that is applied to processes, products, and services so as to increase resource efficiency and reduce risk to humans and the environment. The promotion of CP faces the same social dilemma situation, where some industries effectively prevent and control their emissions to protect the environment while others pursue their individual interest in making profit by ignoring emissions. Voluntary participation and other positive incentives have been widely used to encourage industries to implement CP worldwide. Japan, for example, was one of the earliest known countries to adopt voluntary programs for pollution prevention, which can be traced back to 1952 (Welch and Hibriki, 2002). In general, voluntary agreements were developed between local government and industry to suit specific environmental conditions (Chittock and

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Hughey, 2011). One of the most well-known voluntary programs in the US is the 33/50 program, which was launched by the US Environmental Protection Agency (EPA) in late 1990, targeting 17 major chemicals. All participating companies committed to reduce usage, discharge, and disposal rates of these chemicals by 33% by 1992 and by 50% by 1995 from 1988 values (Borkey et al., 1999). Voluntary initiatives in Canada have been in place at federal and provincial levels since 1988 and have focused on setting targets to reduce chemicals or hazardous byproducts from production processes (Chittock and Hughey, 2011). In Europe, CP was promoted on a voluntary basis from 1987 in several countries, such as the Netherlands and Sweden. Common measures include financial subsidies, taxes, and environmental labeling. In Iran, voluntary CP approaches are collaborative arrangements between individual businesses, industry associations, and regulatory agencies at local and/or national levels, reflecting a “multiple criteria decision making method” (Ghazinoory, 2005).

Iraldo et al. (2009) suggest that in order to protect the environment, governments need to adopt a policy mix instrument combining mandatory and voluntary approaches based on market dynamics, in addition to voluntary measures and programs. The promotion of CP also requires such an instrument. The 1990 US Pollution Prevention Act (PPA) is one of the first national acts in the world to clearly establish a national policy for pollution prevention, focusing on source reduction as the top priority. The Act requires the EPA to develop and implement strategies to promote source reduction, to establish a source reduction program that collects and disseminates information, and to provide financial assistance to States. The Act also clarifies the responsibilities of enterprises, with these mainly being to file annual toxic chemical source reduction and recycling reports. The Act was the first instance in which the US legally approved the substitution of end-of-pipe measures by pollution prevention and represents a radical change in industrial pollution control strategies. In general, the PPA of the US promotes implementation of pollution prevention policies and strategies (Schierow, 1999; United States Congress, 1990). The Integrated Pollution Prevention Control regulation introduced by the European Union is a good and successful example of direct regulation that mixes the characteristics of command and control with flexibility and technological incentives (Testa et al., 2014).

In China, the CP Promotion Law was designed largely on a positive and voluntary basis, as reflected in its title. However, on the basis of experiences in the US, EU, and in other countries, and taking into consideration specific industry characteristics and new environmental management requirements in China, a number of mandatory items and requirements have been included in the Law as negative incentives. One of the most important and practical regulations proposed in the law is the concept of a mandatory CP audit, an innovative element that is central to pollution prevention in China. China is in fact the first country in the world to have issued a “Cleaner Production Promotion Law”, making the implementation of CP practices mandatory for certain enterprises and organizations (Hicks and Dietmar, 2007). This study provides an overview of this mandatory audit system to show how this can effectively promote wider CP scope and encourage a larger number of industries to cooperate in its implementation; the collective efforts of industries could contribute to sound social welfare in resource conservation and environmental protection, so as to help avoid the tragedy of the commons (Hardin, 1968).

2. Methodology

This study commenced with a brief literature review of public goods games and their basic rules. We then reviewed laws,

regulations, policies, and plans aimed at establishing and promoting a mandatory CP audit system in China; these include the following:

- CP Promotion Law of the People's Republic of China, issued in 2002 and revised in 2012;
- The Interim Measures on CP audit, jointly issued by the National Development and Reform Commission (NDRC) and the Ministry of Environmental Protection (MEP) (2004);
- The Administrative Procedures for Conducting CP audit in Key Enterprises, issued by MEP (2005);
- The Administrative Procedures for Evaluation and Acceptance of CP audit in Key Enterprises, issued by MEP (2008a);
- Further Promoting CP audit in Key Enterprises in Depth, issued by MEP (2010a).

Additionally, national plans for environmental protection, heavy metal pollution control, and chemical pollution control were also analyzed for their effectiveness in promoting different aspects of mandatory CP audits.

Table 1 shows all the above-mentioned legislation and policies and explains specific requirements related to mandatory CP audits.

This study also used and analyzed official MEP statistics (2007–2011) regarding the promotion and implementation of mandatory CP audits.

Field visits to various provinces were carried out by the research team in 2008, 2010, 2011, and 2012 to obtain first-hand materials, with these visits focusing on the implementation of mandatory CP audits. During field visits, meetings were organized with local administration, research institutions, and other related stakeholders. Additionally, about 60 enterprises in total were surveyed, including non-ferrous metals, paper, dyeing and textiles, beer, sugar, chemicals, mining, tanning, cement, coke, rare earth minerals, and other key industries.

3. Design of mandatory cleaner production audit system

As noted above, the best policy for turning a population of defectors into a population of cooperators is to use positive incentives before negative ones (Hilbe and Sigmund, 2010). Many different mechanisms have been identified in order to promote or otherwise affect cooperation in public goods games, such as voluntary participation (Perc and Szolnoki, 2010) as a positive incentive. While the government of China positively encourages enterprises to voluntarily participate in CP audits, mandatory CP audit (as a negative incentive) has also been implemented in the country to encourage the cooperation of more and more enterprises in CP activities and to contribute to the environment as public social welfare. The mandatory CP audit system in China aims at urging enterprises generating heavier pollution, with higher energy consumption, or that use and generate hazardous substances to apply CP audits as key tools to identify all potential pollution reduction and energy saving measures, so as to improve resource and energy efficiency, reduce the generation of pollutants, and eliminate or decrease the use and generation of hazardous substances throughout the entire production process.

Governments can develop their own national environmental policies and regulations to create positive incentives for companies to initiate specific environmental improvements (Hillary and Thorsen, 1999). The mandatory CP audit system is such a regulation, requiring national administrative structures and authorities to exercise command and control (including inspection activities by local or state inspection bodies) and enforcement activities (Hillary and Thorsen, 1999). The mandatory CP audit system in China includes government administration as well as enterprises. It

Table 1
Policies and action plans promoting mandatory CP audits in China.

Approved and issued by (year)	Policies and action plans	Promotion of mandatory CP audits
Standing Committee of 9th NPC (2002)	Cleaner Production Promotion Law of P. R. China	Identifies two kinds of enterprises that have to conduct a mandatory CP audit.
NDRC and MEP (2004)	Interim Measures on Cleaner Production Audit	Subdivides CP audits into voluntary and mandatory, proposing specific adoption of mandatory audits.
State Council (2005)	Decision on Strengthening of Environmental Protection	Encourages energy saving and consumption reduction initiatives, and implementation of CP and mandatory CP audits based on the CP promotion law.
MEP (2005)	Administrative Procedures for Conducting CP Audit in Key Enterprises	Stipulates an administrative procedure for conducting a CP audit in key enterprises and other related rules.
MEP (2008a)	Administrative procedures for evaluation and acceptance of CP audit in key enterprises	Establishes a CP audit evaluation and acceptance system and issues "Guidelines on Evaluation and Acceptance of Mandatory CP audit in key enterprises".
State Council (2009)	Directive Opinions on Strengthening Pollution Prevention and Control of Heavy Metals	Identifies industries using and/or discharging heavy metals as requiring a CP audit by law.
MEP (2010a)	Further Promoting CP Audit in Key Enterprises in Depth	Establishes CP annual reporting and announcement systems for key enterprises, organically combining a mandatory CP audit system with other environmental management systems.
NPC's Law Enforcement Inspection Team (2010)	Report on Enforcement Inspection of CP Promotion Law	Clearly requires further strengthening of the CP audit system.
State Council (2011a)	National 12th Five-year Plan for Environmental Protection	Clearly stipulates that key enterprises have to implement a mandatory CP audit every two years.
MEP (2011a)	National 12th Five-year Plan for Integrated Pollution Prevention and Control of Heavy Metals	Requires each province to publish a list of enterprises generating heavy metal pollution that have to conduct a mandatory CP audit, urging these enterprises to carry out this audit, and to compile a CP implementation scheme for heavy metal-related industries. It also requires local governments to preferentially support CP technical demonstration and to establish incentive mechanisms for CP promotion.
State Council (2011b)	National 12th Five-year Comprehensive Work Scheme on Energy Saving and Emission Reduction	Requires governments to publish CP audit schemes and a list of enterprises that need to conduct a mandatory CP audit.
Standing Committee of the 11th NPC (2012)	Cleaner Production Promotion Law (Amended)	Perfects the mandatory CP audit system and enlarges the scope of enterprises carrying out mandatory CP audits.
MEP (2012)	12th Five-year Plan for Pollution Prevention and Control of Hazardous Wastes	Establishes requirements for conducting mandatory CP audits and disseminating cleaner processes and technologies in industries or enterprises involving hazardous waste.
MEP (2013)	12th Five-year Plan for Prevention and Control of Environmental Risks of Chemicals	Requires regular publication of a list of enterprises that need to conduct a mandatory CP audit; also strengthens and improves regulations and requirements aimed at enterprises producing, using, or discharging key chemicals that need to be prevented and controlled due to high accumulative risks or due to high potential for creating an environmental emergency.
State Council (2013a)	Atmospheric Pollution Prevention and Control Action Plan	Requires CP audits to be conducted in steel, cement, chemical, petrochemical, non-ferrous metal smelting, and other key industries. For key fields and weak points of energy-saving and emission-reduction, it requires CP technology transformation through use of advanced and applicable cleaner technologies, processes, and equipment. By 2017, the emission intensity of key industries should decrease by over 30% below 2012 values.
State Council (2013b)	Directive Opinions on Coordinating Contradiction in Industries with Acute Overcapacity	Requires optimization of an industrial structure and significant improvement of the level of CP and pollution control; the level of comprehensive utilization of resources could evidently be promoted within five years with substantial effort.

involves publication by local governments of a list of key enterprises required to conduct a mandatory CP audit, disclosure of environmental information and of CP audit results by the listed key enterprises, supervision of the implementation of mandatory CP audits, and if necessary, evaluation and approval of mandatory CP audit results by local governments (Standing Committee of the National People's Congress, 2002, 2012).

3.1. Scope and targets

The Cleaner Production Promotion Law of China clearly defines three categories of enterprises required to carry out mandatory CP audits. Category 1 includes those enterprises exceeding national or local discharge standards or total load control targets for pollutants set by the relevant local governments. Category 2 covers enterprises whose energy consumption per unit of product exceeds

sectoral limits of energy consumption. Category 3 includes all enterprises using toxic and hazardous materials in production or that discharge toxic and hazardous substances (Standing Committee of the National People's Congress, 2012).

3.2. Implementation procedure

The MEP is responsible for promoting and implementing the mandatory CP audit system. In this regard, it has issued a series of technical documents and regulations, establishing a promotion mode and workflow for the mandatory CP audit system (see Fig. 1). The implementation procedure is as follows:

- (1) *Confirmation and announcement of a list of enterprises required to conduct a mandatory CP audit.* A list of enterprises required to conduct a mandatory CP audit is proposed by

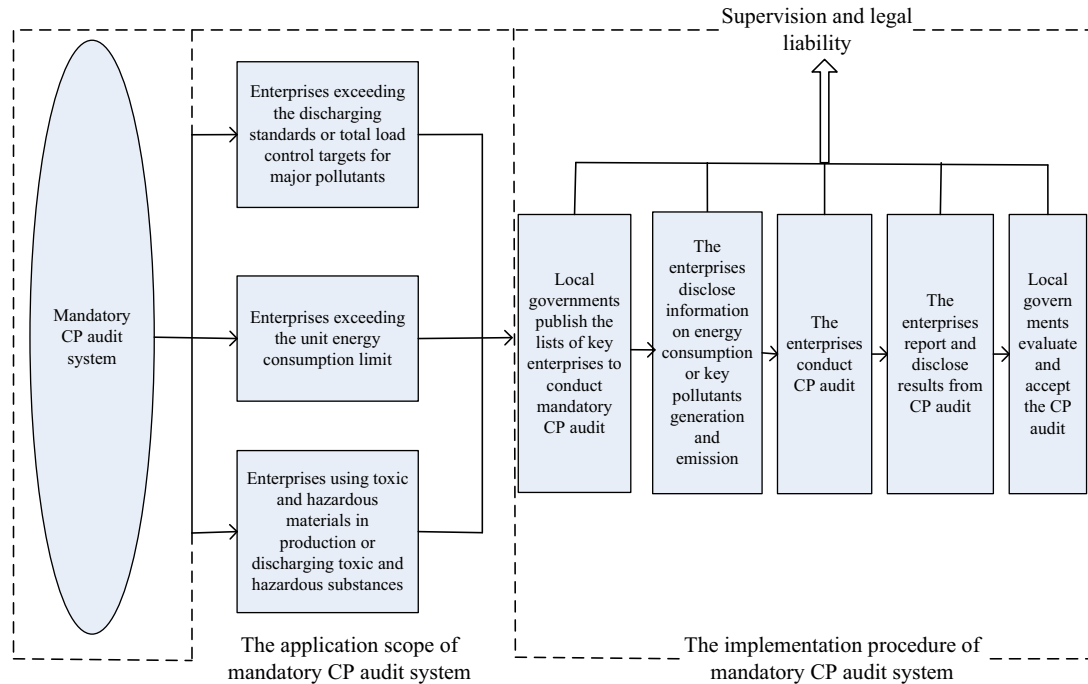


Fig. 1. Implementation procedure for mandatory CP audit system.

environmental protection departments at county level and above. The municipal environmental protection departments verify the list and report it to the provincial environmental protection departments for confirmation and announcement on media.

- (2) *Environmental information disclosure of listed enterprises.* Listed enterprises shall disclose their environmental information within one month of list publication for public review; this includes information on energy consumption and major pollutants generated and emitted.
- (3) *Carrying out of CP audits.* Enterprises are the main bodies responsible for carrying out CP audits. These can be organized and carried out on the enterprises' own initiative, or the enterprises can invite an appropriate CP service provider to assist with completion. Audit reports shall be submitted to local environmental authorities within one year after list publication, and the enterprises shall apply for evaluation by local authorities. Meanwhile, the results of the CP audit will be published via main media.
- (4) *Evaluation and acceptance of CP audit.* Environmental protection authorities or delegated technical support departments will evaluate and accept CP audits. Evaluation comprises a technical review of the CP audit procedure, of the final report, as well as of the feasibility of CP options; this is conducted immediately after completion of the CP audit. Acceptance occurs after all options have been implemented, to check implementation and effectiveness of all medium/high cost CP options proposed by enterprises during this round of CP audit.
- (5) *Supervision and punishment.* The relevant departments at each level of governments should supervise the implementation of mandatory CP audits. Punishments and penalties of up to half a million RMB (equivalent to about 81,000 USD) will be imposed on enterprises that fail to disclose environmental information, that fail to conduct a CP audit, or that report false results, as per the Cleaner Production Promotion Law.

3.3. System design

Government and enterprises are the two major players in the mandatory CP audit system. Enterprises carry out CP audits to contribute towards the safeguarding of public goods, i.e., the environment. The role of government is to provide guidance, supervision, and incentives; this is critical, as is public pressure for improved environmental quality.

- (1) *Mandatory requirements for government administration and the participation of enterprises*

First, local government is obliged to publish the list of enterprises required to carry out a mandatory CP audit, as per the Cleaner Promotion Law. Second, the enterprises in the list are required to disclose relevant environmental information to the public via media, to carry out a mandatory CP audit, and to report the results obtained to local government. Third, local government, if necessary, is obligated to evaluate the results and effects of CP audits completed by listed enterprises. If any government administration and/or listed enterprise fails to do the above, it would be punished by sanctions or fines, or would be required to bear criminal responsibility, or would be obliged to rectify the situation by a specified deadline, or other such measures.
- (2) *Information disclosure to create social and public pressure*

Information is one of the factors influencing the reaction of players in public goods games and sufficient information disclosure can guarantee that all players agree on a common strategy to control public resources with higher efficiency (Ostrom et al., 1994). In designing a mandatory CP audit system for China, information disclosure was therefore considered critical, involving government departments publishing the list of mandatory CP audit enterprises, and enterprises disclosing information on pollutants generated and emitted and on energy consumed, as well as the results from the CP audit. This information disclosure provides possibilities and opportunities for the public to supervise the

business of enterprises, consequently promoting continuous environmental performance improvement in industry through adoption of CP technologies, processes, and equipment, and through the promotion of environmental management.

(3) Encouragement measures and financial support to increase incentives to enterprises and related institutes

In a market economy, enterprises pursue profit maximization. In addition to the internal economic returns from the CP audit itself, external economic incentives are critical and create driving forces for enterprises to implement CP audits (Chen, 2003). The Chinese government has developed various economic incentive measures for CP. For instance, the government recognizes and rewards institutions and individuals that excel in CP. Enterprises using waste in accordance with related laws or using recycled raw materials from production waste enjoy specific tax benefits. Provincial environmental protection departments should provide for 10% or more of environmental protection special funds to be used for evaluation and acceptance of mandatory CP audits. There are also some sources of financial subsidies to cover the costs of CP audits and medium and high cost CP options; these include the pollutant discharge fee, energy saving and emission reduction funds, and CP special funds.

4. Results of mandatory cleaner production audit system

Various previous studies conducted during the initial stage of implementation of the CP Promotion Law have shown that ineffective vertical control, weak inter-agency coordination, and lack of alignment between CP requirements and the core missions and operating procedures of implementing agencies have impeded CP implementation (Geng et al., 2010). In the meantime, sustainable CP also requires enterprises, governments, and consultants to have the capacity to carry out CP projects, including by having access to a pool of qualified consultants and technical specialists and to financing schemes for CP implementation (Hicks and Dietmar, 2007).

Based on the above-mentioned studies, on policies and action plans, and on annual surveys conducted from 2008 to 2011, the effectiveness of mandatory CP audit systems in promoting CP in China has been evaluated on the basis of the four aspects below; this evaluation also considers integration of CP requirements and core missions:

4.1. Shift in environmental management strategies from end-of-pipe treatment towards pollution prevention

During the past five years, CP requirements have been directly included in various national core missions. The practice in implementation of mandatory CP audit systems promotes CP as an effective tool to achieve environmental protection targets and facilitates integration of CP into various national planning instruments, such as the Atmospheric Pollution Prevention and Control Action Plan, the National 12th Five-year Plan on Pollution Prevention and Control of Hazardous Wastes, the National 12th Five-year Plan on the Prevention and Control of Environmental Risks of Chemicals, and the National 12th Five-year Plan on Comprehensive Pollution Prevention and Control of Heavy Metals. All these plans put forward requirements for promoting CP.

The Atmospheric Pollution Prevention and Control Action Plan was approved by the State Council (2013a), indicating joint inter-agency coordination across various related ministries.

The action plan for heavy metals approved by the State Council (Ministry of Environmental Protection, 2011a) clearly stipulates the

promotion of “cleaner production with full support” and use of the mandatory CP audit as the major tool to prevent and control heavy metal pollution; this is also one of the indicators for checking planning performance. The MEP prepared a detailed procedure for evaluating the performance of mandatory CP audits and carried out an overall evaluation of mandatory CP audits completed by key enterprises using heavy metals in their production processes in all 31 provinces in China. In 2013, the implementation of mandatory CP audits was also integrated into the National Comprehensive Inspection on Pollution Prevention and Control organized by the MEP; this means that, in China, the mandatory CP audit has been effectively combined with key environmental protection tasks to improve overall pollution prevention in key industries.

4.2. Rapid increase in CP awareness

Since the CP Promotion Law came into force in 2003, the MEP has promoted, on a large scale, the mandatory CP audit system as a key pollution prevention strategy, with significant progress and effectiveness. Based on data collected from 2008 to 2012, Fig. 2 shows the number of enterprises included in the lists of provincial EPAs requiring mandatory CP audits, those conducting CP audits, audits passing the initial evaluation by local EPAs, and audits passing the final evaluation and being accepted by local EPAs. For example, the number of enterprises conducting CP audits was only 2027 in 2008, but increased drastically (five-fold) to 10,346. These enterprises include major heavily polluting industries in nearly all regions above county level in China. The majority of industries generating heavy metal pollution have carried out CP audits. Along with the promotion of mandatory CP audit systems, the CP awareness of governmental administrations, enterprises, and CP service providers has greatly increased, providing a firm foundation for further promotion of CP in China (Ministry of Environmental Protection, 2008b,2009,2010b,2011b).

4.3. Significant enhancement of CP capacity building

CP capacity building is a priority and provides a foundation for better promotion of CP. All-round implementation of a mandatory CP audit system has greatly enhanced CP capacity building.

4.3.1. CP centers being established from national to local levels

In addition to the national CP center (NCPC), more and more provinces and cities have established local CP centers (CPCs). Up to the end of 2012, there were 21 provincial CPCs and at least 18

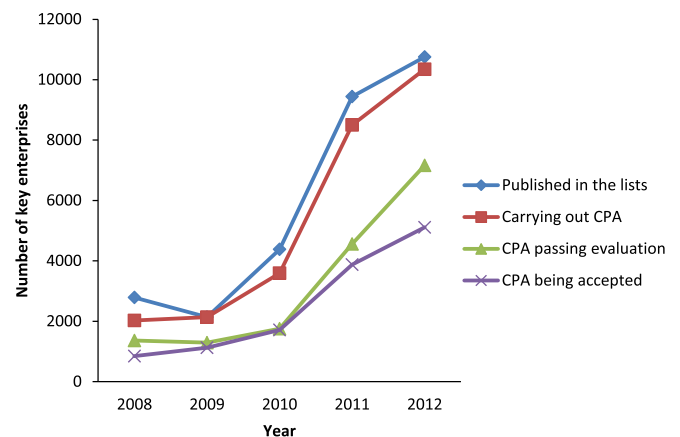


Fig. 2. Implementation of mandatory CP audits by key enterprises in China from 2008 to 2012.

municipal CPCs in China. Among these CPCs, the NCPC provides full-scale support to the MEP for CP policy, technical advice, and capacity building, and provides technical guidance to local CPCs. Most local CPCs play a similar role at local level.

4.3.2. A large number of CP professionals being trained

By the end of 2012, a total of 25,000 people had been trained nationally via five-day in-depth professional training courses, with the breakdown of participants by year (2001–2012) shown in Fig. 3. Participants have mainly originated from CP consulting service providers and from enterprises. These have come to form the main body of professionals responsible for implementation and promotion of CP in China. Additionally, several CP awareness-raising workshops have been organized by local authorities, with more than 50,000 people participating each year (Ministry of Environmental Protection, 2008b,2009,2010b,2011b; Standing Committee of the National People's Congress, 2010; China National Cleaner Production Center, 2012).

4.3.3. Number of CP service providers being engaged

To date, more than 90% of enterprises in China have engaged CP service providers to provide technical support in completing mandatory CP audits. The effectiveness of CP audits is thus largely dictated by the quality of capacities and services provided by CP consulting service providers. As shown in data collected, the number of CP consulting service providers has increased radically, from 9 at the very beginning of the process to 806 at the end of 2012 (Ministry of Environmental Protection, 2008b,2009, 2010b,2011b).

4.3.4. CP expert database being established and updated

At the national level, in 2007 the NDRC and MEP established the national CP expert database. Based on this, some provinces have also established their own CP expert databases. Based on incomplete statistics, there are at least 16 provinces that have established a provincial CP expert database, with 90 experts in each database on average. These CP experts play an important role in CP audits and in the evaluation of CP audits (Ministry of Environmental Protection, 2008b,2009,2010b,2011b).

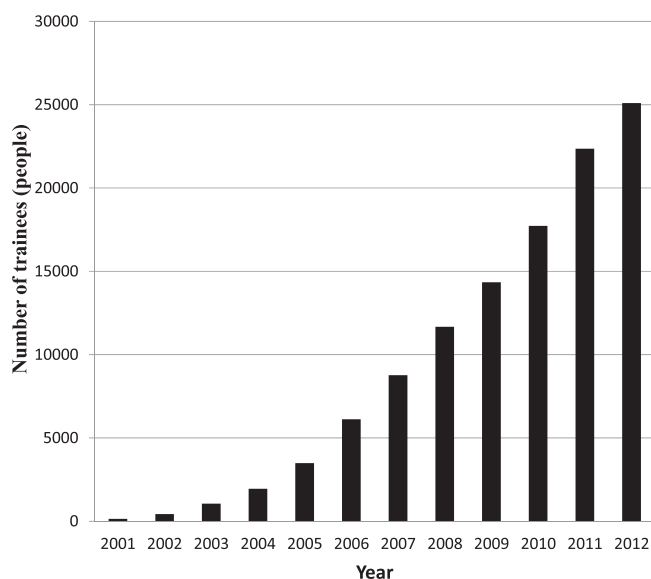


Fig. 3. CP Professionals being trained at national level from 2001 to 2012.

4.4. More and more financial input by enterprises being encouraged

The real effectiveness of CP audits can only be achieved when CP options generated from the CP audit are implemented. Based on statistics from 2009 to 2012, it can be seen that the mandatory CP audit system has, year by year, effectively encouraged enterprises included on mandatory lists to input more and more funds into the implementation of CP options, especially for high/mid cost options. Statistics also indicate that funds for this are mainly generated from the enterprises themselves, with little input from government (Ministry of Environmental Protection, 2008b,2009, 2010b,2011b) (Table 2).

4.5. Mandatory CP audits effectively promote resource efficiency and pollution reduction

Mandatory CP audits have been promoted in China for more than ten years and the number of enterprises carrying out CP audits has increased rapidly. The implementation of CP options effectively promotes resource and energy conservation and pollution reduction, and has produced significant economic and environmental benefits, as shown in Table 3; this outlines pollution reduction from 2008 to 2011 through the implementation of CP options.

5. Discussion and conclusion

It is most common worldwide for CP to be promoted on a voluntary basis. The concept of a mandatory CP audit system is a breakthrough and represents an innovative approach to CP regulation and policy as an element of overall pollution prevention and control strategies in China. In addition to voluntary CP audits, mandatory CP audits are required for key enterprises with higher resource consumption and emissions and that pose higher environmental risks; these audits can evidently guide industries in identifying opportunities for CP throughout the entire production process, increasing overall pollution prevention level. In the case of most developing countries where industrial pollution contributes most to environmental pollution and accidents and where some industries cannot meet national or local discharge or emission standards, the mandatory CP audit system can be referred to as a success story in the promotion of CP and industrial pollution prevention strategies.

The experience of promoting and implementing a mandatory CP audit system in China has shown that the legislative foundation is key. The Chinese CP Promotion Law has played a critical role in the establishment and implementation of the mandatory audit system. When considering the existing end-of-pipe-oriented environmental protection and management frameworks in force in most developing countries, only pollution prevention-oriented legislation can guarantee the establishment and continuous implementation and improvement of a mandatory CP audit system.

Based on the Chinese experience, various factors have been shown to play a critical role, including having clear liabilities and responsibilities of various governmental bodies, enhancing CP

Table 2
Financial input for CP options from 2009 to 2012.

Year	Source	
	Enterprises (million USD)	Governments (million USD)
2009	1930	22.6
2010	2550	45.2
2011	5090	51.6
2012	6430	17.7

Table 3

Resource conservation and pollution reduction through implementation of cleaner production options from 2008 to 2011.

Year	Items				
	Water saved (billion tons)	Energy saved (billion kWh)	Chemical oxygen demand (COD) reduced (ten thousand tons)	SO ₂ reduced (ten thousand tons)	Economic benefits (billion USD)
2008	1.52	4.31	7.3	32.2	1.65
2009	0.41	2.62	6.4	27.7	1.86
2010	1.02	3.72	6.2	14	2.06

capacity at management and technical levels, having a standardized system for supervision of CP practices, comparative informational transparency, and active involvement of industry. The experience of China also suggests that the mandatory CP audit system should be promoted at different stages and in different regions, step by step. While promoting the mandatory CP audit within heavily polluting industries, attention should also be paid to promoting voluntary CP audits in other industries. In addition to considering the number of enterprises carrying out a CP audit mandatorily, attention should also be paid to quality and real effectiveness at industry level.

The design of a mandatory CP audit system in China represents an example of collective control and management policy for public goods, the latter including resources and the environment. Based on the results of the mandatory CP audit system, more and more enterprises have been pushed to cooperate in CP initiatives and the overall CP level of industries has improved. Perc and Szolnoki (2010) conclude that while focusing predominantly on resolving social dilemmas, co-evolutionary rules have thus far not been considered for public goods games. The design and implementation of a mandatory CP audit system to some degree represents a real case for the initial study of co-evolution in public goods games. The story demonstrates to some extent the effectiveness of collective control of resources and the environment by government, so as to avoid the tragedy of the commons in developing countries. However, there are still barriers to promotion of the mandatory CP audit system in China; for instance, some listed industries are unwilling to carry out a CP audit, the benefits from a CP audit can be hard to calculate, and there have been governmental weaknesses in punishing some defectors. Future studies should therefore focus on how to use co-evolutionary rules and positive results from public goods games to promote stable cooperative relationships within groups when there are powerful compulsory regulations from outside the groups, so as to urge more and more enterprises to implement CP initiatives voluntarily and to pursue the maximization of public welfare.

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