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Assessment of China's Energy-Saving and Emission-Reduction Accomplishments and Opportunities During the 11th Five Year Plan

Mark D. Levine, Lynn Price, Nan Zhou, David Fridley, Nathaniel Aden, Hongyou Lu, Michael McNeil, Nina Zheng, Qin Yining
China Energy Group, Energy Analysis Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

Ping Yowargana
Azure International - Beijing

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ABSTRACT

During the period 1980 to 2002, China experienced a 5% average annual reduction in energy consumption per unit of gross domestic product (GDP). The period 2002-2005 saw a dramatic reversal of the historic relationship between energy use and GDP growth: energy use per unit of GDP increased an average of 3.8% per year during this period (NBS, various years). China's 11th Five Year Plan (FYP), which covers the period 2006-2010, required all government divisions at different levels to reduce energy intensity by 20% in five years in order to regain the relationship between energy and GDP growth experienced during the 1980s and 1990s. This report provides an assessment of selected policies and programs that China has instituted in its quest to fulfill the national goal of a 20% reduction in energy intensity by 2010. The report finds that China has made substantial progress toward its goal of achieving 20% energy intensity reduction from 2006 to 2010 and that many of the energy-efficiency programs implemented during the 11th FYP in support of China's 20% energy/GDP reduction goal appear to be on track to meet – or in some cases even exceed – their energy-saving targets. It appears that most of the Ten Key Projects, the Top-1000 Program, and the Small Plant Closure Program are on track to meet or surpass the 11th FYP savings goals. China's appliance standards and labeling program, which was established prior to the 11th FYP, has become very robust during the 11th FYP period. China has greatly enhanced its enforcement of new building energy standards but energy-efficiency programs for buildings retrofits, as well as the goal of adjusting China's economic structure to reduce the share of energy consumed by industry, do not appear to be on track to meet the stated goals. With the implementation of the 11th FYP now bearing fruit, it is important to maintain and strengthen the existing energy-saving policies and programs that are successful while revising programs or adding new policy mechanisms to improve the programs that are not on track to achieve the stated goals.

评估中国“十一五”计划期间节能减排的成就与机遇

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摘要

从 1980 年至 2002 年，中国经历了万元 GDP（国内生产总值）能耗年均降低 5%的过程。从 2002 年至 2005 年，能耗与 GDP 增长关系的历史趋势出现了巨大的逆转：万元 GDP 能耗在此阶段年均增长 3.8%。中国的“十一五”计划，从 2006 年到 2010 年，要求不同层面上的所有政府部门在五年内降低能耗强度 20%，从而获得，八十年代和九十年代中国所实现的能耗与 GDP 增长之间的和谐关系。这份报告对所选的一些政策和项目进行评估，这些政策和项目是中国政府为了实现到 2010 年降低能耗强度 20%的目标而设立的。研究结果表明，中国在实现降低 20%目标的过程中有实质性的进展，“十一五”计划期间实施的许多能效项目似乎也正走在实现其节能目标的轨道上，有的项目的节能量甚至已经超过了其节能目标。从结果看来，似乎大部分的十大重点节能工程，千家企业节能行动，关闭小火电和淘汰落后产能项目都在实现或超过他们“十一五”节能目标的轨道上。中国家电标准和能效标识项目，在“十一五”计划前已成立，但在“十一五”计划期间表现得更为强健。中国大大加强了新建建筑节能标准，但是既有建筑更新改造和中国经济结构调整（从而降低工业能耗比重）的目标似乎并没有在实现其目标的轨道上。这份报告进一步发现，成功主要是由于能源效率或节能的提高，而这些提高目前来说弥补了结构调整上缺乏成功的不足因素。“十一五”计划的实施已有成果，进一步维持并加强那些成功的既有节能政策和项目是很重要的。同时，也进一步改进已有项目或增添新的政策机制来改善目前没有完成节能目标的项目。

Executive Summary

Assessment of China's Energy-Saving and Emission-Reduction Accomplishments and Opportunities During the 11th Five Year Plan

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During the period 1980 to 2002, China experienced a 5% average annual reduction in energy consumption per unit of gross domestic product (GDP). The period 2002-2005 saw a dramatic reversal of the historic relationship between energy use and GDP growth: energy use per unit of GDP increased an average of 3.8% per year during this period. China's 11th Five Year Plan (FYP), which covers the period 2006-2010, required all government divisions at different levels to reduce energy intensity by 20% in five years in order to regain the relationship between energy and GDP growth experienced during the 1980s and 1990s.

The primary purpose of the 11th FYP target was to reverse China's 2002-2005 trend of increasing energy intensity of GDP growth. The baseline for evaluating 2006 to 2008 energy performance in this report is calculated based on 2005 energy intensity, i.e. what energy consumption would have been in these years if amount of energy per unit GDP remained constant. In this approach, achieved energy savings are equal to the difference between the counterfactual frozen 2005 energy intensity baseline and reported actual energy consumption. The frozen 2005 energy intensity baseline was calculated by multiplying the 2005 energy intensity value of 0.1226 kgce/RMB by the GDP values for each year in order to derive the energy consumption that would have occurred if the 2005 energy intensity had not declined during the 2006-2008 period (see Table ES-1). According to this methodology, China achieved a 10% reduction of total energy intensity of GDP growth between 2005 and 2008, which resulted in ~530 Mtce less cumulative energy use than would have been the case if energy intensity had remained constant.

Table ES-1. Frozen 2005 Energy Intensity Baseline and Reported Energy Use (2005-2008)

Indicator	Unit	2005	2006	2007	2008
Frozen 2005 Energy Intensity	Kgce/RMB	0.1226	0.1226	0.1226	0.1226
GDP	Billion 2005 RMB	18,322	20,449	22,982	25,848
Frozen Baseline Energy	Mtce	2,247	2,508	2,818	3,170
Annual Energy Difference	Mtce	0	45	162	320
Cumulative Energy Difference	Mtce	0	45	207	527

This report provides an assessment of selected policies and programs that China has instituted in its quest to fulfill the national goal of a 20% reduction in energy intensity by 2010 (originally announced as "20% more or less" (20%左右). The report finds that China has made substantial progress toward its goal of achieving 20% energy intensity reduction from 2006 to 2010 and that many of the energy-efficiency programs implemented during the 11th FYP in support of China's 20% energy/GDP reduction goal appear to be on track to meet – or in some cases even exceed – their energy-saving targets.

Table ES-2 provides information on the primary energy savings identified for each of the programs reviewed in this report. It appears that most of the Ten Key Projects, the Top-1000 Program, and the

Small Plant Closure Program are on track to meet or surpass the 11th FYP savings goals. China's appliance standards and labeling program, which was established prior to the 11th FYP, has become very robust during the 11th FYP period. China has greatly enhanced its enforcement of new building energy standards but energy-efficiency programs for buildings retrofits, as well as the goal of adjusting China's economic structure to reduce the share of energy consumed by industry, do not appear to be on track to meet the stated goals. The report further finds that the successes are mainly due to increases in energy efficiency or energy conservation; these increases have been sufficient to overcome the lack of success in achieving structural change.

Table ES-2. 11th FYP Energy-Saving Targets and Savings to Date, 2006-2008, Based on Frozen 2005 Efficiency Baseline

Policy/Program	11th FYP Target	Savings to Date 2006-2008
	Primary Energy (Mtce)	
Ten Key Projects	268	102
Buildings Energy Efficiency	112	41
Top-1000 Program	130	124
Small Plant Closures	118	129
Appliance Standards	79	37
Other savings including provincial programs	1146	147
Total Primary Energy Savings	**1709**	**527**

Note: Individual program savings do not add up to the Total Primary Energy Savings value because of overlap between the Ten Key Projects and the Buildings Energy Efficiency and Top-1000 Programs. See report for details regarding how the total primary energy savings was calculated.

It was difficult to adequately assess the progress of the energy-efficiency programs implemented in support of the 11th FYP in detail due to lack of publicly-available systematic reporting and monitoring of these programs. In addition, the information that is available is often reported in units that are not clearly defined, programmatic targets are not clearly delineated as to whether they represent annual or cumulative savings goals through 2010, and conflicting and difficult to interpret information is provided through interviews, reports, and websites. Further, the overall 20% energy/GDP target is a relative target (ratio of energy to economic output), while most of the targets for the individual programs are absolute targets.

This report makes the following recommendations:

Overall

- Maintain existing policies and programs that are successful, including the overall energy savings goal
- Add explicit mechanisms to promote structural change
- Continue to build the National Energy Conservation Center to facilitate information dissemination and training
- Strengthen the capacity of provincial energy conservation centers
- Build capacity to systematically collect and analyze data focused on end-use energy consumption

20% Target

- Continue with 20% Energy Intensity Target
- Allocate target more scientifically, including a bottom-up analysis of energy saving potential
- Add a target for Carbon Intensity

Monitoring, Reporting, Verification

- Create a consistent and transparent system for gathering and analyzing data on energy intensity
- Increase the level of public reporting regarding energy-saving policies and programs
- Standardize the metrics for targets and reporting
- Establish systematic annual data reporting on greenhouse gas emissions

Program Design

- Improve the design phase for energy-saving projects

Buildings Energy Efficiency

- Revise the approach to existing building energy retrofits in cold climates, treating building envelope, control systems, and heat supply together
- Expand the enforcement of building energy standards that have been effective in large urban areas to the rest of the nation improve building energy labels and provide incentives for "green building"
- Continue to place large emphasis on energy management of large-scale public and governmental buildings
- Enhance policy design and effectiveness through expanded surveys, monitoring and establishing meaningful baselines of building energy consumption/efficiency

Industrial Energy Efficiency

- Continue and expand the Top-1000 Program
- Targets should be determined based on energy-saving potential of enterprise or sector
- Energy auditing capabilities need to be improved
- Benchmarking could be simplified so that it can be used by more industries
- Reporting and evaluation need to be strengthened
- Dissemination of information on energy-saving opportunities and experiences is needed

Structural Optimization

- Promote opportunities for structural change within industries
- Address local concerns about small plant closures through further development of transition plans
- Combine market mechanisms with administrative measures
- Create additional mechanisms explicitly focused on structural change

Appliance Standards and Energy-Efficiency Labels

- Revise and strengthen energy performance standards for appliances
- Undertake regular national surveys of energy end-use to assess program effectiveness
- Provide further support for enforcement of existing programs
- Clarify the relationship between mandatory and voluntary efficiency labels
- Increase participation in international networks for enforcement of appliance standards

With the implementation of the 11th FYP now bearing fruit, it is important to maintain and strengthen the existing energy-saving policies and programs that are successful while revising programs or adding new policy mechanisms to improve the programs that are not on track to achieve the stated goals.

执行报告

评估中国“十一五”计划期间节能减排的成就与机遇

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“十一五”计划的首要目标是扭转中国在 2002 年到 2005 年间能耗强度随 GDP 增长而上升的趋势。在这份报告中评估 2006 年至 2008 年能耗情况的基线情景，是基于 2005 年的能耗强度，即如果能耗强度维持不变，在这一阶段将会消耗多少能源。通过这种方法，最终实现的能源节省量，就等于反事实基线情景（保持 2005 年能耗强度不变）与报道的实际能耗之间的差额。以 2005 年能耗强度为不变能耗强度的基线，可通过以下方法计算得出：用 2005 年能耗强度，即 0.1226 千克标煤/元（人民币），乘以当年的 GDP，从而得出如果能耗强度没有下降，在 2006 年到 2008 年会出现的能源消耗（见表 1 *表*）。根据这种方法，中国在 2005 年到 2008 年间能耗强度降低了 10%，与能源强度保持不变的情况相比，实现累计节能量约为 5.3 亿吨标煤。

表 1. 2005 年能耗强度不变的基准线情景与报道的能源消耗（2005-2008）

指 标	单位	2005	2006	2007	2008
2005年能耗强度	千克标煤/元	0.1226	0.1226	0.1226	0.1226
GDP	十亿元（2005年价格）	18,322	20,449	22,982	25,848
基准线情景下的能耗	百万吨标煤	2,247	2,508	2,818	3,170
年度能耗差额	百万吨标煤	0	45	162	320
累计能耗差额	百万吨标煤	0	45	207	527

这份报告对所选的一些政策和项目进行评估，这些政策和项目是中国政府为了实现到 2010 年降低能耗强度 20%的目标（公布的目标是降低能耗强度“20%左右”）而设立的。研究结果表明，中国在实现降低 20%目标的过程中有实质性的进展，“十一五”计划期间实施的许多能效项目似乎也正走在实现其节能目标的轨道上，有的项目的节能量甚至已经超过了其节能目标。

表 2 中给出了这份报告所评估的每个项目的一次能源节省量。从结果看来，似乎大部分的十大重点节能工程，千家企业节能行动，关闭小火电和淘汰落后产能项目都在实现或超过他们“十一五”节能目标的轨道上。中国家电标准和能效标识项目，在“十一五”计划前已成立，但在“十一五”计划期间表现得更为强健。中国大大加强了新建建筑节能标准，但是既有建筑更新改造和中国经济结构调整（从而降低工业能耗比重）的目标似乎并没有在实现其目标的轨

道上。这份报告进一步发现，成功主要是由于能源效率或节能的提高，而这些提高目前来说弥补了结构调整上缺乏成功的不足因素。

表 2. “十一五”计划节能目标和当前实现的节能量，2006-2008 年，基于维持 2005 年能源强度不变的基线情景

政策/项目	“十一五”目标	当前节能量 2006-2008
	一次能耗 (百万吨标煤)	
十大重点节能工程	268	102
建筑节能	112	41
千家企业节能行动	130	124
关闭小火电和淘汰落后产能	118	129
家电标准	79	37
其他节能量（包括省级项目）	1146	147
一次能耗节能总量	**1709**	**527**

注：单一项目的节能量之和并不等于一次能耗节能总量，这是因为十大重点节能工程、建筑节能和千家企业节能行动之间有重复的部分。报告中有关于一次能耗节能总量的详细计算。

由于这些能效项目缺乏公开的且系统的报道和监测，充分细致地评估这些项目的进展情况是困难的。从可获得的信息来看，报道的计量单位通常没有准确的界定，项目目标也缺乏清晰的描述，即这些目标是否为每年的年度目标，还是代表到 2010 年为止所应实现的累计节能目标，而且通过采访、报道和网页得到的信息有互相冲突的情况，难以解读。此外，降低 GDP 能耗强度 20%的总体目标是一个相对目标（即能耗与经济产出的比值），但大多数单个项目的目标却是绝对目标值。

这份报告做出以下的建议：

整体

- 维持成功的既有政策和项目，包括总体节能目标
- 加入明确的机制推动结构调整
- 继续建立国家节能中心的进程，促进信息的传播与培训
- 加强省级节能中心的能力建设
- 加强能力建设，对终端用能情况系统地收集并分析数据

20% 的节能目标

- 继续保持降低能耗强度 20%的目标
- 更科学地分配目标，包括从下至上的节能潜力分析方法
- 加入碳排放强度的目标

监测、上报、验证

- 建立一个有连贯性的透明的收集和分析能耗数据的系统
- 增加关于节能政策和项目公开报道的程度
- 对目标和上报的度量制度进行标准化
- 建立关于温室气体排放的年度数据上报系统

项目设计

- 改进节能项目的设计阶段

建筑节能

- 改善在严寒和寒冷地区推行既有建筑更新改造的方法，整合处理围护结构、控制系统与供暖系统
- 将已在大城市中生效的建筑节能标准扩展到全国，改进建筑能效标识，并为“绿色建筑”提供激励
- 继续强调大型公共和政府建筑的能源管理
- 通过调查的扩大和深入，监测系统和为建筑能耗/能效建立有意义的基准线，来增强政策设计和有效性

工业节能

- 继续保持并扩大千家企业节能行动
- 目标的确立应该基于企业或行业的节能潜力
- 能源审计的能力需要得到提高
- 可进行简化的对标从而应用于更多的工业部门
- 加强数据上报和评估
- 需要传播有关节能机会和节能经验的信息

结构优化

- 在行业内部增加结构调整的机会
- 通过进一步制定过渡方案解决地方对淘汰落后产能的顾虑
- 将行政手段和市场机制相结合
- 建立另外的机制，明确针对结构调整

家电标准和能效标识

- 调整并加强家电能源性能标准
- 对终端能耗进行定期的全国性调查以评估项目的有效性
- 进一步对已有项目的实施执行提供支持
- 明确能效标识和节能认证标志之间的关系
- 增强国际联系网络在家电标准实施中的参与程度

“十一五”计划的实施已有成果，进一步维持并加强那些成功的既有节能政策和项目是很重要的。同时，也进一步改进已有项目或增添新的政策机制来改善目前没有完成节能目标的项目。

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Acronyms

ASQIQ	General Administration of Quality Supervision, Inspection and Quarantine
AWD	adaptive weighted Divisia
BF	blast furnace
BOC	Bank of China
BOF	basic oxygen furnace
Btu	British thermal unit
CADDET	Centre for Analysis and Dissemination of Demonstrated Energy Technologies
CBECS	Commercial Buildings Energy Consumption Survey
CDQ	coke dry quenching
CECA	China Energy Conservation Association
CHP	combined heat and power
CNIS	China National Institute of Standardization
CO_2	carbon dioxide
CPC	Communist Party of China
DOE	Department of Energy
DRC	Development and Reform Commission
EE	energy efficiency
EEI	energy efficiency index
EER	energy efficiency ratio
EMAS	Eco-Management and Auditing Scheme
EPAct	Energy Policy Act of 1992
ESCOs	energy service companies
EU	European Union
FYP	Five Year Plan
g	grams
GDP	gross domestic product
GJ	gigajoule
GW	gigawatts
GWh	gigawatt hours
HVAC	heating, ventilation, and air conditioning
IAC	Industrial Assessment Center
IEA	International Energy Agency
ISO	International Standardization Organization
kgce	kilogram coal equivalent
kW	kilowatt
kWh	kilowatt hour
LBNL	Lawrence Berkeley National Laboratory
LEAP	Long Range Energy Alternatives Planning
LED	light emitting diode
LTA	Long-Term Agreement
LTA2	Long-Term Agreements 2
M&V	monitoring & verification
m^2	square meters
m^3	cubic meters
MBtu	million British thermal units
MEPS	minimum energy performance standards

MIIT	Ministry of Industry and Information Technology
MOF	Ministry of Finance
MOHURD	Ministry of Housing and Urban/Rural Development
Mt	million tons
Mtce	million tons of coal equivalent
$MtCO_2$	million tons carbon dioxide
$MtCO_2e$	million tons carbon dioxide equivalent
MW	megawatt
N.A.	not available
NBS	National Bureau of Statistics
n.d.	no date
NDRC	National Development and Reform Commission
NOVEM	Dutch Agency for Energy and Environment
NSP	new suspension preheater
RE	renewable energy
RECs	Residential Energy Consumption Survey
RMB	Renminbi
SAVE	Specific Actions for Vigorous Energy Efficiency
SI	Standard International
S&L	standards and labeling
SO_2	sulfur dioxide
STEM	Swedish National Energy Administration
tce	ton coal equivalent
TRT	top pressure recovery turbine
TWh	terawatt hours
UK	United Kingdom
U.S.	United States
UEC	unit energy consumption
VSK	vertical shaft kilns
WTO	World Trade Organization

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1. Introduction

During the period 1980 to 2002, China experienced a 5% average annual reduction in energy consumption per unit of gross domestic product (GDP). Government policies and programs implemented during this period focused on strict oversight of industrial energy use, provision of financial incentives for energy-efficiency investments, provision of information and other energy-efficiency services through over 200 energy conservation service centers spread throughout China, energy-efficiency education and training, and research, development, and demonstration programs (Sinton et al., 1998;Sinton et al., 1999; Sinton and Fridley, 2000; Wang et al., 1995). Since energy demand grew less than half as fast as GDP, the need for investment in energy supply was reduced and capital could be used for other investments that supported important social goals. This exceptional emphasis on energy efficiency provided many benefits to China and, in terms of energy-related carbon dioxide (CO_2) emissions and reduced stress on global energy resources, to the world.

The period 2002-2005 saw a dramatic reversal of the historic relationship between energy use and GDP growth: energy use per unit of GDP increased an average of 3.8% per year during this period (NBS, various years). Beginning in November 2005, senior leaders in the Chinese Communist Party and government called on China to reduce energy intensity by 20% in five years in order to regain the relationship between energy and GDP growth experienced during the 1980s and 1990s. China's 11th Five Year Plan (FYP), which covers the period 2006-2010, required all government divisions at different levels to ensure the achievement of this binding energy conservation target and established specific energy-efficiency targets for electricity generation, selected industrial processes, appliances, and transport.

This report provides an assessment of selected policies and programs that China has instituted in its quest to fulfill the national goal of a 20% reduction in energy intensity by 2010.[1] It begins with an overall assessment of the energy use and energy savings achieved through 2008. Next, China's energy use is further evaluated and the relative contributions of activity increases and energy intensity improvements are assessed. Specific policies are then evaluated in terms of energy savings and accomplishment of stated policy goals. Where applicable, Chinese policies and programs are compared to similar programs found in other countries. Finally, recommendations regarding possible improvements to the current policies and programs are provided related to the remaining two years of the 11th FYP and additional recommendations are made related to possible energy-saving activities in the upcoming 12th FYP.

[1] It is noted that the goal was originally announced as "20% more or less" (20%左右).

2. Methodology

Program or policy evaluation is typically undertaken only periodically to investigate why and how things happened within a program and to what extent results are related to policies or other program activities. Evaluations assess programs to determine if they have met goals outlined at the initiation of the program as well as to assess what happened within the program. Evaluations done during the course of a program can provide recommendations to make adjustments and evaluations at the end of a project can identify lessons learned for the design of future programs (Schiller, 2007).

According to the *National Action Plan for Energy Efficiency's Model Energy-Efficiency Program Impact Evaluation Guide* prepared for use in the United States but applicable anywhere, there are three types of evaluations of a program: impact evaluations, process evaluations, and market effects evaluations. Impact evaluations determine how well a program did over a period of time or at the end of the program in terms of savings from technical, economic and market acceptance perspectives. These evaluations are then used to help redesign the program or design future programs. Process evaluations assess how efficiently a program was or is being implemented compared to its stated objectives, with the goal of learning lessons for future programs. Market effects evaluations estimate a program's future effects in the marketplace. The *Model Energy-Efficiency Program Impact Evaluation Guide* provides information and strategies for calculating energy savings and avoided emissions, as well as how to address issues like free-ridership, co-benefits, and uncertainties (Schiller, 2007).

A recent evaluation of the 11th Five Year Plan by the World Bank focused on program implementation and based its assessment on data and policy reviews, assessment of background studies, and interviews with government officials, academics, and others. The evaluation methodology involved describing the situation before the 11th FYP, outlining the key objectives in the 11th FYP, and evaluating the progress to date related to quantitative objectives, indicators, policies, and reforms. Conclusions were made regarding progress and challenges. Suggestions were offered regarding possible policy adjustments for the 11th FYP as well as for future FYPs (World Bank, 2008).

Another evaluation of the 11th FYP – by the Development Research Center of the State Council – does not explicitly define its methodology or information sources, but provides an assessment of the performance of achieving energy conservation and emission reduction targets in the 11th FYP, followed by an evaluation of the main areas where the energy savings occurred. The study also identified areas where progress was not achieved at the level originally planned. The study then provides a description of the major policy measures and an "effectiveness evaluation" and concludes with recommendations and detailed suggestions for policy directions for the second half of the 11th FYP (Feng Fei et al., n.d.).

The evaluation presented in this report was conducted as follows. First, an assessment was made of the overall energy savings attributed to the 11th FYP during the 2006-2008 period. A baseline was developed, as well as estimates of savings from individual policies and programs. Next, annual energy savings were decomposed to begin to understand the relative contributions of structural change and energy efficiency. Finally, a number of individual programs or policies were evaluated in more detail to assess their overall energy savings as well as to determine whether they are meeting their stated goals. More details regarding each of these three components of this evaluation are provided below.

2.1 Assessment of Energy Savings

There is no single path to achievement of China's 11th FYP energy intensity reduction targets. Intensity can be reduced with increasing or decreasing total energy use, depending on the level of annual GDP growth. Growing attention to energy efficiency performance has accelerated the release, updating, and revision of energy consumption, GDP, and energy intensity of GDP data in China. However, reports of these three inter-related data have not always been consistent. For example, energy consumption and GDP data reported by the National Bureau of Statistics (NBS) do not always accord with energy-intensity of GDP reductions reported by the National Development and Reform Commission (NDRC). Given that the primary focus of the 11th FYP is on energy intensity reduction, this study takes those data as input to calculate consistent energy and GDP numbers.

China's energy use is then decomposed to understand the relative contribution of changes in economic activity and in the efficiency of energy use. The adaptive weighted Divisia (AWD) methodology presented in Ang et al. (1992) for energy decomposition is used for this evaluation. This methodology was chosen because the parameters used are not subjective and there is no residual term. Appendix A outlines the methodology in more detail.

In order to assess the impact of energy-saving policies and programs that were implemented during the 11th FYP period, it is necessary to estimate the level of energy consumption that would have occurred in China without these policies and programs. This so-called "counterfactual baseline" can only be estimated since it describes a situation that did not happen – in this case, energy use if China had not adopted its 20% intensity reduction. In this baseline, the energy use relative to GDP is based on that of 2005, consistent with an assumption of continuing increases in energy efficiency offset by continuing growth of heavy industry relative to other economic sectors. The analysis estimated the difference in actual energy use and the energy use of a case in which the 2005 energy intensity (energy use/unit of GDP) is assumed to remain constant in 2006, 2007, and 2008. This 2005 intensity baseline was then compared to both energy savings as reported by official announcements and evaluations and to program- or policy-specific evaluations undertaken as part of this study to determine the savings attributable to the 11th FYP programs versus the savings that would have occurred in the absence of these programs.

2.2 Policy Evaluation 2005-2008

The policy evaluation in this report is conducted in three steps. First, the policy or program is described, including the end-use sectors that are covered. The stated policy or program goals are explained and reported results to date are identified. Second, a quantitative evaluation is made in which a baseline for the specific policy or program is developed and the energy savings are calculated from the baseline. Third, a qualitative evaluation is undertaken in which the current level of progress is compared to the stated policy or program goals, including an evaluation of whether the program features and components were carried out successfully and whether the program savings are in line with the stated goals. If applicable, the policy or program implementation is then compared to international "best practice" to determine whether specific elements were undertaken in a manner consistent with programs found in other countries.

2.3 Energy Units and Conversion Factors

Energy use and energy savings are reported in Chinese units of standard coal equivalent (sce); values are typically expressed as metric tons of coal equivalent (tce) and million metric tons of coal equivalent (Mtce). One tce equals 29.27 gigajoules (GJs) and 27.78 million British thermal units (MBtus).

Energy use and energy savings are reported in both final (site) and primary (source) values that reflect electricity conversion efficiencies as well as transmission and distribution losses. To convert electricity to a final (site), coal equivalent value, the conversion factor of 0.1229kilogram coal equivalent (kgce)/kilowatt hour (kWh) is used. To convert electricity to a primary (source) coal equivalent value, the conversion factor of 0.404 kgce/kWh is used. [2]

CO_2 emissions are expressed in kilotonnes of CO_2. The conversion factors used for calculating CO_2 emissions from energy consumption are taken from the 2006 Intergovernmental Panel on Climate Change *Guidelines for National Greenhouse Gas Inventories* (IPCC 2006). The emission factor for grid electricity is assumed to be 0.85305 kg CO_2/kWh (NBS, 2007).[3]

	Metric Ton Coal Equivalent	**Gigajoules**	**Million British Thermal Units**	**CO_2 Emissions (tCO_2)***
Energy	1	29.27	27.78	2.77
	Metric Ton Coal Equivalent	**Site Electricity (kWh)**	**Source Electricity (kWh)**	**CO_2 Emissions (tCO_2)**
Electricity	1	8137	2475	2.11

* bituminous coal

Costs are reported in Chinese Renminbi (RMB) and U.S. dollars. To convert the costs from US$ to RMB, the conversion factor of 6.84 RMB/US$ is used (BOC, 2009).

Energy savings and CO_2 emissions reductions from programs and policies are reported both as year-to-year annual savings and as annual cumulative incremental savings. For this report, annual cumulative incremental savings are defined as the savings from the previous year added to the savings of the current year.

For example, the savings of 20 Mtce in 2006 from a hypothetical program shown in Figure 1 are added to the savings of 40 Mtce realized in 2007, for an annual cumulative incremental savings of 60 Mtce in 2007 since the 20 Mtce saved in 2006 are still not being consumed (or emitted) in 2007. In 2008, the annual cumulative incremental savings are 40 Mtce saved in 2008 added to the 40 Mtce saved in 2007 and the 20 Mtce saved in 2006 for a total annual cumulative incremental savings of 100 Mtce. It can be argued that the cumulative program savings in 2008 are 20 Mtce for 2006 added to 60 Mtce for 2007 and 100 Mtce for 2008, but this method of adding the savings is not adopted for this report.

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[2] Transmission and distribution (T&D) losses for China's power grid are 7.55% (Kahrl and Roland-Holst, 2006), while average net generation efficiency of fossil fuel-fired power plants in 2009 is 35.20% (NBS, 2008). The national average efficiency of thermal power generation including the T&D loss is 32.55%. Therefore, the actual conversion coefficient from final to primary electricity is 3.07, which would result in lower primary electricity values than those calculated using 0.404 kgce/kWh.

[3] We note that NDRC's Climate Department has released grid-specific electricity emissions factors (http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2413.pdf). This report, however, uses a national average electricity emissions factor.

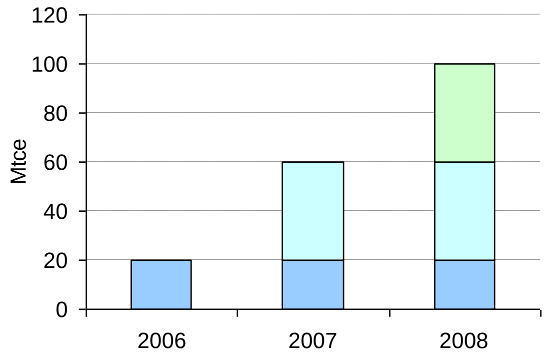


Figure 1. Methodology for Calculating Cumulative Incremental Energy Savings

3. Assessment of Energy Use and Energy Savings During the 2006-2008 Period

After the initiation of institutional reform and opening in the late 1970's, China's energy intensity – defined as energy use per unit of GDP - dropped for more than 20 years. This trend was reversed by the rise of energy intensity of GDP between 2002 and 2005. Given these two countervailing trends, it is an open question as to how energy intensity would autonomously vary from 2005 forward. On the one hand, efficiency improvements and technological innovation should lead to a decline in the amount of energy consumed per unit GDP; on the other hand, reliance on coal and structural shifts to heavy industry would increase energy intensity. It is impossible to know the evolution of energy demand after 2005 if China had not adopted its 20% energy intensity reduction policy.

A constant (2005) energy intensity case has been chosen for this report for the "counterfactual baseline" for two reasons: (1) such a case is intermediate between the rapidly growing energy demand of the immediate preceding three years and the much slower energy demand of the previous decade and longer and (2) it is reasonable to expect that energy efficiency improvements in the 2002-2005 high growth period would continue but that the growth of heavy industry would be moderated somewhat (and in this case counterbalance energy efficiency gains). In this top-down, aggregate analysis, energy efficiency performance improvements are broadly attributed to national policy intervention.

Table 1 provides energy, GDP, and energy intensity data for 2005 through 2008. Energy use values are reported by NBS (NBS, 2007; NBS 2008). Energy intensity reduction values are from NDRC (NDRC, 2009a; NDRC, 2009b).[4] GDP values were then derived using these two values. This method was chosen because the energy values and energy intensity reduction values were the most clearly reported values; GDP values have undergone a series of revisions and may continue to be revised.

Table 1. Energy Use, Energy Intensity, and GDP Data (2005-2008)

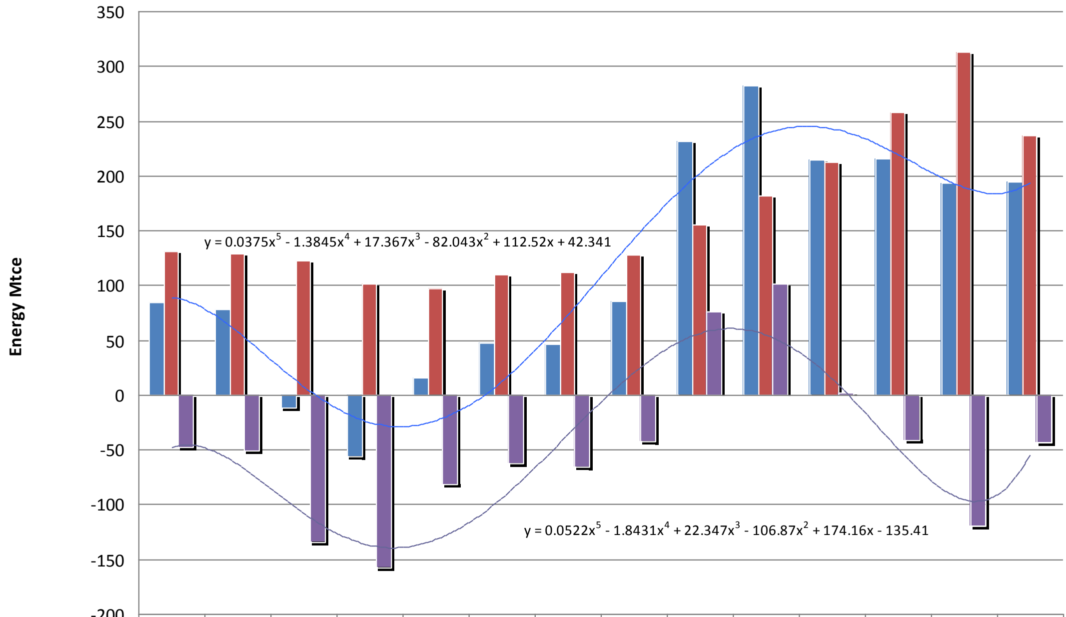
Indicator	Unit	2005	2006	2007	2008
Energy	Mtce	2,247	2,463	2,656	2,850
GDP	Billion 2005 RMB	18,322	20,449	22,982	25,848
Energy Intensity	Kgce/RMB	0.1226	0.1204	0.1156	0.1103
Energy Intensity Reduction	% per year		-1.79%	-4.04%	-4.59%

Figure 2 provides a decomposition of the energy use of China's economy and provides a historic context for understanding the trends during the 11th FYP. The blue bars in the figure represent the change in energy use from the previous year. While the change in energy use has been both positive and negative during the 1995-2008 period, increases of 216 Mtce, 193 Mtce, and 194 Mtce were experienced during 2006, 2007, and 2008, respectively. The red bar illustrates how much of the annual increase (or decrease) was due to a change in "activity", such as the production of raw materials or manufactured goods. The purple bar illustrates how much of the annual increase (or decrease) was due to a change in "intensity" or the amount of energy used per unit of activity. Adding these two effects as represented by red bar and the purple bar results in the total energy use (the blue bar).

This decomposition shows that during the 11th FYP to date, the growth in energy use was due primarily to the large growth in activity (red bar) that began to increase in 2002 and

[4] In December 2009, NBS announced that the energy intensity reduction for 2008 had been revised to -5.2% (Ma Jiantan, 2009). This analysis has not been updated to reflect that revision; doing so would indicate even greater savings than are identified in this report.

peaked in 2007. The decomposition further shows that the growth in energy use was dampened by reductions in energy efficiency, especially in 2007, which offset the growth in activity. Reductions in energy intensity in the secondary sector[5] appear to have made the largest contribution.



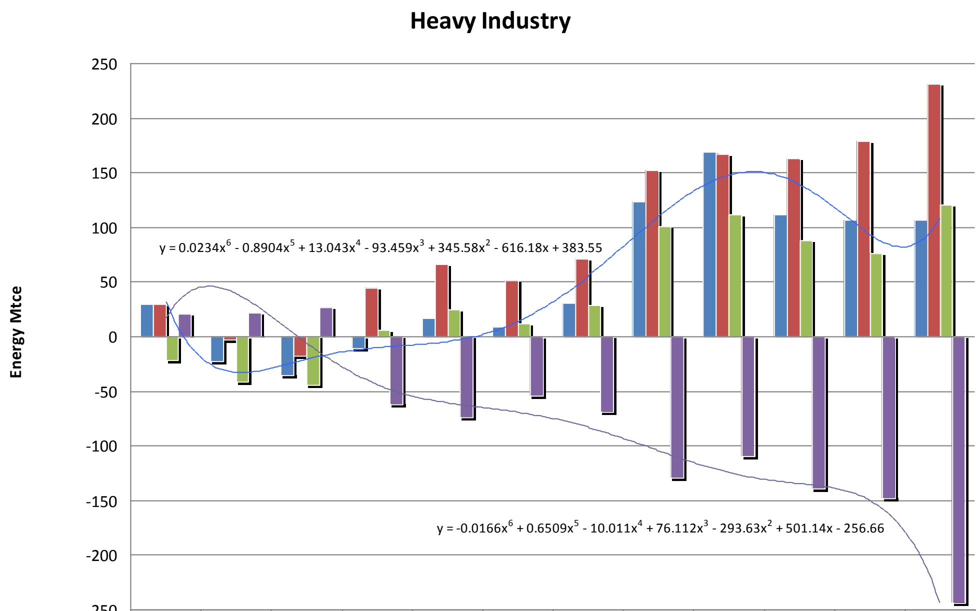
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Δ Energy Use	84.39	77.72	-11.50	-55.84	16.17	47.22	46.46	85.98	231.93	282.37	214.55	215.88	193.13	194.17
Activity	131.585	128.80	123.01	101.80	97.68	110.23	112.32	128.18	155.85	181.36	212.14	257.70	312.64	237.15
Efficiency	-47.195	-51.08	-134.51	-157.64	-81.51	-63.01	-65.86	-42.20	76.08	101.01	2.41	-41.82	-119.51	-42.98

Figure 2. Trends in Energy Use, Activity, and Energy Efficiency for the Chinese Economy, 1995-2008.

Figure 3 provides a disaggregation of the affects of changes in activity, structure, and energy efficiency for heavy industry (defined as ferrous metals, non-metallic minerals, chemicals, non-ferrous metals, fuel, paper, and textiles). Structure is defined as the share of the primary, secondary, and tertiary sectors of the economy.[6] This figure clearly indicates that improvements in energy efficiency offset increases in activity and structural changes, helping to reverse the growth in overall energy use experienced between 2002 and 2004. Energy efficiency improvements were greatest in 2007; unfortunately data are not yet available to assess their impact in 2008.

[5] The primary sector of the economy involves changing natural resources into primary products and includes agriculture, agribusiness, fishing, forestry and all mining and quarrying industries. Most products from this sector are considered raw materials for other industries. The Secondary sector includes those economic sectors that create a finished, usable product: manufacturing and construction. The tertiary sector involves the provision of services to businesses as well as final consumers. Services may involve the transport, distribution and sale of goods from producer to a consumer as may happen in wholesaling and retailing, or may involve the provision of a service, such as in pest control or entertainment. Goods may be transformed in the process of providing a service, as happens in the restaurant industry or in equipment repair. However, the focus is on people interacting with people and serving the customer rather than transforming physical goods.

[6] See Appendix A for further decomposition analyses of specific industrial subsectors.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	29.63	-22.42	-35.97	-11.33	16.94	9.16	30.27	123.76	168.90	111.61	106.57	107.04
Activity	30.05	-3.24	-17.91	44.70	66.44	51.48	70.91	152.58	166.96	162.69	178.64	230.94
Structure	-21.33	-41.40	-44.43	5.98	24.74	11.68	28.76	100.33	111.74	88.17	75.91	120.28
Efficiency	20.91	22.22	26.36	-62.02	-74.24	-54.00	-69.40	-129.15	-109.80	-139.25	-147.98	-244.18

Figure 3. Trends in Energy Use, Activity, Structure, and Energy Efficiency for Heavy Industry in China, 1996-2007.

3.1 Development of a Frozen 2005 Energy Intensity Baseline

The primary purpose of the 11th FYP target was to reverse China's 2002-2005 trend of increasing energy intensity of GDP growth. As noted, the baseline for evaluating 2006 to 2008 energy performance in this report is calculated based on 2005 energy intensity, i.e. what energy consumption would have been in these years if amount of energy per unit GDP remained constant. In this approach, achieved energy savings are equal to the difference between the counterfactual frozen 2005 energy intensity baseline and reported actual energy consumption.

The frozen 2005 energy intensity baseline was calculated by multiplying the 2005 energy intensity value of 0.1226 kgce/RMB by the GDP values for each year in order to derive the energy consumption that would have occurred if the 2005 energy intensity had not declined during the 2006-2008 period (see Table 2 and Figure 4). According to this methodology China achieved a 10% reduction of total energy intensity of GDP growth between 2005 and 2008, which resulted in ~530 Mtce less cumulative energy use than would have been the case if energy intensity had remained constant (see Figure 5).

Table 2. Frozen 2005 Energy Intensity Baseline and Reported Energy Use (2005-2008)

Indicator	Unit	2005	2006	2007	2008
Frozen 2005 Energy Intensity	Kgce/RMB	0.1226	0.1226	0.1226	0.1226
GDP	Billion 2005 RMB	18,322	20,449	22,982	25,848
Frozen Baseline Energy	Mtce	2,247	2,508	2,818	3,170
Annual Energy Difference	Mtce	0	45	162	320
Cumulative Energy Difference	Mtce	0	45	207	527

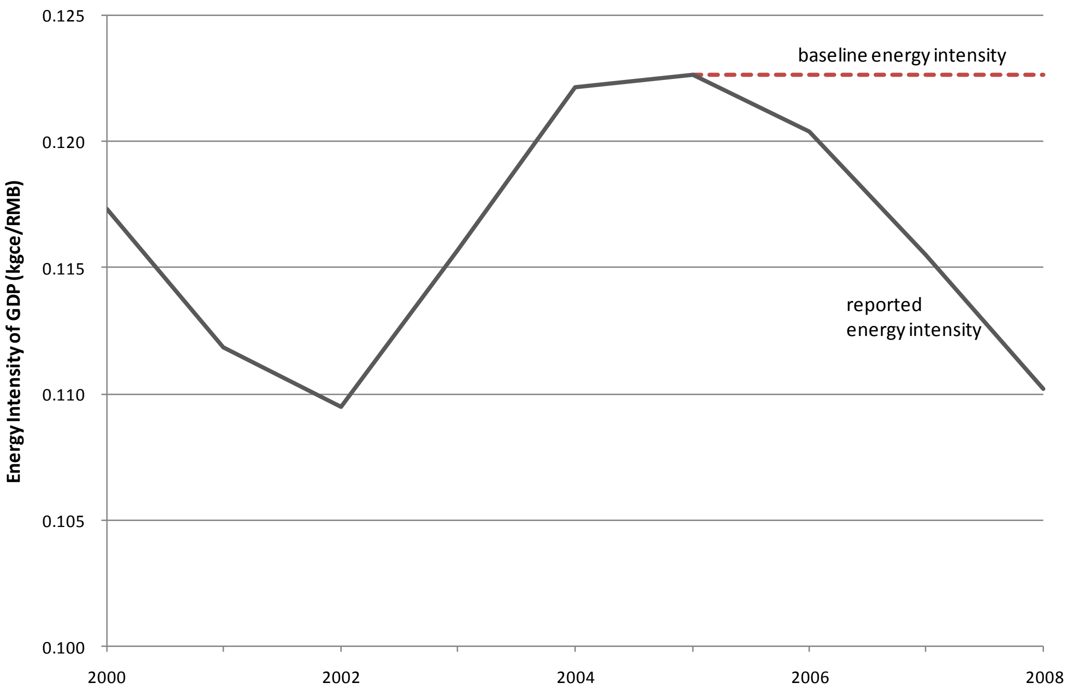


Figure 4. Frozen 2005 Energy Intensity Baseline and Reported Energy Intensity, 2000-2008
Note: figure not zero-scaled.

Following the methodology used in this study, China's total energy use in 2008 was 10% lower than it would have been without policy intervention (see Figure *5*). From 2006 through 2008, total energy consumption was 45 Mtce, 162 Mtce, and 320 Mtce less than it would have been if energy intensity of GDP had remained constant. The cumulative effect of these efficiency improvements has been 527 Mtce less energy use than would have been required at the 2005 energy intensity level.

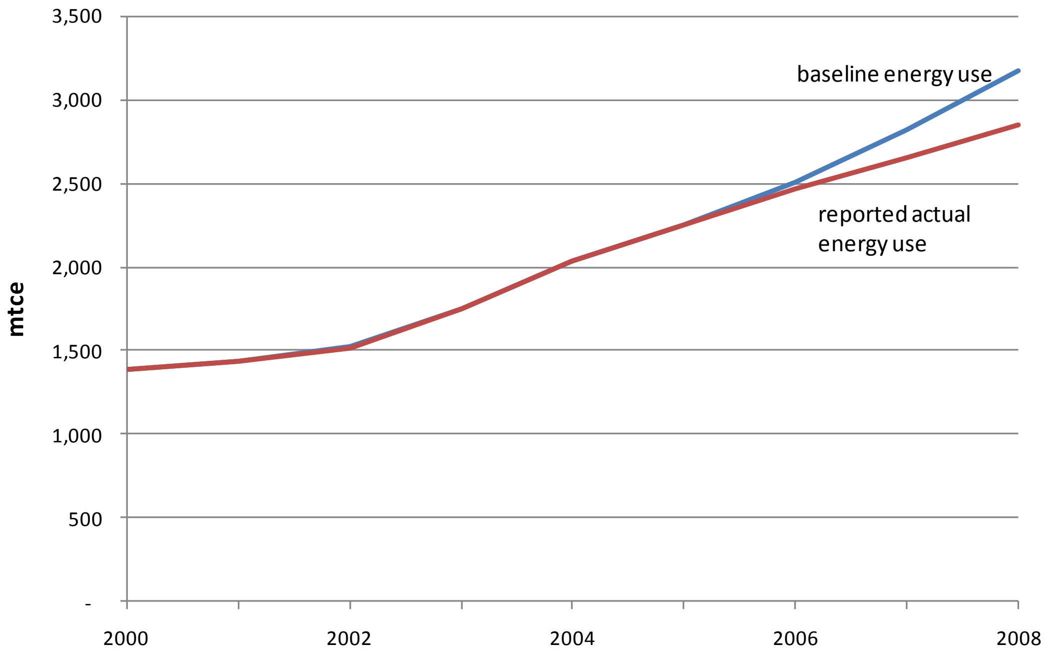


Figure 5. Frozen 2005 Energy Intensity Baseline and Reported Actual Energy Use, 2000-2008

3.2 Overview of 11th FYP Targets and Identified Energy Savings for 2006-2008

The over-arching target of the 11th FYP is a 20% reduction in energy use per unit of GDP. In addition, the Central government has announced target levels for a number of supporting programs reviewed in this report. For example, the Ten Key Projects (discussed in detail below), has an energy-saving target of about 250 Mtce during the 11th FYP. Similarly, the Top-1000 Energy-Consuming Enterprises program has an energy-saving target of 100 Mtce during the 11th FYP.

Section 4 of this report provides a detailed assessment of selected Central government-level energy-saving policies or programs that have been carried out during the 11th FYP, including the savings realized during the 2006-2008 period. The programs reviewed in this paper are: Ten Key Projects, Buildings Energy Efficiency, Top-1000 Energy-Consuming Enterprises Program, Structural Adjustment/Small Plant Closures, and Appliance Standards and Energy-Efficiency Labels. In addition to these programs at the Central government level, there are numerous activities at the provincial level that are not assessed in this report.

Table *3* provides information on the 11th FYP targets for the Central government-level energy-saving policies or programs assessed in this report, along with estimates of the energy savings realized during the 2006-2008 period from these programs. This information is also shown in Figure 6.

This analysis found that the Ten Key Projects have saved a total of 102 Mtce in primary energy during the 2006-2008 period. Within the Ten Key Projects, buildings energy efficiency efforts are estimated to have saved 41 Mtce. The Top-1000 Program is estimated to have saved 124 Mtce during this period. Since the Ten Key Projects includes three project types that have been adopted by Top-1000 enterprises (renovation of coal-fired boilers, waste heat and pressure utilization, and motor system energy efficiency), the potential overlap between the Ten Key Projects and Top-1000 Program was estimated to be 12 Mtce. The overlap for between the energy savings in the Ten Key Projects and the energy savings in both the buildings energy efficiency and Top-1000 Program are accounted for so that there is no double-counting in the overall total national level energy savings (note the negative values for the overlapping savings in Table 3).

This analysis further found that the small plant closures have resulted in savings of 129 Mtce and that the appliance standards have saved 37 Mtce during the 2006-2008 period. It is assumed that the remainder of the savings is the result of a variety of other efforts, including provincial-level energy-savings programs that are not evaluated in this report. Details regarding the savings to date presented in

Table *3*and Figure 6 are provided in the next section of this report.

Table 3. 11th FYP Energy-Saving Targets and Savings to Date, 2006-2008, Based on Frozen 2005 Efficiency Baseline

Policy/Program	11th FYP Target	Savings to Date 2006-2008
	Final Energy (Mtce)	
Ten Key Projects	245	94
Buildings Energy Efficiency	101	35
(Overlap Ten Key Projects and Buildings Energy Efficiency)	-101	-35
Top-1000 Program	100	96
(Overlap Ten Key Projects and Top-1000 Program)	-26	-10
Small Plant Closures	91	106
Appliance Standards	24	11
Other savings including provincial programs	885	115
Total Final Energy Savings	**1320**	**412**
	Primary Energy (Mtce)	
Ten Key Projects	268	102
Buildings Energy Efficiency	112	41
(Overlap Ten Key Projects and Buildings Energy Efficiency)	-112	-41
Top-1000 Program	130	124
(Overlap Ten Key Projects and Top-1000 Program)	-32	-12
Small Plant Closures	118	129
Appliance Standards	79	37
Other savings including provincial programs	1146	147
Total Primary Energy Savings	**1709**	**527**
	Emissions Reduction (MtCO2)	
Ten Key Projects	743	287
Buildings Energy Efficiency	348	100
(Overlap Ten Key Projects and Buildings Energy Efficiency)	-348	-100
Top-1000 Program	235	197
(Overlap Ten Key Projects and Top-1000 Program)	-67	-27
Small Plant Closures	222	242
Appliance Standards	167	78
Other savings including provincial programs	2973	541
Total Emissions Reductions	**4273**	**1318**

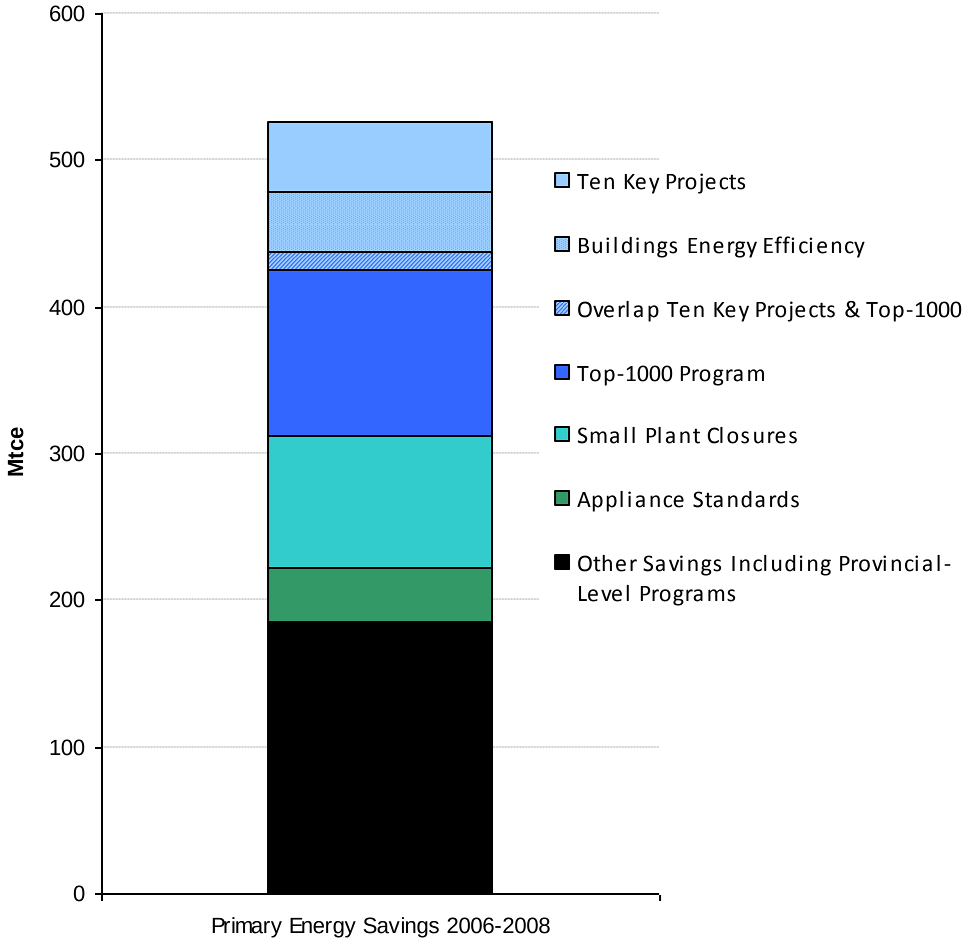


Figure 6. 2006-2008 Estimated Energy Savings from 11th FYP Programs and Policies

4. Policy Evaluation 2006-2008

In recognition of the unsustainable pace of energy demand growth and its associated adverse consequences that had been experienced in China during the early 2000s, the Politburo of the Communist Party issued a communiqué on November 2005 in which it called on the country to reduce energy intensity (defined as energy use per unit of GDP) by 20% in five years. This announcement gave further importance to NDRC's recently-released *Medium and Long-Term Plan for Energy Conservation* (《节能中长期专项规划》) in 2004. The plan set out specific targets for the industrial, transportation, and buildings sectors. The plan's focus is on "Top Ten Priorities" and "Ten Key Projects" (NDRC, 2004).

The "Top Ten Priorities" are:

1) Establish a system for monitoring, evaluating, and public reporting of energy intensity
2) Eliminate and/or reduce production from inefficient industrial processes, technologies and facilities, reduce production from inefficient industrial facilities, encourage high technology industry, and shift production away from energy-intensive industries
3) Implement "Ten Key Projects"
4) Implement "Top 1000 enterprises energy conservation action"
5) Strengthen existing and create new financial incentives for energy efficiency, including preferential tax policies on energy conservation
6) Strengthen energy conservation laws, regulations and standards (e.g., mandatory appliance labels; more aggressive enforcement of building energy codes)
7) Strengthen government programs to gather energy data
8) Establish a national energy conservation center
9) Promote energy efficiency and conservation in government agencies
10) Expand media programs; strengthen training of energy conservation professionals

Shortly after the Politburo announced the national goal of reducing energy intensity by 20%, China's 11th Five Year Plan provided an initial view of the means to achieve this target. The 11th Five Year Plan was approved by the 5th Plenary Session of the 16th Communist Party of China (CPC). It is a binding energy conservation target for local governments and key central government departments, requiring all government divisions at different levels to ensure the achievement of the target. The Plan also establishes specific efficiency targets for electricity generation, selected industrial processes, appliances, and transport. In late 2006, the State Council approved and distributed a scheme disaggregating the 11th Five Year Plan's national energy-saving target into energy-saving targets for each province. The State Council required local governments to disaggregate provincial targets to cities and counties (Zhou, 2006).[7]

Many of the policies and programs to accomplish these Top Ten Priorities were established, implemented, and overseen by Central level government agencies, such as the National Development and Reform Commission (NDRC), the Ministry of Finance (MOF), the Ministry of Housing and Urban/Rural Development (MOHURD), the National Bureau of Statistics (NBS), the State-Owned Assets Supervision and Administration Commission, and the Standardization Administration of China (SAC). In addition, Provincial and local level governments also established and implemented policies and programs in order to meet their assigned energy intensity reduction targets.

[7] For a recent overview of China's energy efficiency policies and programs, see Zhou et al., 2010.

It is not possible to evaluate all of the various energy-efficiency policies and programs that have been implemented under the 11th FYP due to funding and time constraints in addition to a lack of information about many of the programs, especially at the Provincial level.

Thus, this report presents a review of selected key national-level policies and programs that were in place during the 11th FYP in order to evaluate their contribution to the total energy savings achieved between 2006 and 2008 as well as to evaluate their effectiveness. The reviewed policies and programs were selected based on their level of importance to accomplishing the overall target as well as the availability of at least some level of information regarding the program's state goals and achievements to-date.

The selected policies and programs are: 1) Ten Key Projects, 2) Buildings Energy Efficiency, 3) Top-1000 Energy-Consuming Enterprises Program, 4) Structural Adjustment/Small Plant Closures, and 5) Appliance Standards and Energy-Efficiency Labels. In addition, this report provides a review and analysis of the financial incentives provided by the Central government to promote energy efficiency during the 11th FYP.

This report does not attempt to evaluate the numerous provincial-level policies and programs that have been established in each province to compliment the national-level efforts. For example, many provincial-level governments have extended the Top-1000 program to cover additional enterprises within their jurisdiction. It is not possible to evaluate these programs due to a lack of data and reporting on these provincial-level efforts. Also, this report does not address programs for supply-side efficiency or for transportation, both of which are treated in the companion study by Tsinghua University.

4.1 Ten Key Projects

4.1.1 Overview

The Ten Key Energy Conservation Projects ("Ten Key Projects") are a key element of China's *Medium and Long-Term Plan for Energy Conservation* (《节能中长期专项规划》) (NDRC, 2004) and were subsequently incorporated into the 11th FYP to support the binding goal of reducing 20% energy consumption per unit of GDP by 2010.

In 2005, NDRC organized 10 work teams with participation of more than 100 experts to draft a plan for the Ten Key Projects. After eight months of drafting, the report titled *Implementation Suggestions of Ten Key Energy Conservation Projects during the Eleventh Five-Year Plan* (《"十一五"十大重点节能工程实施意见》) ("*Implementation Suggestions*" or *shishi yijian,实施意见*) was jointly released on July 25th 2006by eight government agencies, including NDRC, the Ministry of Science and Technology, the Ministry of Finance, the Ministry of Construction (now the Ministry of Housing and Urban-Rural Development), the General Administration of Quality Supervision, Inspection and Quarantine, the Ministry of Environmental Protection, the Government Offices Administration of the State Council, and the Work Committee of Departments under the Central Committee (NDRC, 2006a).

Stated Policy and Program Goals

Implementation Suggestions states that the essential goal of Ten Key Energy Conservation Projects is to increase energy efficiency through adjusting and optimizing the economic structure, promoting energy-efficient technologies, establishing a strict management system and effective incentive mechanisms. The overall target is to save about 250 Mtce (excluding oil substitution) by the end of the 11th Five-Year Plan. In addition, the energy intensities of major products in key industries are expected to reach or approach the advanced international level achieved at the beginning of 21st century (NDRC, 2006a). It is also estimated by NDRC that the Ten Key Projects will contribute 40% of the overall national-level goal of 20% reduction in economic energy intensity (NDRC, 2006b).

The *Medium and Long-Term Plan for Energy Conservation* provides the following description of the Ten Key Projects (NRDC, 2004):

> **Coal-fired industrial boiler (kiln) retrofit projects.** Currently, there are about 500,000 medium and small boilers available in China. The average unit capacity is only 2.5 tons/hour. The design efficiency is 72 – 80%. The actual operating efficiency is 65% or so. Among these boilers, 90% are coal-burning boilers. The annual coal consumption is 350 – 400 million tons. The potential of coal saving is about 70 million tons (Mt). During the Eleventh Five-year Plan period, China should transform or replace existing medium and small coal-burning boilers (furnaces and kilns) by burning high quality coal, screened lump coal and sulfur fixed coal, and adopting advanced technologies such as circulating fluidize bed and pulverized coal burning and establishing scientific management and operation mechanisms. As a result, the coal-burning industrial boiler efficiency will increase 5 percentage points with coal savings of 25 Mt; the coal-burning furnace and kiln efficiency will increase 2 percentage points with coal savings of 10 Mt.
>
> **District Cogeneration Projects**. Compared with separate generation of heat and electric power, heat efficiency of cogeneration can increase 30%. Heat supply efficiency of district heating is 50% more than that of scattered small boilers. During the Eleventh Five-year Plan period, we should pay attention to establishing 300 MW cogeneration units with environmental protection features in areas where thermal loads for space heating are heavy and thermal loads are relatively concentrated or there is more development potential; in areas with heavy industrial thermal loads, appropriately establish thermal-based back-pressure units according to local conditions; in areas where there are great demands for space heating and less thermal loads, priority develop district heating, and then develop cogeneration after conditions are mature; in the medium and small cities, establish heat-electricity-coal gas cogeneration with taking circulating fluidized bed as major technology, and distributed cogeneration and heat-electricity-cooling cogeneration with clean energies as fuels, rebuild the current heat supply through scattered small coal-burning boilers into the district heating. In 2010, popularization rate of district heating in urban areas will increase from 27% in 2002 to 40%, the heat supplying by newly increased cogeneration units will be 40 GW and the annual energy savings will amount to 35 Mtce**.**
>
> **Waste Heat and Pressure Utilization Projects.** During the Eleventh FYP period, iron and steel integrated enterprises should practice coke dry quenching (CDQ), power generation through blast furnace top pressure difference (TRT), improve power generation by using blast furnace coal gas and recovery and reuse of basic oxygen furnace (BOF) gas, and thus 2.66 Mtce will be saved. In the production line with daily output of above 2,000 tons cement, we should every year establish 30 power generating units with using medium and low temperature residual heat, and thus 3 Mtce will be saved per year; through exploitation of ground coal-bed gas and gas drawing from ground, waste mine and under mine, annual utilization of methane

gas shall reach 1 billion cubic meters (m3) which equals a saving of 1.35 Mtce annually.

Petroleum Conservation and Substitution Projects. During the Eleventh Five-year Plan period, in the electric power, petrochemical, metallurgical, building material, chemical, and transport industries, we should replace fuel oil (light oil) with clean coal, petroleum coke and natural gas, accelerate transmission of electricity from the western to the eastern region of China and substitute small oil burning unit; implement fuel economy standard for motor vehicle and supporting policy and system and adopt various measures to save oil; implement clean automobile action plan and develop hybrid vehicle. Popularize gas vehicle among such fields as city public buses and taxies. Promote methanol and alcohol-powered automobiles and accelerate the progress of the coal liquefaction projects and develop substitute fuels, and thus can save and substitute 38 million tons petroleum**.**

Motors Energy Efficiency Projects. At present, the total capacity of various types of electric motors in China is approximately 420 gigawatt hours (GWh). The actual operating efficiency of these motors is 10-30 percentage points lower than that of foreign countries, and electric power consumption of these accounts for 60% of the total in China. During the Eleventh Five-year Plan period, great efforts should be made to popularize high-efficiency energy saving motor and rare-earth permanent magnet electric motor. In coal, electric power, non-ferrous metal and petrochemical industries, high efficiency energy saving fans should be optimized, pump and compressor and popularize the control technologies of variable frequency speed adjustable and automatic system, so as to raise operating efficiency for 2 percentage points, and save 20 terawatt hours (TWh) electric power annually.

Energy System Optimization Projects. Key energy-intensive industries should optimize their energy systems. That is, make energy system efficiency to reach the highest level of the same industry or approach the advanced international level by system optimization design, technological transformation and management improvement. During the Eleventh FYP period, above efforts should be particularly made in metallurgy, petrochemical and chemical industries. It is expected to decrease the integrated energy consumption of related enterprises and promote their competitiveness in the market.

Building Energy Conservation Projects. During the Eleventh FYP period, residential buildings and public buildings shall execute strict standard of 50% energy saving. Meanwhile, we should accelerate the reform of heat supply system and promotion of energy-saving construction technologies and products. By making the above efforts, we may save 50 Mtce, respectively. At the same time, we should carry out energy conservation retrofit for existing buildings in the northern regions where space heating is required, and great efforts should be conducted to comprehensive energy conservation renovation for existing hotels and restaurants.

Green Lighting Projects. Electric power use by lighting accounts for about 13% of China national power use. The ratio of high-efficiency energy saving fluorescent lamp to incandescent lamp is 1:2.6. Substitution of high efficiency fluorescent lamp for incandescent lamp can save 70-80% electric power. Substitution of electronic ballast for traditional inductive ballast can save 20-30% electric power. Traffic signal incandescent lamps are replaced by light emitting diode (LED), which can save 90% electricity. During the Eleventh Five-year Plan period, great effort should be made to spread high-efficient and energy-saving lighting systems, and tri-phosphorus fluorescent lamp in public facilities, hotels, commercial buildings, office buildings, stadiums and gymnasiums and residential buildings. Besides, we should carry out automation retrofit for the production assembly line of high efficiency lighting appliances, and thus we can save 29TWh electricity.

Government Agency Energy Conservation Projects. Energy consumption in government agencies (including public finance supported sectors such as defense, education, and public services) is increasing rapidly, causing large expenditures for energy use. Energy conservation implementing in government agencies not only can decrease their energy consumption and save administrative expenditures, but also with the government leading effect, promote energy conservation in the whole society. During the Eleventh Five-year Plan period, we should focus our efforts on making energy conservation retrofits for government buildings and their space heating, air-conditioning and illumination systems. The area of government buildings that is renovated according to the standard of building energy saving will represent 20% of the total areas of government buildings. Popularize application of high-efficient and energy-saving products, and include these products into government procurement lists. Reform public service cars, and take a lead to procure low oil consuming cars. The Central Government should take a lead to make pilot for this. In 2010, the energy consumption per building area of the Central Government Agencies and that per capita will decrease 10% on the base of 2002.

Energy Saving Monitoring and Testing, and Technology Service System Building Projects. During the Eleventh Five-year Plan period, we should take measures such as updating monitoring and testing equipment, strengthening personnel training, and adopt new market-oriented mechanisms of energy performance contracting to strengthen capacity building of energy saving monitoring and testing centers at provincial level and in major energy intensive industries; carry out energy conservation law enforcement by laws and conduct related monitoring and testing (supervision). These centers should be capable of providing a series of services including diagnosis, design, financing, renovation, operation and management for enterprises, administrative agencies and educational institutions.

A summary of the detailed targets for each of the Ten Key Projects is shown in Table 4. According to *Implementation Suggestions*, enterprises will take the lead to implement various projects while the government will push and guide in investment through financial allocation, pricing mechanisms, and tax policies. Financial funding from the central government typically is provided from two sources: central budget funding and central fiscal funding. In 2007, total government investment for the Ten Key Projects was about 5.58 billion RMB ($816 million). Of this, 800 million RMB ($117 million) was allocated from central budget funding to support 136 sub-projects in waste heat and waste pressure utilization, energy system optimization, and building energy conservation with an estimated energy saving of 5.2 Mtce. Another 4.78 billion RMB ($699 million) from fiscal funding was allocated to reward, instead of subsidize, enterprises that achieved their energy-saving goals (NDRC, 2008c). A theoretical estimation of energy savings from this incentive mechanism is about 20.3 Mtce, as reported by NDRC (NDRC, 2008c).

Table 4. Targets for Ten Key Projects

Ten Key Projects	Targets
Renovation of Coal-Fired Industrial Boilers (Furnaces)	▪ Coal-fired industrial boilers: increase efficiency by 5%, save 25 Mt coal during 11th FYP ▪ Coal-fired industrial furnaces: increase efficiency by 2%, save 10 Mt coal during 11th FYP
Combined Heat and Power Generation at District Level	▪ Increase penetrate rate of urban district heating from 27% in 2002 to 40% ▪ Install 40 gigawatts (GWs) new combined heat and power (CHP) units ▪ Save 35 Mtce annually by 2010
Waste Heat and Waste Pressure Utilization	▪ Iron & steel industry: save 2.66 Mtce annually through adoption of CDQ, TRT, and recovery of blast furnace (BF) and BOF gases ▪ Cement industry: save 3 Mtce annually by installing 30 sets of low-temperature waste heat generation on production lines that exceed 2000 tons/day ▪ Utilize 1 billion m3 of waste gases from coal mining and extraction, which is equivalent of saving 1.35 Mtce annually by 2010
Petroleum conservation and Substitution	▪ Conserve and substitute 38 Mt petroleum during 11th FYP
Motors Energy Efficiency Projects	▪ Increase efficiency by 2%, saving 20 TWh annually by 2010
Energy System Optimization	▪ Optimize energy system in metallurgical, petrochemical and chemical industries ▪ Reduce comprehensive energy intensities and increase competitiveness
Building Energy Conservation	▪ Total target is to save 100 Mtce during 11th FYP[8] ▪ Enforcing building codes in new buildings: 62 Mtce ▪ Building retrofits and heating supply system reform: 16 Mtce ▪ Energy management in large public buildings: 11 Mtce ▪ Renewable energy adopted in buildings: 11 Mtce
Green Lighting	▪ Save 29 TWh during 11th FYP
Government Procurement of Energy-Efficient Products	▪ Retrofit 20% of governmental buildings (in terms of floor space) ▪ Reduce 10% in energy consumption per floor space and energy consumption per person compared to the level of 2002
Energy Conservation Monitoring and Evaluation System	▪ Strengthen capacity building at provincial and major industrial energy conservation centers

Source: NDRC, 2006a; MOHURD, 2007; Cai et al., 2009; China Construction Newspaper, 2007.

Reported Results

According to Chinese reports, in the first three years of the 11th FYP, total investment from the central budget and central fiscal funding to support Ten Key Projects was around 15 billion RMB ($2.2 billion) (Xu Kexin, 2009). The savings of Ten Key Projects from 2006-2008 is estimated at around 150 Mtce (Lv Wenbin, 2009; Cai Zhihua, 2009).

[8] This value has also been reported to be 108 Mtce (not including Green Lights) or 110 Mtce (including Green Lights), with the increase in savings from the enforcement of building codes (NDRC, 2007a; MOHURD, 2006; China Construction Newspaper, 2007).

4.1.2 Quantitative Evaluation

Evaluation of the Ten Key Projects is difficult due to lack of information regarding the activities and savings undertaken for each of the projects. Some of the savings from industrial sector projects, such as renovation of coal-fired industrial boilers, waste heat and waste pressure utilization, and motor system energy efficiency, are most likely also counted in the savings attributed to the Top-1000 enterprises.[9] In addition, targets were not defined or tracked for the energy system optimization, government procurement, or energy conservation monitoring and evaluation system projects, making evaluation of these programs impossible.

Baseline for Evaluation of Ten Key Projects
Due to the general, more guidance-related, nature of the Ten Key Projects as well as the lack of any specific reporting mechanism that is tracking the progress of each of the projects, it is not possible to establish a baseline to evaluate the progress of these projects.

Calculated Savings from Ten Key Projects
Table 5provides LBNL's calculated savings from the Ten Key Projects for 2006-2008, assuming the goals set out in the 11th FYP are met. For those goals that were expressed as a savings amount to be accomplished "during the 11th FYP", the savings goals were assigned at levels that compounded savings so that earlier year savings are assumed to persist. This method was applied to the savings goals for energy efficiency in buildings, energy-efficient lighting, renovation of coal-fired industrial boilers, and oil conservation and substitution.[10] For those goals that were expressed as an annual savings target for 2010, it was assumed that the target will be reached in 2010, with smaller annual savings starting in 2006 and growing to the 2010 target. This method was applied to the savings goals for district level combined heat and power projects, waste heat and pressure utilization, and motor system energy efficiency.

The table provides annual estimates of the savings that would need to be achieved if the 11th FYP goals are all met by the end of 2010. It also provides the total calculated savings from each of the Ten Key Projects in 2010, as well as the calculated savings during the 2006-2008 period.

[9] Note that the buildings sector energy efficiency measures included in the Ten Key Projects as well as the Top-1000 Program are discussed in more detail in subsequent sections of this report.
[10] The value for oil conservation and substitution includes only 8 Mtce for oil conservation (out of the total goal of 54 Mtce) because 7 of the 8 efforts outlined focus on fuel substitution, while only one focuses on oil saving.

Table 5. Calculated Final and Primary Energy Savings and Carbon Dioxide Emissions Reductions from Ten Key Projects

Ten Key Projects	Goal or target as reported in the 11th FYP	2006	2007	2008	2009	2010	11th FYP Target	Cumulative 2006-08
		Final Energy Savings (Mtce)						
Energy Efficiency in Buildings	saving 100 Mtce during 11th FYP	7	13	20	26	33	98	39
Energy-Efficient Lighting	save 29 TWh during 11th FYP	0.24	0.48	0.71	0.95	1.19	3.56	1.43
Renovation of Coal-Fired Industrial Boilers	35 Mt coal during 11th FYP (25 Mtce)	1.67	3.33	5.00	6.67	8.33	25	10
District Level CHP Projects	save 35 Mtce annually in 2010	5	10	15	20	35	85	30
Waste Heat and Pressure Utilization	7.01 Mtce/year in 2010	2	3	4	5	7	21	9
Oil Conservation and Substitution	save/substitute 38 Mt oil during 11th FYP (54 Mtce)	0.53	1.07	1.60	2.13	2.67	8	3
Motors Energy Efficiency	saving 20 TWh/yr (2.5 Mtce/yr) in 2010	0.3	0.5	0.8	1.3	2.5	5.2	2
Total Final Energy Savings		16	31	47	62	89	245	94
		Primary Energy Savings (Mtce)						
Energy Efficiency in Buildings	saving 100 Mtce during 11th FYP	7	13	20	27	33	100	40
Energy-Efficient Lighting	save 29 TWh during 11th FYP	0.78	1.56	2.34	3.12	3.91	11.72	4.69
Renovation of Coal-Fired Industrial Boilers	35 Mt coal during 11th FYP (25 Mtce)	1.67	3.33	5.00	6.67	8.33	25	10
District Level CHP Projects	save 35 Mtce annually in 2010	5	10	15	20	35	85	30
Waste Heat and Pressure Utilization	7.01 Mtce/year in 2010	2	3	4	5	7	21	9
Oil Conservation and Substitution	save/substitute 38 Mt oil during 11th FYP (54 Mtce)	0.53	1.07	1.60	2.13	2.67	8	3
Motors Energy Efficiency	saving 20 TWh/yr (2.5 Mtce/yr) in 2010	0.8	1.6	2.5	4.1	8.1	17	5
Total Primary Energy Savings		17	34	50	68	98	268	102
		Carbon Dioxide Emissions Reductions ($MtCO_2$)						
Energy Efficiency in Buildings	saving 100 Mtce during 11th FYP	22	43	65	86	108	323	129
Energy-Efficient Lighting	save 29 TWh during 11th FYP	1.65	3.30	4.95	6.60	8.25	25	9.9
Renovation of Coal-Fired Industrial Boilers	35 Mt coal during 11th FYP (25 Mtce)	4.6	9.2	13.8	18.5	23.1	69	28
District Level CHP Projects	save 35 Mtce annually in 2010	14.4	28.8	43.1	57.5	100.7	244	86
Waste Heat and Pressure Utilization	7.01 Mtce/year in 2010	5.8	8.6	11.5	14.4	20.1	60	26
Oil Conservation and Substitution	save/substitute 38 Mt oil during 11th FYP (54 Mtce)	1.08	2.16	3.25	4.33	5.41	16	6
Motors Energy Efficiency	saving 20 TWh/yr (2.5 Mtce/yr) in 2010	0.21	0.43	0.64	1.07	2.10	4	1
Total CO_2 Emissions Reductions		49	96	142	188	267	743	287

Source: NRDC, 2006a. Note: Estimated savings from energy systems optimization, monitoring and evaluation systems, and government procurement of energy-efficient products programs not included in this table since no targets or goals could be indentified for these programs. Also, value for oil conservation and substitution includes only 8 Mtce for oil conservation because 7 of the 8 efforts outlined focus on fuel substitution, while only one focuses on oil saving.

4.1.3 Qualitative Evaluation

Comparison of Progress to Stated Policy Goals

Given the assumptions and calculation method outlined above, it is estimated that if the projects are on track to achieve the 2010 goals, they would have achieved a total primary energy savings of 102 Mtce during the 2006-2008 period. Since it has been reported that the total program has saved 150 Mtce to date (Lv Wenbin, 2009; Cai Zhihua, 2009), it appears that the program is on track to meet or surpass the 11th FYP goal.[11]

It is difficult, though, to evaluate each of the stated goals of the Ten Key Projects due to lack of reporting. For example, there are many specific goals outlined within the Ten Key Projects (e.g. to increase the efficiency of coal-fired industrial boilers by 5%; to install 40 GW of new CHP units, to increase motor system energy efficiency by 2%, etc.), but it is not obvious how such goals are tracked or evaluated.

Sporadic reports of progress in different sub-sectors or Provinces are provided, such as the following:

- NDRC reported that 136 sub-projects were supported by central budget funding in waste heat and waste pressure utilization, energy system optimization, and building energy conservation with an estimated energy saving of 5.2 Mtce (NDRC, 2008c).
- In Shanghai, there were 243 energy-conservation projects in 2007 with a total investment of 3 billion RMB ($439 million). The savings was estimated at about 870,000 tce, which was largely from Energy System Optimization, Waste Heat and Waste Pressure Utilization and Renovation of Coal-Fired Industrial Boilers (Furnaces) (NDRC, 2007f).
- Xi'an, the capital city of Shaanxi Province, has gained 110 million RMB ($16 million) from both central and provincial energy-conservation funding. Among this, 25.7 million for this year (2009) is to mainly support building energy efficiency, green lighting and other Ten Key Projects, and to encourage key energy-using companies to implement coal-saving, electricity-saving, waste heat utilization and industrial boiler renovation projects (Shaanxi Provincial Office, 2009).
- Hebei Province has set targets for their Ten Key Projects, which are: by the end of 2010, build up the capability to save 23 Mtce annually through 62 key energy-saving projects (Hebei Provincial Government, 2008).
- Weifang City of Shandong Province implemented 66 projects in 2007, with a total investment of 8.73 billion RMB ($1.28 billion). By June 2008, 26 projects were completed with an energy-saving capacity of 173,000 tce per year (Weifang News, 2008).

In addition, annual evaluation of the Provincial progress on their target under the national 20% target was undertaken in the Spring of 2007 and 2008. In 2007, this effort was relatively small and resulted in a short report to the State Council, which then issued brief update on the progress. In 2008, the effort was expanded and 9 teams were dispatched to the 31 Provinces, autonomous regions and municipalities. This work was led by NDRC and included officials from the Ministry of Industry and Information Technology (MIIT), Ministry of Housing and Urban/Rural Development (MOHURD), Ministry of Transportation, National Bureau of Statistics (NBS), State-Owned Assets Supervision and Administration Commission of the State Council, and other government organizations along with experts from the

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[11] It has been stated that the goal for the Ten Key Projects is an energy savings of 250 Mtce. However, adding the individual targets, as shown in the table above, results in overall program primary energy savings of 268 Mtce. It is not possible to explain the discrepancy given the information at hand.

Energy Research Institute, the National Institute of Standardization, the China Energy Conservation Association (CECA), etc. In each Province, the evaluation consists of review of the self-evaluation report submitted by each Province, 2-3 days of field evaluation including visits to 1-2 municipalities and 3-5 energy-intensive enterprises, discussions with the Provincial governments, and review of Provincial government documents regarding the projects implemented. The Provincial government report and the evaluation team report are both submitted to NDRC and the final report is then submitted to the State Council. The reports are not available to the public (Tian, 2009).

Comparison of Policy Implementation to International "Best Practice"

International "best practice" regarding the development and implementation of energy-efficiency programs involves a multi-step process, as illustrated in Figure *7*. Once the program policy objective is determined, then how those objectives will be met by different programs must be established. Once the list of programs is identified, then the individual programs must be designed and implemented. Program monitoring and evaluation, which should be included as a key program design element, will provide feedback regarding the progress in accomplishment of the policy objective, the relative success of the various programs implemented to achieve the policy objective, and the effectiveness of the specific program being evaluated.

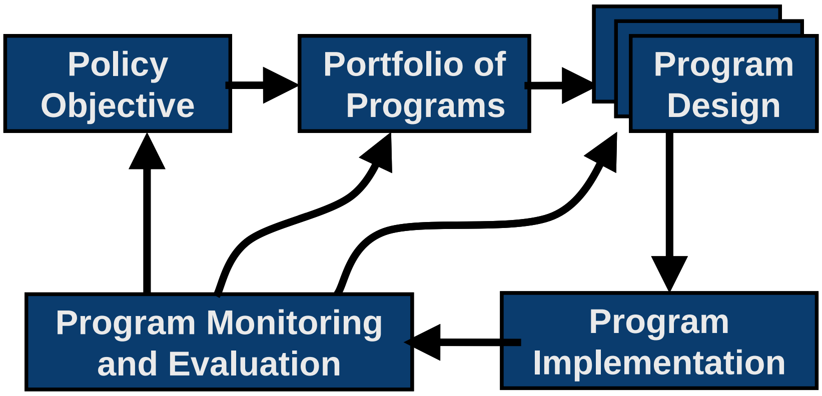

Figure 7. Best Practice Steps for Development and Implementation of Energy-Efficiency Programs

Source: based on Vine and Tannenbaum, 2009.

In the context of the Ten Key Projects, the policy objective is to increase energy efficiency of specific targeted areas, with an overall energy savings target of 250 Mtce, in support of the national 20% energy intensity reduction goal. The portfolio of programs for the Ten Key Projects is clearly identified in the *Medium and Long-Term Plan for Energy Conservation* (NDRC, 2004).

A key step that appears to be lacking or are weakly defined in the development of the Ten Key Projects is in the program design phase. Program design involves the following:

- Setting program objectives, schedules, and targets
- Identifying the target energy consumers
- Identifying energy-efficiency measures
- Developing an implementation strategy, including key milestones
- Developing funding mechanisms or incentives
- Disseminating information to program participants, establishing communication channels
- Establishing a monitoring plan, including project tracking and indicators

- Establishing an evaluation plan

Had there been sufficient time, these steps should have been undertaken for each of the Ten Key Projects.[12] For example, for the Waste Heat and Waste Pressure Utilization project, the program objectives, target energy consumers, and identified energy-efficiency measures are clearly set out as:

- Integrated iron and steel enterprises:
    - should practice coke dry quenching (CDQ)
    - power generation through blast furnace top pressure difference (TRT)
    - improve power generation by using blast furnace coalgas
    - recover and reuse BOF gas
- Cement plants of 2000 tons per day or larger:
    - establish 30 power generating units using medium and low temperature residual heat
- Methane recovery:
    - through exploitation of ground coal-bed gas and gas drawing from ground, waste mine and under mine

The targets for achieving these goals, however, are not so clearly defined. Overall, it is stated that the targets must be achieved "during the eleventh five-year plan period." Energy-saving targets for each of the three areas are provided as 2.66 Mtce for iron and steel, 3 Mtce for cement, and 1.35 Mtce annually for methane recovery. The methane recovery target explicitly states that it is an annual target, but the steel and cement targets are not explicitly defined as either over the full 11th FYP period or annual targets. In addition, it is unclear whether the annual targets are expected to be met equally each year, including the first year when the programs are just being initiated, or whether the annual target can be averaged over the 5 years.

International best practice program design would ensure that the annual and total program targets were clearly established from the program onset, with energy savings most likely increasing over the lifetime of the program.

From the available documents describing the Ten Key Projects, it appears that their implementation is the responsibility of each Province as well as of the steel and cement sectors, although no clear implementation strategy seems to have been developed. Such an implementation strategy would outline the targeted savings by Province by sector, providing key milestones for implementation upon which to judge program progress. Without such an implementation strategy it is impossible to know whether the program goals are realistic and without milestones it is impossible to know whether the implementation is on track or if the program needs some adjustments.

[12] China established a Green Lighting program in 1993. This program is implemented in collaboration with the United Nations Development Program and the Global Environment Fund. The program has been well-designed and implemented and can be used as a model for other program design in China (Liu Hong and Zhou Dadi, 1997).

4.2 Buildings Energy Efficiency

4.2.1 Overview

Building energy consumption accounts for 25% of the total primary energy use in China (Zhou et al., 2007).[13] Total floor area was approximately 58 billion square meters (m^2) in 2007 (NBS, 2008).[14] Two billion $m^2$of building space have been added each year during the past several years (TUBERC, 2008). This is thought to represent half of the construction in the entire world (Xinhua, 2007).[15]

China adopted building energy standards in stages, starting with an energy design standard for residential buildings in the Heating Zone of north China in 1986. This was followed by a standard for tourist hotels in 1993, for residential buildings in the Hot-Summer Cold-Winter Region of central China in 2001, and for Hot-Summer Warm-Winter Region of south China in 2003. A national energy-efficiency design standard for public buildings (the term used in China to refer to commercial buildings) was adopted and implemented in 2005. Lastly, a revised national energy design standard for residential buildings that combines the three previous regional standards has been under development since 2005 and was expected to be completed in early 2007, but has been delayed without announcement of an expected date of implementation.

Earlier standards for residential buildings set targets to reduce building energy consumption compared to pre-existing construction by 30% in 1986 and by 50% in 1995. The 2005 standard for public buildings set the target at 50% energy reduction compared to pre-existing buildings. In addition to national or regional standards, there have been local standards in major cities, such as Beijing, Shanghai, Wuhan, and Chongqing.

China has a centralized Ministry of Housing and Urban-Rural Development (MOHURD) under the State Council (see Figure 8) which is responsible for regulating a building industry that[16] is by any measure by far the largest in the world. A network of Construction Commissions in the major cities works under local government administration and is supervised by the provincial Construction Department. Similar to the Construction Commissions, these provincial Construction Departments work under the provincial government and are

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[13] The building energy consumption data has been adjusted based on the data estimation that has been performed to support the Lawrence Berkeley National Laboratory (LBNL) China bottom-up end use model. This estimate reflects the energy by end use (e.g., space heating), information not available from official data reported in China's Statistical Yearbooks. For details, refer to Zhou and Lin (2008). Note this is operating energy only not including embedded energy in buildings.

[14] Urban building floor area is obtained from the 2008 China Statistical Yearbook. Statistical information is not available for the rural building floor area. We estimate the floor area using per capita floor space of houses from Table 9-37, Housing Conditions of Rural Household by Region (2007), and rural population from Table 3-4, Population by Urban and Rural residence and Region in 2008 China Statistical Yearbook (2007).

[15] There are no official data available to support the figure, however, given that close to half of the world's cement and iron and steel are produced and consumed in China, the statement may not be unreasonable.

[16] In 2008, under the institutional reform framework, China's Ministry of Construction (MOC) was transformed into the Ministry of Housing, and Rural-Urban Development (MOHURD). Significant adjustments in the responsibilities of the new ministry include establishing the authority of MOHURD to resolve housing problems for low income families, to address, housing security, and to promote sustainable urban development.

supervised by the MOHURD. Provincial and city level authorities in the building sector (Construction Commissions and Provincial Construction Department) oversee building construction, including the granting of building permits and the enforcement of building codes, as well as a parallel network of building research institutes to provide technical expertise and support to the MOHURD and the building industry. Within MOHURD, building energy standards fall under the jurisdiction of the Department of Standards and Norms. The technical development of building energy standards is the responsibility of the Department of Science and Technology, in collaboration with building research institutes, universities, and industry representatives. For example, for the current residential and public building standards, Code Compilation Committees were organized under the leadership of the China Academy of Building Research. For the 11th Five Year Plan, the Department of Science and Technology (DST) is responsible for energy efficiency retrofits of existing buildings, monitoring and energy management in government and large-scale public buildings, as well as renewable energy application, whereas the Department of Urban Development is in charge of carrying out the heat supply system reform task. Building code enforcement falls under the Department of Quality and Safety's jurisdiction, and the DST is also supporting the task by assembling expert team and conducting random checking (Figure 9).

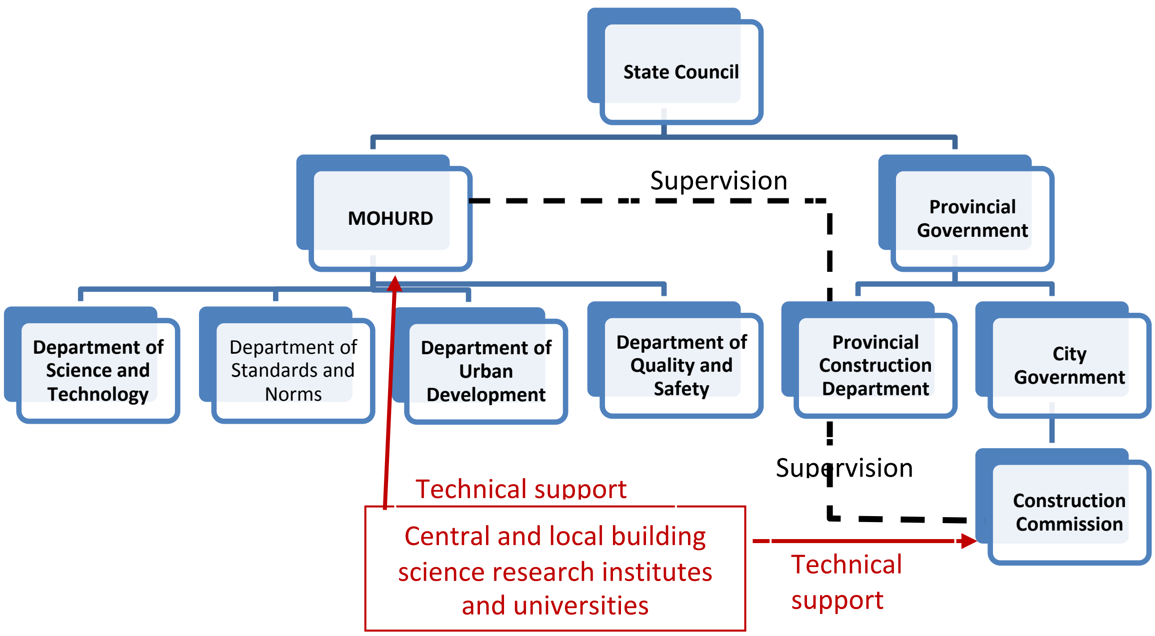

Figure 8. Government Organization Chart in Building Energy Efficiency

To realize the energy-saving goal stated in the 11th FYP and implement the various policies and measures, leading groups of key officials were established at the responsible government agencies at all levels (provincial, city, district and national levels). In 12 provinces (city, district), an energy-saving coordination leading group that involves the Departments of Finance, Construction, and the Development and Reform Commissions (DRCs) has further been established. Corresponding agencies have also been set up at each city. In Shanxi province, energy conservation supervision agencies have been established at both provincial and city levels with a total of 111 staff members. In Shanghai, 19 districts have set up energy conservation management offices, with a total staff of 101.

A summary of policies and regulation measures adopted to promote and/or require energy efficiency in buildings during the 11th Five Year Plan is shown in Table 6.

Table 6. Policies and Regulation Measures for China's Building Sector

Category	Measures	Year of Release	Who is responsible	Sectors covered	Geographical coverage	Target	Relevant information
Regulations	Regulations on energy efficiency in civil buildings	2008	MOHURD (MOC)	Residential, government office and commercial (public) buildings	National	N. A.	14 provinces (city, district) have issued energy conservation regulations or relevant legislation on resource conservation and wall material renovation (Qiu, 2009)
Standards	Various energy conservation design standards	1987-2004	MOHURD (MOC)	Residential, government office and commercial (public) buildings	National	Energy conservation design standard has a 50% energy saving target compared to early 1980's level	Cities that are more developed can go further by requiring 65% energy savings. Beijing and Tianjin have already started to implement this target
Policy	Urban heating system reform	2003	MOHURD (MOC)	Residential	Northern area	Pricing of heat by usage rather than by floor area	N. A.
Policy	Energy efficiency retrofit in northern area district heating	2008	MOHURD (MOC)	Residential	Northern area	Retrofitted area to reach 150 million m^2 by 2010	A fiscal subsidy was also released to support this work.
Fiscal Policy	Special fund for demonstration projects of renewable energy in buildings	2003	MOF & MOHURD (MOC)	Residential, commercial & public buildings	National	200 demonstration projects during 11th FYP period	Until late 2008, a total of 359 demonstration projects were supported
Fiscal Policy	Subsidy for demonstration projects of solar PV application in buildings	2009	MOF & MOHURD (MOC)	Residential, commercial & public buildings	National	N. A.	N. A.
Policy	Energy conservation management n government office buildings and large-scale public buildings	2007	MOHURD (MOC)	Government office buildings and commercial buildings larger than 20,000 m^2	National	Total energy consumption to decrease by 20%, resulting in 11-15 million tce energy saving	A fiscal subsidy was also released to support this work.
Policy	Promotion of energy efficient lighting products	2007	NDRC	Lighting	National	Distribute 50 million and 100 million lamps in 2008 & 2009, respectively	In 2008, approximately 62 million lamps were distributed, realizing 3.2 billion kWh energy saving
Policy	Supervision and inspection work of energy conservation and emission reduction work in the building sector	2007 & 2008	MOHURD (MOC)	General	National	N. A.	N. A.

Stated Policy and Program Goals

In 2006, the State Council required MOHURD's predecessor, the Ministry of Construction (MOC), to draft a bill to strengthen energy efficiency in buildings. This *Building Energy Conservation Regulation Ordinance Bill* was expected to come into effect in the beginning of 2007, but was delayed to October 2008 and renamed to *Civil Building Energy Conservation Ordinance* (MOC/MOHURD, 2008*)*. The bill includes regulations in six areas: building energy management systems, energy efficiency rating systems, energy consumption statistics, energy-saving retrofits, construction practices, and licensing of new buildings (Wu, 2009). For new buildings, the law requires full implementation of the standard and tightens it in some regions to 65% reduction compared to buildings without insulation. For existing buildings, it requires government buildings (and large public buildings) to take the lead in energy retrofits. It also promotes the use of renewable energy by encouraging local jurisdictions to support such applications.

Although the building standards cover all new construction in China, in 2006 just 60% of new buildings in large urban areas met the energy-saving standard during the design stage and only 38% at the construction stage, according to a survey conducted by MOHURD. In southern China, the percentages were just 10% and 8%, respectively (Wu, 2009). However, since the announcement of the 11^{th} FYP, MOHURD has strengthened the enforcement effort and a systemic enforcement and monitoring approach has been put in place to improve the compliance rate. Inspection and random checking have been implemented at all levels of the government from the county-city level to the central government. Based on these efforts, more recent survey results show very much higher implementation rates: in 2008, 98% at the design phase and 81% at construction phase (Qiu, 2009).

In addition to the standards and encouragement of energy retrofits, the bill requires MOHURD to propose a method for energy-efficiency labeling of buildings (to be mandatory for residential and most commercial buildings); to establish a uniform system for collecting and analyzing energy consumption data; to establish three levels of products and practices in buildings categories – desired, restricted, or prohibited – based on energy consumption; and to encourage local governments to provide incentives for energy efficiency measures in new and existing buildings. These efforts remain exploratory, but are expected to have increasing impacts over the coming years.

Under the framework of the 11th FYP's 20% energy intensity reduction target, the energy-saving target for the building sector is 100 Mtce in primary energy units (Wu Y., 2009). According to the allocations of the building energy-saving target, as shown in Figure 9, savings of 62 Mtce will be achieved through the strengthening of enforcement of the building energy efficiency codes, 16 Mtce will be from existing building retrofits and heat supply system reform, followed by 11 Mtce from energy management of government office buildings and large scale public buildings, and 11 Mtce from adoption of renewable energy sources. In addition, there is a goal of saving 29 TWh through the Green Lights program. Even though all of these savings goals are included in the Ten Key Projects (described in the preceding section of this report), they are each discussed separately in this section.

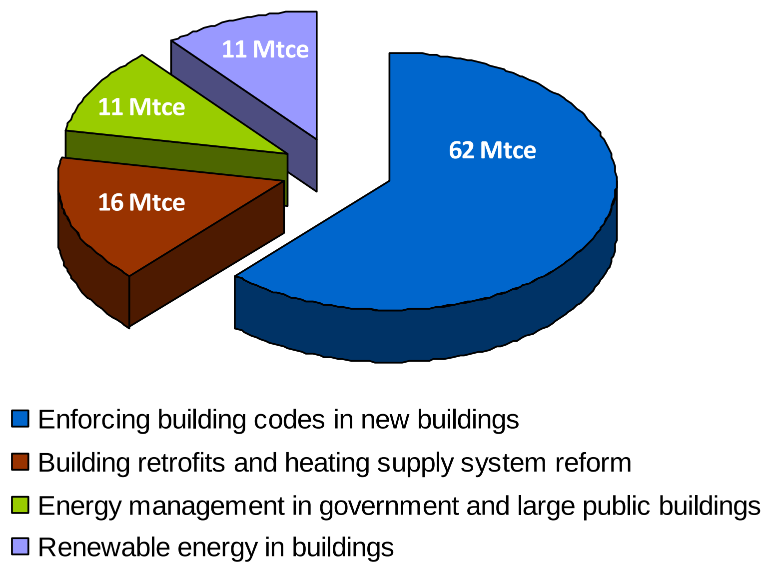

Figure 9. Breakdown of Building Sector Primary Energy-Saving Target in the 11th FYP (Mtce)
Source Cai, et al., 2009, Wu Y., 2009.

Reported Results

Implementation of most of the building energy-efficiency programs began in 2007 and 2008 and these programs are still at the demonstration phase. As such, there are no savings that have been officially reported to date. The exception is for the efforts related to existing building retrofits, discussed below.

4.2.2 Building Energy Efficiency Codes

4.2.2.1. Quantitative Evaluation

Baseline for Evaluation of Building Energy Efficiency Codes Savings

Earlier standards for residential buildings set targets to reduce building energy consumption compared to construction prior to 1986 by 30% in 1986 and by 50% in 1995. For public (commercial) buildings, the 2005 standard for public buildings set the target at 50% energy reduction compared to the energy use in buildings built in the 1980's. Of the 50% saving target, 13-25% is expected to be achieved from improvements to the building envelope, 16-20% from improvements in the heating, ventilation and air-conditioning (HVAC) system, and 7-18% from lighting efficiency improvements (Feng et al., 2009). In this evaluation, the baseline is buildings built in the 1980s in China. See Appendix B for information regarding the baseline values.

Calculated Savings from New Building Energy Efficiency Codes

Savings from building codes arise from two separate policy initiatives. The first of these is the establishment of codes for new residential and commercial buildings that mandate a 50% reduction in heating energy consumption relative to the existing stock. The second is an initiative beginning in 2006 to significantly improve the level of enforcement of these codes in order to raise compliance rates in both building design and construction phases, although the enforcement number are very encouraging there hasn't been a review of the quality of the inspection.

Regarding enforcement, Table 7 provides information on historical and projected compliance rates for the design and construction phases, indicating that compliance was reported to be high for both phases by 2008 (Qui, 2009 and Wu, 2009). These high compliance rates are for construction in urban areas. Building energy codes do not apply in rural areas, which constitute a substantial fraction of overall construction.

Table 7. Compliance Rate of Energy Efficiency Standards in Urban Areas

	Rate of Compliance with Building Energy Efficiency Codes							
	2001	**2004**	**2005**	**2006**	**2007**	**2008**	**2009 (projected)**	**2010 (projected)**
Design phase	5%	54%	59%	96%	97%	98%	100%	100%
Construction phase	2%	20%	23%	54%[17]	71%	81%	92%	100%

Source:2001-2008 Qiu, 2009, Wu, 2009. 2009-2010 projections based on LBNL assumptions

In order to estimate savings from the building energy efficiency codes initiatives, two counterfactual baselines were established. The first, labeled the "No Building Codes" scenario, assumes the absence of building codes and thus no reductions in new building heating and cooling intensity. In the second "Moderate Enforcement Scenario", building codes exist and the building code construction phase compliance rate trend from 2001-2005 is assumed to continue without acceleration. These enforcement rates are assumed to hold for both urban residential and commercial buildings. No enforcement of codes is assumed for rural buildings.

The "No Building Codes" scenario energy consumption for buildings is based on LBNL estimates of building floor space and end use intensities (Zhou, et al., 2007), modified to represent constant level of heating and cooling loads at 2000 levels, at which time the building stock was largely unaffected by building codes. For the actual building code enforcement and the "Moderate Enforcement" scenarios, reduction in new building heating and cooling energy were combined with LBNL construction estimates and enforcement rates in Table 7 to derive total energy consumption for buildings. No reduction in heating load is assumed for buildings using district heat. In the absence of increased occupant control of heating within buildings, we assume the same amount of heat will be supplied to the building independent of shell measures. Therefore, while building codes may result in a higher degree of occupant comfort in such buildings, energy consumption will be unaltered.

Finally, we produce a scenario in which savings result from both establishment and enforcement of building codes. The difference between the "Moderate Enforcement" case and the "No Building Codes" case yields the savings due to moderate code implementation. Savings from new enforcement are given by the difference between the "Actual Enforcement" case and the "Moderate Enforcement" case. Table 8 provides these savings in final and primary energy. Figure 10 illustrates the primary energy savings from these activities.

[17] According to interview with MOHURD (Wu,2009), the jump in compliance rate from 2005 to 2006 may be because of poor survey data and lack of a stringent effort to understand the situation in the years before 2005.

The analysis shows that if no improvements from codes had been made to new buildings relative to the stock, heating and cooling primary energy would have been 17 Mtce higher than it actually was in 2008. If the current trends continue, leading to total enforcement of 100% by 2010, heating and cooling primary energy will be 31 Mtce lower in that year relative to the No Building Codes case. Cumulative savings from building codes between 2006 and 2008 total 36 Mtce, and could reach 90 Mtce by 2010 according to current trends. Assuming that prevailing enforcement trends would have continued in the absence of additional actions taken, the initiative to significantly increase enforcement roughly doubled the energy savings of building codes as a whole. The newly reported data shows energy saved by new energy-saving buildings built in January-October 2007 equals to 5 Mtce (Qiu, 2008), and the figure increased to 9 Mtce of energy saving in 2008 (Qiu, 2009), which validates our estimates.

Table 8.Final and Primary Energy Savings due to Establishment and Enforcement of Building Codes

		2006	2007	2008	Projected 2009	Projected 2010	Cumulative 2006-08
		Final Energy Savings (Mtce)					
Establishment of Building Codes	Residential	1.1	1.5	2.0	2.6	3.2	4.6
	Commercial	1.1	2.8	4.8	7.1	9.7	8.6
	All Buildings	2.2	4.2	6.7	9.6	12.9	13.2
Building Codes Enforcement	Residential	0.3	0.7	1.3	2.0	2.7	2.3
	Commercial	3.7	5.2	6.9	8.8	11.1	15.7
	All Buildings	4.0	5.9	8.2	10.8	13.8	18.0
Total	Residential	1.4	2.2	3.3	4.5	5.9	6.9
	Commercial	4.8	7.9	11.7	15.9	20.8	24.3
	All Buildings	6.1	10.1	14.9	20.4	26.7	31.2
		Primary Energy Savings (Mtce)					
Establishment of Building Codes	Residential	1.9	2.6	3.4	4.3	5.3	8.0
	Commercial	1.1	2.8	4.8	7.1	9.7	8.6
	All Buildings	3.0	5.4	8.2	11.4	14.9	16.6
Building Codes Enforcement	Residential	0.5	1.3	2.2	3.3	4.4	4.0
	Commercial	3.7	5.2	6.9	8.8	11.1	15.7
	All Buildings	4.2	6.4	9.1	12.1	15.6	19.7
Total	Residential	2.4	3.9	5.6	7.6	9.7	12.1
	Commercial	4.8	7.9	11.7	15.9	20.8	24.3
	All Buildings	7.1	11.8	17.2	23.5	30.5	36.4

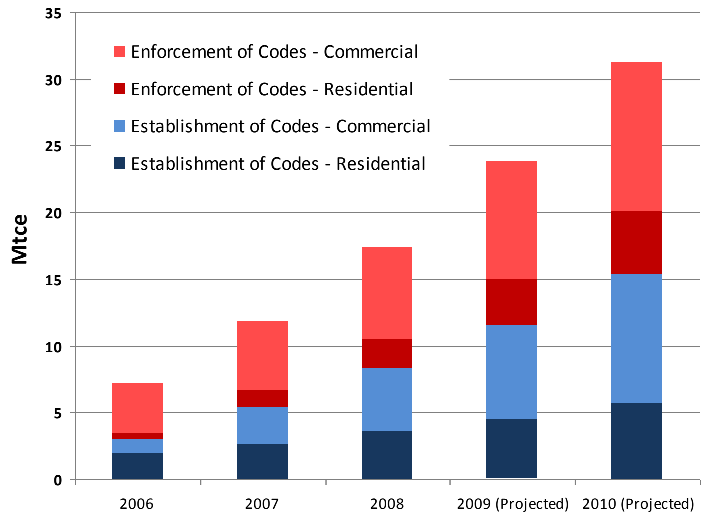

Figure 10. Annual Primary Energy Savings due to Establishment and Enforcement of Building Codes

4.2.2.2. Qualitative Evaluation

The main goal for new buildings in the 11th FYP is the full enforcement of the building energy codes, which calls for 50% intensity reduction from building prior to codes. Based on economic affordability and other conditions, some regions are encouraged to increase the energy-saving target to 65%. As a result, more stringent energy-saving targets (up to 65%) have been implemented in Beijing and Tianjin, and will soon be followed by Shanghai and Chongqing. Other areas such as Inner Mongolia, Shandong, Henan, and Hebei Provinces have also partially implemented more stringent local energy saving standards. During the 12th Five Year Plan period, all new buildings are expected to meet the 65% saving target (Hao, 2009).

Supervision and enforcement for energy efficiency in new buildings is conducted through regular inspection for new construction and random inspections. Regular inspection for new construction follows a “loop system”. This is done under the existing market entry control system through a series of administrative licenses. New construction projects have to first apply for land use permit from local planning authority. In this phase, the Planning Bureau works together with the Construction Commission to inspect whether the main facade, lay-out, and shape of the design meet the energy efficiency requirements. The local construction department will then evaluate and approve the blueprint and engineering plans. Once the construction blueprints have been evaluated to ensure compliance with mandatory energy standards, the local construction department will issue the construction permit. If the proposed construction plan or blueprints fail to receive approval, permits will not be issued and construction cannot begin. Once construction on the new building begins, the building design and construction enterprises and respective supervisory units are responsible for obtaining energy labeling certification, verification of construction completion and insulation quality assurance. In the construction phase, inspection is carried out to assure compliance with the energy conservation standard before the construction license is issued. Another inspection to confirm compliance with energy efficiency standards is conducted at the final acceptance phase of the project. Finished projects failing to comply with the standards at this stage are not accepted by the Construction Commission and thus are considered to be illegal construction. Because developers pay fees that support the compliance agencies, there is reason for concern about the integrity of the process. However, our discussions with officials indicate that there are strong incentives for compliance, as neither the accredited verifying institute nor the construction contractor or developer would risk their licenses to cheat.[18] An illustration of this process is shown in Figure 11.

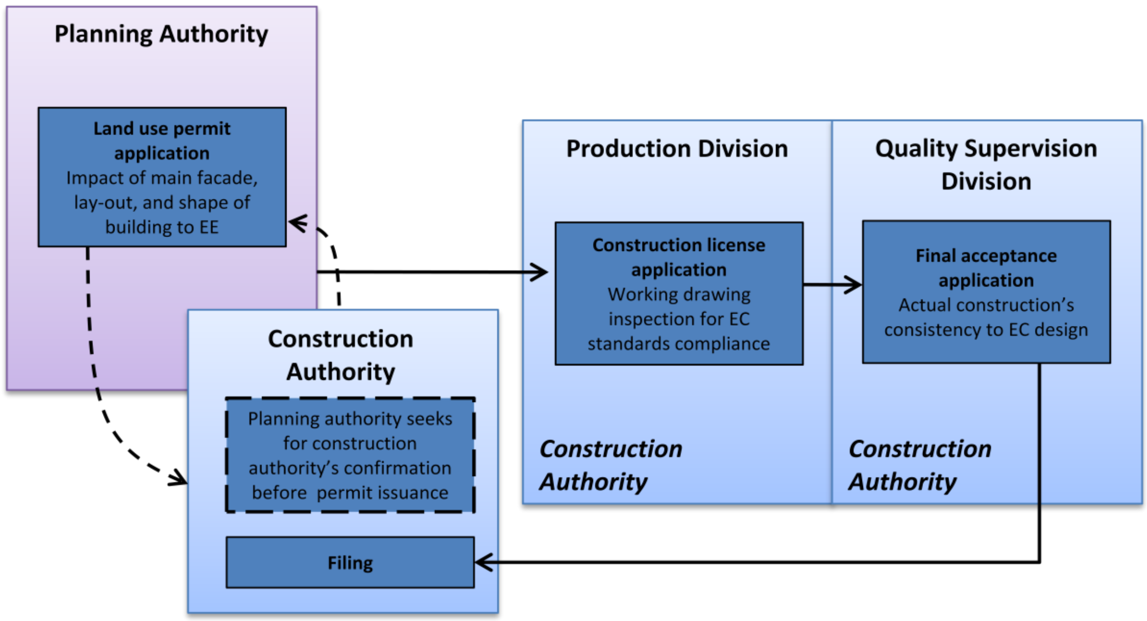

Figure 11. Illustration of Loop Inspection System of Energy Conservation Standard Compliance

Random inspections related to energy conservation and emission reduction have been conducted twice since 2008 (for 2007 and 2008 projects). The inspections are carried out by an evaluation team organized by MOHURD. The evaluation teams are sent to 20 provinces. Each team each consists of 10-20 experts and is in charge of evaluating 3 provinces. The team evaluates energy conservation work of the provincial Construction Commissions. They then evaluate three cites at three different levels: provincial capital, one random prefecture-level city, and one random county-level city. After the local evaluation, random checks on projects are then conducted. Projects that failed the random inspection are penalized through high fines, decreased certification level, and/or cancellation of their certification.

The inspection process is done through investigation of the submitted documents and construction drawings, and is checked with computer simulation results. Some adjustments are made based on weather data. After the building has been built, annual monitoring and checking of the energy consumption by fuel is conducted for all government buildings and large office buildings. Measurement of building performance such as the heat conduction value (U value) of the wall is conducted a year after the operation. For residential buildings, spot inspection is also carried out for selected residential districts each year. The costs of the inspection or energy audit are borne by the central and local government through their energy-saving funds (Wu, 2009). For other public buildings and residential buildings, public notices have also been used. At the construction site, the energy performance of a building including energy efficiency and

[18] This is validated through the personal communications with various construction companies.

renewable energy measures adopted are written on a banner that informs the public; this information is also written in the building/house purchase contract, the certificate of quality guaranty, as well as the occupant's Instructions. These documents are legally binding.

The majority of the inspections is carried out by the local government. The expert team at the central level mostly reviews paper documents. There are three to five institutes in each province that are accredited to conduct inspections (Wu, 2009), with the exception that Beijing and Shanghai each have about 10 institutes. On average, there are 20 to 30 people working in each institute, which makes the total number of inspectors in each city approximately 60 to 150 (Hao, 2009). However, the institutes, such as local building science research institutes, generally are responsible for many tasks, with inspection being only one of them. This suggests that staffing may not be adequate to perform the inspections adequately. Nonetheless, the compliance rate after these measures were taken has increased dramatically, as noted in Table 7 for urban areas. The compliance rate is considered to be accurate at the prefecture level cities, whereas the compliance rate remains ambiguous for the small county level cities.

4.2.3 Existing Building Retrofit and Heat Metering Reform

4.2.3.1 Quantitative Evaluation

Baseline for Evaluation of Existing Building Retrofit and Heating Supply Measurement Reform
MOHURD and MOF jointly released the *Opinion on Implementation of Heating System Measurement and Energy Conservation Retrofit for Existing Residential Buildings in Northern Heating Areas* targeted at the retrofit of 150 million m^2 floor area.

The goal is to realize 50% of heating intensity reduction after the retrofit compared with buildings built in the 1980s, and an additional 20% reduction through the heat supply measurement reform by the end of 2010. Since the average heating intensity of the existing buildings used in this estimate is 25 kgce/m^2, this implies savings of 12.5 kgce/m^2 after the retrofits (Wu, 2009)[19] as well as savings of 5 kgce/m^2 after the heating supply reform. This target can be further broken down to an estimated saving of 2 Mtce from retrofits for the 150 million $m^2$and another 14 Mtce from the heat supply reform including the heat pricing reform for the 2.7 billion m^2 of urban buildings that have district heating system (Wu, 2009). The target was further disaggregated and assigned to provincial governments (see **Table 9**) (Zhao, 2009).

The retrofit consists of installation of heat metering and temperature control equipment, retrofitting the heat supply network for heat balance, and energy-efficiency retrofit of building envelopes (Zhao, 2009). The specific measures for the heat metering and temperature control retrofit includes installation of heat meter devices in boiler rooms and heat stations; meter installation in the heat entrance of the building or building group if the buildings have very similar characteristics; and development of a methodology to disaggregate the heat use. Measures for the heat supply network reform include energy-efficiency improvement in the heat supply source and heat station (boilers, etc.); replacement of the network and installation hydraulic balance valves as needed; and installation of thermostat valves and regulating valves with automatic temperature control function together with pipe system replacement to

[19] The intensities vary by region; for instance, the average heating energy intensity in Beijing is 22.45 kgce/m2 after the retrofit, the intensity is supposed to be reduced to half at 11.27 kgce/m2.

improve the indoor heating system. Building envelope retrofits mostly targeted exterior windows, walls, and roofs with measures such as double-glazed windows, window frame sealing, more efficient windows, external insulation of the walls, and direct inverted roof insulation.

Table 9. Existing Building Retrofit Area Target Allocations for 2010

Province	Retrofit target (millionm^2)	Province	Retrofit target (millionm^2)
Beijing	25	Shanxi	4.6
Tianjin	13	Shaanxi	2
Liaoning	24	Gansu	3.5
Shandong	19	Inner Mongolia	6
Heilongjiang	15	Xinjiang	7
Jilin	11	Ningxia	2
Hebei	13	Qinghai	0.3
Henan	3.6		

Source: Zhao Jing and Wu Yong, 2009

Calculated Savings from Existing Building Retrofit and Heat Metering Reform

In 2008, about 39.5 million m^2 of building area was retrofit, realizing primary energy savings of 270,000 tce energy saving (Qiu, 2009). In 2009, the plans are to retrofit 53.5 million m^2 heating area, bringing the total retrofitted area to 93 million m^2.[20] The project has been implemented only since 2008, so the sum of the areas retrofitted from 2008 to 2010 represents the cumulative total for the entire 11th Five Year Plan.

By the end of 2009, the total retrofitted area will be the 62% of the total target, leaving another60 million m^{2}to be completed in the remaining year. It may be possible to meet target for total retrofitted area, but even if this is the case, the energy savings target will be missed by a considerable margin. The total estimated primary energy saving in 2008is only 0.27 Mtce, accounting for merely 14% of the overall target. We attribute the low savings to (1) the incomplete installation of energy efficiency measures in the houses that have been retrofit and (2) the choice of occupants to take the benefits of energy efficiency in improved indoor temperature rather than energy savings.[21]

For the heating supply measurement reform project, only 21 million m^2 of building area have completed the heat metering reform, accounting for less than 1% of the targeted floor area (see Table **10**). The poor performance in heating supply reform can be partially explained by the fact that thus far only five provinces (Beijing, Tianjin, Shanxi, Gansu and Jilin) have released policies on heat metering prices and charges. A second problem is that the governmental authority over the heating supply companies is separated from the authority over energy retrofits of buildings, and the incentive thus far provided applies only to the building retrofit.

[20] China Heat Supply Information Net, August 2009. http://www.reliangbiao.com/jszx/show.asp?id=1420

[21] A large percentage of the households that were retrofit only installed a heat meter rather than carrying out the full range of retrofit measures, in part because the incentive provided (50 RMB/m^2, or \$7.3/m^2) was not sufficient to induce the decision to purchase other, more expensive measures.

Table 10. Proposed Target and Estimated Achievement to Date for Existing Building Retrofits

		2008*	Target 2010
Existing Building Retrofit	Retrofit floor area (million m^2)	39.5	150
	Estimated Savings in kgce per m^2	6.75	12.5
Heat System Reform	Heat supply reform floor area (million m^2)	21	2660**
	Estimated Savings in kgce per m^2	N.A.	5
Primary Energy Savings (Mtce)			
Existing Building Retrofit	Energy Saving (Mtce)	0.27	1.9
Heat System Reform	Energy Saving (Mtce)	<0.1	13.3
	Total Primary Energy Savings (Mtce)	<0.4	15.2[22]

* The program had not started by 2008; we thus present the numbers only for 2008.
** NBS, 2008.[23]

Another key barrier to the implementation of the program is the lack of a reasonable and feasible financing channel for the owner as well as an economic model for heat supply companies. These companies, which are key players in this activity, generally lack enthusiasm since the retrofit will increase their costs without necessarily increasing income. The method of reimbursing companies for the cost of heat does not take into account the cost of the investment of the end use equipment necessary for the heat metering retrofit. The profit margin has already become low due to the recent increase in coal prices, and together with the relatively long payback period for such projects it is difficult for companies to make the retrofit investments. Although some successful cases exist such as the residential district of Bao Steel in Inner Mongolia, where the central and local government budget and the enterprise paid the majority of the cost as well as some energy service companies projects in Chengde, Hebei and Lanzhou, Gansu province, a systematic, widely applicable and mature financing scheme is lacking (Nengyuan net, 2009). In any case, the progress made in the heat supply system reform has not been promising, leaving the achievement of the target largely in question in this particular area.

[22] This is derived number based on above mentioned methodology, and does not exactly match the announced target. There are no official data on how the target is calculated and assumptions made.
[23] Based on the total area of centralized heating in 2006 (NBS, 2008).

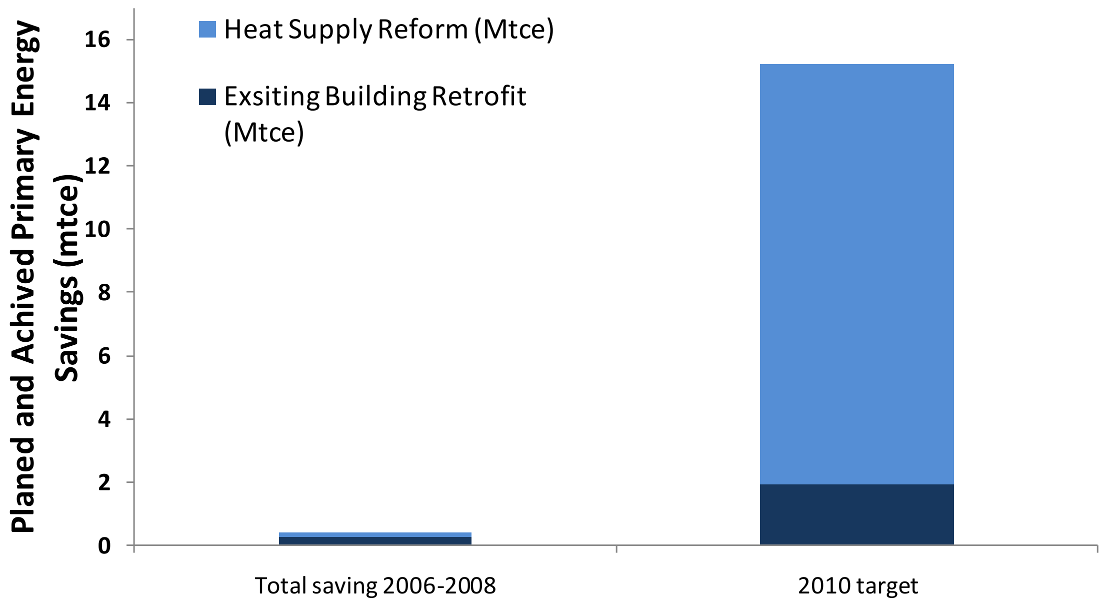

Figure 12.Targeted and Achieved Energy Savings through Existing Building Retrofit and Heat Supply Reform

4.2.3.2 Qualitative Evaluation

Policies set up to target existing buildings include *Heat Supply System Measurement and Energy Conservation Retrofits for Existing Residential Buildings in Northern Heating Areas* and *Energy Management in Government Office Buildings and Large-Scale Public Buildings*.

Heat Supply System Measurement and Energy Conservation Retrofit for Existing Residential Buildings in Northern Heating Areas

Energy conservation efforts in the northern heating areas are closely related to heating system reform. This reform was first discussed in 2003, with the main purpose of creating a market-based mechanism to replace heating welfare. One of the core tasks is to replace billing by heated area by actual or estimated use of heat.

As a part of the urban heating system reform, MOC (now MOHURD) also released *Interim Management Measures of Urban Heating Price* in 2007. The policy provides for heating prices constructed from a fixed price (dependent on floor area) and a price based on heat usage. The fixed price can be in the range of 30%-60% of the total heat price. The guidance also stipulates that new buildings should install heat-measuring devices, while existing buildings should also be equipped with heat measuring devices if affordable.

In late 2007, MOF released an incentive policy for heating system measurement and energy-efficiency retrofits. The policy was designed by MOC (now MOHURD), granting incentives to provincial governments. The provincial governments then allocate the fund on a project basis. Retrofit projects supported by the policy include three tasks: building insulation, indoor heating system meter and temperature control device installation, and heat source and network pipeline retrofit. The incentive is 55 RMB/m^2 (\$8/m^2) for retrofit in the severe cold zone and 45 RMB/m^2 (\$6.6/m^2) for energy retrofit in the cold zone.[24] The calculation also includes coefficients for different project types and project progress. The funding is divided for the three tasks indicated above in proportion of 1:3:6 to give different funding allocation to projects with higher energy-saving potential and to encourage retrofit projects to be conducted earlier. Approximately 10% of the incentive (6 RMB/m^2, or \$0.88/m^2)[25] was initially given to the provincial government, with settlement of the remaining amount conducted in the end of the year after measuring actual energy-saving effect. The total allocated funding from the central government until the end of 2008 reached 1.54 billion Yuan (Wu, 2009). Other than the incentive from the central government, provincial governments are also required to release provincial level incentive policies (Wu, 2009).

Regarding enforcement, MOHURD is currently designing an acceptance mechanism for energy-efficiency retrofit projects of northern area heating (Wu, 2009). The acceptance mechanism involves a 3rd party verifier in the calculation of the energy-saving amount. The preliminary design of the acceptance procedure is shown in Figure 13.

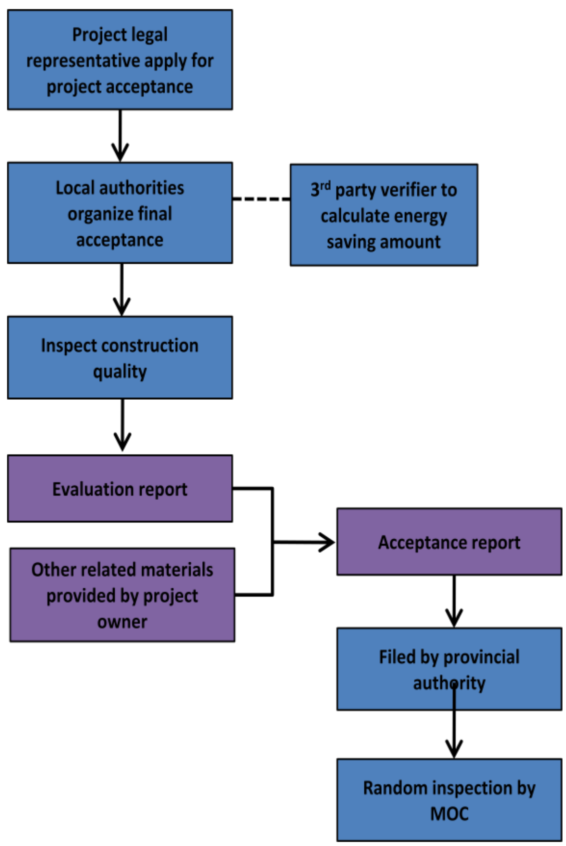

Figure 13. Preliminary Design of Acceptance Procedure for Energy Conservation Retrofit Projects of Northern Area Heating

[24] The average cost for existing building energy-efficiency retrofits in northern China is estimated to be 150-350 RMB/m^2 (\$22-51/m^2) (Wu, 2009; and http://www.jzcad.com/bbs/archiver/tid-52789.html)
[25] http://www.jzcad.com/bbs/archiver/tid-52789.html

4.2.4 Energy Management of Government Office Buildings and Large-Scale Public Buildings

4.2.4.1 Quantitative Evaluation

Baseline for Evaluation of Energy Management of Government Office Buildings and Large-Scale Public Buildings

In 2005, the reported building floor area in China was approximately 42 billion m^2, and public (commercial) buildings floor area was 4.5 billion m^2, accounting for 10.7% of the total. Of this, 0.33 billion m^2 is large scale public buildings (TUBERC, 2009) and together with government office buildings, the total building floor area covered in this program is 0.8 billion m^2 (Jin et al., 2009). The average size of a large public buildings is 33,000 m^2 (TUBEERC, 2009),[26] and the average energy intensity excluding space heating of these buildings is 142.4 kWh/m^2/year. The average energy intensity of the government office buildings excluding space heating is estimated to be 82 kWh/m^2.

Calculated Savings from Energy Management of Government Office Buildings and Large-Scale Public Buildings

The target is to reduce the energy intensity of these buildings by 20% by 2010[27], equivalent to savings of 11 Mtce.[28] Although the government plan has a specific target for energy savings from each program, there are no official data or publications that report the savings to date. In addition, little information has been made public either on the calculation methodology or on the definition of the baseline, thus making it difficult to estimate the actual savings to date. Through extensive literature search and interviews with experts, we assembled information to provide a plausible estimate of energy savings. This is based on estimates of floor area and average energy intensities of the government buildings and large-scale public buildings. The assumptions and results of this estimate are presented in Table 11 and Figure 14.

The total floor area of these buildings is estimated to be 0.8 billion m^2, and the derived energy consumption (excluding space heating energy) was approximately 84 TWh in 2005. In 2010, the floor area will increase to 0.89 billion m^2, and the energy consumption will have dropped to 75 TWh even with new floor area, assuming a decrease in energy intensity of 20%. The derived accumulative energy savings from 2005 to 2010 is 11 Mtce, which is consistent with the target stated in MOHURD's *Notice of Strengthening the Implementation of Energy Management in Government Office Buildings and Large-Scale Public Buildings*. There are no published results on savings to date (2005-2008); however, if the program goal has been achieved, the savings is estimated to be 4.56 Mtce.

[26] Derived from the total number of large scale public buildings of 10,000.

[27] MOHURD has estimated savings based on experience that approximately 10-15% of the savings could be achieved through energy management (Wu, 2009). The saving is estimated to be cumulative over the five years.

[28] http://www2.tyqgzx.gov.cn:8888/qgbwww/zcfg/gjxzcfg/2009-06-24/143.html

Table 11. Primary Energy Savings of the Energy Management Program in Government Buildings and Large-Scale Public buildings

		Public Buildings	Government Buildings	Large-Scale Public Buildings
Total Floor area (billion m^2)	2005 2008 2010	4.5 5.1[30]	0.46 0.50[29] 0.52	0.33 0.36 0.37
Energy Intensity (kWh/ m^2-year)	2005 2008 2010	30-60	81[31] 70 64.8	142.4 114[32]
Total Estimated Energy Consumption (TWh)	2005 2010	135-270	37.26 33.696	46.99 42.18
Total Estimated Cumulative Savings 05-08 (Mtce) Total Savings Target 05-10 (Mtce)			4.56 11.23	

Source: TUBERC, 2009; Jin, et al., 2009; Zhou et al., 2007.

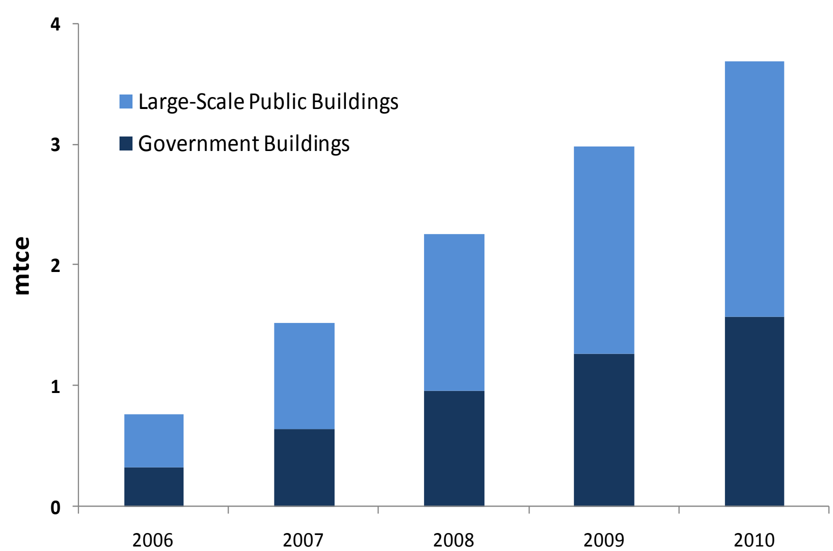

Figure 14. Estimated Program Savings Due to Energy Management in Government Buildings and Large-Scale Public Buildings

[29] Applying the growth rate of the public building floor area estimated in Zhou et al. (2007)
[30] Based on LBNL estimate (Zhou et al., 2007)
[31] Based on personal communication
[32] The target is to reduce energy intensity by 20% by 2010, equivalent to 11-15 Mtce (http://www2.tyqgzx.gov.cn:8888/qgbwww/zcfg/gjxzcfg/2009-06-24/143.html). MOHURD estimated savings based on experience that 10-15% of the savings could be achieved through energy management (Wu, 2009).

4.2.4.2 Qualitative Evaluation

China's government office buildings and other large-scale public buildings use more energy per m^2 than other forms of buildings. In China, energy conservation efforts in this area concentrate mostly on establishing a supervision and management system and on implementing energy efficiency retrofit measures. This supervision and management system consists of recording energy consumption statistics, performing energy audits, and certifying the energy-efficiency of the building.

To further enhance the energy statistics work in this field, MOHURD has conducted an energy consumption survey of 11,607 government office and large-scale public buildings. MOHURD also carried out an energy audit of 768 buildings and 59 universities, releasing the energy consumption status of these 827 buildings to the public. In addition, a pilot project in 324buildings in Beijing, Shanghai, Tianjin, and Shenzhen has also been carried out. In these pilot buildings, energy metering devices in each building energy consumption element (e.g. lighting system, elevators, heating, etc) were installed and connected in real-time to a database. By implementing this measure, comprehensive energy consumption statistics with detailed breakdowns have been gathered.

Apart from above measures, MOHURD is planning an energy consumption quota system for government office buildings and large-scale public buildings (Wu, 2009). This energy consumption quota system is expected to play a large part in stimulating a 5% decrease in total energy usage in the building sector. This plan will be released in the next 2 years. To support this work, MOF has provided about 100 million RMB ($14.6 million) for 24 cities (Cai et al., 2009).

With energy consumption statistics and energy audits in buildings as a basis, MOF will also provide a subsidy as a financial support to energy-efficiency retrofit projects under the framework of the energy management contracts. Provincial or city level projects will receive 50% loan interest subsidy, while projects in the central level will get 100% loan interest subsidy.

4.2.5 Other Building Energy Policies and Programs

4.2.5.1 Renewable Energy Application in Buildings

Renewable energy applications in buildings were put forward by the State Council's *Notice on Issue of Comprehensive Work Scheme of Energy Conservation and Emissions Reduction*. In September 2006, MOF and MOC released *Interim Management Measures of Special Fund on Renewable Energy Application in Buildings*. The fund provides partial financial support with a subsidy determined according to the actual cost of different technologies. Technologies supported include solar energy (hot water, air conditioning, PV, and lighting), ground source heat pumps, sea water or waste water source heat pumps, etc. Table 12 provides information on the renewable energy demonstration projects undertaken during 2006-2008.

Outside the central government effort, provincial efforts in this area have also been identified. Shenyang city in Liaoning province has a target of using ground source heat pumps in 650 million m^2 of buildings by the end of 2010, while Chongqing provides financial support for renewable energy applications in building ranging from 800 RMB/kilowatt (kW) ($117/kW) to 900 RMB/kW ($132/kW).

Table 12. Approved Demonstration Projects of Renewable Energy Application in Buildings

Year	Number of Applicants	Approved Projects	Total Area (million m^2)	Capacity (kWp)
2006	173	82	10.26	3084.5
2007	233	130	14.11	N/A
2008	255	147	14.82	5665
Total	**661**	**359**	**39.19**	**8944.3**

Note: kWp = kilowatt peak

In March 2009, MOF and MOHURD released a subsidy policy supporting demonstration projects applying solar PV in buildings. The subsidy standard for this policy is 20 RMB/watt peak (Wp) ($2.9/Wp), which will cover nearly half of the investment.

4.2.5.2 Efficient Lighting Products Promotion

Promoting high energy-efficiency lighting products is one of the 10 Key Energy Conservation Projects in the 11th FYP. This is achieved through giving indirect subsidies to tender- winning companies producing efficient lamps such as self-ballasted fluorescent, fluorescent T5/T8 lamps, metal halide lamps, high pressure sodium lamps, LED lamps, etc. These products will then be sold to the public at a 30%-50% lower price than the tender price.

In 2008, NDRC planned to promote the installation of 500 million lamps and exceeded the target by promoting 620 million lamps. These lamps will generate 3.2 billion kWh energy savings and 3.2 million tons CO_2 equivalent ($MtCO_2e$) emission reduction. For 2009, NDRC planned to promote the installation of 1 billion efficient lamps.

Provincial governments have also released local level policies supporting the efficient lighting policy. Beijing municipal government is now promoting "1 RMB lamps" ($0.15 lamps) through an additional 40% local subsidy. Shanxi province and Nanning city government have also provided 15%-40% additional subsidy for consumers with different economic levels.

4.2.5.3 Building Energy Efficiency Evaluation & Labeling

In 2008, MOHURD established its building energy-efficiency labeling system with the purpose of increasing public awareness of building energy consumption, and at the same time directing the development of the building industry toward a more energy-efficient path. The labeling system is also intended to provide a quantitative basis for energy-saving assessments that are used in the implementing incentive policies.

MOHURD issued its building energy efficiency label with 5 levels of efficiency after conducting an evaluation that consists of three assessment items: basic assessment, compulsory standard compliance, and optional assessment. The basic assessment evaluates the efficiency level of the HVAC system. Energy consumption of the HVAC system per unit area is then compared to a baseline to calculate energy-savings. The baseline used is the national building energy-efficiency standard that requires 50% energy saving target.

Different grades (one to five *s) are given to the buildings based on the level of energy saving generated (see Table 13). The compulsory standard compliance is a re-checklist of whether the building complies with national standards. Finally, the labeling system gives an additional score for the application of renewable energy (RE), natural lighting and ventilation, advanced new energy efficiency (EE) technology and products, and energy consumption management.

The first experimental group of buildings participating in the building energy-efficiency evaluation and labeling are spread in 20 provinces and cities. Among these buildings are also voluntary projects other than demonstration projects financed by the MOHURD and MOF. Until June 2009, 20 buildings have been labeled in the demonstration projects with final levels of achievement ranging from 1-3 stars.

Table 13. MOHURD Building Energy Efficiency Label Grading System

Basic Assessment Item Energy saving level	Compulsory Assessment Item	Optional Item	Levels
50%-65%	Meet all mandatory standards	Additional points based on application of renewable energy, natural lighting and ventilation, advanced new EE technologies and products, and energy management.	★
65%-75%			★★
75%-85%			★★★
>85%			★★★★
>85% (Label will be upgraded if the score in this item reaches 65 (out of 100))			★★★★★

4.2.6 Comparison of Policy Implementation to International "Best Practice"

4.2.6.1 Data collection

The energy saving target set for buildings is ambitious, with very favorable energy reduction and carbon emission implications if the target is achieved. China has implemented serious policies and measures to support the target, and some have achieved significant results, such as the building codes enforcement. However, almost no official data have been released on respective savings to date of each program, and evaluation and actual measurement has not been followed up to verify the savings, except for a few demonstration projects in residential building retrofit and the government and large scale buildings.

This report has attempted to estimate the savings to date based on best available data and the government plan; however, more meaningful analysis needs a much more extensive effort for basic data collection and surveys than has been carried out. A solid data collection framework provides a foundation for defining the baseline, evaluating policy, and conducting market analysis, which in turn better informs the policy decision process, and therefore helps policy makers to select policy instruments best suited to meet policy objectives and decide on required adjustments to existing policies.

In the U.S., the *Commercial Buildings Energy Consumption Survey* (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures (U.S. EIA, 2008a). Commercial buildings include all buildings in which at least half of the floor space is used for a purpose that is not residential, industrial, or agricultural, so they include building types that might not traditionally be considered "commercial," such as schools, correctional institutions, and buildings used for religious worship. The CBECS was first conducted in 1979; the eighth and most recent survey was conducted in 2003. CBECS is currently carried out on a quadrennial basis. CBECS provides number of buildings, floor areas, and energy consumption by fuel by different building types and sizes, as well as energy consumption by end use equipment. The *Residential Energy Consumption Survey* (RECS) is a similar survey targeting residential buildings that is also conducted every four years (U.S. EIA, 2008b). This survey samples approximately 4,400 households to represent the 111.1 million housing units in the U.S. in 2005 through two data-collection stages: household questionnaires (interviews in person) and fuel and electricity supplier surveys. Consumption by end use is then estimated by use of regression equations. The survey includes indicators such as housing physical characteristics, household demographic characteristics, penetration of energy end uses devices per characteristic of equipment, indicator of use, energy consumption by end uses, and expenditures data by product type.

4.2.6.2 Baseline Definition and Target Setting

Even though the energy-saving targets for China's building sector have been established and disaggregated to the province level, these is little clarity on how the baseline was determined, how the target was set, and the methodology for disaggregating the target. (The same can be said for the national target as the 20% intensity reduction target was not done by sectoral approach which would require comprehensive evaluation of the potential in each sector.)

For the existing building energy retrofit program, the proposed target heating intensity after the retrofit would be 12.5 $kgce/m^2$, which is already much lower than current German and Swiss standards. In addition, with the further reduction target through heating supply system reform, heating intensity will need to be reduced to 7.5 $kgce/m^2$, slightly higher than the level defined for a passive house in Germany (see Figure 15). This illustrates the high ambition level of the target and could be one of the factors for the rather weak actual performance in this area.

For new buildings, there is a common misinterpretation of the so-called "energy-saving target" of the energy-efficiency standards. The various standards actually stipulate a 50% higher heat resistance of the building envelope. This leads to a false assumption that buildings built in compliance to these standards would actually generate 50% heating energy savings. However, it is unclear whether the intensity will actually be reduced. The thermal performance of the buildings and heating supply system could meet energy efficiency standards and use as much energy for heating as a building not meeting the standard for several reasons. If no heating controls are in place, window openings in winter can be used to achieve comfort when the building is overheated. Alternatively, if heating controls are built into the building but at a central level (especially for HVAC systems in commercial buildings), the thermostat setting may be higher than a building with local controls, Or, for residential building in the north, occupants may take the benefits of more efficient buildings as improvement in comfort rather than in reduced heat. Research on this subject suggests that although the implementation of more stringent building standards has been firmly enforced, there is still no significant decrease in the energy consumption (Wei, 2009). Better heat resistance in buildings is not supplemented with energy efficient home appliances and controllable heating system..

Therefore, a systematic methodology for development of baseline assumptions, assessment of energy-saving potentials, measured energy use, and use of this information to construct targets that result in significant and measureable impacts is necessary for the future

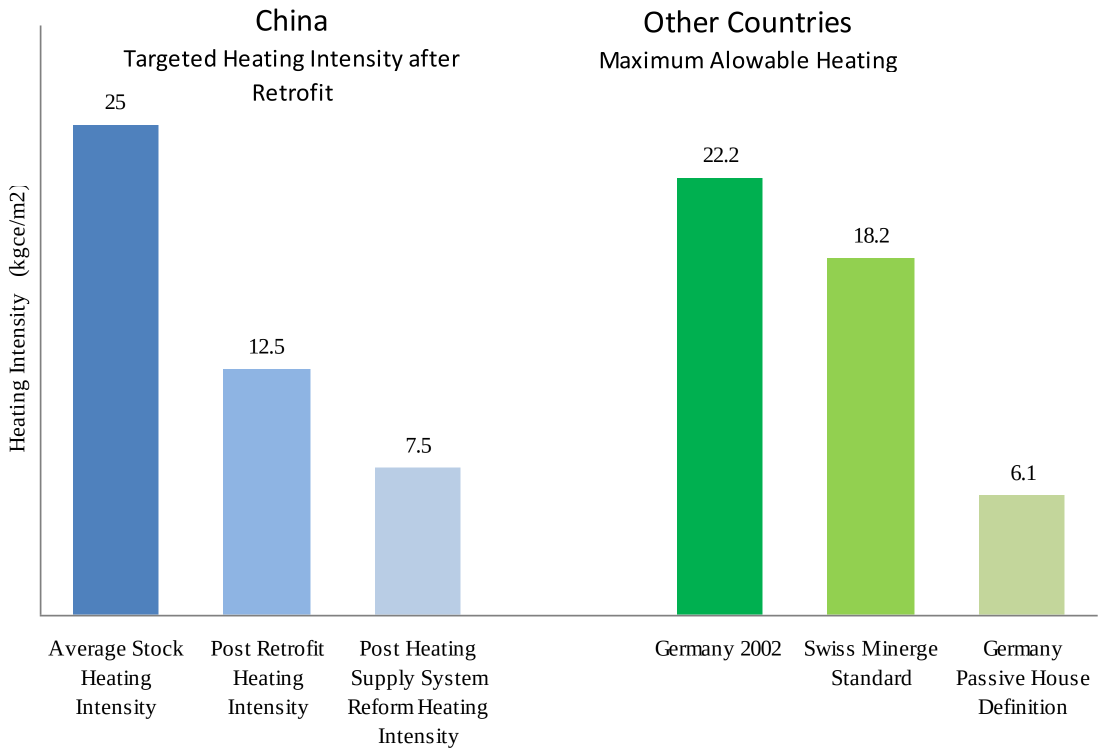

Figure 15. Comparison of Baseline and Target Heating Intensity for Building Retrofit and International Standards[33]
Source: Gauzin-Muller, 2002 and IEE, 2008.

4.2.6.3 Benchmarking

Benchmarking is a common way to evaluate a building's energy performance. Benchmarking of energy use provides means to compare a building to other buildings or national average or best practice, helps the policy maker or owner of the building to understand the current situation, determine the baseline, and set an energy-saving target. However, this approach has not been fully undertaken during the 11th FYP. In general, benchmarking in buildings can be categorized as follows:

- Building codes in different countries
- Peer-to-peer benchmarking
- Self performance over time
- Self performance to national or regional average and best practice

[33] Chinese electricity conversion factor (1kWh=0.404 kgce) was applied to all intensity numbers, to exclude the power generation fuel mix effect.

The indicators could be total energy intensity, heating intensity, or building envelope thermal efficiency.

A comparison of the Chinese building energy-efficiency codes to the U.S. ASHRAE standard shows that the Chinese standards are less comprehensive and not as stringent as those in the United States (Hong, 2008).Currently, heat loss through exterior walls is about 3–5 times higher in Chinese buildings as in similar buildings in Canada or Japan. Loss through windows is over twice as high (Zhou and Lin, 2008). Table 14 provides a comparison of the buildings standards for heat transfer in selected countries.

Table 14. Comparison of the Building Standards in Heat Transfer Coefficients in Selected Countries

Country	External wall	External window	Roof
Beijing(China)	1.16-0.82	3.5	0.80-0.60
Russia	0.77-0.44	2.75	0.57-0.33
Berlin (Germany)	0.5	1.5	0.22
Hokkaido (Japan)	0.42	2.33	0.23
Canada	0.36	2.86	0.23 _0.4
USA	0.32–0.45	2.04	0.19
Sweden	0.17	2.5	0.12

Source: Jing et al., 2009

As previously noted, additional major losses are caused by imbalances in the temperature in different parts of a building and inability to control heat use in central heating systems, commonly forcing consumers to open windows as the only means to regulate overheating.

As mentioned above, if a systematic survey and data collection scheme such as CBECS and RECS as applied in the United States, the actual energy consumption data could be utilized for benchmarking and setting meaningful targets, and opening up the possibility of setting targets beyond codes. For instance, a number of countries have definitions of low energy buildings or passive houses. Passive housing is considered to be today's leading building principle for low heating energy consumption houses. A truly low energy house would have meet and overall energy intensity target that includes all end uses (heat, hot water, and household electricity). In many cases, the passive house standards have provided different energy requirement by regions, and by type of the buildings (single family vs. multi-use apartments).

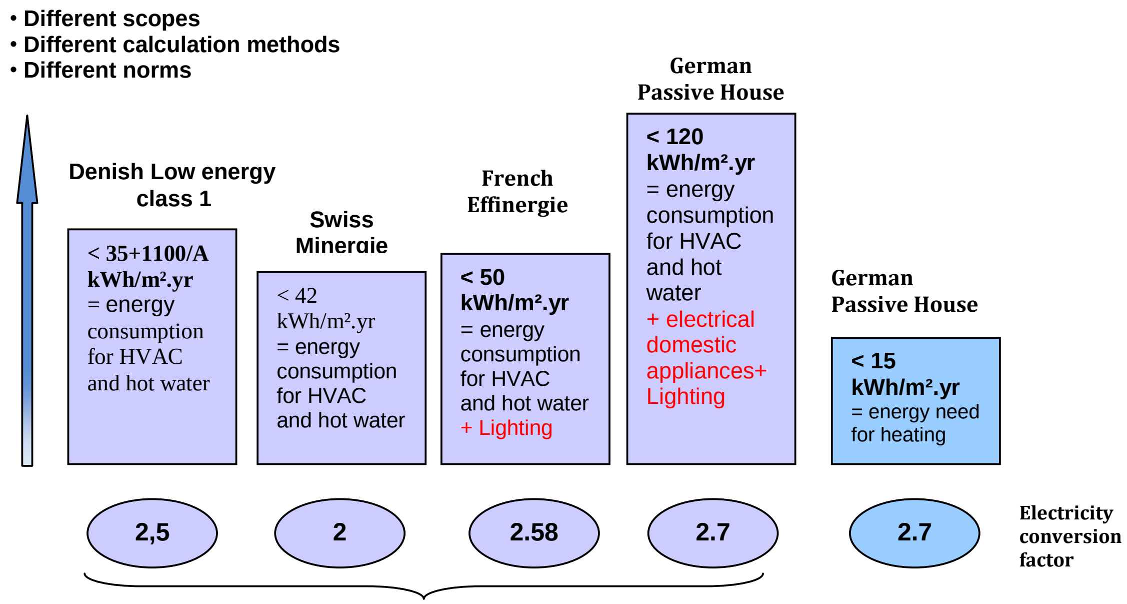

Figure 16. Comparison of Different Building Low-Energy Performance Standards

4.2.6.4 Evaluation and Enforcement

In China, the building code compliance rate is in general considered to be accurate at the prefecture level cities, whereas the compliance remains ambiguous for the small county level cities. The evaluation process itself seems to be adequate and effective, when the process has strictly followed the guidelines and procedures. It is not possible from the surveys to know whether the checks were thorough, whether the construction quality is high, or what fraction of buildings passed the test without meeting the standard. Considering the amount of the new construction, more staff and capacity building is likely needed to improve the inspection and evaluation work.

4.3 Top-1000 Energy-Consuming Enterprises Program[34]

4.3.1 Overview

One of the key initiatives for realizing China's 20% energy intensity reduction goal is the Top-1000 Energy-Consuming Enterprises program (Top-1000 program) which has set energy-saving targets for China's 1000 highest energy-consuming enterprises. The Top-1000 program was launched by the Department of Resource Conservation and Environmental Protection of the National Development and Reform Commission (NDRC), the National Bureau of Statistics (NBS), the State-owned Assets Supervision and Administration Commission (AQSIQ), the Office of National Energy Leading Group, and the General Administration of Quality Supervision, Inspection and Quarantine in April 2006 (NDRC, 2006c).

The industries included in the Top-1000 Energy-Consuming Enterprise program are large-scale enterprises in nine major energy-consuming industries that each consumed a minimum of 180,000 tce in 2004: iron and steel, petroleum and petrochemicals, chemicals, electric power generation, non-ferrous metals, coal mining, construction materials, textiles, and pulp and paper. The iron and steel and chemical industries dominate in terms of number of enterprises; the iron and steel enterprises also dominate in terms of energy consumption.

In 2004, these enterprises consumed an average of 0.67 Mtce of comprehensive energy each. Average energy consumption per enterprise ranged from a low of 0.35 Mtce for the enterprises in the building materials sector to a high of 1.07 Mtce for the enterprises in the petroleum and petrochemicals sector. The energy consumption of the enterprises in the iron and steel sector was also high, averaging 1.0 Mtce; all of the remaining enterprises averaged 0.67 Mtce or lower.Top-1000 program enterprises are spread throughout China, with the largest number of enterprises in the coastal area of the East Region (268 enterprises) where Shanghai as well as a number of more developed provinces are located and the North Region (268 enterprises), followed by the South Central Region (192 enterprises) where Guangdong and the Pearl River Delta industrial area are located. The Northeast, Southwest, and Northwest Regions have 102, 97, and 81 enterprises, respectively.

Stated Policy and Program Goals

The major targets of the Top-1000 Energy-Consuming Enterprise program are to significantly improve the Top-1000 enterprises' energy efficiency; reduce unit energy consumption to the national advanced level for all major products; have some enterprises attain either the international advanced level or the national leading level to promote the improvement of the whole sector's energy efficiency; and achieve energy savings of 100 million tons of coal equivalent in the 11th FYP period.

According to the implementation plan of the program, the Top-1000 enterprises are expected to establish an energy conservation organization, formulate energy efficiency goals, establish an energy utilization reporting system, conduct energy audits, conduct training, formulate an energy conservation plan, adopt energy conservation incentives, and invest in energy efficiency improvement options. The enterprises are required to report their energy consumption by fuel quarterly to NBS (NDRC, 2006c).

[34] Some of the material in this section is excerpted from Price et al., 2008a and Price et al., 2010.

The national government has established and publicized the guiding principles and goals of the program and published a list of the Top-1000 enterprises by name. The energy saving authorities of the province, district, or city are directed to collaborate with related organizations to lead and implement the Top-1000 program, including the tracking, supervision, and management of the energy-saving activities of the enterprises. The local authorities are directed to oversee and "urge" the enterprises in their energy management, energy auditing, and energy reporting requirements. They are directed to improve their monitoring of the enterprises through audits and sampling and to promote the use of new mechanisms such as target-setting agreements and encourage enterprises to meet energy saving targets and attain international advanced levels ahead of schedule (NDRC, 2006c).

Reported Results

In September 2007, NDRC and NBS held a workshop in Shenyang, China to release the *Top-1000 Enterprises Energy Use Report 2007* (《千家企业能源利用状况（2007）》) (NDRC and NBS, 2007). The report documents the energy consumption, energy intensity, energy management activities, and the energy-efficient technology and equipment used based on statistics submitted to NBS by 954 enterprises and information from the energy audit reports of 942 enterprises. The data indicated that the final energy consumption (not accounting for losses from electricity generation, transmission, and distribution) of the Top-1000 enterprises had increased from 733 Mtce in 2005 to 797 Mtce in 2006. Shandong, Hebei, Liaoning, Shanxi, Jiangsu, and Henan Provinces accounted for 50% of the total energy consumption of the Top-1000 enterprises.

The number of enterprises within each sector remained relatively stable between 2004 and 2006 (values for 2005 were not reported), with slight decreases in the steel, petroleum/petrochemical, construction materials, and non-ferrous metals sectors and a slight increase in the electric power sector. Overall, the initial list of 1008 enterprises issued in 2004 was revised to reflect the fact that 19 enterprises were added to the program and 29 enterprises dropped out for various reasons including closure and consolidation, bringing the total number of Top-1000 enterprises in 2006 to 998.

Between 2005 and 2006, energy consumption grew in enterprises in the petroleum/petrochemical, chemicals, electric power, coal mining, and paper sectors and decreased in the non-ferrous metals and construction materials sectors. In 2006, enterprise energy consumption fuel shares were 36.1% coal, 21.3% crude oil, 12.97% electricity, 8.91% coke, 1.91% heat, 1.48% natural gas, and 17.33% other energy sources such as petroleum diesel, fuel oil, LPG, washed coal, coal gas from blast furnace, and coke oven gas.

Energy savings results were calculated by NDRC and NBS by multiplying the 2006 production (e.g. tons or kWh) of 36 industrial products, ranging from crude steel to synthetic ammonia to polyester fiber, by the 2005 unit energy consumption for each product to determine what the 2006 energy use would have been if energy efficiency had not improved between 2005 and 2006. This value was then subtracted from the actual 2006 energy consumption value for these products to determine the energy savings. The calculation resulted in savings of 14.92 Mtce (437 PJ) for the products for which this calculation could be made. The report then estimates that including the remaining industrial products that are not explicitly accounted for in the calculation would result in total energy savings of 20 Mtce in 2006. In 2008, NDRC reported that the Top-1000 Program enterprises saved 38.17 Mtce in 2007 (Liu Jingru et al., 2009). While detailed information about the savings is not available, NDRC did report that the enterprises invested over 50 B RMB¥ ($7.3B) in technology innovation and implemented over 8,000 energy-saving projects in 2007 (Zhao, 2008). In November 2009, NDRC announced that the Top-1000 program had reached its target energy savings of 100 Mtce (NDRC, 2009c).[35]

4.3.2 Quantitative Evaluation

Baseline for Evaluation of Top-1000 Energy-Consuming Enterprises Program

In order to assess the Top-1000 program goal of 100 Mtce savings by the end of 2010, as well as to make projections of other possible outcomes, a baseline energy use scenario for the Top-1000 Program must first be developed since there is no official 2010 "business-as-usual" energy consumption value from which the energy savings of the Top-1000 enterprises will be measured. The national-level 20% target for 2010 assumes an average GDP growth rate of 7.5% from 2005 to 2010, which implies that energy use will only increase at an average rate of 2.8%. However, both GDP and energy use have been growing much faster recently. In 2006, total energy consumption reached 2,463 Mtce, a 9.6% increase from 2005, while the GDP growth rate was 10.7% (NBS, 2007). However, energy use of the Top-1000 Program enterprises only grew at a rate of 6.7% per year between 2004 and 2006.[36] Assuming this rate continues, final energy consumption of the Top-1000 Program enterprises would grow from 733 Mtce in 2005 to 1016 Mtce in 2010 under a baseline, business-as-usual scenario.[37]

Reported Savings from Top-1000 Energy-Consuming Enterprises Program

If energy savings continue to be realized at the rate experienced in 2006 – 20 Mtce/year - the Top-1000 program will be able to meet the overall program goal of 100 Mtce savings by the end of 2010. Given the baseline scenario projected above, meeting the program goal in this "Meets Target" scenario means that the Top-1000 enterprises would consume 916 Mtce (final energy) in 2010. Another possible "Exceeds Target" scenario is based upon the combined reported 2006 and 2007 savings of 58 Mtce (final energy) in which the enterprises were already more than half-way to the 2010 goal at the end of 2007. Continuation of annual final energy savings of 38 Mtce for 2008, 2009, and 2010 would lead to cumulative final energy savings for the Top-1000 program of 172 Mtce, reducing total final energy use in 2010 to 844 Mtce.

Top-1000 program 2006 energy-related CO_2 emissions are estimated to be 2,432[38] $MtCO_2$based on the data provided in the 2007 evaluation report that explains that the 2006 energy consumption of 797 Mtce was made up of the following fuel shares: 36.1% coal, 21.3% crude oil, 12.97% electricity, 8.91% coke, 1.91% heat, 1.48% natural gas, and 17.33% other energy sources such as petroleum diesel, fuel oil, LPG, washed coal, coal gas from blast furnace, and coke oven

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[35] This announcement was not accompanied by any type of detailed report and thus cannot be evaluated at this time.

[36] Calculated based on 2004 and 2005 actual energy use and 2006 actual energy use plus reported savings. Note that there were 1008 enterprises in the program in 2004. By 2006, 19 enterprises were added and 29 enterprises dropped out of the program, resulting in a total of 998 enterprises.

[37] Unlike the other programs reviewed in this report, energy use for the Top-1000 program is reported using a site (final) electricity conversion factor, not a source (primary) value.

[38] Using the site (final) electricity conversion factor, this value is 2,432 MtCO2. However, for this report electricity was converted using the source (primary) value.

gas (NDRC and NBS, 2007). Table 15 provides the details of the calculation of energy-related CO_2emissions.

Based on this calculation, the Top-1000 program energy consumption scenarios presented earlier can be converted to energy-related CO_2emissions scenarios (see Table 15). Based on the energy consumption projection, the baseline CO_2 emissions for the Top-1000 Program enterprises are projected to grow from 1723 $MtCO_2$ in 2005 to 2388 $MtCO_2$ in 2010. If the program goal is met, as shown in the "Meets Target" scenario, energy-related emissions for the Top-1000 enterprises would be 2153 $MtCO_2$, a cumulative savings of 235 $MtCO_2$. Under the "Exceeds Target" scenario that assumes that the reported 2007 savings of 100 $MtCO_2$ are repeated in 2008, 2009, and 2010, the 2010 energy-related CO_2 emissions would be 2040 $MtCO_2$ and cumulative 2010 emissions reductions would be 348 $MtCO_2$. Table 16 provides the estimated energy use and CO2 emissions as well as the savings for each of these scenarios.

Table 15. Estimated Top-1000 Program 2006 Energy-Related CO_2 Emissions

	Coal	Coke	Crude Oil	Natural Gas	Heat	Electricity	Other	Total
Fuel Share (%)	36.1	8.91	21.3	1.48	1.91	12.97	17.33	
Energy (Mtce)	288	71	170	12	15	103	138	797
Emissions ($MtCO_2$)	811	193	361	19	34	718	294	2429

Notes: Fuel emission factors from IPCC, 1996. Electricity emission factor = 0.8531 kg CO_2/kWh. Emission factor for "other" assumed to be the same as for crude oil (2.15 t CO_2/tce), since it falls between coal (2.88 tCO_2/tce) and natural gas (1.64 tCO_2/tce).

Table 16. Estimated Top-1000 Energy Savings and Energy-Related CO_2 Emissions Reductions for the Meets Target and Exceeds Target Scenarios

Scenario	2005	2006	Estimated 2007	Estimated 2008	Projected 2009	Projected 2010	Savings 2006-2008
Final Energy (Mtce)							
Baseline	733	817	863	911	962	1016	
Meets Target	733	797	823	851	882	916	
Exceeds Trends	733	797	805	815	828	844	
Savings – Meets Target		20	20	20	20	20	100
Savings - Exceeds Trends		20	38	38	38	38	172
Primary Energy (Mtce)							
Baseline	950	1059	1119	1181	1247	1317	
Meets Target	950	1033	1067	1104	1144	1188	
Exceeds Trends	950	1033	1055	1079	1108	1139	
Savings – Meets Target		26	26	26	26	26	130
Savings - Exceeds Trends		26	49	49	49	49	223
Emissions ($MtCO_2$)							
Baseline	1723	1921	2028	2142	2262	2388	
Meets Target	1723	1921	1934	2001	2074	2153	
Exceeds Trends	1723	1921	1906	1944	1989	2040	
Savings – Meets Target		47	47	47	47	47	235
Savings - Exceeds Trends		47	75	75	75	75	348

Due to limited data availability, it is difficult to assess how much of these reported savings are due to the activities and policies associated with the Top-1000 program and how much would have occurred in the absence of the program. Table 17 compares the energy intensity of the Top-1000 enterprises to the average energy intensity in China for four products, showing that the Top-1000 enterprises were significantly less energy-intensive than the national average for steel and cement production, only slightly better for electric power production, and not as efficient as the national average for the production of synthetic ammonia.

The table also provides information on the percent improvement in energy intensity for these four industries for both the average in China and for the Top-1000 enterprises between 2005 and 2006, showing that the rate of improvement for the Top-1000 enterprises was lower for steel, cement, and synthetic ammonia, and the same for electric power. This information raises questions regarding how much of the Top-1000 savings can be attributed to the program. Data for additional products and for later years of the program are required to make such an assessment. In addition, the data for China includes the performance of the Top-1000 program enterprises. Data that separates the Top-1000 enterprises from the rest of the enterprises in China is required to fully understand the performance of the Top-1000 enterprises.

Table 17. Comparison of Energy Intensity Improvement of Selected Products in China and the Top-1000 Enterprises

	Unit	Average 2005		% Improvement 2005-2006	
		China	Top-1000	China	Top-1000
Steel	kgce/t	760	642	5.3	3.7
Cement	kgce/t	159	115	3.6	2.1
Electric power	gce/kWh	377	368	0.8	0.8
Synthetic ammonia	kgce/t	1210	1507	4.2	3.5

Sources: NDRC, 2004; NDRC and NBS, 2007, Wang Qingyi, 2008.

4.3.3 Qualitative Evaluation

Comparison of Progress to Stated Policy Goals

Table 18 provides a list of the Top-1000 program stated goals and obligations for enterprises and the government, along with information on the status of achievements of these goals and obligations. The status of achievement of the **overall goals** during the first year of the program can be evaluated based on the information provided in the *Report on the State of the Energy Use of the Top-1000 Enterprises* (NDRC and NBS, 2007).

Regarding the goals to reduce unit energy consumption to domestic best practice level for all major products and to have some enterprises attain either international best practice levels or sector best practice levels, the report provides information on the energy intensity, referred to as the unit energy consumption (UEC), of selected major products which indicates that of the 13 products evaluated, all had lower energy intensities than the national average (see Table 19). Additionally, the energy intensity of 5 of the 13 products is better than the international advanced level (NDRC and NBS, 2007).

Regarding the goals to significantly improve the Top-1000 enterprises' energy efficiency and to improve the energy efficiency of each sector, Table 19 shows that between 2005 and 2006 UEC values decreased for major products in all sectors with the exception of electrolytic aluminum, refined zinc and polyester fiber (staple) production. The reductions in energy intensity ranged from 0.2% to 28.2%, with the lowest improvements seen for the production of electric power, sodium hydroxide (ionic membrane 30%), soda, coal mining, and machine-made paper and paper board. The largest energy intensity reductions were experience in the production of melting copper, melting lead, copper products, aluminum products, machine-made pulp, cloth, and certain fibers (NDRC and NBS, 2007).

Regarding the overall goal to achieve energy savings of approximately 100 Mtce during the 11th FYP, the reported energy savings for 2007 of 20 Mtce (NDRC and NBS, 2007) and for 2008 of 38 Mtce (Zhao, 2008) indicate that the program is on target to meet this goal. NDRC has recently reported that the program goal was reached in 2009.

The status of achievement of the **enterprise and government obligations** can be evaluated based on the *Report on the State of the Energy Use of the Top-1000 Enterprises* (NDRC and NBS, 2007) as well as interviews and other recent reports. Table 19 provides details regarding the activities of enterprises and the governments regarding these obligations. Overall, it appears that the enterprises and governments involved in the Top-1000 program have generally met their obligations regarding the various activities to be conducted.

Table 18.Status of Achievements Compared to Stated Goals and Obligations of the Top-1000 Program

Stated Goals and Obligations	Status of Achievements
Overall	
Reduce unit energy consumption to national advanced level for all major products	Unit energy consumption of all 13 selected products is below the national average level (NDRC and NBS, 2007). 3 of the 6 products for which national advanced levels are available either meet or are below national advanced levels (Catalogue of Maximum Energy Consumption of Major Industrial Products in Gansu Province, 2008)
Have some enterprises attain either international advanced level or national leading level	Unit energy consumption of steel, coal mining, synthetic ammonia (coal feedstock), calcium carbide, and flat glass is below the international advanced level (NDRC and NBS, 2007).
Significantly improve the Top-1000 enterprises' energy efficiency	Unit energy consumption values decreased for major products in all sectors, with the exception of electrolytic aluminum, refined zinc and polyester fiber (staple) production (NDRC and NBS, 2007).
Improve the energy efficiency of each sector	
Achieve energy savings of approximately 100 Mtce in the 11th Five-Year period	On target to save 100 Mtce in 2010: 20 Mtce achieved in 2006 (NDRC and NBS, 2007) and 38.17 Mtce saved in 2007 (Liu Jingru et al., 2009).
Enterprises	
Establish an energy conservation organization	Energy management was implemented in most of the Top-1000 enterprises based on the three-level structure, which consisted of the plant, workshop and energy use equipment. Full-time or part-time energy management sections were established in more than 95% of the Top-1000 enterprises (NDRC and NBS, 2007).
Formulate energy efficiency goals	Among 953 enterprises who singed Energy Conservation Target Responsibility Document, 391 enterprises exceeded their targets, or 41% of the total; 456 enterprises have completed their targets, which accounts for 47.8% of the total; 32 enterprises basically finished their targets, about 3.4%; and 74 enterprises failed to complete targets, which represent another 7.8% (Liu Jingru et al., 2009).
Establish an energy utilization reporting system	Energy management systems were established in all enterprises that established energy management sections. The systems include energy purchase management system, energy use management system, quota assessment of each production process, etc. Most of the top-1000 enterprises implemented the three-level energy measuring management. In the first and second level, the equipping rate of energy measuring instruments was relatively high, which was more than 90% for the first level and more than 80% for the second level. In the third level, the equipping rate of energy measuring instruments was relatively low, which was about 60%. More than 50% of the top-1000 enterprises had strong foundation for energy statistics management, full-fledged statistics sections and qualified statisticians. Less than 20% of the top-1000 enterprises had weak foundation for energy statistics management (NDRC and NBS, 2007).
Conduct energy audits	942 enterprises conducted energy audits in late 2006 and early 2007 (NDRC and NBS, 2007; Liu Jingru et al., 2009). Energy audits were conducted by local energy conservation centers, ESCOs, and universities (Yu Cong, 2008).

Conduct training	
Formulate an energy conservation plan	Enterprises completed the work of energy conservation planning in the first half of 2007 (Liu Jingru et al., 2009).
Adopt energy conservation incentives	Some enterprises use energy savings to give bonuses (Yu Cong, 2008).
Invest in energy efficiency improvement options	Top-1000 enterprises invested over 50 B RMB¥ ($7.3B) in technology innovation and implemented over 8,000 energy-saving projects in 2007 (Zhao, 2008). 70% of the Top-1000 enterprises have allocated specific funds for energy conservation (Yu Cong, 2008).
Report energy consumption by fuel quarterly to NBS	There are more than 10 forms on the China Energy Supervision Net website that enterprises are required to fill out and use to report data on-line (Wang Jingbo, 2009). In 2006, 954 enterprises reported data to NBS (NDRC and NBS, 2007).
Government	
Lead and implement the program, including tracking, supervision, and management of the energy-saving activities of the enterprises	
Oversee and "urge" the enterprises in their energy management, energy auditing, and energy reporting requirements	Training for the enterprises on the use of the on-line data reporting forms and system has been conducted (Wang Jingbo, 2009).
Improve monitoring of enterprises through audits and sampling	22 energy monitoring centers have been established (Yu Cong, 2008). The State Council conducted an evaluation in 30 provinces, focusing on the Top-1000 enterprises (Yu Cong, 2008). If there are any discrepancies or inconsistencies in the on-line data reporting, local government officials and staff from the local energy conservation centers are sent to investigate (Wang Jingbo, 2009).
Promote the use of new mechanisms such as target-setting agreements	A number of provinces have extended the Top-1000 program to additional enterprises by signing target-setting agreements.
Encourage enterprises to meet energy saving targets and attain international advanced levels ahead of schedule	Energy efficiency standards have been issued for 22 energy-intensive products (Yu Cong, 2008).

Table 19. Comprehensive Energy Consumption of Major Products from Selected Top-1000 Sectors

Index	Unit	Average Level of Top-1000 Enterprises in 2006	Reduced over 2005	International Advanced Level	National Average Level	National Advanced Level*
Steel	kgce/t	618	3.7%	642	741	562
Coal	kwh/t	41	0.3%	56	-	41
Power Supply (coal-fired electricity)	gce/kwh	365	0.8%	312	366	-
Aluminum ingot (AC electricity consumption)	kwh/t	14733	0.8%	14100	14795	14646
Synthetic ammonia	kgce/t	1453	3.5%	990(gas) 1570(coal)	1650	1192 (gas) 1500 (coal)
Sodium hydroxide (ionic membrane)	kgce/t	983	3.8%	910	1080	-
Sodium hydroxide (diaphragm)	kgce/t	1373	2.2%	1250	1493	-
Soda	kgce/t	422	0.2%	345	461	-
Calcium carbide	kgce/t	1206	2.8%	1800	2300	-
Crude oil processing	kgce/t	77	4.2%	73	104	-
Ethylene	kgce/t	972	5.7%	786	1003	960
Cement	kgce/t	113	2.1%	102	156	
Flat glass	kgce/box	16	4.0%	22	22	18

Source: NRDC and NBS, 2007; *Catalogue of Maximum Energy Consumption of Major Industrial Products in Gansu Province, 2008.
Notes: (1) The comprehensive energy consumption index adopted the statistical data of the Top-1000 enterprises, which was compiled by the National Bureau of Statistics; the data of international and national level came from the related professional organizations and research reports. (2) In terms of comprehensive energy consumption index of the top-1000 enterprises, the electricity was converted to standard coal using the heating value, i.e. the standard coal efficiency conversion factor for electricity is 0.1229 kgce/kwh. Chinese glass production is better than international best practice because there are only a few glass enterprises in the Top-1000 program.
"International advanced level" is defined by Wang Qingyi as the average level of leading countries (Wang, 2008).

Table 20.Unit Energy Consumption (UEC) and Energy Savings of Major Energy-Intensive Products for Selected Top-1000 Sectors, 2005 - 2006

Comprehensive Energy Consumption (Unless Noted Otherwise)	Unit	UEC 2005	UEC 2006	% UEC Reduced	Energy Savings in 2006 (10,000 tce)*
Iron and steel					
Steel	kgce/t	642.11	618.22	3.7%	704.48
Electric power					
Net coal consumption rate (for power supply)	gce/kWh	367.97	365.04	0.8%	190.58
Chemicals					
Sodium hydroxide (ionic membrane 30%)	kgce/t	489.84	488.29	0.3%	0.42
Sodium hydroxide (ionic membrane 98.5%)	kgce/t	678.62	653.03	3.8%	0.97
Sodium hydroxide (diaphragm 30%)	kgce/t	919.93	868.53	5.6%	12.40
Sodium hydroxide (diaphragm 42%)	kgce/t	1217.87	1191.01	2.2%	2.33
Sodium hydroxide (diaphragm 96%)	kgce/t	1071.13	1014.68	5.3%	2.25
Soda	kgce/t	422.48	421.61	0.2%	0.75
Calcium carbide	kgce/t	1240.32	1205.92	2.8%	5.72
Synthetic ammonia	kgce/t	1506.82	1453.45	3.5%	293.90
Petroleum and petrochemicals					
Crude oil processing	kgoe/t	80.60	77.20	4.2%	128.85
Ethylene	kgce/t	1030.86	972.02	5.7%	35.46
Coal					
Comprehensive electricity consumption for coal	kgce/t	40.66	40.52	0.3%	11.76
Nonferrous metal					
Melting cooper	kgce/t	499.15	428.78	14.1%	10.71
Aluminum oxide	kgce/t	881.70	836.57	5.1%	46.30
Electrolytic aluminum	kgce/t	1923.39	1982.05	-3.0%	–33.13
Melting lead	kgce/t	906.16	650.96	28.2%	5.23
Refined zinc (electrolytic zinc)	kgce/t	904.34	959.51	-6.1%	–3.58
Copper products	kgce/t	2199.42	1912.05	13.1%	1.38
Aluminum products	kgce/t	520.58	415.59	20.2%	4.57
Construction materials					
Cement	kgce/t	115.26	112.88	2.1%	38.05
Flat glass	kgce/box	16.17	15.52	4.0%	0.49
Float glass	kgce/box	17.03	15.80	7.2%	6.39
Paper					
Machine-made paper and paper board	kgce/t	560.25	558.02	0.4%	3.02
Machine-made pulp	kgce/t	276.96	241.34	12.9%	9.52
Textiles					
Yarn	kwh/t	2287.98	2237.66	2.2%	0.89
Cloth	kwh/hm	19.30	16.67	13.6%	0.27
Printing and dyeing cloth	kgce/hm	107.28	92.96	13.3%	2.49
Silk fabrics	kgce/hm	12.44	11.85	4.7%	0.01
Viscose fiber (staple)	kgce/t	1355.32	1168.47	13.8%	4.75
Viscose fiber (filament)	kgce/t	5804.37	5516.92	5.0%	1.42
Polyamide fiber	kgce/t	668.92	588.09	12.1%	0.98
Polyester fiber (staple)	kgce/t	143.48	163.24	-13.8%	–2.79
Polyester fiber (filament)	kgce/t	273.80	216.67	20.9%	4.12
Acrylic	kgce/t	983.67	927.86	5.7%	0.73
Polyvinyl alcohol fiber	kgce/t	2332.33	2183.27	6.4%	0.57

Source: NDRC and NBS, 2007

* This is calculated as the total production (e.g. tons or kWh) for each year multiplied by the energy intensity and then the total 2006 value is subtracted from the total 2005 value to get the total energy savings in 2006.

Comparison of Policy Implementation to International "Best Practice"

The Top-1000 program was based on experience gained over three years through a pilot program with two steel mills in Shandong Province that relied heavily on European experiences with voluntary agreement programs (Price, et al., 2005a). The Top-1000 Program was designed quickly in 2006 in support of China's 20% energy/GDP reduction goals. As such, some elements of the program have been designed or implemented differently than in similar programs in other countries. In addition, as discussed below, the Top-1000 Program is generally less structured than similar national-level programs in other countries.

In this section, international experience in the areas of target-setting, energy auditing, supporting policies, information dissemination, and monitoring, is first discussed and then the experience with these key program components in the Top-1000 program is described. Suggestions are made for improvements that may be implemented during the remaining years of the program or that can be seen as lessons learned for any possible follow-on programs.[39]

Target-Setting

The process for establishing energy efficiency or GHG emission reduction targets begins with an assessment – by the company or an independent third party – of the energy efficiency or GHG mitigation potential of each industrial facility. Assessment results are then provided to the government as the basis for target-setting negotiations.

In the United Kingdom's (UK's) Climate Change Agreement program, there were 44 sector agreements representing about 5,000 companies and 10,000 facilities. The government obtained information regarding energy efficiency potential in energy-intensive industries through guides and case studies produced within the Energy Efficiency Best Practices Program (Shock, 2000) as well as through scenarios of industrial sector carbon dioxide emissions (ETSU, 1999). In addition, individual companies estimated their energy efficiency potential and provided this information to their trade associations who then negotiated with the government to set a target for the entire sector.

In the Netherlands, Long-Term Agreements (LTAs) between the Dutch Ministries and industrial sectors were established in support of the overall national energy-efficiency improvement target of a 20% reduction in energy efficiency between 1989 and 2000. In total, 29 agreements were signed involving about 1,250 establishments. Sector-specific energy-efficiency potential studies were the basis for distributing the targets among the various industrial sectors. Following the studies, NOVEM,[40] the Dutch Agency for Energy and Environment, established an inventory of economically-viable measures that could be implemented by the companies in each industrial sector and based on this inventory set a target for energy efficiency improvement for each sector (Nuijen and Booij, 2002). While most industries adopted a target of 20% reduction, some negotiated different levels due to the particular circumstances of their industrial sector.

The Dutch Benchmarking Covenants, which began in 2001, use a benchmarking approach for target-setting in which an expert third party undertakes a study of the international best practice in terms of energy efficiency for each participating company's processing plants. The

[39] Some of this discussion is based on material presented in McKane et al., 2007 and Price et al., 2008b.

[40] Now SenterNovem.

results of the international best practice benchmarking study are then sent to the Benchmarking Commission to verify the accuracy and completeness of the expert third party's methods and results of the study (Commissie Benchmarking, 1999).

In Japan's Keidanren Voluntary Action Plan on the Environment, which commits to stabilizing greenhouse gas emissions of Keidanren members at 1990 levels by 2010, numerical savings targets were set voluntarily by 38 sectors in 1997. The number of sectors has since grown to 58, including 35 from industrial and energy-converting sectors. Individual targets are set following technical and economic analyses of energy-saving technologies and potential. Of the 35 industrial sectors, 12 committed to absolute CO_2 emissions reduction targets, 9 to CO_2 intensity reduction targets, 5 to absolute energy use reduction targets, and 15 to energy intensity targets (Wakabayashi and Sugiyama, 2007).

In the Top-1000 program, targets were set by NDRC for each enterprise in order to support the provincial-level targets and to reach the overall savings target of 100 Mtce for the Top-1000 program. Initially, NDRC set preliminary targets for each enterprise taking into consideration their general situation such as which industrial sector they belonged to since the potential energy savings vary by sector, as well as the general technology level of the enterprise, if known. The targets were not based on detailed assessments of energy-savings potential of each enterprise or each industrial sector. This approach was taken due to time constraints. Since the Top-1000 program was designed in support of the 11th Five Year Plan which began in 2006, it would have been necessary to start the target-setting process three or four years prior to follow international practice, which was impossible given both the time pressure and the large number of participating enterprises. The resulting target of 100 Mtce only represents 15% or less of the required savings of 646 to 700 Mtce (depending upon the assumed growth rates) to meet the 2010 goal of reducing energy use per unit of GDP. Given the energy-intensity of these industries, more detailed assessments may have identified higher potential energy savings for these industries and a more ambitious goal could have been set for the Top-1000 program based on the potential savings identified.

Energy Auditing[41]

Auditing enterprises involves collecting data on all of the major energy-consuming processes and equipment in a plant as well as documenting specific technologies used in the production process and identifying opportunities for energy efficiency improvement throughout the plant, typically presented in a written report. Tools, informational materials, and other energy efficiency products are often furnished during the audit. Some audit programs, like the U.S. Department of Energy's Energy Savings Assessments program, provide a directory or network of accredited auditors.[42]

The International Energy Agency's (IEA's) project on Energy Audit Management Procedures within the European Union's Specific Actions for Vigorous Energy Efficiency (SAVE) Programme outlines the core elements of an energy audit: evaluating the present energy consumption, identifying energy saving possibilities, and reporting. The report explains that there are many types of energy audits that vary in scope and complexity. Scan-type audits identify the major energy-consuming areas of a facility and point out energy-saving measures that can be applied.

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[41] Excerpted from Price et al., 2008b.
[42] http://www1.eere.energy.gov/industry/bestpractices/qualified_specialists.html

An example of a scan-type audit is a walk-through audit for facilities with simple energy-consuming systems, typically small and medium sized industrial facilities. Another scan-type audit is a preliminary energy audit which is typically performed by a team of energy experts and provides a breakdown of the facility's current energy consumption and identifies probable energy-saving measures. More in-depth analyzing audits include system-specific audits that identify the energy-saving potential of one specific system, device, or process; selective audits in which the auditor focuses on specific systems seeking those with the major energy-saving opportunities; targeted audits in which certain low energy-consuming areas are excluded from the audit; and comprehensive energy audits that cover all of the facility's energy consumption, including mechanical and electrical systems, process supply systems, and all energy using processes (MOTIVA et al., 2000).The SAVE project produced a number of information sources, including a *Guidebook for Energy Audit Program Developers* that provides information on training, authorization, quality control, monitoring, evaluation, energy audit models, and auditor tools based on auditing programs in 16 European countries (Väisänen, H., et al., 2003), a *Topic Report on Auditors' Tools* that discusses a variety of auditing tools used within European auditing programs (ADEME, 2002), and a *Topic Report: Training, Authorisation, and Quality Control that discusses* energy auditor training, authorization of energy auditors, and quality control of energy audits (Väisänen and Reinikainen, 2002).

Individual plant audits conducted as part of the Dutch Long-Term Agreements included a description of the sector, an assessment of the plant's energy consumption in the base year, a survey of opportunities for energy-efficiency improvement, and a description of the monitoring and energy management techniques used. Identified energy-efficiency measures were grouped in five categories: good housekeeping/energy management, retrofit or strategic investments, energy-efficiency investments, cogeneration, and other measures (e.g. changes in feedstock). The individual enterprise audits were done by the company itself and/or by independent consultants. The results of the audits were reported to an independent government agency, and provided the basis for final discussions and negotiations between the industries and the government to establish the final target for the sector. The assessments were further used as a basis for the company Energy Savings Plan which included an assessment of energy consumption in the base year, a survey of opportunities for energy-efficiency improvement, monitoring and energy management, research and development of new energy-efficient technologies, and demonstration projects of energy-saving measures (Nuijen, 2002a).

As part of the Danish CO_2 Tax Rebate Scheme for Energy-Intensive Industries, energy audits of individual plants were conducted by independent, approved consultants. The energy audit was required to include the following: an energy balance for the plant with a detailed breakdown of energy consumption by processes, description of the energy-efficiency projects at the plant, including potential future projects, recommendations for energy management, and recommendations for energy conservation investments (Ezban et al., 1994). The purpose of the energy audit was to identify all profitable energy measures. In heavy processes (like greenhouse heating and production of food, sugar, paper, cement and glass) profitable refers to energy efficiency with a payback period of less than four years. In light processes (energy tax of the company exceeds 4% of the company's value added) profitable is defined by a payback period less than six years. The energy audits were carried out by either by consultants or company staff. The audits were verified by an independent certified verification agency. Sector-wide reports were also prepared. These reports provide a sector-wide analysis of energy consumption and production processes and identify the general potential for energy-efficiency improvement in the companies within the sector (Togeby et al., 1998).[43]

The Swedish National Energy Administration (STEM), as a part of the EKO Energi Agreements, provides a comprehensive inventory and analysis of energy use in a company's production and premises, and includes a list of possible actions to be taken. STEM also provides a comprehensive material flow analysis as well as an introductory comparison of the company's environmental awareness and management and guidelines based on the Eco-Management and Auditing Scheme (EMAS) or International Standardization Organization (ISO) 14001 standards(Uggla and Avasoo, 2001).

The U.S. Department of Energy (DOE)'s Industrial Assessment Centers (IACs), located at 26 universities throughout the U.S., perform in-depth assessments of industrial facilities including a detailed evaluation of potential savings from energy efficiency improvements, waste minimization and pollution prevention, and productivity improvements. The assessment team surveys the plant and takes engineering measurements that are the basis for the detailed analysis with related cost, performance, and payback time estimates. These results are then presented to the plant in a confidential report with findings and recommendations.[44] In 2001, the IACs performed 590 facility assessments that identified 3,350 energy efficiency recommendations with an average simple payback time of 0.9 years. Of those, facilities implemented 1,550 (46%) of the recommendations and the implemented recommendations had an average simple payback time of 0.5 years (Muller, 2001).

In 2006, the U.S. DOE's Industrial Technologies Program initiated the Save Energy Now program that provides trained energy experts to perform Energy Savings Assessments at the most energy-intensive manufacturing facilities in the U.S. The purpose of the assessments is to identify immediate opportunities to save energy and money, primarily by focusing energy intensive systems such as process heating, steam, compressed air, fans, and pumps.[45] In 2006, the Save Energy Now program completed 200 assessments at large manufacturing plants and found that the typical large plant can reduce its energy bill on average by over $2.5 million (17.1 million RMB) per plant, for a total of $500 million (3.4 billion RMB) in identified energy cost savings and over 4 million metric tons of CO_2 emissions reductions. The assessments targeted the largest energy-consuming manufacturing plants, consuming 1 trillion British thermal units (Btus) or more annually, and six industries (over 80% of the assessments were in these industries): chemical manufacturing, paper manufacturing, primary metals, food, non-metallic mineral products, and fabricated metal products. Six-month follow up surveys indicated that about 7% of the recommendations have been implemented, saving an estimated $30 million (205 million RMB) annually and more than 70% of the recommendations have been implemented, are in progress, or are planned for implementation (Wright et al., 2007). Assessment reports, which include near-term, medium-term, and long-term opportunities for

[43] The obligation to do an energy audit before signing a voluntary agreement was removed in the revised scheme (2002). Instead of the energy audit, the participating companies must now do an energy flow screening covering the most energy-intensive parts of their production process. The purpose of the energy flow screening is not to identify profitable energy savings projects, but to identify areas or parts of the production process that are relevant to study further in special investigation (Ericsson, 2006).

[44] http://www.iac.rutgers.edu/database/about.php

[45] http://www1.eere.energy.gov/industry/saveenergynow/assessments.html

energy saving, are provided to the company and also posted on DOE's Energy Savings Now website.[46]

During the winter and spring of 2007, the Top-1000 enterprises undertook energy audits that documented the current energy consumption situation at the enterprise and identified energy efficiency opportunities. The enterprises then developed energy action plans outlining how they expect to meet their energy-saving targets. While some Top-1000 enterprises have the expertise to conduct energy audits and identify energy efficiency opportunities, a number of enterprises found this task difficult due to the lack of qualified auditing personnel and needed to hire outside experts for assistance (Lu, 2006). The audits were often not very detailed, incomplete, did not analyze the data, and contained useless information (Ma, 2008). There are a variety of outside experts that can provide energy auditing services including private consulting firms, energy service companies, provincial energy conservation centers, and the China Energy Conservation Association (CECA). The technical expertise and abilities of these organizations varies widely, with some highly skilled in energy auditing and others in need of significant training. The most qualified provincial energy conservation centers in the area of energy auditing are in Sichuan, Jiangsu, and Henan provinces, and in addition Shanghai and Shandong energy conservation centers are well qualified in energy conservation work (Jiang, 2006). The Shanghai Energy Conservation Service Center and the Jiangsu Energy Conservation Training Center have both completed training on motor system optimization through the China Motor System Energy Conservation Program (McKane et al., 2003). Remaining problems, however, include the lack of standards and guidance for energy auditing and lack of capacity both within enterprises and within other organizations that perform energy audits.

Supporting Policies

Internationally, programs similar to the Top-1000 program also typically establish a harmonized set of supporting programs for participating enterprises. Ideally, such policies and programs should be in place at the commencement of the program so that enterprises have a full understanding of the type and range of support they will receive as they set out to achieve their targets. Such policies typically include financial incentives, technical assistance, rewards and publicity for enterprises that reach targets, and sometimes penalties for failure to reach targets. Financial incentives for investing in energy-efficiency technologies and measures include targeted grants or subsidies, tax relief, and loans for investments in energy efficiency. Tax relief for purchase of energy-efficient technologies can be granted through tax exemptions, tax reductions, and accelerated depreciation. A common approach is to provide a list of technologies for special tax treatment (Price et al., 2005b). In countries such as Denmark, the Netherlands, Sweden, and the U.S., funding covering 40% to 100% of the cost of energy-savings assessments is provided, often as a benefit of participating in target-setting programs (WEC, 2004).[47] In the Climate Change Agreements in the UK (DEFRA, 2004) and the Danish energy efficiency agreements (Togeby et al., 1999), incentives for meeting agreed-upon targets are provided in the form of a reduction of the required energy tax.

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[46] http://www.eere.energy.gov/industry/saveenergynow/partners/results.cfm

[47] The exception to this approach is the European Union's Emissions Trading Scheme where the EU countries allocated emissions targets on the basis of past emissions while only small efforts are being made to account for a company's ability to abate its emissions, but with a complex trading market in place to enable enterprises to sell excess emissions credits or purchase emissions credits to cover gaps between their actual performance and their target.

Supporting policies and programs for the Top-1000 program were not established prior to the announcement of the program. Instead, the *1,000 Enterprise Energy Conservation Action Implementation Plan* (NDRC, 2006c), which was issued in April 2006, outlined that that government would begin efforts to "strengthen energy saving supervision management according to the law, implement strengthened energy savings tax and fiscal policy, increase support level of energy saving improvement projects, establish energy saving technology dissemination new mechanism, and honor and award advanced models". Numerous supporting policies have, however, been established over the three years since the Top-1000 program commenced.

Although given the time constraints for developing and implementing the Top-1000 Program, it is understandable that the full program was not established at the time it was announced, this did weaken the initial impact of the program due to lack of clarity regarding what the central government would offer to the enterprises and how the program should be implemented at the provincial level. For example, in November, 2006, a number of provincial government officials who were given provincial level energy/GDP reduction targets in addition to responsibility for overseeing successful implementation of the Top-1000 program for those enterprises located in their province, expressed concern and confusion over the establishment of both provincial and national level policies and programs in support of the Top-1000 Program at the Energy Foundation's *Forum on Implementing China's 2010 20-Percent Energy Efficiency Target*. As described earlier, a number of these supporting policies and programs have subsequently been developed and put in place during 2006 and 2007, while others are still in discussion or have not yet been established.

Information Dissemination

Internationally, information dissemination is an important component of target-setting and other industrial energy efficiency programs. Technical information sources such as energy efficiency guidebooks, databases, software tools, and industry- or technology-specific energy efficiency reports are produced in many countries (Galitsky et al., 2004). The U.S. Department of Energy's (U.S. DOE's) Industrial Technologies Program provides many software tools for assessing energy efficiency of motors, pumps, compressed air systems, process heating and steam systems.[48] The U.S. DOE also provides case studies that describe energy-efficiency demonstration projects in operating industrial facilities in many industrial sectors and sourcebooks, tip sheets, technical fact sheets and handbooks, and market assessments. Case studies providing information on commercial energy-saving technologies for a number of industrial sectors are also provided by the Centre for Analysis and Dissemination of Demonstrated Energy Technologies (CADDET).

Energy efficiency reports or guidebooks provide information on existing and new technologies and measures as well as energy management practices. The Canadian Industry Program for Energy Conservation's sector-wide energy efficiency guides provide information on energy efficiency measures for many sectors. The U.S. ENERGY STAR for Industry Energy Guides include both process-specific and utility energy efficiency measures for breweries, cement, corn refining, fruit and vegetable processing, glass, motor vehicle assembly, petroleum refining, and pharmaceuticals. As part of the Dutch Long-term Agreements 2 (LTA2), SenterNovem and

[48] See http://www1.eere.energy.gov/industry/bestpractices/software.html

representatives of the sector develop and maintain a "measurement list" of possible efficiency improvements that consists of a detailed description of the measure, investment costs, energy savings, returns on investment and if financial support is available for the measure.[49]

The Top-1000 program currently has not developed a systematic means for gathering or disseminating energy efficiency information sources to the participating enterprises.[50] As previously mentioned, the Top-1000 program did develop materials for a 2-day workshop that was held for the Top-1000 enterprises in five cities throughout China in October 2006.[51] The Top-1000 web page on NDRC's website, however, simply provides short news articles reporting on related notices, meetings, and Provincial activities.

Monitoring (Measuring, Reporting, Verifying)

International experience indicates that is extremely important to establish effective monitoring guidelines at the beginning of an energy-efficiency or target-setting program. Clear and transparent monitoring guidelines should be outlined that give enterprises an overview of what needs to be reported, when it should be reported, how it should be reported and to whom. Enough detail should be provided at the beginning of the project about how the project's savings will be documented and what level of accuracy is desired. Ideally, monitoring also includes verification by an independent third party that will validate the submitted information and oversee the monitoring procedures. It is important to clearly define the monitoring process, outline the format and requirements of monitoring reports, and provide clear definitions regarding energy use and energy saving measures. According to the U.S. *National Action Plan for Energy Efficiency*, a monitoring and verification (M&V) plan should include the project description, inventories (where appropriate), description of the proposed measure(s), estimates of energy savings, a budget for M&V, and proposed construction and M&V schedules (Schiller, 2007).

The monitoring requirements of the Dutch LTAs, which were outlined in a handbook (Novem, 1999), involved annual reporting on the energy-efficiency improvement achieved, including data on total energy use, the Energy Efficiency Index level achieved, and progress on the projects carried out to reach the Energy Efficiency Index for that year. Corrections were allowed for changes in the mix of products, extra energy use as a result of stricter environmental regulations, and the degree of capacity utilization of existing product installations (Hoogovens Technical Services, 1992; NIJSI and MEA, 1992).The annual reports were submitted to an independent third party to check the reported values for accuracy (Nuijen, 2002b).

Companies that take part in the Dutch LTA2s are required to submit annual monitoring reports to SenterNovem on the progress they have made implementing their energy conservation plan (ECP). SenterNovem uses the corporate monitoring report to assess whether a company is

[49] SenterNovem presents lists with energy efficiency improvements for more than 20 sectors on their website: http://www.senternovem.nl/mja/tools/maatregellijsten/index.asp. To determine the return on investment (ROI), SenterNovem developed a tool to determine ROIs of measures. This Excel tool can be downloaded from: http://www.senternovem.nl/mmfiles/tvt_ncw_tcm24-111964.xls (in Dutch).

[50] The Energy Foundation has funded Lawrence Berkeley National Laboratory to develop energy efficiency guides, which are being translated by ERI, that identify international energy-efficiency technologies for a number of energy-intensive industries.

[51] The presentations from that workshop are posted on the NDRC website: http://hzs.ndrc.gov.cn/jnxd/t20061108_92567.htm

making enough effort to realize its ECP by evaluating the company's energy efficiency goals, the measures intended to be employed, and the schedule for reaching the goals. The report provides data on the improvement in energy efficiency in the relevant facility/facilities compared to 1998 (the reference year), and the realized emissions reduction of CO_2. SenterNovem presents the LTA branch reports in a yearly brochure, thus providing an overview of the energy-saving measures taken by Dutch companies and the results they have achieved (SenterNovem, 2005; Novem, 1999). For the Dutch Benchmarking Covenants, an independentBenchmarking Verification Bureau monitors the covenant, verifying that each company has completed the different stages in the benchmark process, ensuring that the definition of the world lead is adequate, determining that the energy efficiency plan has been properly developed, and providing feedback on this to the company and to the competent authority (Commissie Benchmarking, n.d.).

Each entity participating in the UK Climate Change Agreements is required to report primary energy used for each type of fuel, carbon emissions, throughput, product mix adjustments, and emission trading adjustments for the target period. The UK Department for Environment, Food, and Rural Affairs provides detailed guidance, including spreadsheets, related to a number of issues such as changes in corporate ownership, accounting for combined heat and power, and use of emissions trading (DEFRA, 2008).

Companies participating in the Japanese Keidanren Voluntary Action Plan perform annual surveys of their achievements, which are made public. In addition, the Advisory Committee on Natural Resources and Energy and the Industrial Structure Council also annually review the surveys submitted by the industries. Within Keidanren, there is also an Evaluation Committee that evaluates and provides feedback on the industry reports (Wakabayashi and Sugiyama, 2007).

In China, NBS is in charge of collecting data from the enterprises for the Top-1000 program. There is a generic spreadsheet that can be used for all Top-1000 plants to report their energy consumption by fuel quarterly on-line. The Top-1000 reporting is directly to NBS online via a website, not through regional statistical bureaus. The data collection is done in this manner to improve accuracy and reliability, to make it easier for the enterprises, and to reduce work for regional statistical bureau staff members. NBS will release information on average or total energy use or energy use by industry, but not by specific enterprise. Enterprise-specific data is, however, provided to NDRC. Capacity building is needed for training for enterprises to operate the on-line reporting system, for development of an indicator system, for development of standards for boundary setting, and for data analysis. As currently structured, there is little transparency in the data reporting for the Top-1000 Program. To date, there has only been one officially-released summary report on the progress of the program. This report was based on data provided in the "P207" report of the Top-1000 enterprises, compiled by NBS, as well as from a summary of the energy audit report of the Top-1000 enterprises (NDRC and NBS, 2007). These internal reports are not available to the public. While NDRC does send experts to the provinces on an annual basis to evaluate the Top-1000 program progress, there is no independent 3rd party review or verification of the reported results at the enterprise, sector, provincial, or national level.

4.4 Structural Optimization/Small Plant Closures

4.4.1 Overview

The 11th FYP identifies optimization of industrial structure as a one of the central themes in the implementation of the "scientific development concept", as a reflection of the developments and changes that occurred during last decade. After China's accession to the World Trade Organization (WTO) in December 2001, China's leadership has seen a combination of high growth rates in GDP along with a reversed trend in energy consumption, particularly in industrial sector.

From 1980 to 2001, primary energy use in China has enjoyed a 4% annual average growth rate while GDP grew at 10% each year; however, primary energy use has dramatically surged by 13% from 2002 to 2006, even though GDP kept increasing at 10% annually (constant 2000 RMB) (NBS, various years). More importantly, the dominance of industry, which represented 65% of primary energy use in 2000 and currently is up to 69% in 2006, has further strengthened (NBS, various years). Similar to the trend of total primary energy consumption, the AAGR of industrial energy use has increased from 4% during the period of 1980-2001 to 15% during 2002-2006 (NBS, various years). Thus, as displayed in Figure 17, China's total primary energy use and industrial energy use is highly correlated.

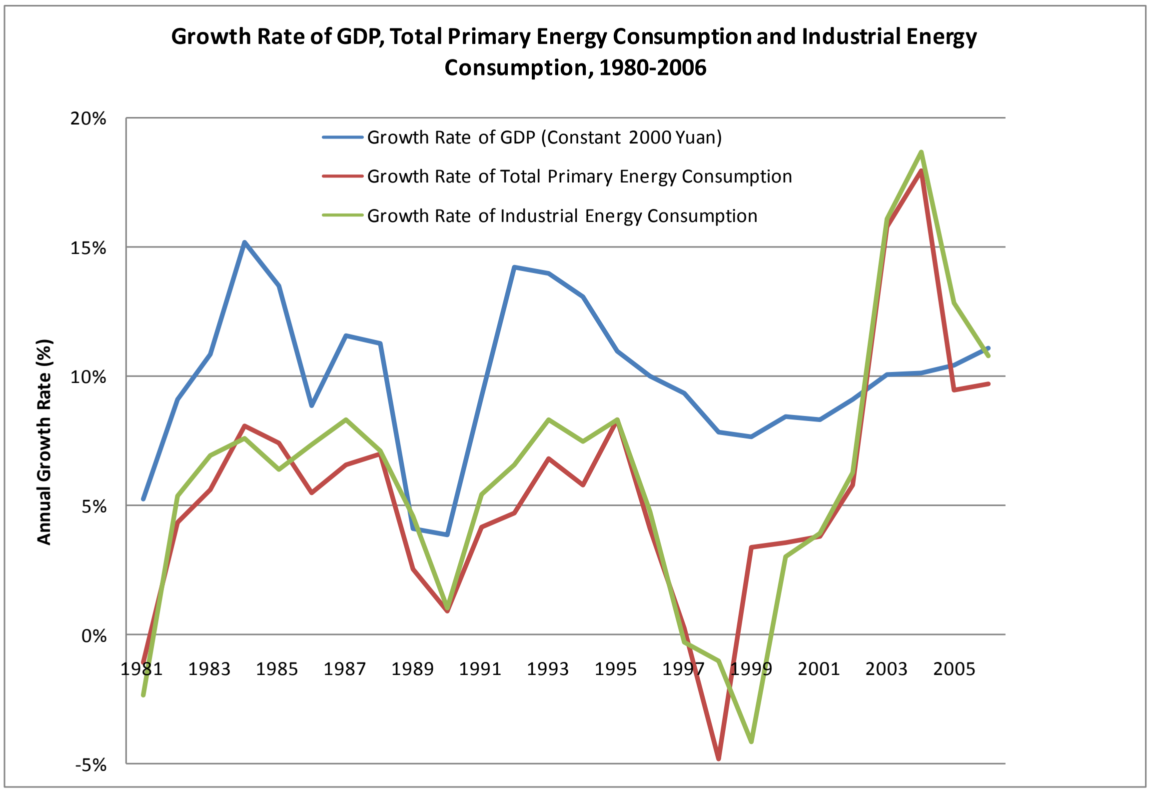

Figure 17. Growth Rate of GDP Compared to the Growth Rate of Industrial Energy Consumption, 1980-2006

The 11th FYP calls for “a more rational structure of industries, products, and industrial organization” and an increase in the ratio of service sector value-added to total GDP of 3 percentage points. Despite this goal, Figure 19 shows that the share of industrial sector energy use has grown from 69% of total energy use in 2000 to 72% of total energy use in 2007 (NBS, various years). In addition, the share of GDP attributed to the secondary sector of the economy[52] increased from 45.9% in 2000 to 48.6% in 2007 (NBS, 2007).

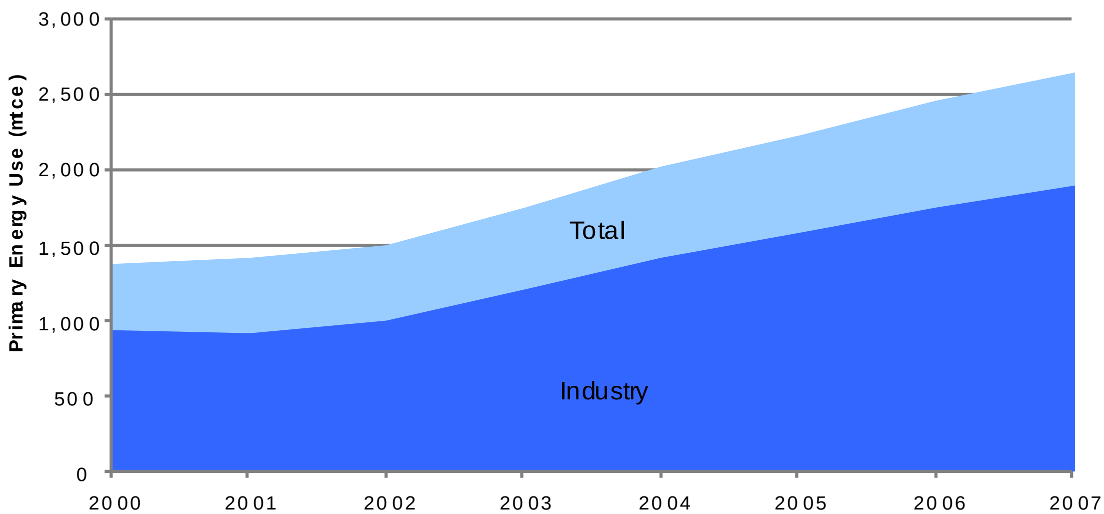

Figure 18. Share of Industrial Sector Energy Use in Total Energy Use, 2000-2007
Source: NBS, various years.

Due to market demand and high prices of energy-intensive products, existing manufacturers continued producing from smaller facilities. For example, from January to October in 2006, steel production by medium-and-large iron and steel enterprises increased 15.6%, but steel production from plants with capacities less than 1 million tons increased 30%. By 2006, steel production from the top ten largest iron and steel enterprises in China represented 34.35% of the total production, which was a decrease from that of 2005 (35.38%). In 2007, the top 10 enterprises accounted for 36.8% of total crude steel production (Shan and Wang, 2007). In spite of closing small plants, the existing inefficient plants continue to contribute disproportionately to energy use.

Compared to the international market, major Chinese energy-consuming industries are still less active in mergers and acquisitions. Although the discussions and preparations appear to be ongoing, the real progress in building stronger and larger companies is limited. In addition, after mergers and/or acquisitions, some enterprises are still operating on their own, with

[52] The primary sector of the economy involves changing natural resources into primary products and includes agriculture, agribusiness, fishing, forestry and all mining and quarrying industries. Most products from this sector are considered raw materials for other industries. The Secondary sector includes those economic sectors that create a finished, usable product: manufacturing and construction. The tertiary sector involves the provision of services to businesses as well as final consumers. Services may involve the transport, distribution and sale of goods from producer to a consumer as may happen in wholesaling and retailing, or may involve the provision of a service, such as in pest control or entertainment.

independent development plans. Thus, the effect of integrating and optimization is incomplete. For example, there were 5,028 cement enterprises by the end of 2007 with a total clinker production of 956.3 Mt. The four largest cement enterprises produced 11.9% of China's total clinker production, while the top ten companies produced 19.43%, and the top 60 companies produced 32% (CCA, 2008). By 2008, annual production capacities of 18 cement enterprises had exceed 10 Mt of cement, compared to only ten companies in 2005 (CCA, 2009).

Regarding small plant closures, China's State Council announced a *Comprehensive Working Plan of Energy Conservation and Emission Reduction* on May 23, 2007 to accelerate the speed of closing small plants and phasing out outdated capacity in 14 high energy-consumption industries: electric power, iron-making, steel-making, electrolytic aluminium, ferroalloy, calcium carbide, coking, cement, coal, plate glass, pulp and paper, alcohol, monosodium glutamate, and citric acid (State Council, 2007a). The analysis below focuses on the program related to small plant closures.

Stated Policy and Program Goals

Table 21 provides information on the specific closure goals for the 14 industrial sub-sectors. The policy states that these plants must be closed and estimates that the closures will save 118 Mtce[53] and reduce 2.4 Mt of sulfur dioxide (SO_2) by 2010.

Table 21. 11th Five-Year Plan Targets for Small Plant Closures and Phase-Out of Outdated Capacity

Industry	11th FYP Targets
Electricity	50 GW
Iron-making	100 Mt
Steel-making	55 Mt
Electrolytic aluminium	0.65 Mt
Ferroalloy	4 Mt
Calcium carbide	2 Mt
Coking	80 Mt
Cement	250 Mt
Coal mining (production)	305 Mt
Glass	30 million weight cases
Pulp & paper	6.5 Mt
Alcohol	1.6 Mt
Monosodium glutamate	0.2 Mt
Citric acid	0.08 Mt

Source: State Council, 2007a; NDRC, 2007g; CCA, 2009; Lv, 2009.

Reported Results

Table 22 provides information on the reported capacity that has been closed by the end of 2008 (NDRC, 2009a; NDRC, 2009b). Results have only been reported for 10 of the 14 sub-sectors.

[53] It is assumed that this represents net energy savings in final energy.

Table 22. Small Plants Closure and Phase-Out of Outdated Capacity Results, 2006-2008

Industry	Unit	11th FYP Targets	Realized Capacity Closures 2006-2008*	Share of Target
Coal mining (production)	Mt	305	250**	82%**
Cement	Mt	250	140	56%
Iron-making	Mt	100	60.59	61%
Steel-making	Mt	55	43.47	79%
Electricity	GW	50	38.26	77%
Pulp & paper	Mt	6.5	5.47	84%
Alcohol	Mt	1.6	0.945	59%
Monosodium glutamate	Mt	0.2	0.165	83%
Electrolytic aluminum	Mt	0.65	0.105	16%
Citric acid	Mt	0.08	0.072	90%
Coking	Mt	80	n/a	
Ferroalloy	Mt	4	n/a	
Calcium carbide	Mt	2	n/a	
Glass	M weight cases	30	n/a	

Source: State Council, 2007a; NDRC, 2007g; CCC, 2008; Feng Fei et al., n.d.; *NDRC, 2009a and 2009b.
** 2007 data for closed capacity. The number of closed coalmines in 2007 is only about 45% of that of 2005.
Note: n/a = not available

Detailed information regarding the results of this policy is not available for all sectors. Below, information is provided regarding the policies and closures for the electric power, cement, iron, and steel industries. Following the descriptions for each of these sectors, an assessment of the results of this program to date is provided based on available information.

Coal Mining
The development goal of the coal industry for the 11th Five-Year Plan is to focus on "integrating coal industry and developing coal industry orderly," as elaborated in the *Eleventh Five-Year Plan of Coal Industry Development* by the State Council and NDRC in January 2007 (NDRC, 2007g). "Integration" means upgrading and/or merging small-and-medium coalmines, and thus restructuring the industry. "Orderly development" on the other hand, aims at adopting clean technologies, paying attention to resource conservation and environmental protection, as well as enhancing operation and safety management.

Somewhat different from other energy-intensive sectors, the Chinese government puts a cap on the number of small-size coalmines (which refers to coalmines with capacities no more than 300,000 tons per year) and the amount of coal production from them for 2010. According to *The Eleventh Five-Year Plan of Coal Industry Development*, there were 20,622 coalmines that produced 1 billion tons of coal in 2005. The target for 2010 is to reduce the number of small coalmines to 10,000 and limit the production below 700 million tons. Main coal-producing and coal-consuming provinces and municipalities are grouped into seven geographical areas, with individual targets given to each province and region (NDRC, 2007g).

Electric Power Sector

The electric power sector in China has experienced rapid growth recent years, building approximately 100 GW of capacity per year from 2002 to 2005. Both coal consumption and SO_2 emissions from power plants account for more than half of the national total. Coal consumption per kilowatt hour of Chinese coal-fired plants was 45g higher than the advanced international level in 2007. Smaller plants (<100 megawatt/unit), which represent 30% of total installed capacity, are the major contributors to the high energy consumption and pollution (NDRC, 2007b). The average coal consumption of small coal power units is about 490 grams (g)/kWh, with an efficiency rate at 25.08%. Some smaller units' values are even more than 700 g/kWh, which is about 17.56% in efficiency. To support the 20% reduction goal in energy use per unit of GDP of the 11th FYP, on January 20th, 2007, State Council approved a plan to close 50 GW of small coal-fired power plant capacity, which was drafted by NDRC and the Energy Office (State Council, 2007b).

The closure plan focuses on small coal-fired (or oil-fired) electric power units including enterprises' self-supplied units and units for wholesale. There are five types of small units that are targeted: 1) coal-fired units with capacity under 50 MW/unit, 2) coal-fired units with capacity under 100 MW/unit that have been operating for twenty years, 3) all types of units that have completed the service duration with a capacity under 200 MW/unit, 4) coal-fired units that have a 10% higher coal consumption than the average provincial level or 15% higher than the national level, 5) all types of units that do not meet the environmental protection emissions requirements. Cogeneration plants that do not meet the local or national levels after renovation or have higher coal consumption when not supply heating should be closed as well (State Council, 2007b).

Stated Policy and Program Goals

The stated target is to close 50 GW of capacity during the 11th FYP period, from 2006 to 2010. It is estimated that if all the small coal-fired plants are replaced with large units, savings of 90 Mt of coal[54] and reductions of 1.8 Mt of SO_2will be realized. This represents a decline of 10% and 13.5% in coal consumption and SO_2 emissions, respectively, based on 2005 data (NDRC, 2007b). To achieve these goals, three companion policies were established.

Link Small Unit Closures to Large Unit Construction Approval

In this policy, the Central government incentivizes the closure of small units by allowing provinces to replace small units with larger facilities. The central government is encouraging enterprises to undertake mergers, acquisitions, or restructure with small coal-fired plants first, before new construction begins.

Generating Dispatching Mechanism

Historically, the Chinese electric power generation allocation system allotted the same generation hours to both large and small units and did not account for differences in energy consumption (NDRC, 2007b). This system provided incentives for enterprises or local governments to invest in coal-fired plants, but neglected the advantages of cleaner and more efficient large units. On August 2, 2007, the State Council released a policy of *Power Generation Dispatching for Energy Conservation*, which was developed by NDRC, the Ministry of Environmental Protection, the State Electricity Regulation Commission and the Energy Office.

[54] This is equivalent to about 65 Mtce, assuming a conversion factor of 0.7143 kgce/kg raw coal.

Under the new policy, environmental protection was incorporated into the system, and renewable energy units, such as wind power, solar power, hydro, biomass generation were given higher priority to coal-fired or oil-fired power plants. For coal-fired power plants, the order of generation dispatching is based on energy consumption and pollution levels, i.e., the more energy-efficient, the higher ranking it can obtain (State Council, 2007c). China is conducting pilots for implementation of this dispatching policy in Guizhou, Sichuan, Jiangsu, Guangdong, and Henan provinces. In addition, the State Electricity Regulatory Commission, NDRC, and National Energy Administration have jointly developed specific compensation rules to minimize the local impacts of the reduced dispatchable capacity from inefficient coal-fired units.

Pricing/Subsidy Mechanism

The State Council policy requires local governments to manage grid purchasing prices from small coal-fired plants. It is stated in the policy that grid purchasing prices in all small coal/oil-fired plants should be reduced to lower or equal to local average level, and no additional subsidies are allowed (State Council, 2007b). Detailed regulations, scope, price reductions, and implementing methods are outlined in *Notice on Reducing Grid Purchasing Prices from Small Coal-fired Plants,* which was released on April 2, 2007 (NDRC, 2007c).

It is also mentioned in State Council policy that closed small coal-fired plants can still obtain quotas in the first few years (the maximum is three years), and the closed plants can receive economic compensation from selling quotas to large power units (State Council, 2007b). The generation quotas that can be sold will decrease each year. Provincial and municipal governments are authorized to set up detailed subsidy policies in their areas, and then report to NDRC.

Reported Results

In 2007, China closed 553 small coal-fired power generation units, with a capacity of 14.38 GW, which is almost 44% above the 2007 closure target. As stated in the policy of *"Link Small Unit Closures to Large Unit Construction Approval*", by the end of 2007, after closing small units the same amount of electricity is generated by large units but coal usage was reduced by 18.8 Mt, SO_2 emissions were reduced by 0.29 Mt, and CO_2 emissions ware reduced by 37.6 Mt annually**.** In 2008, reported closure of small coal-fired plants was 16.69 GW, which is 3.69 GW or 28.4% above the original target. In 2009, NDRC reported that a total of 38.26 GW of small electric power generation units had been closed from 2006 to 2008 (NDRC, 2009a) (see Table 23).

Table 23. Small Coal-Fired Electricity Plant Closures, 2006-2008

Year	Closed Capacity (GW)	Initial Targets (GW)	Compared to Targets
2006	3.14	n/a	n/a
2007	14.38	10	+43.8%
2008	16.69	13	+28.4%
Total Reported	**38.26**		

Source: NDRC, 2008b; Energy Bureau, 2009; NDRC, 2009a.

*Note: total does not equal sum of individual years, but was reported in June 2009 as the achievements of 2006-2008.

n/a = not available.

Cement Industry

Stated Policy and Program Goals

Under the industrial adjustments listed by NDRC, the goals for cement industry are to: a) increase the proportion of new suspension pre-heater (NSP) kilns from 45% in 2005 to 70% by 2010; b) eliminate 250 Mt of obsolete cement production capacity, with an annual phase-out rate of 50 Mt; c) promote industrial integration, which is to reduce the number of cement companies to 3,500 with an average production capacity of 0.4 Mt; d) require each of the top ten largest cement companies to reach an annual production capacity of over 35 Mt; and e) tighten coal consumption requirement from to 130 kg/ton of clinker to 110 kg/ton of clinker, and lower energy consumption per unit product by 25% and the dust emission by 50% (NDRC, 2006d).

Reported Results

In 2007, 1066 enterprises agreed to close their outdated production lines and also agreed to renovate and transform production lines, including some that planned to close the entire cement plants.
Table **24**shows the top 5 provinces in terms of closure scale.

By the end of 2007, more than 480 vertical shaft kilns (VSK) cement production lines were closed, and 45 Mt of obsolete VSK clinker production capacity was eliminated. At the same time, the share of New Suspension Pre-heater (NSP) kilns increased from 46% in 2006 to 51% in 2007 (Xu, 2008) and to 62% in 2008 (Liu Ming, 2009). In 2009, NDRC reported that 140 Mt of cement capacity had been closed during the 2006-2008 period (NDRC, 2009a).

Table 24.Major Closures in the Cement Industry, 2007

Province	Number of Enterprises	Closed Production Lines
Shanxi	151	211
Henan	102	163
Hunan	92	103
Hebei	76	110
Fujian	69	92

Source: NDRC, 2007d.

Iron & Steel Industry

In 2004, the iron and steel industry in China consumed about 300 Mtce, accounting for 15% of national energy consumption, but its industrial value added only contributed 3.14% of national GDP. One main factor causing the high energy-intensity and low economic value of this industry was the high share of low-quality production capacity. By the end of 2004, the production capacity of small blast furnace steel-making (<300 m^3) was around 100 Mt out of 420 Mt of total steel-making capacity, and small converter and electric furnace (<20 ton) was 55 Mt, which represented 27%, and 13% of total production capacity in steel-making (NDRC, 2006e).

Although China's iron and steel industry has seen a rise in the number of enterprises over the past years, the level of industrial concentration has dropped rather than increased. In 2005, 69 national key enterprises produced roughly 80% of the steel, which was 3.7% less than the previous year.

Stated Policy and Program Goals

It was originally proposed to phase-out small blast furnace (<300 m^3) and small converter and electric furnace (<20 ton) by the end of 2007 in the 2005 revised Industrial Structure Adjustment Guidance Catalogue (《产业结构调整指导目录》). But as one official from NDRC pointed out, considering the existing difficulties and large burdens on local provinces, such as Hebei and Shanxi, the target was postponed for three years, i.e., by the end of 11th FYP (Xue and Yu, 2006). In June 2006, NDRC announced that China had decided to phase-out 100 Mt of outdated production capacity in iron-making, as well as eliminating 55 Mt of outdated production capacity in steel-making with purposes of adjusting structure, increase industrial concentration, and forming 2-3 large steel corporations that are internationally competitive (NDRC, 2006e). Through closing inefficient production capacity, it is estimated that 17 Mtce in energy consumption, 90,000 tons of SO_2 emissions, and 30 Mt of water use can be reduced in 2007, while 50 Mtce in energy use, 0.4 Mt. of SO_2 emissions, and 100 Mt of water can be reduced by 2010 (Zeng, 2007; NDRC, 2007e). Table 25displays the key targets for iron and steel industry.

Table 25.Key Steel Industry Small Plant Closure Targets

Year	Targets	
2007	Close 30 Mt of capacity in iron-making	Close 35 Mt of capacity in steel-making
2010	Reduce physical energy intensity from 0.76 tce/t steel in 2005 to 0.73 tce/t steel	
	Reduce fresh water intensity from 12 ton/t steel in 2005 to 6 ton/t steel	
	Reduce SO_2 emission intensity to 2.64 kg SO_2/t steel	
	Form 2-3 large steel corporation at the level of 30 Mt of production capacity	
	Top 10 steel enterprises produce more than 50% of China's steel production	

Source: Zeng, 2007.

On December 27, 2007, Zhang Guobao, vice-chairman of NDRC signed "Responsibility Documents" with 18 provinces/municipalities/cities to close and phase-out outdated production capacity in iron and steel industry. By the end of 2007, commitments to phasing out backward production capacity by 2010 from provinces have reached to 89.17 Mt of iron-making and 77.76 Mt of steel-making.

Reported Results

In 2009, NDRC reported that 60.59 Mt of backward iron smelting capacity was closed along with 43.47 Mt of steel capacity (NDRC, 2009a).

4.4.2 Quantitative Evaluation

Baseline for Evaluation of Small Plant Closures Policy

In order to determine whether the small plant closures that occurred during the 2006-2008 period were driven by policy guidance or would have happened anyway under normal market conditions where smaller, inefficient facilities are phased out due to higher operating costs or other reasons, LBNL evaluated data on historical plant closures of the electric power sector to see if the rate of closure increased during the 11th FYP.

China started to close small coal-fired power plants in 9th FYP. During 1998-2002, the closed capacity peaked in 1999 with 3,360 MW. However, it began to level off with an annual growth rate of closed capacity of -4% from 1998-2002, and closing small and inefficient power plants stopped completely in 2003-2004, due to power supply shortages experience in China at that time. Phasing-out small coal-fired plants resumed by the last year of 10th FYP in 2005 and began to ramp up quickly in the 11th FYP, with an annual average growth rate of closure capacity of 115% from 2005 to 2008. Contrary to the progress in 9th FYP and early years of 10th FYP, with an average closed capacity rate of -4%, China reversed course and the aggregate closed capacity from 2006-2008 was 34,210 MW, as shown in Figure 19.

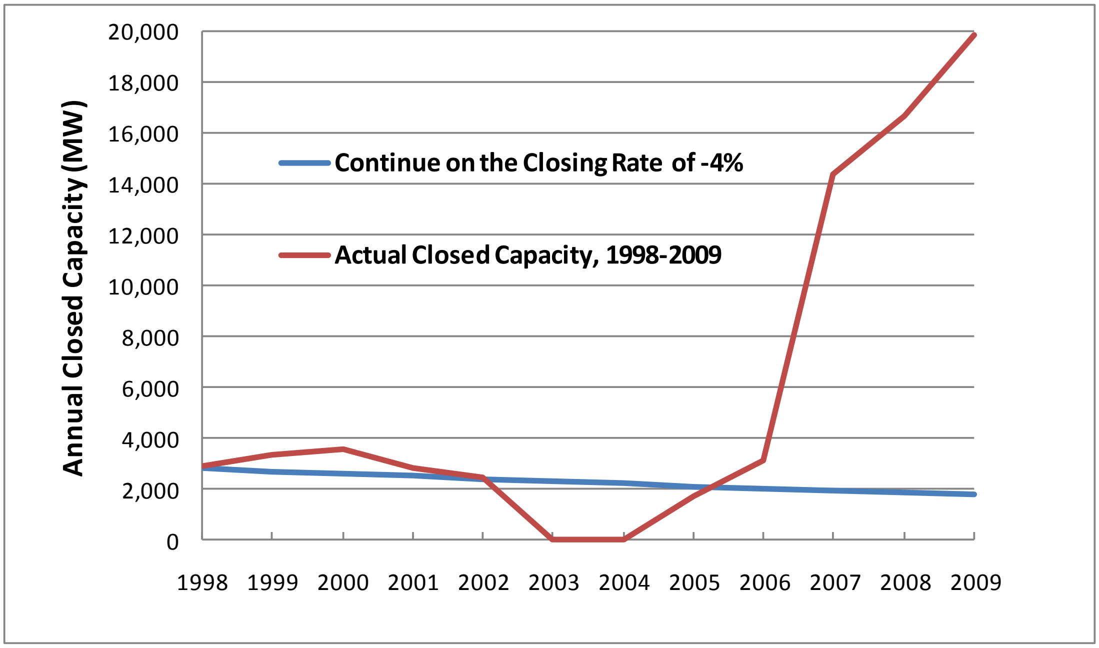

Figure 19. Actual Annual Closed Capacity Compared Baseline Closure Rate of -4%

Calculated Energy Savings from Small Plant Closures Policy

In order to calculate the energy savings from the closure of small plants, LBNL undertook two calculations. Both calculations relied on typical energy intensity values for small, inefficient plants and for more efficient plants (see Table 26).

The first calculation was an estimate of the gross energy savings from the closure of the reported plant capacity for those plants where information was available both regarding the amount of closed capacity and the typical energy intensity of small, inefficient plants. This was done by multiplying the closed plant capacity for each sector by the typical energy intensity value. Information was available to complete this calculation for six sectors: electricity, iron-making, steel-making, cement, electrolytic aluminium, and pulp and paper-making. Five of these six sectors (excluding electrolytic aluminium) represent the largest sectors in terms of targeted closures and together the six sectors represent 84% of the total capacity targeted for closure of the 14 sectors. The total estimated gross energy savings from the small plant closures of the six sectors for which information was available is 231 Mtce final energy and nearly 450 Mtce primary energy (see Table 27).

Table 26. Assumed Energy Intensity Values for Small, Inefficient Plants and Efficient Plants For Six Industrial Sub-Sectors.

Industry	Unit	Small, Inefficient Plant Energy Intensity	Efficient Plant Energy Intensity	Source
		Final Energy		
Cement	kgce/t	146	106	(1)
Iron-making	kgce/t	457	427	(2)
Steel-making	kgce/t	1175	758	(3)
Electricity	gce/kWh	440	315	(4)
Pulp & paper	kgce/t	584	323	(5)
Electrolytic aluminium	kgce/t	5500	4820	(6)
		Primary Energy		
Cement	kgce/t	175	134	(1)
Iron-making	kgce/t	466	433	(2)
Steel-making	kgce/t	1611	885	(3)
Electricity	gce/kWh	440	315	(4)
Pulp & paper	kgce/t	753	506	(5)
Electrolytic aluminium	kgce/t	10940	9110	(6)

Sources: *NDRC, 2009a and 2009b; (1) Zeng Xuemin, 2008; (2) EBCSY, 2009; (3) Zhang and Wang, 2007; Aden et al., 2009; (4) Feng Fei, et al., n.d.; (5) Feng Fei, et al., n.d.; LBNL, 2008; (6) Aden et al., 2009.

The second calculation was based on the fact that even though the small, inefficient plants were closed, absolute capacity (and production) from these sectors continued to grow, indicating that the closed plants were replaced by more efficient plants. As such, the net difference in energy consumed by the small, inefficient plants and the energy consumed by more modern facilities that presumably replaced the closed plants was calculated for the six sectors for which information was available. The total estimated net energy savings from the replacement of inefficient capacity with more efficient facilities resulted in savings of 63Mtce final energy and 150 Mtce primary energy (see Table 27).

Assuming these savings represent about 60% of the total savings from all 14 subsectors, we estimate that the gross savings to date are 385 Mtce final energy and 427 Mtce primary energy while the net savings are about 106 Mtce final energy and 129 Mtce primary energy.[55]

[55] The State Council stated that China's goal was to save 31.5 Mtce and reduce 400,000 tons of SO2 in 2007 (State Council, 2007a).

Table 26. Estimated Final and Primary Energy Savings and Carbon Dioxide Emissions Reductions from Small Plants Closure and Phase-Out of Outdated Capacity, 2006-2008.

Industry	Small, Inefficient Plant Energy Use 2006-2008	Efficient Plant Energy Use 2006-2008	Net Realized Energy Savings 2006-2008
	Final Energy (Mtce)		
Cement	20.5	15	5.5
Iron-making	28	26	2
Steel-making	51	33	18
Electricity	128	92	36
Pulp & paper	3	1.5	1.5
Electrolytic aluminium	0.6	0.5	0.1
Total Final Energy 6 Sectors	**231**	**168**	**63**
Total Final Energy 14 Sectors	**385**	**280**	**106**
	Primary Energy (Mtce)		
Cement	25	19	6
Iron-making	28	26	2
Steel-making	70	38	32
Electricity	128	92	36
Pulp & paper	4	3	1
Electrolytic aluminium	1	0.9	0.1
Total Primary Energy 6 Sectors	**256**	**180**	**77**
Total Primary Energy 14 Sectors	**427**	**298**	**129**
	Emissions Reductions ($MtCO_2$)		
Cement	47	34	13
Iron-making	63	59	4
Steel-making	117	75	41
Electricity	294	210	83
Pulp & paper	7.3	4.0	3
Electrolytic aluminium	1.3	1.2	0.2
Total Emissions Reductions 6 Sectors	530	384	145
Total Emissions Reductions 13 Sectors	**883**	**640**	**242**

Sources: *NDRC, 2009a and 2009b; (1) Zeng Xuemin, 2008; (2) EBCSY, 2009; (3) Zhang and Wang, 2007; Aden et al., 2009; (4) Feng Fei, et al., n.d.; (5) Feng Fei, et al., n.d.; LBNL, 2008; (6) Aden et al., 2009.

4.4.3 Qualitative Evaluation

Comparison of Progress to Stated Policy Goals

Capacity closures to date have been reported for ten sectors (see Table **22**). To be on track, closures should be at 60% of the target by the end of 2008. Seven of the ten sectors have reached or surpassed that target, with four sectors significantly ahead of the target. Two other sectors (cement and alcohol) are nearly at the 60% target, while one sector (electrolytic aluminium) is significantly below the target, realizing only 16% of the scheduled capacity closures by the end of 2008. Overall, for the reported sectors, it appears that this program is on or ahead of schedule to meet the 2010 capacity closure targets.

When compared to the overall program goal of 118 Mtce net energy savings in final energy, it appears that the program has saved an estimated 76% of the total goal in the first three years, which is ahead of schedule.

For the electricity sector, 38.26 GW of capacity was closed by the end of 2008 which is 77% of the stated 2010 closure target. Net energy savings through 2008 of 36.45 Mtce were calculated, which is 56% of the stated 2010 goal of about 65 Mtce savings. Thus, while plant closures in terms of capacity appear to be ahead of schedule, actual energy savings are not quite at the 60% level needed to be on target at the end of 2008.

One of the stated goals of the cement sector is to increase the proportion of new suspension pre-heater (NSP) kilns from 45% in 2005 to 70% by 2010. Since the share of NSP kilns reached 62% in 2008, it seems likely that this goal will be achieved. Another goal is to eliminate 250 Mt of obsolete cement production capacity, with an annual phase-out rate of 50 Mt. The cement sector has closed 140 Mt of capacity in 3 years, which is just slightly below the target.

For iron-making, the 60.59 Mt of capacity was closed through 2008, 61% of the target closure goals of 100 Mt. For steel-making, 43.47 Mt of capacity was closed during this period, which is 79% of the 2010 target.

4.5 Appliance Standards and Energy-Efficiency Labels

4.5.1 Overview

In recent years, China has become one of the world's largest producers and consumers of household appliances as urban and rural ownership rates grew at an extraordinary pace. By 2008, for example, each of China's 190 million urban households had on average 1.3 color televisions, with nearly all households owning a clothes washer, refrigerator and air conditioner by 2008 in contrast to very limited ownership two decades earlier. In the same year, China produced 82 million air conditioners with exports of 29 million (35% of production), and 48 million refrigerator/freezers with exports of 20 million (43% of production) (NBS, 2009). As China continues its economic transition from a developing to developed country, urbanization and rising disposable incomes are expected to drive demand for appliances and related energy services. In fact, sustained rises in appliance ownership have already corresponded to growing residential electricity use at an annual average rate of 13.9% between 1980 and 2007 (NBS, various years).

In light of the rapid rise in household appliance ownership, China's first equipment energy efficiency standards program was established in 1990 to cover most common household appliances such as refrigerators, air conditioners, clothes washers, televisions, radios and electric fans. However, inconsistencies with international standards and test methods and insufficient focus on implementation limited the effectiveness of these initial standards. Within the last decade, however, greater government attention on appliance standards and related energy efficiency labels has emerged in key policy documents and the creation of two new labeling programs.

Stated Policy and Program Goals

While the concept of appliance efficiency standards were introduced as early as 1989 in the Standardization Law of the People's Republic of China and the complementary Regulations for the Implementation of the Standardization Law, standards were not specifically endorsed until the late 1990s with greater regulatory attention on energy conservation. Specifically, the National Energy Conservation Law of China (中华人民共和国节约能源法) provided the regulatory basis of mandatory energy efficiency standards for energy-consuming products and equipment and helped motivate program improvements. It also promoted the concept of energy efficiency labels in Article 18 and laid the regulatory foundation by discussing possible punitive measures for counterfeit labels (National People's Congress, 1997). In 1999, the China National Institute of Standardization (CNIS) began the process of revising single-period mandatory energy efficiency standards and developing new standards to follow international best practice while the China Standards Certification Center launched a new voluntary energy efficiency endorsement labeling program targeting the top 25% most efficient products (Figure 20). In 1999, NDRC issued the Management Method for Energy Conservation Products Certification to establish the administrative framework for certifying standards and the voluntary endorsement label. In 2002, the General Administration of Quality Supervision, Inspection and Quarantine (ASQIQ) issued legal authority for its local offices to enforce safety, efficiency and other standards (APEC, 2009).

The *Medium and Long-Term Plan for Energy Conservation* issued by NDRC in 2004 further supported the development and implementation of appliance standards and energy labels by addressing weaknesses with lagging efficiency standards, inadequate compliance and slack enforcement of Energy Conservation Law efforts (NDRC, 2004). In particular, it encouraged more stringent revisions of energy efficiency standards, tightened market entry and the use of market mechanism to stimulate demand for energy-efficient consumer products as important principles of energy conservation. Household and office electric appliances were also included as a key subcategory for energy conservation within the building sector and implementation of energy efficiency standards and labeling was identified as a key project. The plan also included 2010 energy efficiency goals for four household appliances and products, as illustrated in Table 27.

Table 27. Medium and Long Term Energy Conservation Plan Goals for Appliances

Product	Measure	2000	2010 Goal
Room Air Conditioner	Energy Efficiency Ratio	2.4	3.2 - 4
Electric Refrigerator	Energy Efficiency Index*	80%	50% - 62%
Household Gas Cooker	Thermal Efficiency	55%	60% – 65%
Household Gas Water Heater	Thermal Efficiency	80%	90% - 95%

Source: NDRC, 2004.

*Energy Efficiency Index is defined as the percentage of maximum allowable energy under an efficiency standard that is used by a product. A lower index or percentage reflects greater efficiency relative to the standard.

With greater regulatory attention, China now has minimum energy performance standards (MEPS) for around 30 different types of appliances and equipment, including those common in the residential sector such as refrigerator/freezers, air conditioners, washing machines, televisions, and rice cookers, common commercial equipment such as computer monitors, printers, chillers and lighting products, and industrial equipment such as transformers and motors. The MEPS mandate the maximum allowable energy consumption for a given appliance product and each MEPS revision typically increased stringency by about 10% over the previous level. In order to provide manufacturers with longer lead times for design and production of new products, new and revised standards since 2003 have included a second period “reach standard” of even greater stringency with a typical 3-year lead time to implementation.

In 2005, a mandatory categorical energy information label known as the China Energy Label was established following legal provisions in the Energy Conservation Law with supporting regulation and support for implementation in the *Product Quality Law* and *Legislation on Certification & Accreditation*(Jin and Li, 2006).The administration of the China Energy Label program along with details on supervision and implementation, penalties and other supplementary provisions were established in the *Administrative Regulations on the Energy Efficiency Label* (Jin and Li, 2006). At its launch in March 2005, the label was implemented for use only on refrigerators and air conditioners. The China Energy Label includes five categories of efficiency, ranked from 1 (highest) to 5 (MEPS), and a given product’s rating is based on self-reported energy consumption data from manufacturers. Since 2005, the label has expanded to include washing machines and unitary air conditioners with further expansion to nine more appliances in 2008, and the label categories were revised in some cases to just three efficiency levels (1 to 3) for products such as lighting with fewer natural efficiency thresholds. Complementary to appliance standards, the Energy Label is intended to promote consumer awareness and market transformation.

Reported Results

A China National Institute of Standardization (CNIS) study of the China Energy Label's impact on market transformation from March 1, 2005 to March 1, 2006 indicated that a shift had already occurred in the distribution of energy efficiency in models supplied to the market. For air conditioners, the share of efficient models in grades 1 and 2 increased moderately by 6% with corresponding 10% decrease in shares of the least efficient models at grade 5 and below (Jin and Li, 2006). The 30% share of models that failed to meet the revised MEPS was eliminated. For refrigerators, share of the most efficient grade 1 models increased by 13% while the share of average grade 3 models decreased by 9%. 4% of models that did not meet MEPS were eliminated. This market study, however, did not report on estimated national energy savings from these market shifts.

Figure 20.China Energy Information Label (left) and Endorsement Label (right)

4.5.2 Quantitative Evaluation

In 2007, a study was undertaken at Lawrence Berkeley National Laboratory to evaluate the impact of China's appliance standards and voluntary labeling program on major appliance types. For this study, a customized Long Range Energy Alternatives Planning (LEAP) model of eleven products was developed covering the years 2000 to 2020. This bottom-up, technology-specific model allows detailed characterization of energy intensity as well as appliance characteristics such as saturation, vintage, retirement functions as well as demographic characteristics of the economy. For saturation, forecasts to 2020 were developed for each product based on China's own projections (where available) and the historical experience in countries such as Korea, Japan and the U.S. The model included a baseline scenario and an efficient standards and labeling (S&L) policy scenario from which savings of the S&L program could be calculated. The analysis focused only on the standards or voluntary labeling efficiency criteria that were implemented as of 2007 and applicable "reach" standards to be implemented for air conditioners, refrigerators, televisions and lighting in the near future. Although the mandatory energy information label for refrigerators and air conditioners was implemented in 2005, it was not included in the analysis because insufficient data prevented the completion of a comprehensive market impact analysis.

Table 28.China Appliance Efficiency Standards and Voluntary Labels Covered in Evaluation

Product	Type	Standard No.	Year of Implementation
Refrigerators	MEPS &Label	GB12021.2-2003	1999; 2003
Room Air Conditioners	MEPS & Label	GB19577-2004	2000; 2005
TVs	MEPS & Label	GB 12021.7-2005; T17—2002	2002, 2006
Clothes Washers	MEPS & Label	GB 12021.4-2004	2004
Computers	Label	T22-2003	2004
Printers	Label	T18-2003	2003
DVD/VCD Players	Label	T25-2003	2004
Linear Fluorescent Lamps	MEPS & Label	GB 19043-2003	2003, 2006
CFLs	MEPS & Label	GB 19044-2003	2003
Gas Water Heaters	MEPS & Label		2007

Source: Fridley et al., 2007.

Baseline for Evaluation of S&L Program

The baseline scenario for evaluating the impact of S&L programs is based on the absence of any appliance efficiency policy and assumes that an appliance's energy intensity as measured by unit energy consumption is frozen at the average level of when the first standard was implemented. In the case of refrigerators, for instance, the average energy consumption through 1999 was examined and used as the baseline energy consumption through 2020 for the base scenario. In contrast, the efficiency policy scenario assumes that the unit energy consumption stipulated by the 1999, 2003 and 2008 (reach) standards are met in its 2020 assessment.

Calculated Savings from S&L Program

For each scenario, the total energy consumption of each appliance (measured in terms of electricity) is calculated by the model using given assumptions about unit energy consumption, saturation, lifetime, and stock of the appliances. For some products such as refrigerators and air conditioners, expected changes in the average size of models (refrigerators) and of usage patterns (air conditioners) also impact total electricity consumption. By comparing the total energy consumption for the base or frozen efficiency scenario with the S&L policy scenario, energy savings from the appliance standards and voluntary labeling program can be estimated. Specifically, since the only difference between the two scenarios is the efficiency level of appliances resulting from S&L efforts, the subsequent divergence in modeled energy consumption can be attributed to the S&L program.

The calculated standards and labeling program savings to date and projected savings for 2009 and 2010 for the major appliance products are presented in terms of primary energy (Mtce), final energy (TWh) and CO_2 emissions below.

Table 29. Annual Appliance Savings in Primary Energy (Mtce), 2006-2010

Appliance	2006	2007	2008	2009 (Projected)	2010 (Projected)	2006-2008
Clothes Washer	0.06	0.07	0.07	0.08	0.09	0.20
TV	0.73	1.24	1.92	3.13	4.45	3.89
Refrigerator	5.55	6.90	8.19	9.41	10.48	20.64
Air Conditioner	2.33	3.14	3.97	5.22	6.49	9.45
Video Cassette Player	0.13	0.22	0.32	0.43	0.56	0.66
Computer	0.03	0.05	0.08	0.11	0.14	0.16
Printer	0.01	0.01	0.01	0.02	0.03	0.03
Lighting	0.50	0.61	0.73	0.79	0.85	1.84
Total	9.34	12.22	15.29	19.19	23.09	36.86

Note: based on conversion of 0.404 kgce primary energy input per kWh

Table 29 shows that in primary energy terms, the cumulative energy savings to date (2006 to 2008) is estimated to be 36.9 Mtce. With 2009 and 2010 projected savings from appliance standards and labeling, total primary energy savings could reach 79 Mtce during the 11th FYP period.

In final energy terms, the cumulative savings from 2006 to 2008 total 91.3 TWh (see Table 30). For the entire 11th FYP period with projected 2009 and 2010 savings, standards and labeling efforts could result in cumulative savings of 195.9 TWh with year-on-year savings ranging from 23 to 57 TWh.

Table 32 shows that the cumulative CO_2 emission reductions associated with electricity savings from the appliance standards and labeling efforts during the 11th FYP period total 83 $MtCO_2$ from 2006 to 2008. On a year-on-year basis, CO_2 emissions would decrease by 21$MtCO_2$ in 2006 to nearly 52 $MtCO_2$ in 2010.

Table 30. Cumulative Appliance Savings in Final Energy (TWh), 2006-2010

Appliance	2006	2007	2008	2009 (Projected)	2010 (Projected)	2006-2008
Clothes Washer	0.16	0.16	0.18	0.20	0.22	0.49
TV	1.82	3.06	4.75	7.75	11.01	9.63
Refrigerator	13.74	17.07	20.27	23.29	25.94	51.08
Air Conditioner	5.78	7.78	9.83	12.92	16.06	23.38
Video Cassette Player	0.32	0.53	0.79	1.07	1.37	1.64
Computer	0.07	0.12	0.19	0.27	0.35	0.38
Printer	0.01	0.02	0.04	0.05	0.07	0.07
Lighting	1.23	1.51	1.81	1.96	2.12	4.55
Total	23.13	30.26	37.85	47.50	57.15	91.24

Note: based on conversion of 0.404 kgce primary energy input per kWh

Table 31. Cumulative CO_2 Emission Reductions from Appliances (Mt), 2006 - 2010

Appliance	2006	2007	2008	2009 (Projected)	2010 (Projected)	2006-2008
Clothes Washer	0.14	0.15	0.16	0.18	0.20	0.45
TV	1.66	2.79	4.33	7.06	10.03	8.77
Refrigerator	12.51	15.55	18.47	21.21	23.63	46.53
Air Conditioner	5.26	7.09	8.95	11.77	14.63	21.30
Video Cassette Player	0.29	0.49	0.72	0.97	1.25	1.50
Computer	0.06	0.11	0.18	0.24	0.32	0.35
Printer	0.01	0.02	0.03	0.05	0.06	0.07
Lighting	1.12	1.37	1.65	1.78	1.93	4.15
Total	21.07	27.56	34.48	43.27	52.06	83.11

Note: based on China's 2005 electricity generation mix with calculated CO_2 emission intensity of 0.8531 kgCO2/kWh

As seen in all the above tables, the bulk of standards and labeling energy savings and associated CO_2 emission reduction will come from efficiency improvements in energy-intensive appliances such as refrigerators, air conditioners and television sets.

Besides this LBNL study on the impact of China's standards and labeling programs, there have not been other domestic studies or comprehensive evaluations of energy savings from MEPS and the China energy labels. However, CNIS has plans underway to begin releasing an annual report estimating the annual and cumulative energy and emissions impacts.

Challenges to Quantitative Evaluation

Evaluation of the impact of MEPS is complicated by the varying degrees of data quality. In some cases, such as household ownership of major appliances, time series data from the 1980s exist for use in estimating total stock of ownership. In contrast, data on annual sales or shipments are difficult to acquire, and where available, are not tied to efficiency distribution. Data on efficiency distribution have improved with the creation of the energy information label, but these data cannot be production-weighted to derive average model efficiency. Further, in the absence of national residential consumption surveys such as the US *Residential Energy Consumption Survey* (U.S. Energy Information Administration, 2008), undertaken 12 times since 1978, it is not possible to calibrate modeled data with actual survey data. In China, where rapidly rising incomes have likely resulted in rapid changes in demand for energy services such as cooling, only one survey from 1999 exists from which to understand national and regional patterns of air conditioner usage (a new air conditioner survey is currently underway and is expected to be completed by October 2010). In addition, the absence of national survey data also makes it difficult to calibrate residential end-use energy consumption with aggregate sector consumption as reported by the NBS, although limited local survey data have been gathered.

Compliance Testing and Enforcement

In the past few years, the central government has increased efforts to improve the enforcement and monitoring mechanisms for appliance energy efficiency standards. Launched in 2006, an unprecedented sample checking and testing program purchased and tested 43 models of refrigerators, room air conditioners and washers from retailers in the major cities of Guangzhou, Beijing and Hefei. The first round of check-testing presented mixed results on the implementation and enforcement of the selected appliance standards, with a range of noncompliant product models in the three cities and overall compliance rates of 81 percent for refrigerators, 71 percent for freezers and higher rates of 91 and 90 percent for air conditioners and washers, respectively (Zhou et al., 2008). The 2006 test results also showed notable variations in performance and noncompliance rates between product models sold in high-end, first-tier appliance retailers and second and third-tier retailers such as local appliance markets. In the case of refrigerators, the first-tier retailer compliance rate of 85% contrasted greatly with the 57% compliance rate in second-tier retailers in Guangzhou.

In 2007, appliance check-testing was repeated with a larger sample size of 73 models in the same cities. There was overall improvement in compliance rates for all three tested products with the number of non-compliant models decreasing from 11 out of 54 in 2006 to only 3 out of 73 models in 2007 (Zhou et al., 2008). On the regional level, Beijing not only achieved higher compliance rates for refrigerators (from 86 percent to 100 percent), but also achieved 100 percent compliance for air-conditioners and 94 percent for clothes washers. Unlike results in the previous year, no major variations in compliance were observed between different appliance markets in 2007. The third round of check-testing, focused on building capacity at the local level to evaluate a larger variety of models and types, and round-robin testing of room air conditioners are currently underway and expected to be completed by December 2009.

These past two years of check-testing have revealed that consistent testing and monitoring are critical to identifying enforcement weaknesses and improving compliance with appliance efficiency standards. The first year of check-testing had relatively small sample size representing less than 1 percent of product models on the market and despite expanded testing in 2007, the sample size was still much smaller than the goal of regular check testing for 20 percent of product models on the market. The goal is ambitious, as China's appliance sector remains largely unconsolidated, with over 250 companies producing over 3000 models of clothes washers alone (see Table 32). Unlike mature appliance markets, where the top ten companies may produce over 90% of the models, the fairly dispersed scale of China's appliance market remain a challenge to full enforcement of standards and labeling requirements.

Table 32. Manufacturers and Models of Selected Major Appliances

Product Type	No. of Companies	No. of Product Models
Refrigerators	139	5630
Room Air-Conditioners	82	7852
Clothes Washers	257	3291
Unitary Air-Conditioners	18	934

Source: CNIS

The early check-testing rounds further highlighted sample selection concerns with uneven distribution in the grade of testing samples selected for each product. Because testing results also varied significantly when tested in different laboratories, assessing the consistency of test results between laboratories through round-robin testing is crucial to the effectiveness of the standards.

Expanding China's verification testing programs to cover more models and products and developing a plan for ramping up the national verification testing program over the next three to five years are important next steps in strengthening appliance standards implementation. This will be particularly important as the information labeling program gains more visibility and expands to additional product categories.

4.5.3 Qualitative Evaluation

Comparison of Progress to Stated Policy Goals

The 2010 efficiency goals for the four appliances in Table 33 have been met in part, but in the absence of sales data by efficiency level, it is not possible at this point to quantify the proportion of the market that these higher efficiency appliances have captured. For room air conditioners, the 2010 goal of achieving an energy efficiency ratio (EER) of 3.2-4 was in part reached by 2005, when the EER requirement for class 1 and 2 air conditioners were set at 3.4 and 3.2 respectively, with all air conditioners subject to a minimum EER of 3.2 in the reach standard for 2009. (This standard remains under revision but it expected to be implemented in 2010). For refrigerators, a new standard went into effect in April 2009, in which the energy efficiency index (EEI) of classes 1, 2, and 3 all reached the 2010 target of 50-62%. For household gas water heaters, only class 1 water heaters have achieved the 2010 target of 90-95%, with the requirement of that class now at 94-96%. Household gas cookers, however, remain less efficient than the 2010 target, with the 2008 standard specifying a minimum thermal efficiency of 55%, compared to the 2010 target of 60-65%.

While China has made major strides with its MEPS revisions and two labeling programs, analysis reveals that there are still several program components that can be improved. For some appliances like clothes washers, MEPS revisions have lagged behind as the market average efficiency of vertical washers is already higher than the 2004 minimum efficiency standard, suggesting that the standard could have been tighter. Similarly, the energy efficiency thresholds for the refrigerator energy label based on the 2005 refrigerator MEPS (strengthened in 2009) resulted in over 65% of refrigerators meeting the requirements of the class 1 and class 2 efficiency levels (class 2 being equal to the specification of the voluntary energy efficiency label), diluting the impact of efficiency labeling for that product. These situations may be a result of the fast pace of development in China's appliance market. In contrast to countries where the appliance market is largely saturated, China's appliance market remains very dynamic and rapidly growing, with changes in model design and technology evolution at times outpacing the timeline of standards development and revision. In terms of the current standards-setting structure, this may suggest that second-tier or "reach" standards could be set considerably tighter, depending on product type, to capture these additional possible savings.

In support of the 11th FYP goals to promote consumer awareness of appliance efficiency and stimulate market transformation, China has undertaken new efforts to target the growing rural appliance market. Specifically, China launched a "Home Appliance Move Into the Countryside" (家电下乡) pilot program in December 2007 for rural households in Henan, Shandong and Sichuan provinces. This program provides a 13% rebate to rural residents who purchase selected brands of efficient appliances from qualifying retailers. The central government provides financial support for 80% of the rebate while the provincial governments provide the remaining 20% (Xinhua, 2009a). In February 2009, the program was expanded to cover ten product categories and eligibility was extended to rural residents throughout China.

Currently, the rebate program covers color televisions, refrigerators and freezers, mobile phones, washing machines, computers, water heaters, motorcycles, air conditioners, induction cooktops, and microwave ovens (Xinhua, 2009a). Qualifying appliances under the rebate program must be manufactured by fifteen pre-selected Chinese manufacturers, including the major manufacturers of Haier, Hisense and Changhong (Subler, 2008). The appliance products must also be priced below given price caps, although the Ministries of Finance and Commerce cancelled the price caps in July 2009 (Ministry of Commerce, 2009). To promote consumer awareness of the China Energy Label and market transformation, the rebate is only given to qualifying air conditioners and washers in Classes 1 and 2, and qualifying refrigerators in Class 1 of the Energy Label (Cheng, 2009). The Ministry of Commerce, which is responsible for program enforcement, has also taken initiative to enforce the program's efficiency requirements by launching a seven-month crackdown on illegal sales of substandard and fake home appliances (Xinhua, 2009b). While news sources have reported rural purchases of more than 16 million units of home appliances since December 2007, the lack of data on specific market shares and efficiency classes of purchased appliances under the rebate program precludes in-depth analysis of the rebate's impact on rural market transformation (Xinhua, 2009b).

Despite the Ministry of Commerce's recent efforts, enforcement in general remains a key issue in the success of China's standards and labeling program as financial, administrative and infrastructure support for the program can be strengthened. As previous experiences with the National Energy Conservation Law have shown, the existence of only a legal framework for standards and labels is insufficient and greater emphasis on implementation and enforcement is needed. The absence of up-to-date impact evaluations of standards and labeling efforts and shortage of sales data by efficiency classes in China's rapidly evolving appliance market are other crucial remaining areas of weakness.

Comparison of Policy Implementation to International "Best Practice"

Best practice in standards and label development is determined in part by national objectives. For some countries, the primary goal may be to reduce growth in energy use and lower energy costs; for others, the primary goal may be reduction of CO_2 emissions. In general, the purpose of a standards and labeling program is to move the efficiency of equipment to a socially optimal level, and ideally, standards and labels work together to continuously increase these efficiency levels (Waide, n.d.).

Best practice in implementation of standards and labeling policy is based on a number of foundations, including:

- a clear mandate for the program through legislation defining stakeholder roles and responsibility, and the process through which standards and labels will be developed
- a defined methodological approach to standards development
- sufficient funding and trained personnel for both standards and label development, implementation, and monitoring and compliance(Waide, n.d.)

Although China has a strong legal foundation for standards and labeling under the *Energy Conservation Law*, this law and its implementing regulations do not specify the stakeholders to participate in the process, nor does it indicate the methodology by which standards are to be developed. In the US, for example, the framework legislation for standards development—the Energy Policy Act of 1992 (EPAct)—requires by law that the Department of Energy develop "standards to the maximum level of energy efficiency that is technically feasible and economically justified". Such a legal mandate suggests, for example, that Least Life-Cycle Cost Analysis be a methodological tool in standards development in order to maximize the technically and economically feasible efficiency gains.

In voluntary energy efficiency labeling, a leading example of best practice implementation has been recognized in the U.S. Energy Star program. Since its creation in 1992, Energy Star has maintained stringent labeling criteria by consistently revising its residential and office product specifications to reflect changing market conditions and the increased penetration of efficient models. In particular, the Energy Star program typically only qualifies the top 20-25% most efficient products on the market (Karney, 2007). Earlier certified products such as dishwashers, refrigerators and freezers and clothes washers have also undergone several revisions in labeling criteria as the market share of Energy Star qualified models increases. Moreover, Energy Star has undertaken a novel approach to accelerate market transformation by creating linkages of its program to other local and national efficiency programs. For example, Energy Star has developed extensive partnerships with state governments, utilities, small businesses, retailers and non-profits where subsequent rebates and outreach campaigns have helped influence consumer decision-making.

Although China cooperated with Energy Star for many years in the implementation of its own voluntary energy efficiency label, and adopted many approaches and practices from Energy Star, an increasing number of products subject to voluntary labeling specifications have been subsumed within the mandatory standards program, which in turn decides the timeline of specification development and revision, thereby reducing the flexibility of the voluntary label to be revised to reflect product efficiency changes in the market. In addition, the introduction and expansion of use of the mandatory energy label, with its three-to-five efficiency categories overlapping with the voluntary energy efficiency label has the potential to introduce confusion to buyers over efficiency labeling.

China's Energy Label was modeled after the European Union (EU) energy label, a prominent categorical label introduced in 1992 which features classes A through G for ranking appliance models. In recent years, however, the EU label's market transformation success has resulted in challenges in keeping its thresholds up to date and reflective of market conditions. Because the EU label thresholds are not linked to MEPS and thus not automatically updated when the MEPS are revised, it has undergone format revisions in 2003 and most recently in 2009 to tighten the efficient class thresholds in response to market transformation. In 2003, the new classes of A+ and A++ were introduced to further distinguish amongst efficient products as 20-50% of products in the market had already reached the most efficient A class (Lebot, 2004). In March 2009, proposals to replace the A+ and A++ classes with new A-20%, A-40% and A-60% classes to express how much better a product is beyond class A was endorsed by the EU Commission (EU, 2009). Although these proposed changes provide more detailed information to consumers in theory, a recent survey showed that the new layout change and introduction of additional beyond class A definitions confuses consumers and weakens the effect of the label on consumer awareness and decision-making (Heinzle and Wüstenhagen, 2009). In contrast, the China energy label's linkage to MEPS is useful in that MEPS revisions automatically include revision of the label thresholds. However, this implies greater need for China to revise its MEPS in a timeframe that address market shifts in appliance efficiency levels for both its standards and labeling programs to work together most effectively.

Directly related to the growing need for consistent and timely MEPS revision is the need for program evaluations to identify weaknesses in program design and implementation and to help measure the program's overall impact. Best practice evaluations can include both process evaluation that measures how well a program is functioning and impact evaluation that can help determine the energy and environmental impact of the program (Vine, 2001). Evaluation objectives may also differ between efficiency standards and labeling programs, as evaluation of standards program is intended to focus on manufacturers and changes in efficiency shares of market models. Evaluation of labeling programs, in contrast, should provide information on understanding the sales and purchase process of consumers in order to assess labeling impact on retailers and consumers (Vine, 2001). International best practice examples include EU's comprehensive evaluation of its energy labeling program two years after the program implementation in 1992 and the U.S. Energy Star's evaluation studies. By launching two separate studies to assess issues with legislative compliance and implementation and sales-weighted energy efficiency, energy and emission trends, the EU evaluation identified regional differences in implementation and total energy savings and emission reductions associated with the programs (Vine, 2001). Similarly, Energy Star has also conducted formal evaluations of many of its labeled products to verify savings claims, improve the accuracy of future saving estimates and improve program design (Brown, 2000). Other important evaluation components of the Energy Star program include tracking of sales data by the Department of Energy to assess changes in market shares and independent regional program evaluations by Energy Star partners such as local utilities.

While China has made clear progress in launching compliance check-testing and recent round-robin testing, remaining data insufficiencies and the paucity of domestic-run evaluations indicate that much more can be done in terms of evaluation. More specifically, monitoring and verification of product performance relative to MEPS and energy labels are inadequate as even the check-testing sample sizes were too small and represented only 1% of models on the market in 2006 (Zhou et al., 2008). A key obstacle to more comprehensive monitoring and evaluation efforts is the shortage of resources and funding. Besides small staff size of only six full-time staff members, the recently established China Energy Label Center also does not have a regular budget for monitoring label compliance and thus lack regular auditing or verification testing programs (Zhou et al., 2008).

5. Findings

5.1 Overall 20% Energy Intensity Goal

China has made substantial progress toward its goal of achieving 20% energy intensity reduction from 2006 to 2010. Although it is too early to know if China will achieve the goal, it seems likely that the target will be met or nearly met. It is noted that the goal was originally announced as "20% more or less" (20%左右). Considering that energy use per unit of GDP had increased between 2002 and 2006, the achievements of the 20% intensity reduction program are substantial. Not surprisingly, the program began slowly as it was necessary to create regulations, administrative systems, and concrete actions in order to turn the energy economy back to one with declining energy intensity. The energy intensity declines of -1.8%, 4.0%, and 4.6% for 2006, 2007, and 2008, respectively, show that capabilities of reducing energy intensity continued to grow during the period.

Reductions in energy intensity can be the result of two changes in the energy system: increase in energy efficiency of both supply and demand and structural change. Structural change refers to one of three phenomena: (1) reduction of the proportion of the industrial sector in the overall economy; (2) relative increase of less energy-intensive industrial subsectors as compared with energy-intensive subsectors; or (3) lower energy-intensive products within a subsector. Aggregating all three effects indicates that structural change resulted in an increase of energy intensity in 2006 and 2007. Structural change in these two years accounted for 15% to 20% of the overall increase in energy use. Thus, the success in meeting the 20% intensity target through 2007 is due to increases in energy efficiency or conservation; these increases have been sufficient to overcome the lack of success in achieving structural change.

It has been possible to track performance of the overall energy economy in reducing energy intensity; however, evaluating individual energy-savings programs and policies to determine the magnitude of their contributions has been difficult due to lack of data. In most cases, the results are based on calculated savings from known details of the programs (appliance standards), surveys (enforcement of building codes), or statements by government officials indicating the magnitude of savings without documentary sources. In spite of the limitations of these approaches, the results documented in this report should be viewed as meaningful albeit imprecise; the overall achievements in pursuing the energy intensity goal argue that these programs have been successful.

5.2 Energy-Saving Programs

Given these caveats, this assessment found that many of the energy-efficiency programs implemented during the 11th FYP in support of China's 20% energy/GDP reduction goal appear to be on track to meet – or in some cases even exceed – their energy-saving targets. Based on the information gathered through interviews, reports, and websites, it appears that most of the Ten Key Projects, the Top-1000 Program, and the Small Plant Closure Program are on track to meet or surpass the 11th FYP savings goals. China's appliance standards and labeling program, which was established prior to the 11th FYP, has become very robust during the 11th FYP period, as illustrated by the development of new or revised standards that have met three out of four of the *Medium to Long-term Energy Conservation Plan's* 2010 energy-efficiency targets. The evidence suggests that China has greatly enhanced its enforcement of new building energy standards with calculated impacts that are on track to meet the goals. However, the energy-efficiency programs for buildings retrofits, as well as the goal of adjusting China's economic structure to reduce the share of energy consumed by industry, do not appear to be on track to meet the stated goals.

It was difficult to adequately assess the progress of the energy-efficiency programs implemented in support of the 11th FYP in detail due to lack of publicly-available systematic reporting and monitoring of these programs. In addition, the information that is available is often reported in units that are not clearly defined (e.g. whether electricity is accounted for at the site, 0.1229 kgce/kWh, or source, 0.404 kgce/kWh, value), programmatic targets are not clearly delineated as to whether they represent annual or cumulative savings goals through 2010, and conflicting and difficult to interpret information is provided through interviews, reports, and websites. Further, the overall 20% energy/GDP target is a relative target (ratio of energy to economic output), while most of the targets for the individual programs are absolute targets (e.g. savings of 100 Mtce by 2010 for the Top-1000 program), making it difficult to relate the individual programs to the overall energy intensity goal.

Ten Key Projects

Based on reported savings to date, it appears that the Ten Key Projects are on track to meet or surpass the 11th FYP goal of 250 Mtce primary energy savings. However, evaluation of the Ten Key Projects is difficult due to lack of information regarding the activities and savings undertaken for each of the projects.

Some of the savings from industrial sector projects, such as renovation of coal-fired industrial boilers, waste heat and waste pressure utilization, and motor system energy efficiency, are most likely also counted in the savings attributed to the Top-1000 enterprises.

Targets were not defined or tracked for the energy system optimization, government procurement, or energy conservation monitoring and evaluation system projects, making evaluation of these programs impossible.

Buildings Energy Efficiency

Overall, analysis in this report indicates implementation of the energy standards for new buildings in large urban areas is on track to meet the target. Surveys suggest that in large urban areas the compliance is almost 100% for the design phase and more than 80% during enforcement. However, the survey data on which compliance is assessed are not documented nor is there indication of their statistical accuracy. The codes are not in rural areas or in small cities. If enforcement is extended to these areas and is documented, cumulative primary energy savings from new building standards could reach or exceed the 90 Mtce target by 2010.

The challenge in retrofits of existing buildings is not unique to China. There has been little progress in most developed countries. The policy to encourage energy retrofits in existing buildings is far behind target, with limited and inadequate implementation to date. An effective program is especially needed in the cold or very cold weather zones where heating is supplied at low efficiency, control systems in are lacking in most buildings and the buildings built before 2000 are generally of poor thermal quality. The heat supply pricing reform, essential for success of energy-savings programs, is behind schedule and is hampered by the lack of a suitable mechanism and clear responsibility for carrying out the reform in many provinces.

There is widespread use of highly energy-intensive building materials, and little consideration for life-cycle energy use. New standards for building materials are needed; authority for building materials and energy efficiency standards is in separate agencies, rendering the development and subsequent enforcement of standards for building materials problematic.

For government office buildings and large-scale public buildings, energy management improvements are estimated to have saved 4.6 Mtce between 2005 and 2008, and should reach a cumulative primary energy savings of 11.2 Mtce by 2010, in line with the target.

Institutionally, China has benefited from a centralized Ministry of Housing and Urban-Rural Development (MOHURD) and a network of municipal Construction Commissions. MOHURD has worked with the Ministry of Finance to offer incentive mechanisms for building shell measures, but has not adequately addressed major barriers such as changes in urban heating prices and it has no authority over the choice of building materials. More financial mechanisms are needed. Developers lack incentives to include energy-efficient design and materials, and heating supply companies lack incentives to improve the efficiency or install controls on their systems. The lack of official reports and absence of standardized data-gathering and baseline definition methodologies make it difficult to determine building energy use and savings. Other data limitations, such as infrequent surveys on building characteristics and energy consumption patterns, further hamper efforts to monitor progress toward 11th FYP goals. Finally, the allocation of building sector energy targets appears not to result from scientific study and has therefore likely led to a mismatch of energy-saving potential and actual energy saving achievements in the building sector.

Nonetheless, the progress China has made in the establishment of the building energy efficiency policy systems is notable: a comprehensive enforcement scheme for new buildings has been established and strictly followed in the large cities where much of the construction takes place; a legal framework for energy efficiency policy is well-established and utilized; the central government has provided incentives and encouraged provinces and cities to provide incentives of their own; and the government officials has worked to update building energy standards.

Top-1000 Energy-Consuming Enterprises Program

Overall, the Top-1000 Enterprises Program appears to be successful. With reported final energy savings of 20 Mtce in 2006, 38 Mtce in 2007, and 36 Mtce in 2008, the program is on track to meet its cumulative final energy-saving target of 100 Mtce. In terms of the program goal of improving energy efficiency, unit energy consumption (physical energy intensity) decreased for major products in most sectors since the launch of Top-1000, with the largest improvements in non-ferrous metals but lagging in electrolytic aluminum processing. However, due to limited data availability, it is difficult to assess how much of these reported savings are directly attributable to the Top-1000 program and how much would have occurred in the absence of the program. Many Top-1000 enterprises already had energy intensities better than the national average and some—in steel, coal mining, synthetic ammonia, and glass—surpassed international advanced levels. Greater public availability of data would enable further analysis on program effectiveness.

The use of energy-saving agreements signed by high-level representatives from government and the enterprises has been very effective for stimulating action in the Top-1000 program. With the list of Top-1000 enterprises made public and promotion of government officials contingent on meeting targets, substantial attention and resources were directed to the program. Top-1000 enterprises invested over 50 billion RMB¥ ($7.3B) in technology innovation and implemented over 8,000 energy-saving projects in 2007. Some provinces, such as Shandong, Shanxi, Jiangxi, and Jiangsu, extended the program to a wider scope of enterprises, indicating potentially longer lasting benefits of the program. More than 95% of the enterprises established an energy management office, while the rate of equipping with energy measuring instruments varied from 60% to 90% at different levels of the factories. Energy audits were conducted at nearly all the enterprises in the program, but capabilities and audit quality varied widely. In terms of data reporting, training on the on-line reporting system was conducted for all enterprises, more than half of the enterprises were found to have strong statistical capabilities, while 20% had notably weak capabilities.

Due to rapid implementation, program targets were established without detailed assessments. The program target of 100 Mtce final energy savings represents only 15% of total required energy savings in the 11th FYP, yet the Top-1000 enterprises represent the highest energy consumption in the economy. A more ambitious goal likely could have been set based on assessment of potential savings in industrial sub-sectors. Implementation experience thus far identified the need for greater training and capacity building—at industrial enterprises, energy service and technology providers, and government agencies—to conduct audits, reporting, and energy-saving activities. Supporting policies for the Top-1000 program, such as energy efficiency standards for industrial products, are being developed as the program progresses, and more are needed to realize greater improvements.

Structural Adjustment/Small Plant Closures

Industry is, and remains, the largest sector in China during the 11th FYP, both in terms of energy consumption and GDP contribution. The 11th FYP calls for “a more rational structure of industries, products, and industrial organization” and an increase in the ratio of service sector value-added to total GDP of 3 percentage points. Despite this goal, this evaluation finds that the share of industrial sector energy use has grown from 69% of total energy use in 2000 to 72% of total energy use in 2007. In addition, the share of GDP attributed to the secondary sector of the economy increased from 45.9% in 2000 to 48.6% in 2007.

To assist structure optimization, the program of phasing out obsolete production capacity in 14 energy-intensive industrial subsectors was established. Capacity closures to date have been reported for ten sectors. To be on track, closures should be at 60% of the target by the end of 2008. Seven of the ten sectors have reached or surpassed that target, with four sectors significantly ahead of the target. Two other sectors (cement and alcohol) are nearly at the 60% target, while one sector (electrolytic aluminum) is significantly below the target, realizing only 16% of the scheduled capacity closures by the end of 2008. Overall, for the reported sectors, it appears that this program is on or ahead of schedule to meet the 2010 capacity closure targets.

When compared to the overall program goal of 118 Mtce net primary energy savings, it appears that the program has saved an estimated 76% of the total goal in the first three years, which is ahead of schedule.

Despite the progress in closing small and inefficient plants, the overall structure of China's industrial sector remains inefficient. While the plant closures have had a positive effect in moving toward the 20% energy intensity target, overall industry-wide factors have had a much larger impact in the opposite direction. Due to strong market demand and high prices of energy-intensive products, existing manufacturers had more incentives to continue producing from smaller facilities. Compared to the international market, major Chinese energy-consuming industries are still less active in mergers and acquisitions, and still have not realized efficiency gains from consolidated production. Difficulties remain at the local level, where government officials are reluctant to give up tax revenues and jobs from local enterprises subject to closure. Some small steel enterprises have even resisted closure by increasing production.

Appliance Standards and Energy-Efficiency Labels

China possesses one of the world's most active appliance standards and labeling programs. In the 10 years since the first modern minimum energy performance standards (MEPS) went into effect in 1999, these standards have been extended to about 30 products, resulting in significant increases in energy efficiency performance. During the 11^{th} FYP, the program underwent further acceleration, with annual development of standards expanding from 3 to 6 products, including some new products which have never been subject to MEPS in the past. By 2010, three out of four efficiency targets of the *Medium to Long-term Energy Conservation Plan* are likely to be met or exceeded.

Even so, there remain process issues with the current standard-setting process that need to be resolved. For example, the bundling of MEPS, the reach standard, the energy label thresholds and the voluntary endorsement label specification in one official document precludes the revision of any one element, such as the voluntary label specification, on a timeline separate from the revision of all four elements. As a result, disconnects can develop between changing market conditions and the existing label thresholds as a high percentage of models qualifies as efficient, thus diluting the label's impact. This suggests that the voluntary label specification may benefit from independence to develop its own revision schedule.

The introduction of a reach standard to give manufacturers longer lead time for future compliance has been important in signaling future efficiency requirements, but falters in actually facilitating the implementation of more stringent standards as the reach standard is announced without corresponding energy labeling thresholds or voluntary label efficiency specifications. As a result, although a more stringent reach standard has already been developed, the standard-setting process must still be reopened at each point in time to revise the labeling thresholds. While opening the reach standard for reevaluation may be useful in a time of rapid market change, it draws heavily on staff time and effort that could be focused on other products or efforts.

Lastly, the lack of consolidation in the appliance manufacturing industry has hampered enforcement of the standards and labeling programs. With more than one hundred companies manufacturing refrigerators and clothes washers, check-testing to verify enforcement can only capture a small portion of the market and more resources are required for enforcement.

6. Recommendations

Overall

Maintain existing policies and programs that are successful
With the implementation of the 11th FYP now bearing fruit, it is important to maintain and strengthen the existing energy-saving policies and programs that are successful, including the policy of setting an overall energy savings goal. A great deal of time and effort was invested in gathering and analyzing data, in training personnel to track and manage energy use, in developing implementation guidelines across sectors, and in creating financial incentives for energy saving. These efforts can yield further benefits over time and should be continued, rather than moving to new policies and programs in the 12th FYP.

Add explicit mechanisms to promote structural change
In the 11th FYP, the main mechanism for promoting structural change was one program for phasing out obsolete production capacity (i.e., small, inefficient enterprises). This program, despite good progress, proved to be insufficient to achieve the desired increase in the economic share of the service sector, or the related decrease in the economic share of industry. Additional mechanisms are needed to address structural change in a stronger and more explicit manner. Mechanisms could include further energy pricing reform, control of market access, and further change in tax policies on energy-intensive products and industries.

Continue to build the National Energy Conservation Center to facilitate information dissemination and training
Implementation of multiple policies and programs will benefit from the full establishment of the announced National Energy Conservation Center. At present, it is difficult for provincial energy conservation centers to share experience or seek training without the full realization of the national center. The National Energy Conservation Center can serve as a central contact point for sharing information on energy-saving technologies, operations and management practices, case studies of successful enterprises and local programs, and international best practices. A national center can also provide training, guidance documents, and software tools with standardized methodologies to provincial energy conservation and energy supervision centers. The National Energy Conservation Center - one of the “Top Ten Priorities” listed in 2004 - should be made operational as soon as possible.

Strengthen the capacity of provincial energy conservation centers
During the 11th FYP, important steps were taken revitalize China’s system of provincial energy conservation centers. However, much more needs to be done to strengthen the capacity of these implementing organizations. Further training for existing staff, and addition of staff with technical (as well as administrative) capabilities, would help at the local level. Enhanced coordination through a national center, including the use of standardized auditing and benchmarking protocols, would help to create consistency across the provincial centers. Even as market-based technical services companies develop (e.g., ESCOs), governmental energy conservation centers should strengthen technical expertise to monitor and verify energy improvements at the enterprises in their jurisdiction.

Build capacity to systematically collect and analyze data focused on end-use energy consumption
A key feature of successful energy-saving programs across countries is the implementation of a systematic data collection and reporting system for end-use energy consumption. Such a system enables government and businesses to analyze energy use patterns and identify savings opportunities on an economy-wide basis. Examples from the U.S. include the *Commercial Building Energy Consumption Survey* (CBECS), the *Residential Energy Consumption Survey* (RECS), and the *Manufacturing Energy Consumption Survey* (MECS). Such capacity could be built at organizations such as the Energy Research Institute, the National Energy Conservation Center, or the National Bureau of Statistics.

20% Target

Continue with 20% Energy Intensity Target
It appears that the energy intensity target provided strong motivation for action and it is recommended that China set another target for energy intensity reduction for the 12th FYP. There are compelling reasons to believe that the level of 20% is reasonable. During the 11th FYP the government spent the early years developing mechanisms to design, disseminate, implement and enforce a large number of energy-savings programs. For the coming 12th FYP, the apparatus of government in promoting energy-savings policies and programs is already in place, and further gains could be expected. International experience is that more detailed, bottom-up analyses of the potential for energy savings will continue to identify opportunities. One remaining need for target achievement is programs aimed at structural change to discourage the expansion of energy-intensive industry and to direct new capital investment to less energy-intensive economic output. It may be necessary to separate the structural change goal from the energy intensity goal and then address the structural change issue using different mechanisms.

Allocate target more scientifically, including a bottom-up analysis of energy saving potential
For the 12th FYP, there is opportunity for scientific analysis to better inform the allocation of the energy intensity target across provinces and sectors. In particular, a bottom-up analysis considering the energy and economic situation in each province or sector would help to determine realistic energy-saving potential, and thereby provide a better basis for target allocation. Methodologies and experience with allocation of absolute energy and carbon targets from the Netherlands, UK, and elsewhere can be utilized, with modification for China's energy intensity target.

Add a target for Carbon Intensity
Given the government's recent international announcements regarding climate change, it is reasonable to have a target for reduction of carbon intensity (CO_2 emissions per unit of GDP) as well as energy intensity, and to monitor the progress in achieving both. In general, it should be easier to achieve a given carbon intensity reduction than to achieve the comparable energy intensity reduction. Everything that contributes to energy efficiency counts toward the carbon intensity target, while low carbon energy sources are only credited to the carbon intensity target.

Monitoring, Reporting, Verification

Create a consistent and transparent system for gathering and analyzing data on energy intensity
Reliable information is essential to all aspects of China's energy intensity goal. Improvements are needed to make data reporting consistent across enterprises and provinces, and to clearly establish the methodologies for analyzing the data and assessing the performance of programs that reduce energy intensity.

Increase the level of public reporting regarding energy-saving policies and programs
At present, it is difficult even for energy experts to obtain necessary data to monitor and verify the progress of energy-saving programs and policies. Much more information should be made available publicly. Public sharing of data would increase attention to energy-saving programs, encourage consistency in data reporting, and encourage enterprises and government offices to achieve their goals. The lack of publicly reported data makes it difficult for Chinese experts to evaluate and publish on the data in peer-reviewed journals.

Standardize the metrics for targets and reporting
In the 11th FYP, a mix of metrics were utilized to establish targets for different programs and sectors, such as final energy savings (Mtce) for the Top-1000 enterprises program, or a target of a 3 percentage point increase in the share of the service sector. While continuing to pursue targets suitable to each program, the 12th FYP should have more standardization in establishing targets, reporting energy data, and quantifying progress toward targets. It is recommended that energy savings be tracked and reported in primary energy units, acknowledging and accounting for the generation, transmission, and distribution losses from electricity production when reporting on energy use and savings in the end-use sectors. The relationships between the overall energy intensity target and individual program target metrics should be made explicit. To avoid confusion, targets for each energy-saving program should indicate both the annual savings and the cumulative savings during the FYP period.

Establish systematic annual data reporting on greenhouse gas emissions
In support of the carbon intensity target (CO_2/GDP) announced by President Hu Jintao in September 2009, a systematic means of gathering annual data on greenhouse gas emissions is needed. Initially, reporting could focus on CO_2, and later be expanded to other greenhouse gases. Reporting by provinces and individual enterprises would augment China's national greenhouse gas inventory and energy data reporting.

Program Design

Improve the design phase for energy-saving projects
In analyzing the Ten Key Projects for energy saving in the 11th FYP, the need for improvement in the design phase was observed across the projects. Recognizing that the 12th FYP may organize projects somewhat differently than in the past, to address overlap with other programs, the following recommendations are applicable to the design of continuing or new programs.

- Clearly set program objectives, schedules, and targets
- Identify the target energy consumers
- Specify the energy-efficiency measures and other mechanisms to be utilized in the program
- Develop an implementation strategy, including key milestones

- Develop funding mechanisms or incentives to support implementation
- Disseminate information to program participants, and establish communication channels
- Establish a monitoring plan, including project indicators (metrics) and monitoring procedures
- Establish an evaluation plan

International best practice program design would ensure that the annual and cumulative program targets are clearly established from the program onset, with energy savings most likely accelerating over the lifetime of the program. A clear implementation strategy would outline the targeted savings by province and by sector, providing key milestones for implementation upon which to judge program progress. Without such an implementation strategy it is impossible to know whether the program goals are realistic, and without milestones it is impossible to know whether the implementation is on track or if the program needs adjustment.

Buildings Energy Efficiency

Revise the approach to existing building energy retrofits in cold climates, treating building envelope, control systems, and heat supply together.

Because heating represents a significant portion of energy use in existing buildings, more attention should be paid to building retrofit projects and heat supply reform. The existing program consisting primarily of incentives for retrofits is deficient because it fails to address institutional reform (specifically the problems due to the division of responsibility between the heat supply companies and buildings bureaus needed to bring together improvements in heat supply with energy efficiency measures); because the pace of energy pricing reform is too slow; and because there is not adequate scientific consideration of the best and most cost-effective measures to achieve more efficient heating supply, building energy retrofits, and building energy control systems simultaneously. Such an integrated program needs to be established quickly to serve as the basis for implementation during the 12th Five Year Plan period. Pilot efforts need to be carried out so that the full policy program can be implemented more quickly.

Expand the enforcement of building energy standards that have been effective in large urban areas to the rest of the nation improve building energy labels and provide incentives for "green building."

Continued attention to enforcement of new building energy-efficiency standards and the measurement of actual energy use are needed to ensure that efficient designs lead to real energy savings in operation. Energy efficiency policies need to be implemented in medium-small and small cities and in rural areas. Further incentives are needed to encourage "green buildings" with advanced energy efficiency features. The criteria for green buildings need to place significant emphasis on energy efficiency features of these buildings. In addition, there is a need to develop better characterization of building energy through life-cycle analysis, to identify and limit the use of energy-intensive building materials.

Continue to emphasize energy management of large-scale public and governmental buildings.

Large-scale public buildings use 10-20 times more than residential buildings. A more robust system should be set up. Such a system would include performing in-depth energy audits of existing buildings, gathering data on building energy performance (preferably before and after retrofit for existing buildings), monitoring the effects of occupant choice in the operation of buildings (temperature set points; schedules of HAVC systems; window openings; and so forth), public reporting on the energy use of buildings; expansion of the use of building energy labels; and extension of the program to medium-sized buildings in large and medium-sized cities.

Enhance policy design and effectiveness through expanded surveys, monitoring and establishing meaningful baselines of building energy consumption/efficiency.
Standardization of data-gathering methodologies and greater public availability of data are needed to inform 12^{th} FYP policy design and monitoring. Building energy consumption data and data reporting methodologies should be made more transparent for better evaluation of policy progress, including analysis by outside independent organizations. Surveys on building characteristics and energy consumption patterns that are representative of national building stock should be conducted on a regular basis. A scientific baseline needs to be developed to reflect the energy efficiency improvement in buildings and the increasing demand for more comfort and delivered energy services. In addition, benchmarking protocols should be developed to monitor building energy consumption and allow better comparison among buildings.

Industrial Energy Efficiency

Continue and expand the Top-1000 Program
It is recommended that the Top-1000 Program be continued during the 12th FYP, extended to include additional large, energy-intensive enterprises, and strengthened to be more effective.

Targets should be determined based on energy-saving potential of enterprise or sector
Best practice internationally is to set energy-saving targets based on an understanding of what the enterprise or the sector can actually achieve. In the Netherlands, UK, and Japan, studies of the energy-saving potential of industrial sub-sectors informed both the government and the enterprises. In the UK, companies went further and estimated their own energy-efficiency potential and provided this information to their trade associations who then negotiated sector-based targets with the government. Target-setting in China should be based on an assessment of the actual potential of either the Top-1000 enterprises individually, or the key sectors included in the Top-1000 program.

Energy auditing capabilities need to be improved
International best practice is to set specific standards or guidelines for conducting energy audits that clearly outline the scope and procedures to be used to conduct an assessment. Standardized methodologies, auditing tools, training for energy auditors, and reports that provide detailed recommendations are key elements of a high-quality auditing program. Energy auditing standards, guidebooks, tools, and training should be developed and disseminated to enterprises, sector associations, universities, energy conservation centers, and any other entities involved in energy auditing in China. There is a need for the government to establish a single clearinghouse to maintain and update the standards, guidebooks, tools, and training material. Such a clearinghouse can be in an existing organization or a new one. It is essential that substantial resources be committed to such a clearinghouse and that the clearinghouse be maintained on a long-term basis.

Benchmarking could be simplified so that it can be used by more industries
During the 11th FYP, a number of pilot projects involving industrial energy benchmarking tools were carried out. Some benchmarking tools contain detailed information on industry-specific process, but could be simplified for greater use. Wider availability of benchmarking tools would help more enterprises track their energy use, understand their competitiveness (or disadvantage) in terms of energy efficiency, and find energy-saving opportunities.

Reporting and evaluation needs to be strengthened
A notable weakness in the Top-1000 program and other industrial programs is the lack of public reporting and third party verification of energy use and savings. Because an online reporting system has been established, it would be relatively easy to make more of the data accessible in an aggregated or anonymous manner to protect confidential plant-level. Verification by organizations other than the enterprises or supervising government offices is needed to ensure that savings are real and that 12th FYP goals can be achieved.

Dissemination of information on energy-saving opportunities and experiences is needed
Information dissemination is an important component of industrial energy-efficiency programs across countries. The establishment of a National Energy Conservation Center would greatly help to facilitate information dissemination. A national center could help to compile technical information sources such as energy efficiency guidebooks, databases, software tools, and industry- or technology-specific energy efficiency reports. Such guidebooks and databases can provide information on existing and new technologies and measures as well as energy management practices. While some efforts have begun during the 11th FYP, such as development of training materials in 2006, additional compilation and dissemination of energy saving options are needed for the 12th FYP.

Structural Optimization

Promote opportunities for structural change within industries
At present, energy-intensive industries in China still have a large potential for efficiency gains through mergers and consolidation. While balancing local needs and desired structural change, economies of scale should be further promoted in heavy industry. Adoption of international best practices in energy management and technologies would also encourage efficiency gains in industrial enterprises and discourage low-quality inefficient plants.

Address local concerns about small plant closures through further development of transition plans
Currently, managers and officials' recognition of the importance of small plant closures and structural optimization does not match the expectations from the central government. Though many provincial leaders are beginning to emphasize energy efficiency and resource conservation, others are not taking sufficient actions and are concerned about local impacts on revenues and jobs. To enhance implementation, further support for transition plans could be offered. How to establish a phasing-out mechanism for different sectors (iron and steel, cement, power sector, or others) is a major question to consider for the next phase of structural change programs. Key factors such as central and provincial negotiations, employment issues, social safety, and economic and social conditions in different regions should be considered as well.

Combine market mechanisms with administrative measures
Market mechanisms, such as energy pricing reform and tax incentives, can be combined with administrative measures to encourage a structural shift away from energy-intensive, low value-added production. Administrative measures can provide a push by the government to the local enterprises with binding targets, market access and other requirements, or guidelines. Market mechanisms can provide a pull by favoring efficient enterprises and eliminating backward enterprises.

Create additional mechanisms explicitly focused on structural change
Additional specific mechanisms are needed to promote structural change. In the 11th FYP China developed a series of policies to close small, inefficient plants, but these policies alone are not enough to realize desired structural change. Additional measures are needed, such as energy price reform (coal, electricity, gasoline, and diesel), resource and consumption taxes, further adjustments to import and export taxes, and consideration of energy or carbon taxes.

Appliance Standards and Energy-Efficiency Labels

Revise and strengthen energy performance standards for appliances
Continuous and timely revisions to MEPS are still very important in a rapidly changing appliance market. Because a number of products subject to MEPS have not undergone revisions in recent years, all of the Chinese MEPS should be addressed during the 12th FYP period to reflect recent changes in the appliance market. Besides improving the stringency and relevance of existing standards, China may also need to consider introducing new standards as non-MEPS products begin to increase market penetration. For instance, there are currently MEPS for clothes dryers in the U.S. and Canada and mandatory labels in many other countries including Australia and the EU, and MEPS for dishwashers in the U.S., Russia, Israel, and Korea. Although China currently has very low levels of market penetration for both products, developing MEPS and an energy label for dishwashers could be particularly important if dishwashers become more common in urban households as more efficient models can reduce water and energy use by nearly 1/3rd.

Undertake regular national surveys of energy end-use to assess program effectiveness
Impact evaluation is very important in terms of assessing the impact of the standards and labeling program, and to provide context and input to future standards development or revision. Such evaluations, however, are hampered by the broad lack of end-use data by appliance in both residential and commercial sectors. Regularly undertaken national surveys modeled after the US *Residential Energy Consumption Survey* (RECS) or the *Commercial Building Energy Consumption Survey* (CBECS) would provide a wealth of data to improve prioritization of standards development, the setting of appropriate efficiency levels, and assessment of program impact.

Provide further support for enforcement of existing programs
Despite substantial improvements in implementation, remaining obstacles exist in enforcement of the standards and labeling programs. In the past few years, China has embarked on check-testing and most recently, round-robin testing of its appliance standards and labeling for select appliances. The program, however, lacks sufficient financial and human resources for administration and implementation.

Clarify the relationship between mandatory and voluntary efficiency labels

Because of the functional overlap between the China Energy Label and the voluntary endorsement label, as the China Energy Label becomes increasingly applied to more products, there should be an effort to define the link between the two labeling programs, particularly with respect to such programs as government energy efficiency procurement. At the same time, periodic reviews of the China Energy Label should be conducted to understand its market transformation impact, though such actions as efficiency distribution surveys and consumer surveys.

Increase participation in international networks for enforcement of appliance standards

Finally, as a major player in world mandatory energy-efficiency labeling programs but with aspects of weakness in enforcement, China should consider participating in international or regional networks that help facilitate information exchange and coordination between national governments on the enforcement issue. In joining such networks, China can benefit from the exchange of best practices in compliance and enforcement with other network members. One example of such a network would be the International Energy Agency's 4E Initiative and its working group on verification and enforcement, which was started in 2007 to help identify and tackle barriers in implementing end-use equipment efficiency policies. By bringing together diverse countries such as Austria, Korea, Netherlands, the UK and the U.S., the 4E initiative plays an important role in facilitating collaboration, extension of existing activities and tackling efficiency issues related to global trade and harmonization.

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9. Appendixes

Appendix A
The Approach to Decomposing Energy Demand Growth into Changes in Economic Output, Energy Efficiency, and Industrial Structure

This analysis decomposes annual energy consumption in order to understand the contribution of three effects: the first is economic output (activity), the second is energy efficiency, and the third is industrial structure. The activity effect shows the energy consumption change caused by changes in production activity, holding changes in energy efficiency and the energy proportion of each sector (structure) constant. The effect of energy efficiency is shown with activity and industrial structure held constant. The effect of industrial structure is shown with the other two factors held constant. The methodology to aggregate data is applied using in two sectors: secondary and tertiary.[56] In the secondary sector, the sub-sectors of ferrous metals, non-metallic minerals, chemical, non-ferrous metal industry and fuel industry are assessed in detail.

A Divisia index is used to estimate sectoral shift and real intensity change components of overall intensity changes. An often-cited advantage of Divisia is that can be used in a rolling base year. That is more useful because comparisons only using a fixed base year become less meaningful as the period considered grows. But the typical Divisia method results in a residual, so variations are used such as the Parametric Divisia Methodology (PDM), AWD (adaptive weighted Divisia) and RDM (Refined Divisia Method).

Both PDM and RDM need to define some parameters for the equations subjectively; they cannot decompose the energy completely because of the residuals. In this report, the ADW method is used to avoid the subjective definition of parameters which might influence the findings. AWD can decompose the objects completely without residuals.

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[56] The primary sector of the economy involves changing natural resources into primary products and includes agriculture, agribusiness, fishing, forestry and all mining and quarrying industries. Most products from this sector are considered raw materials for other industries. The Secondary sector includes those economic sectors that create a finished, usable product: manufacturing and construction. The tertiary sector involves the provision of services to businesses as well as final consumers. Services may involve the transport, distribution and sale of goods from producer to a consumer as may happen in wholesaling and retailing, or may involve the provision of a service, such as in pest control or entertainment. Goods may be transformed in the process of providing a service, as happens in the restaurant industry or in equipment repair. However, the focus is on people interacting with people and serving the customer rather than transforming physical goods.

$$\frac{E^t}{E^0} = D_{act} D_{eff} D_{str}$$

$$D_{act} = \exp\left[\Delta Y\left(\frac{1}{Y_0} + \gamma\Delta\frac{1}{Y_t}\right)\right]$$

$$D_{eff} = \exp\left[-\sum_i \ln\left(\frac{I_i^t}{I_i^0}\right)\left(y_i^0 + \alpha_i \Delta y_i\right)\right], \qquad D_{str} = \exp\left[-\sum_i \ln\left(\frac{S_i^t}{S_i^0}\right)\left(y_i^0 + \beta_i \Delta y_i\right)\right]$$

$$\gamma = \frac{\ln\frac{Y_t}{Y_0} - \frac{\Delta Y}{Y_0}}{\Delta Y * \Delta\left(\frac{1}{Y_t}\right)}, \qquad \alpha_i = \frac{\Delta I_i\left(\frac{S_i^0}{I^0}\right) - \ln\left(\frac{I_i^t}{I_i^0}\right)y_i^0}{\Delta y_i \ln\left(\frac{I_i^t}{I_i^0}\right) - \Delta\left(\frac{S_i}{I^t}\right)\Delta I_i}, \qquad \beta_i = \frac{\Delta S_i\left(\frac{I_i^0}{I^0}\right) - \ln\left(\frac{S_i^t}{S_i^0}\right)\Delta y_i}{\Delta y_i \ln\left(\frac{S_i^t}{S_i^0}\right) - \Delta\left(\frac{I_i}{I^t}\right)\Delta S_i}$$

D_{act} shows the coefficient of energy consumption change caused by changes in production activity.

D_{eff} shows the coefficient of the energy consumption change caused by efficiency.

D_{str} shows the coefficient of the energy consumption change caused by industry structure.

E^0 shows total energy used at base time, E^t shows total energy used at t time, E_i^t shows the i sector energy used at t time ;

$S_i^t = \frac{E_i^t}{E^t}$ shows the i department energy use structure;

Y^t shows added value at t time; Y_i^t shows the i sector value at t time;

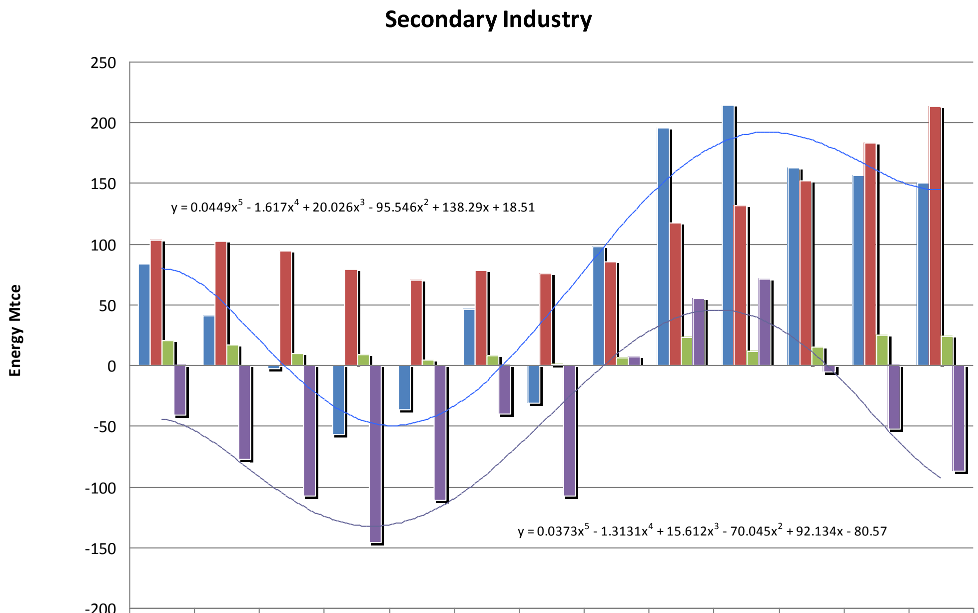
$y_i^t = \frac{Y_i^t}{Y^t}$ shows proportion of the i sector value in the total added value at t time;

$I^t = \frac{Y^t}{E^t}$ shows the average sector efficiency at t time ;

$I_i^t = \frac{Y_i^t}{E_i^t}$ shows the i sector energy efficiency at t time ;

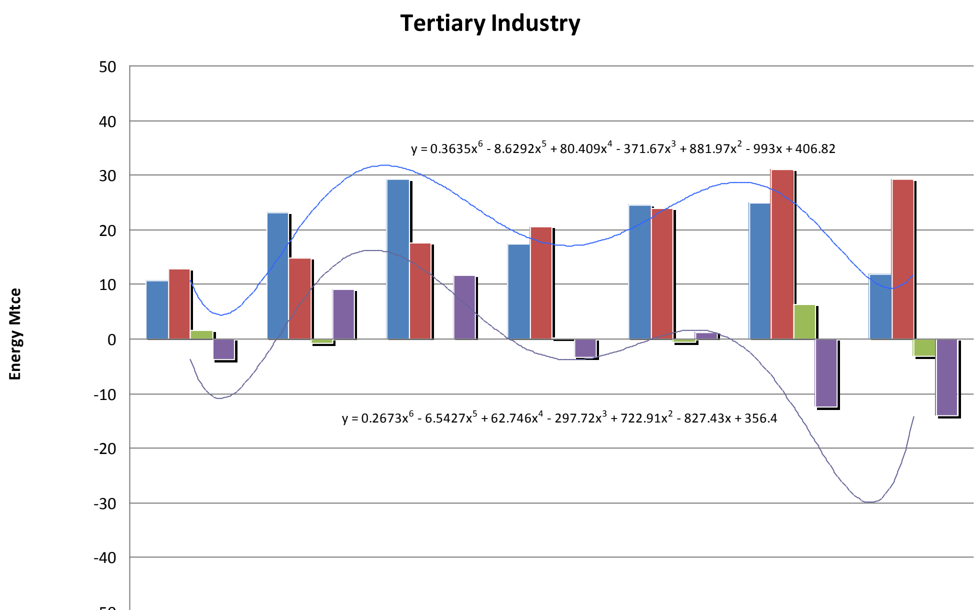
Decomposition of China's Industrial Energy Use

Figure A-1 shows the efficiency change is curvilinear from 1995 to 2007. The efficiency effect is very positive effect for 2003 and 2004 and makes the energy consumption rising up very quickly with the activity effect and structure effect. But it began to drop down from 2005 to 2007.Structural shift among the secondary industry has always had a very small positive effect on total energy consumption change especially almost zero at 2001 (see Figure A-2). It also show that the secondary industry rebound of the total energy consumption of China. The growing share of the industrial sector tends to cause total energy consumption to increase and other things change small. Figure A-2 shows the efficiency effect dropped down very quickly for 2007 and 2008. The energy consumption reduction is high because the structure and efficiency effects are both negative, although the activity effect is high at 2008.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	83.36	41.31	-2.42	-56.71	-36.12	46.46	-30.96	98.34	195.90	214.73	162.48	156.45	150.30
Activity	103.4421	101.94	94.80	79.53	70.69	78.38	75.58	85.36	117.35	131.78	152.06	183.37	213.44
Structure	20.89941	16.85	10.23	9.26	4.32	7.97	1.22	6.22	23.38	11.62	15.63	25.22	23.93
Efficiency	-40.98151	-77.48	-107.45	-145.50	-111.14	-39.89	-107.76	6.77	55.16	71.33	-5.22	-52.14	-87.07

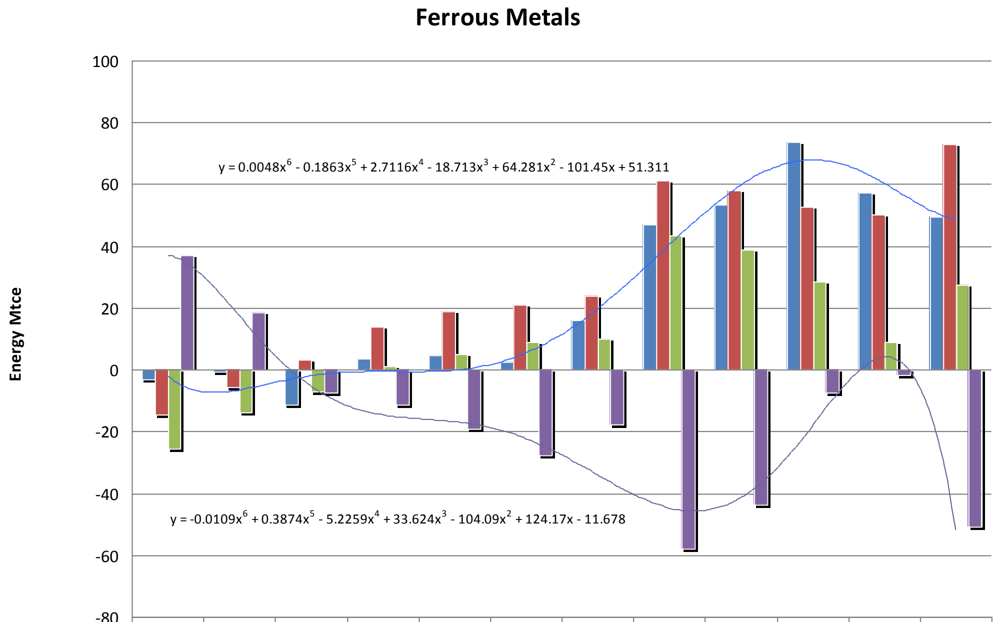
Figure A-1. Secondary industry energy consumption analysis of China



	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	10.63	23.08	29.25	17.36	24.45	25.00	11.95
Activity	12.78	14.81	17.68	20.64	23.99	31.00	29.16
Structure	1.59	-0.73	-0.05	0.13	-0.65	6.41	-3.21
Efficiency	-3.74	9.00	11.62	-3.41	1.11	-12.41	-14.01

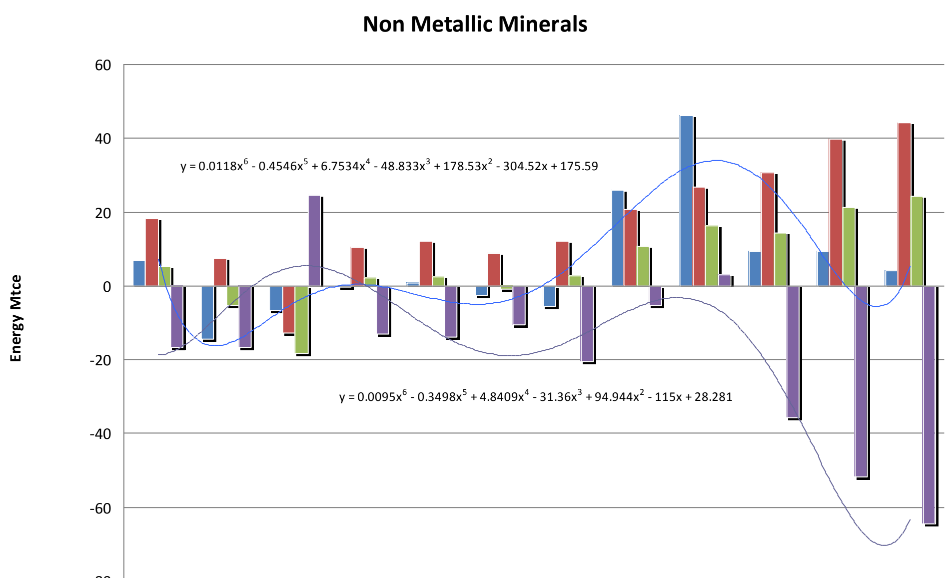
Figure A-2. Tertiary industry energy consumption analysis of China

Figure A- to A-9 provide information on the activity, structure, and efficiency effect for a number of industrial sub-sectors in China.



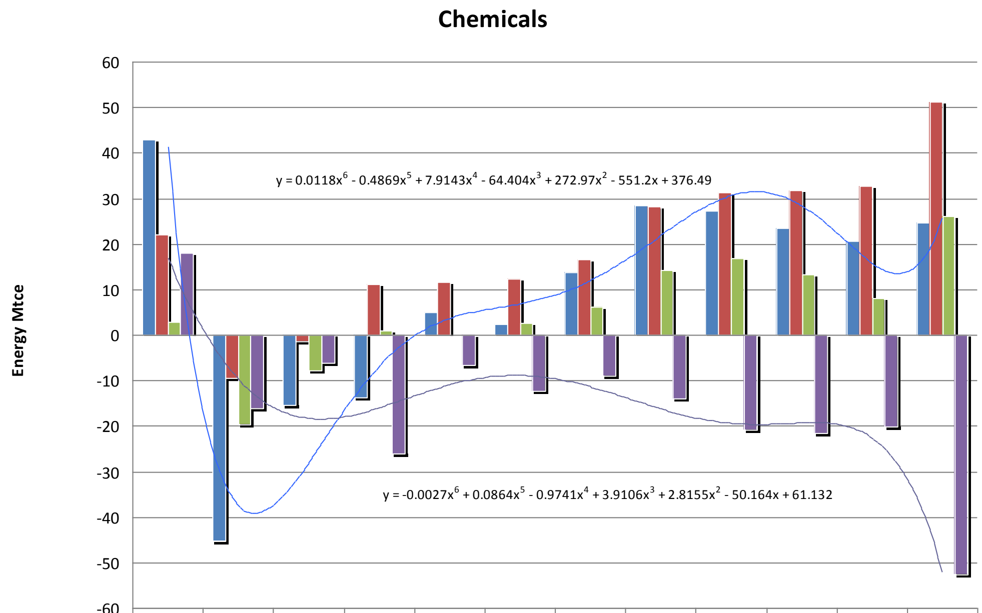
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	-3.19	-0.83	-11.18	3.51	4.57	2.36	16.02	47.00	53.45	73.76	57.34	49.62
Activity	-14.61	-5.64	3.23	13.90	18.75	20.90	23.71	61.28	58.06	52.85	50.37	72.99
Structure	-25.51	-13.68	-7.03	0.97	4.94	9.06	9.96	43.61	38.96	28.35	8.85	27.42
Efficiency	36.92	18.48	-7.39	-11.36	-19.12	-27.60	-17.65	-57.90	-43.58	-7.45	-1.87	-50.79

Figure A-3. Ferrous metals sub-sector energy consumption analysis of China



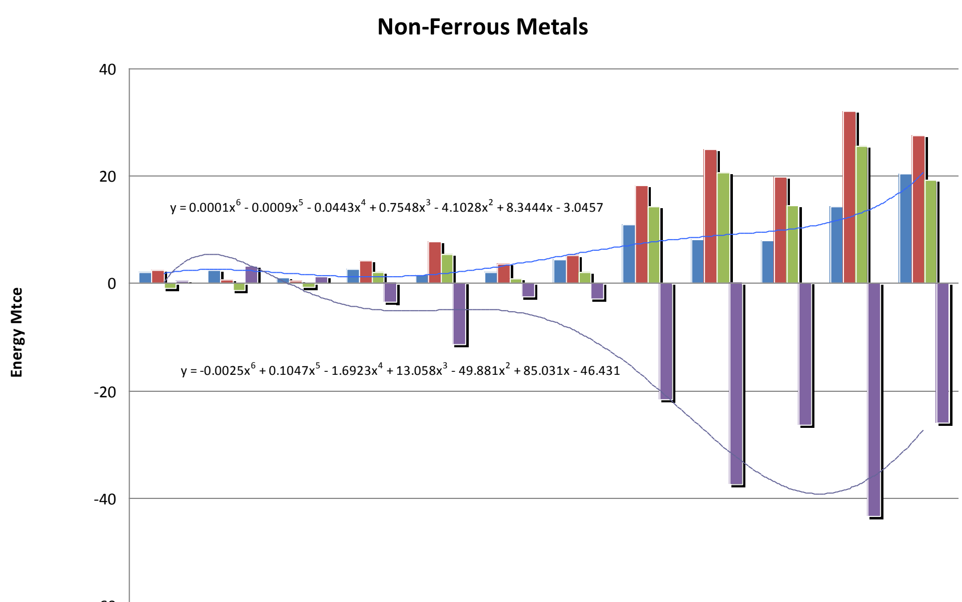
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	6.89	-14.53	-6.60	-0.22	0.82	-2.59	-5.71	26.03	46.21	9.26	9.34	4.06
Activity	18.26	7.45	-12.83	10.48	12.04	8.82	12.21	20.61	26.91	30.58	39.68	44.25
Structure	5.15	-5.40	-18.40	2.27	2.58	-0.90	2.60	10.69	16.19	14.39	21.35	24.41
Efficiency	-16.52	-16.58	24.63	-12.97	-13.80	-10.50	-20.52	-5.26	3.11	-35.71	-51.69	-64.59

Figure A-4 Non-metallic minerals sub-sector energy consumption analysis of China



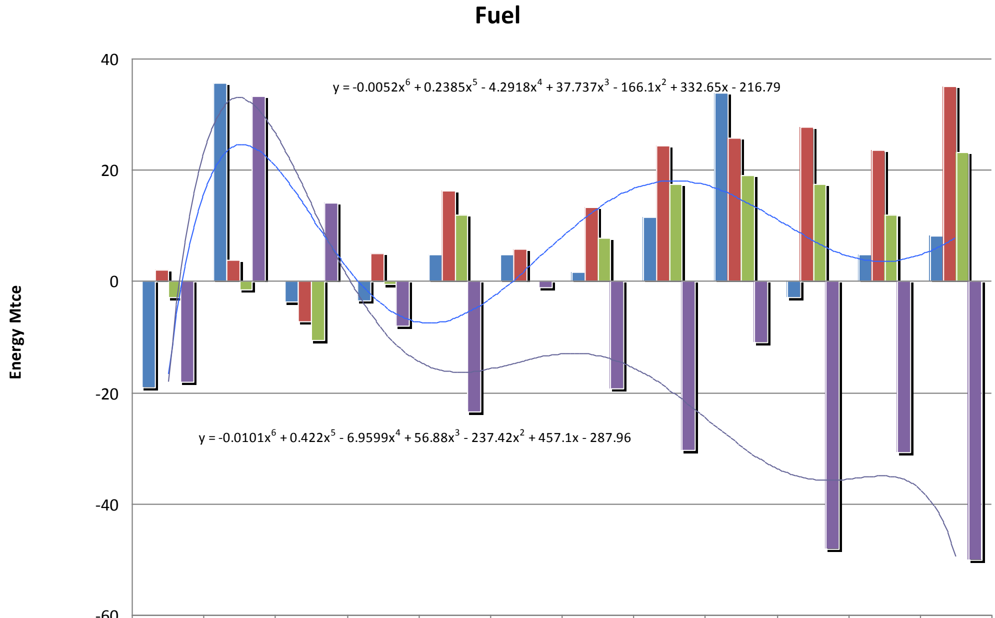
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	42.97	-45.24	-15.50	-13.84	5.05	2.40	13.82	28.36	27.25	23.59	20.74	24.66
Activity	21.97	-9.58	-1.48	11.20	11.62	12.22	16.58	28.11	31.22	31.73	32.82	51.21
Structure	2.92	-19.61	-7.78	1.06	-0.03	2.56	6.27	14.32	16.90	13.37	8.06	26.13
Efficiency	18.08	-16.04	-6.24	-26.11	-6.55	-12.38	-9.03	-14.08	-20.87	-21.51	-20.15	-52.68

Figure A-5. Chemical industry sub-sector energy consumption analysis of China



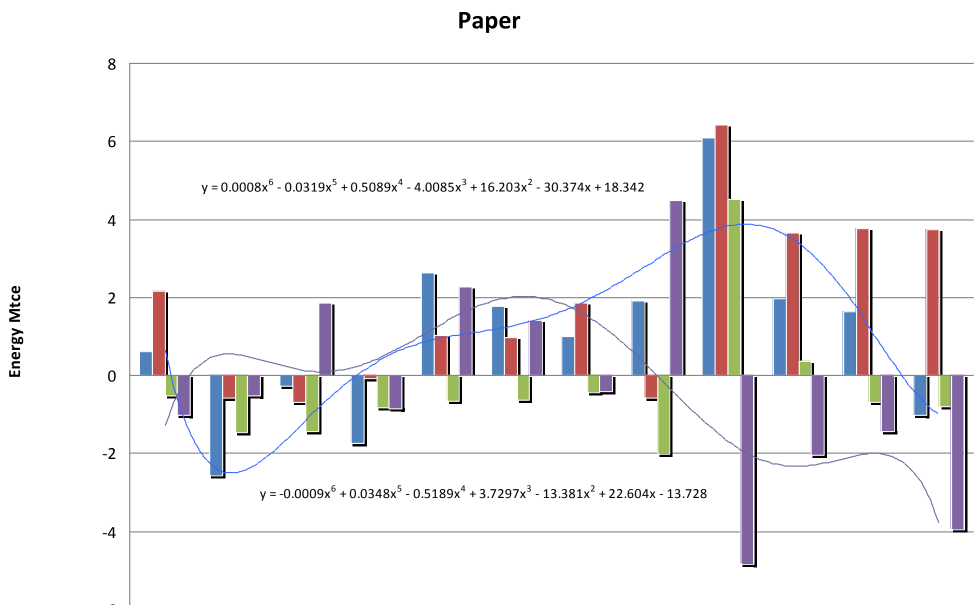
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	1.99	2.47	0.98	2.74	1.76	2.14	4.47	10.87	8.20	7.97	14.33	20.53
Activity	2.43	0.62	0.41	4.19	7.79	3.68	5.19	18.25	25.03	19.85	32.17	27.46
Structure	-0.91	-1.30	-0.71	2.12	5.33	0.96	2.12	14.22	20.72	14.58	25.62	19.16
Efficiency	0.47	3.14	1.29	-3.57	-11.37	-2.49	-2.85	-21.59	-37.55	-26.46	-43.47	-26.09

Figure A-6. Non-ferrous metal sub-sector energy consumption analysis of China



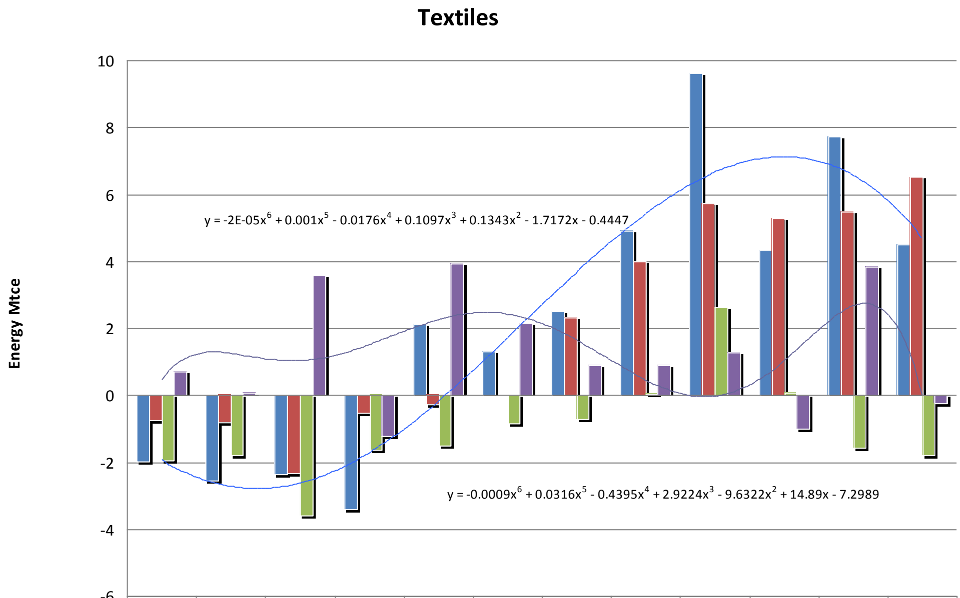
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	-19.02	35.71	-3.68	-3.52	4.75	4.85	1.68	11.50	33.79	-2.96	4.82	8.16
Activity	2.00	3.91	-7.24	4.93	16.23	5.86	13.22	24.33	25.73	27.68	23.60	35.03
Structure	-2.98	-1.41	-10.51	-0.45	11.91	0.01	7.81	17.49	18.97	17.48	12.03	23.16
efficiency	-18.03	33.21	14.07	-8.01	-23.39	-1.03	-19.36	-30.31	-10.91	-48.12	-30.81	-50.03

Figure A-7. Fuel sub-sector energy consumption analysis of China



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	0.62	-2.57	-0.27	-1.75	2.63	1.77	1.00	1.91	6.09	1.98	1.64	-1.01
Activity	2.16	-0.58	-0.68	-0.08	1.02	0.98	1.85	-0.56	6.43	3.66	3.76	3.75
Structure	-0.52	-1.47	-1.44	-0.83	-0.65	-0.63	-0.45	-2.01	4.50	0.36	-0.69	-0.80
Efficiency	-1.02	-0.53	1.86	-0.84	2.26	1.42	-0.40	4.49	-4.85	-2.04	-1.43	-3.96

Figure A-8.Paper sub-sector energy consumption analysis of China



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Δ Energy Use	-1.99	-2.55	-2.35	-3.39	2.12	1.32	2.50	4.92	9.62	4.33	7.73	4.51
Activity	-0.74	-0.81	-2.33	-0.54	-0.28	-0.00	2.31	3.99	5.73	5.28	5.48	6.52
Structure	-1.95	-1.80	-3.58	-1.63	-1.52	-0.83	-0.70	0.05	2.62	0.07	-1.58	-1.78
Efficiency	0.70	0.06	3.57	-1.22	3.92	2.15	0.89	0.88	1.28	-1.01	3.83	-0.23

Figure A-9. Textiles sub-sector energy consumption analysis of China

Appendix B. Baseline Values for Buildings Efficiency Program Evaluation

Table B-1 provides energy intensity and efficiency values for typical public buildings constructed in the 1980s in four locations in China.

Table B-1. Energy Intensity and Efficiency Values of the Typical Public Buildings Built in 1980s in Four Locations in China

Components	Value	Harbin	Beijing	Shanghai	Guangzhou
Exterior walls	U-value (W/m^2 °K)	1.28	1.70	2.00	2.35
Roofs	U-value (W/m^2 °K)	0.77	1.26	1.50	1.55
Windows	U-value (W/m^2 °K)	3.26	6.40		
Windows	SC/SHGC	0.80/0.70			
Lighting	LPD (W/m^2)	25			
Heating	Coal-fired boiler efficiency	55%	55%	55%	55%
Cooling (water-cooled chillers)	COP for centrifugal chillers COP for screw chillers	4.2 3.8	4.2 3.8	4.2 3.8	4.2 3.8

Lighting intensity is based on the standard GB 50034-2004.
W/m^2= watts/square meter
°K =degrees Kelvin
SC/SHGC = shading coefficient/solar heat gain coefficient
LPD = lighting power density
COP = coefficient of performance

Table B-2 and Table B-3 show the key requirements in the new standard for lighting and building envelope requirements for the Hot Summer Cold Winter region, respectively. Lighting intensity in the typical 1980s building was 25 watts/square meter (W/m^2); the new requirements range from 11 to 18 W/m^2). The values in Table B-3 for building envelope requirements can be compared to the typical building in Shanghai, which is in the Hot Summer Cold Winter region.

Table B-2. Lighting Requirements of Selected Building and Space Types

Space	Maximum LPD (W/m^2)
Office buildings	
Typical office room	11
Conference room	11
High-class office room	18
Hotels	
Guest room	15
Lobby	15
Schools	
Classroom	15
Lab	11

Source: GB50034-2004
LPD = lighting power density
W/m^2= watts/square meter

Table B-3. Envelope Requirement in the Hot Summer Cold- Winter Region

Building envelope component	Maximum K heat transfer coefficient (W/(m^2 K))		
Roofs		0.70	
Exterior wall (Including non-transparent curtain wall)		1.0	
Suspended floors or projecting floor slabs with the		1.0	
Underside exposed to outdoor air			
Exterior window (including transparent curtain wall)		Maximum K heat transfer coefficient W/(m^2 K)	Maximum shading coefficient [East, South, West/North)
Single orientation exterior window (including transparent curtain wall)	WWR0.2	4.7	-
	0.2 < WWR0.3	3.5	0.55/-
	0.3 < WWR0.4	3.0	0.50/0.60
	0.4 < WWR<0.5	2.8	0.45/0.55
	0.5 < WWR0.7	2.5	0.40/0.50
Skylights		3.0	0.40

Source: Tianzhen Hong, 2009.