2014 Market Analysis of China Energy Efficient Products (MACEEP)

March 2016
version 1.1

(original November 2014)

CLASP.ngo

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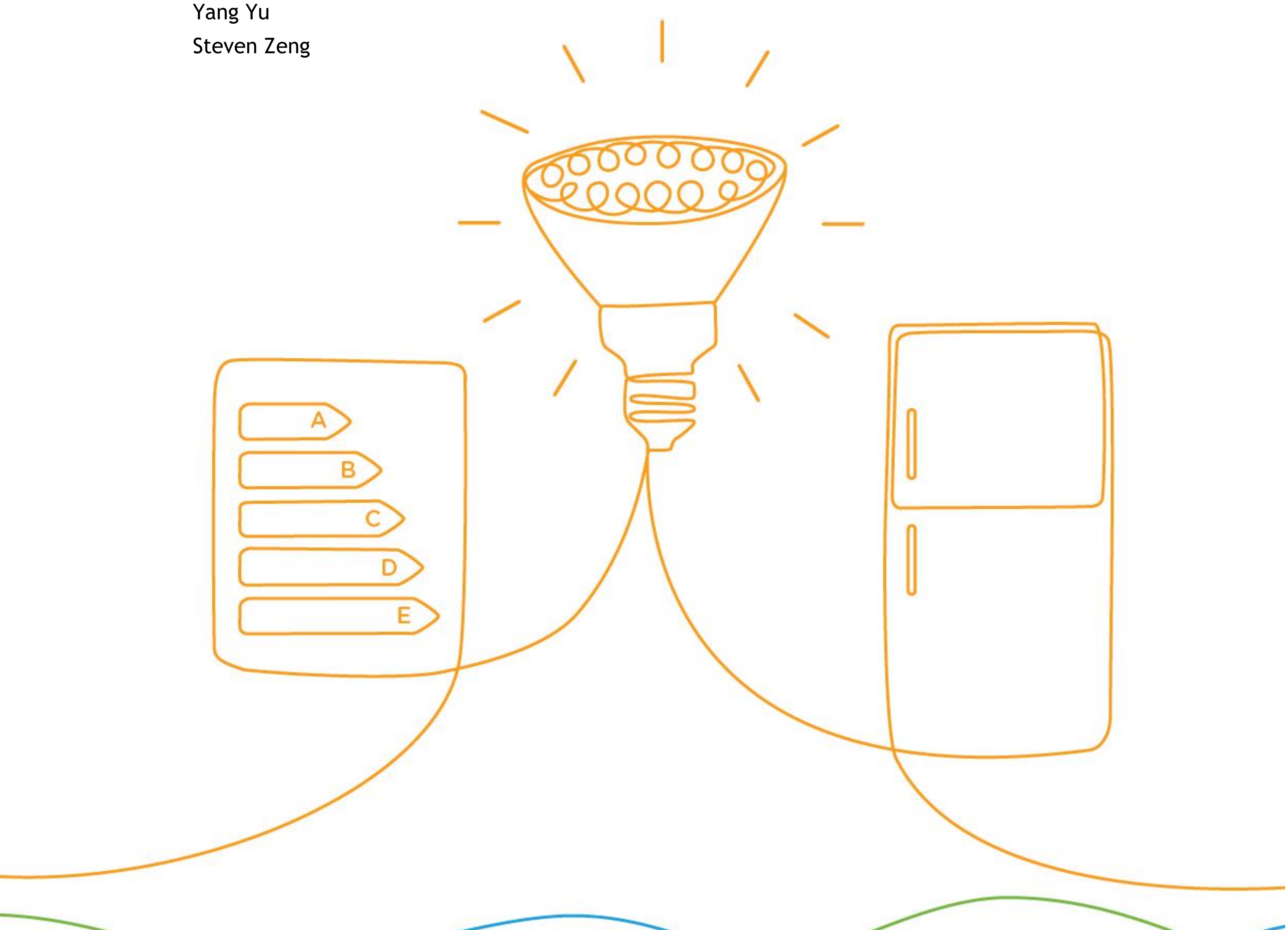

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Revision History

Version 1.1 issues to correct misreported data in Table 11 on page 38. The table originally gave the M and N values from the 2003 version of the refrigerator standard. This has now been corrected to show the 2008 values as intended.

Acknowledgements

This report was prepared by the China office of CLASP. Primary authors of the report were

Jayond Li: air conditioners, televisions and washing machines

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Steven Zeng: cross-product support

In addition, during the preparation of the report the authors received extensive support from the management of the CLASP China office. In particular, the authors would like to thank Steven Zeng, Director of CLASP's China Program, who provided guidance and sufficient resources to ensure successful completion of the study.

We would also like to thank our international expert, Stuart Jeffcott, who provided technical and editorial support during the report preparation, and Mike Scholand, who reviewed the whole report.

Extended Executive Summary

China is the world's largest manufacturing hub for household appliances and, for many appliances, now also has the highest annual sales and number of products installed. Over the past two decades, a range of appliance types have been widely adopted among urban households, and many of households are now at a point where they are ready to replace their existing appliances with newer models. More recently, the penetration of appliances into rural areas has been accelerating, partly as a result of increasing wealth levels in these regions, and partly through specific government initiatives aimed at stimulating appliance ownership in these areas. Consequently, under a business as usual scenario, energy consumption and associated GHG emissions related to the expansion of appliance usage will grow rapidly.[1]

Fortunately, it appears that consumers are becoming increasingly aware that energy saving are a key factor to consider when evaluating appliances for purchase. Furthermore, the Government of China's 12th Five Year Plan includes energy saving and emissions reduction as mandatory indicators of social development, and sets a goal to reduce energy intensity per capita by 16% by 2015, relative to 2010.

However, China's appliance market is very large and increasingly sophisticated. Product development is accelerating, with shorter design and production phases, leading to shorter shelf lives for products in the market. Thus, developing policies that are appropriate for rapidly evolving products and relevant to the disparate market segments is increasingly challenging. This situation is made significantly worse by limited real data on the energy and efficiency performance of products within the market place.

In 2012, CLASP identified an opportunity to collect and analyze market data that would help Chinese policymakers set achievable and more stringent targets for upcoming revisions to minimum energy performance standards. CLASP partnered with other organizations to undertake this analysis for a range of appliances, resulting in the publication of the Market Analysis of China Energy Efficient Products (MACEEP 2013) and a parallel study on energy savings potential. MACEEP was, and continues to be, the only third party study of its kind to be conducted based on independently-collected market data. Given the success of MACEEP 2013 in increasing market knowledge and identifying key areas for policymakers to address, in 2013-2014 CLASP has undertaken a second Market Analysis of China Energy Efficient Products (MACEEP 2014). This analysis examines how the market has evolved and what the impact of new regulations has been on some of the products analyzed in MACEEP 2013, and has been expanded to include other significant energy consuming appliances.

[1] Under a Business as Usual scenario, the nine products featuring in the MACEEP 2013 study had projected growth in energy consumption of 670 TWh to 820 TWh between 2015 and 2030.

The MACEEP 2014 study provides a transparent picture of the levels of efficiency and comparative energy consumption of six domestic appliances currently for sale in China: room air-conditioners (both fixed and variable speed), instantaneous gas and electric water heaters, refrigerators, televisions and washing machines. The data for this study was drawn from surveys of products available on the market in October 2013, supplemented by information from public sources such as the China Energy Label website and the China National Bureau of Statistics. In a number of cases, further analysis was conducted based on data drawn in March 2014 from product registrations at the China National Institute of Standardization.

The MACEEP 2014 analysis of six domestic appliances clearly demonstrates that the actions taken by Chinese policymakers to date (including the development and implementation of minimum energy efficiency standards, product labelling and other interventions) have resulted in substantial improvements in the energy efficiency of these products. However, the analysis also shows there are considerable additional energy and cost savings that could result from further actions by policymakers.

Within the six individual appliance analyses, 43 recommendations have been made for improving China's energy efficiency policies, ranging from refining the energy label to technical revision of standards. In each case these recommendations are specific to the appliance and justified on the evidence presented in the analysis of that appliance. However, when reviewing the individual appliance conclusions and recommendations together, there are a number of overarching themes that may be of significant interest to policymakers. These summary conclusions and recommendations are as follows.

Immediate energy saving opportunities

Significant energy saving opportunities are immediately available through relatively simple revisions to the minimum energy performance requirements for fixed and variable speed air conditioners, refrigerators and water heaters. Potentially appropriate minimum energy performance requirements are proposed in the relevant appliance analyses below. Policymakers should be reassured that, in general, there is little evidence to suggest such revisions would have an adverse impact on product price. However, it may be necessary to support some manufacturers in adapting to higher performance requirements if a change in production is necessary.

Revise current strategy for developing energy efficiency Tiers

The strategy currently being pursued by Chinese policymakers when developing energy efficiency standards has resulted in a situation where, for most types of appliances, a large proportion of models are qualified at higher efficiency levels, or "Tier 1" and "Tier 2". As there has been clear and sustained improvement in the efficiency of many products, there is evidence that this strategy is working. This is possibly because there is no incentive for manufacturers to apply premium pricing to Tier 1 products, and thus there is no price barrier preventing consumers from selecting efficient products. This may be leading to less efficient products only accounting for a limited market share, making it easy for policymakers to eliminate these products when revising/updating energy efficiency standards.

However, the current strategy means that consumers do not have the opportunity to preferentially select the most efficient products at the point of purchase (i.e., if Tier 1 products only counted for less than 5% of available models on the market, consumers would be able to differentiate them from other regular or less efficient models). Moreover, there is limited incentive for manufacturers to develop new products of higher efficiency, since they will not be distinguished in the market. Therefore, policymakers may wish to consider an alternative strategy whereby future revisions to the energy efficiency Tiers for all appliances will introduce new performance requirements, such that:

- Tier 1 requirements are set at the efficiency level of the best performing appliance in the market at that time (thus creating the equivalent of a "Top Runner" target – i.e., the top 5% of products in terms of energy efficiency – to encourage the development of new high performance products), or at some other similarly-ambitious efficiency level that satisfies the desires of policymakers;
- The Tier 2 requirements dictate that only the top 10% of efficient appliances are eligible for qualification at the time the standard is introduced; and,
- The remaining products are evenly distributed across the remaining labeling categories.

Furthermore, an automatic revision of the Tier requirements should be initiated when 10% of models in the market achieve Tier 1 performance, or 25% of models achieve Tier 2 performance. This would ensure that higher efficiency products are continually differentiated from other appliances on the market.

Such a strategy would allow consumers to choose higher-efficiency products and allow policymakers to more effectively pursue other policy support measures that target the best performing products. This strategy is also in line with current (or likely) developments in other countries such as Australia, Canada, Korea, and Japan – where premium products are effectively identified in the market, or automatic standards revisions are undertaken when approximately 25% of products reach a level considered to define premium efficiency.

A more detailed review will be conducted in future MACEEP studies to learn which of the two strategies mentioned above is more suitable for China's situation.

Make efficiency requirements technology neutral

Currently, a number of appliances with the same functionality qualify for different energy efficiency tiers and minimum performance requirements because these appliances are based on different technologies. For example, variable and fixed speed air conditioners (and air conditioners with and without heating functionality), impeller and drum washing machines, LED TVs and PDP TVs, and various types of water heater have differing test procedures and energy performance requirements. This is very likely to mislead consumers as to the relative performance of the various appliance types, and is likely to lead to inadvertent purchases of products that consume more energy than necessary.

Therefore, this study strongly recommends that policymakers attempt to ensure that all appliance standards are based on technology-neutral test methods and performance requirements. It should again be noted that some manufacturers may require additional policy support to shift production where their existing product range is adversely affected by the switch to a technology-neutral standard.

Consider the wider environmental implications of products when developing energy efficiency standards

The primary purpose of the current energy efficiency standards regime is to save energy. However, energy saving in itself is not the primary goal, but simply a mechanism through which other goals are achieved, for example reduction in the use of natural resources, reductions in the emissions that accelerate global warming, and reductions in consumer expenditures on energy. Thus the focus on energy saving alone in the development of energy efficiency standards may not yield optimal outcomes. For example, it *may* be appropriate to make the efficiency requirements for air conditioners less stringent should they use refrigerants with lower global warming impact. Hence, when developing energy efficiency standards, a switch to a wider remit encapsulating the overall environmental impact of the product (as is the case in the EU) may be appropriate.

Research consumer usage patterns

Real life use of products by consumers in their homes directly impacts several factors in the development of energy efficiency standards. It affects projections of energy consumption and saving potentials, the accuracy and relevance of test methods, and determines the actual energy used by the consumer in their household. Despite this, very little public information appears to be available on current consumer usage patterns for the majority of appliances in China. A separate study conducted by CLASP provides the basis for an understanding of consumer usage patterns for a number of products. It is recommended that this study be extended to capture usage patterns for a wider group of products and, if possible, to undertake nationwide in-household monitoring of actual product usage and energy consumption.

Revise labels to be more understandable to consumers

Currently, a number of the criteria displayed on energy labels are not assisting consumers in selecting the most efficient or lowest energy-consuming appliance. For example, the declared energy efficiency index (EEI) of televisions, “hot water production rate” of electrical storage water heaters, and the thermal efficiency (η) of gas water heaters have little meaning to consumers, and are therefore unlikely to impact their purchasing decisions.

Further, using efficiency as a measure of comparative performance is not always beneficial. For example, a 50” TV of Tier 1 will probably use *more energy* than a 45” TV of Tier 2, but that information is not communicated effectively on the label. A consumer aiming to purchase efficient products may purchase the 50" unit due to its apparent higher efficiency, but ultimately that unit will consume more energy.

Therefore, the study recommends that a typical daily, monthly, or (ideally) annual energy consumption figure be included on the label for most products, similar to that which is used for refrigerators. This is already a nominal requirement of the energy labeling management rules.

In the longer term, the calculation of energy consumption should be based on typical usage patterns established by the research into consumer usage patterns.

Require energy labels to reflect typical product performance, and review allowable testing and labeling tolerances

There is evidence to suggest that some manufacturers are reporting energy performance values on appliance energy labels that are higher or lower than the typical performance of the model. This has the potential to lead to the development of inappropriate revisions to the affiliated energy efficiency standard or hamper the development of a more appropriate one. It can also lead consumers to select an appliance that is not appropriate for their needs or that fails to meet their expectations of energy consumption.

Therefore, the study strongly recommends that policymakers require declarations of energy efficiency and other performance indicators on an energy label in order to accurately reflect the true performance values reported in the test certificate submitted with the label application. This test certificate must represent the *typical* performance of the model under production conditions. Furthermore, once clarity is achieved in product claims, policymakers may wish to re-examine the tolerances – the allowable level of variance between test results – in test methods and labeling claims to ensure they are appropriate for each appliance type.

Revise some test methodologies and thresholds for performance

A number of potential shortcomings have been identified in existing test methodologies, particularly for TVs and water heaters. Policymakers may wish to encourage revision of these test procedures, possibly through the adoption of existing and accepted international methodologies, to ensure that the performance of the appliance is represented accurately. This information is essential for consumer decision-making and for the development of appropriate policy measures.

Similarly, an issue has been identified in the use of linear functions and adjusted volumes as the basis for regulation of refrigerated appliances. The current Energy Efficiency Standard is based on a linear function and adjusted appliance volume to derive the energy efficiency performance Tiers and the associated minimum energy performance levels. However, the use of such a linear function *and* adjusted volumes has the effect of increasing the price of smaller units and/or improving the apparent efficiency of larger appliances. Either (or, worse, both) of these outcomes is giving an incentive for consumers to purchase larger appliances which leads to higher overall energy consumption. The approach used in China is in line with current practice in the majority of countries around the world. However, Chinese policymakers may wish to consider a move to curved exponential functions based on adjusted appliance surface area as a basis for minimum performance and Tier thresholds. Such an approach would more effectively respond to the inherent increase in efficiency as product sizes increase, and removes the potential for the perverse outcome of increased unit volumes improving apparent unit efficiency but also increasing consumption.

Consider a technical study of standby modes and other product-specific characteristics to assist in future energy efficiency standards development

In general, existing energy efficiency standards have some Tier or minimum performance requirement related to the "standby" of the appliance. Typically these standards refer to a single standby mode; for example, "off-mode power", where a unit is plugged into the main power supply but the appliance is switched off. However, with the advent of microprocessor control and additional appliance functionality, an increasing number of appliances have varying standby modes. For example, televisions have "fully off", "standby with no activity", instant "on" functionality, internet connectivity, and so on – all of which have varying levels of energy consumption that are not currently captured by existing Chinese test methodologies. Therefore, policymakers may wish to conduct a technical study examining appropriate appliances to establish the type and extent of standby modes currently available. This study, in combination with consumer research on typical usage patterns, should identify any additional standby modes that result in significant energy consumption and are commonly used by consumers.

Similar technical studies are also recommended to consider:

- How heating performance should be better regulated, the comparative real life energy consumption of variable speed versus fixed speed, and the impact of refrigerants (see below) on air conditioners.
- Typical operating loads (or range of loads) of gas water heaters in Chinese households, to allow consideration of whether full load or part load should be the primary operating condition under which performance is measured, or whether some combined value of the two thermal efficiency results would be most representative of Chinese operating conditions.
- Developing a standardized test method for 3D TVs as soon as possible, and including it in the next revision of the EES. Current evidence *suggests* 3D TVs have the potential to use substantially less energy than 2D equivalents.

The results of these technical studies can then be integrated into the testing and energy efficiency standards for that appliance. Similar research is under way in other parts of the world, and there is potential for Chinese policymakers to collaborate with, or learn from, these studies.

Improve the collection of sales data

The majority of analyses in this report was conducted on a product basis rather than a sales weighted basis due to limited access to sales data. This study found that although the results of sales and models analysis are often similar, this is not always the case and has the potential to distort findings. For example, particularly efficient or inefficient products may sell in significantly larger quantities than an average product on the market. If policymakers are similarly limited in their access to sales figures for products, it may lead to similar potential distortions in the analyses conducted for the development of energy efficiency standards and associated energy saving projections.

Therefore, policymakers may wish to require suppliers of registered appliances to supply annual sales figures for those appliances as part of the registration requirement. While this may sound impractical, policymakers may wish to know that such a requirement is part of the registration requirement in Australia, Canada, and Korea (and as part of the USA ENERGY STAR program). If suppliers do not provide annual sales data in these economies, registration of the product is cancelled. Nevertheless, it should be recognized that implementation of such an approach can face initial barriers from industry, who perceive such data to be commercially sensitive, but the experience from elsewhere indicates that policymakers can secure the data *and* benefit from improved market knowledge and resulting improved policy making.

Reorient the focus of future subsidy programs

There is little doubt that the use of subsidies promoting efficient appliances has achieved the primary goal of stimulating national demand for high efficiency appliances and increasing their penetration into rural areas. However, in some cases, the subsidies have been supporting products that are highly efficient, yet still consume very high levels of energy. For example, LED-backlit televisions with very large screens may be highly efficient, but will still consume over twice as much power as a television of half the screen size.

Therefore, if policymakers wish to consider the use of subsidies in the future to promote energy efficient products, they may wish to consider:

- Only providing subsidy support for Tier 1 or higher products, ideally with the best in market (“Top Runner”);
- Setting a maximum cap on total energy that can be consumed by the appliance. This introduces the concept of sufficiency in addition to efficiency – i.e., not subsidizing expensive products of large size or volume, and/or those containing sophisticated but energy-consuming functions.

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Glossary and Acronyms

Acronym/ Abbreviation	Meaning
AC	Air Conditioner
APF	Annual Performance Factor (variable speed air conditioners)
AQSIQ	General Administration for Quality Supervision, Inspection and Quarantine (in China)
BC, BC/CD, BCD, BCDW	Designations of refrigerated appliance types in Chinese energy efficiency standards, respectively refrigerator, refrigerator or freezer units, combination refrigerator freezer units, and combination refrigerator freezer units with compartments side by side
CC	Cooling Capacity (in the context of this report, used for air-conditioners)
CCFL	Compact Fluorescent Lighting (in the context of this report, used for backlighting of monitors and TVs)
Cd	Candela, the unit of luminance (in the context of this report associated with televisions and monitors
CNIS	China National Institute of Standardisation
COP	Co-efficient of performance (for air-conditioners)
CQC	China Quality Supervision Centre
CRT	Cathode Ray Tube (television)
CSTE	Cooling Season Total Energy consumption (variable speed air-conditioners)
CSTL	Cooling Season Total Load (variable speed air-conditioners)
EEI	Energy Efficiency Index (defined as the measured efficiency of the product under test divided by the nominal energy efficiency of a “standard” product).
EEI_{ref}	The nominal reference value(s) defined in the Energy Efficiency Standard for televisions, used in the calculation of a television’s EEI.
EER	Energy Efficiency Ratio (metric for fixed speed air conditioners)
EES	Energy Efficiency Standard
EET	Energy Efficiency Tiers as defined in the Chinese GB standards
EFF	Energy Efficiency Performance metric (used to measure on-mode performance of monitor in cd/W)
ESP	Energy Saving Potential (referring to Energy Saving Potential (ESP) Study for Nine Appliances in China, CLASP 2013)
EU	European Union
FS	Fixed Speed (in this context of this report for air conditioners)
GB Standards	The Chinese standards used to define the test methods, energy efficiency Tiers and the minimum energy performance requirements (the GB designation is drawn from the Romanized pinyin version of Chinese and standards for GuoBiao meaning National Standard)
GWP	Global Warming Potential

Acronym/ Abbreviation	Meaning
HSPF	Heating Season Performance Factor (variable speed air conditioners)
HSTE	Heating Season Total Energy consumption (variable speed air conditioners)
HSTL	Heating Season Total Load (variable speed air conditioners)
Hz	Frequency in Hertz
kg	Kilogram
kWh	Kilowatt Hour
L	Liter (volumetric measure)
LCD	Liquid Crystal Display (in the context of this report, used in televisions)
LED	Lighting Emitting Diode (in the context of this report, used for backlighting of monitors and TVs)
Lux	Lighting output (in the context of televisions)
MACEEP	Market Analysis of China Energy Efficient Products
MEPR	Minimum Energy Performance Requirement, i.e., the limiting level defining the least efficient unit that can legally be supplied to the market.
MEPS	Minimum energy performance Standards
Min	Minute
MPa	Mega Pascals
NDRC	National Development and Reform Commission
H	Used to denote thermal efficiency in a number of Chinese standards.
ODP	Ozone Depleting Potential
Off-mode standby	The power consumption of an appliance when the appliance is switched off, but still connected to the mains power supply.
OLED	Organic LED
PDP	Plasma Display Panel (in the context of this report, used in televisions)
RMB	Renminbi (Chinese unit of currency)
SAC	Standards Administration Committee of China
SEAD	Super-efficient Equipment and Appliance Deployment Initiative
SEER	Seasonal Energy Efficiency Ratio (variable speed air conditioners)
SS	Screen Size (for TVs in inches)
Top Runner	A Japanese product efficiency program whereby government and industry reach agreement on the efficiency of products to be sold in the future (based on a fleet average of sales)
TV	Television
TWh	Tera-Watt Hour
UK	United Kingdom
USA/US	United States of America
USB	Universal serial bus [a type of high speed connection between computing and peripheral devices]

Acronym/ Abbreviation	Meaning
USD	US Dollar
V	Electrical voltage (unit Volts)
VSD	Variable Speed Drive
W	Watts, the SI unit for power (joule/second)
2D	2 Dimension
3D	3 Dimension

Introduction

China is the world's largest manufacturing hub for household appliances and, for many appliances, now also has the highest level of sales and number of products installed. In the past two decades, a range of appliance types have been widely adopted among urban households, and many of households are now at a point where they are ready to replace their existing appliances with newer models. More recently, the penetration of appliances into rural areas has been accelerating, partly as a result of increasing wealth levels in these regions, and partly through specific government initiatives such as Appliances to Rural Areas, intended to stimulate appliance ownership in these areas. Consequently, under a business as usual scenario, energy consumption and associated GHG emissions related to the expansion of appliance usage will grow rapidly[2].

Fortunately, it appears that consumers are increasingly paying attention to energy saving as one of the key factors to consider when evaluating which appliances to purchase[3]. Furthermore, the Government of China's 12th Five Year Plan (2011-2015)[4] includes energy saving and emissions reduction as one of the mandatory indicators of social development, and sets a goal to reduce energy intensity per capita by 16% by 2015, relative to 2010.

To achieve this goal, the Chinese government has chosen to focus on end-use energy consuming products and has indicated that high priority will be given to projects promoting wider production and use of high-efficiency products. Under the national policy of Energy Saving and Emission Reduction, three major incentive programs have recently been completed: Old to New, Appliances to Rural Areas, and the Subsidy Program for Energy Efficient Products (refer to Policy section below). These programs set direct and indirect requirements on the energy efficiency of products, and, as demonstrated by some of the products reviewed in this report, have brought about fundamental changes to the market. These outcomes show that the Chinese Government not only realizes the importance of high-efficiency products to the Energy Saving and Emission Reduction policy, but it is also dedicated to promoting high-efficiency products via national policies and programs.

However, China's appliance market is very large and increasingly sophisticated. Product development is accelerating, with shorter design and production cycles, leading to shorter shelf lives for products in the market. Thus, developing policies that are appropriate for rapidly evolving products and increasingly disparate market segments is challenging. This situation is made worse by limited current, comprehensive and accurate data on the energy and efficiency performance of products within the market place.

In 2012, CLASP identified an opportunity to collect and analyze market data that would help Chinese policymakers set achievable and more stringent targets for upcoming revisions of minimum energy performance standards (MEPS) for various energy-

[2] Energy Saving Potential (ESP) Study for Nine Appliances in China, CLASP 2013.
[3] Market Research on the Impacts of China's Energy-Efficient Appliance Subsidy Program on Customer Behavior, CLASP, 2013.
[4] http://www.gov.cn/2011lh/content_1825838_2.htm

consuming appliances. With support from the US Energy Foundation, CLASP partnered with Top10 China and several international experts to conduct the Market Analysis of China Energy Efficient Products (MACEEP 2013), as well as a parallel study on energy saving potential (ESP)[5] that could result from more stringent policy measures and improved product efficiency. Given the success of MACEEP 2013 in increasing market knowledge and identifying key areas for policymakers to address, in 2013-2014 CLASP has undertaken a second Market Analysis of China Energy Efficient Products (MACEEP 2014). This analysis examines how the market has evolved and what the impact of new regulations has been on some of the products analyzed in MACEEP 2013, and has been expanded to include other significant energy using appliances in the domestic sector.

MACEEP 2014 provides a transparent picture of the levels of efficiency and comparative energy consumption of six domestic appliances currently for sale on the Chinese market: air-conditioners (both fixed and variable speed), instantaneous gas and electric water heaters, refrigerators, televisions and washing machines. The study also provides suggestions for policy interventions that could lead to improved efficiency and/or reductions in the energy consumption of these appliances in the future. Sections 1-5 of the report contain individual analyses for each product, including (with slight variations):

- *Product background information,* including a definition of the product scope; production, sales, and stock levels and associated projections of energy consumption; product usage patterns; relevant national test methods and relationships to international standards; national energy efficiency standards, and levels of applicable economic stimulus subsidies.
- *Appliance performance information,* which provides a snapshot of the current efficiency distribution and energy consumption of the appliance within China, as well as efforts to correlate the levels of efficiency and consumption with a range of product, market, and policy variables (e.g., product size, price, and labeling requirements).
- *Stringency comparison between old and new MEPS,* where appropriate. Not all metrics for energy efficiency levels are directly comparable, and some conversions and/or assumptions were made to make the analysis possible.

The following sections detail the approach and methodology used in the MACEEP research, as well as the major policy interventions in China to date that influence product efficiency.

Approach and Methodology

Unless otherwise specifically referenced, all data in this report has been gathered from three primary sources, detailed in Table 1 below. Overall, the data in the individual product analyses derive from over 8,000 individual appliance models.

[5] Energy Saving Potential (ESP) Study for Nine Appliances in China, CLASP 2013.

Table 1: Summary of the major data sources used in the research (primary data collected October 2013)

Source	Data gathered	Notes
On-line retailer websites: • www.jd.com • www.zol.com.cn • www.suning.com • www.gome.com.cn	Source of data on products available in the market in October 2013 and associated product attributes. Attributes are product specific, but include information such as: • Product model numbers; • Energy Efficiency (EE)and EE Tiers; • Size/Volume/Capacity; • Power; • Type; • Price.	Single data collection in October 2013. Where attribute values varied by supplier, one supplier was chosen to be the reference rather than the average value across suppliers. The selection is based on personal experience and some verification tests.
Products' energy label information from the China Energy Label website	Data on product registration.	To verify attributes information from online retailer websites.
National Bureau of Statistics (NBS)	Macro national and regional demographic data ranging from population to product ownership levels.	
Miscellaneous publications and reports	Mainly macro statistics and generic technical information on certain product types such as shipment, stock, products' average lifetime, etc.	

The data used in all product-level analyses are based on a snapshot of models available on the market in October 2013. This data was collected purely from online sources and do not represent a full database of all models available in China at that time. However:

- The number of models available from the online sources used is greater than the number of models available in any single store;
- Many online retailers seek to capture markets from first Tier to third and fourth Tier cities[6], so their product lines are more diverse than many on-street retailers.

Therefore, it is believed that the October 2013[7] snapshot should represent a good approximation of the market for most products at the time.

[6] Chinese cities are categorized in a 1 to 4 scale related to size and levels of development. Tier 1 cities are the largest, most developed urban areas, and Tier 4 cities the converse.

In some cases, not all product parameters were available for all models in a particular data set; for example, product size/volume or price may not have been known for a number of models. For each individual product analysis, there is a specific sub-section that provides details of the total number of models analyzed and a listing of the product attributes/parameters for which data were available. Where analysis is conducted on fewer than this number of models due to incomplete data, this deficiency is noted in the analysis. However, no attempt has been made to evaluate the impact of any such data omission.

In the majority of cases, the data analysis was conducted on a model (*not* sales) basis. Therefore, for some elements of the analysis, this *may* inappropriately skew market characterization towards the lower selling products. However, where possible, a comparison is made with "top sellers" from the retail sources used. In general this analysis indicates a close correlation of results from analysis based on "top sellers" and analysis based on available models only. This supports the anecdotal evidence, which suggests overall model availability in China is unsurprisingly focused on the areas of highest sales (i.e., the most popular product types and sizes.) Therefore, although there may be a minimal amount of skew introduced by the low selling product types (and non-quantifiable in some cases), the use of product-weighted averages will give a broad indicator of the overall purchase patterns and changes in stock.

Additional data collection

For a number of the products reviewed (variable speed air-conditioners, TVs and washing machines), revisions to the efficiency metrics, test methodologies, and performance and labeling requirements came into force at the same time as the original data collection. To gain an insight into the impact of these regulatory changes, a second data collection activity was undertaken in March 2014. However, this second data collection was based on model *registration*, rather than on models necessarily available in the market. However, it should be recognized that this sampling methodology may be somewhat limited as:

1) Not all products registered will necessarily appear on the market;
2) As products registered under the preceding regulations are still allowed onto the market for a one-year transition period, suppliers may be preferentially registering (or re-registering) products that perform well under the new regulatory requirements while continuing to supply other products under previous registrations.

However, the degree of bias introduced into the analysis is unknown.

Policy Interventions

There is a very broad range of national and local policy actions affecting the market for appliances in China. Such policies include minimum energy performance standards, certification and labeling schemes for high efficiency products, mandatory procurement

[7] The *potential* exception to this statement is instantaneous gas water heaters, where alternative channels of distribution may be significant. However, the specific limitations and potential impact on the analysis are discussed in more detail in the specific analysis of this product.

lists, efficient product subsidy programs, and more. For the purposes of this research, however, the national policies that are thought to have most impact on the efficiency of household appliances, and which are considered in the analysis, are outlined below.

Minimum Energy Performance Standards

According to China National Institute of Standardization (CNIS)'s website, by the end of 2013, there were energy efficiency standards in place for 58 household and industrial products[8]. The Government has also planned to develop or revise 40 energy efficiency standards during the 12th Five Year Plan period (2011-2015)[9]. These energy efficiency standards have proven to be effective tools in eliminating inefficient products, pushing the market towards higher efficiency.

The exact formulation and names of these standards requirements (and the associated labeling scheme) can be confusing, especially to international audiences for whom similar terminology may have fundamentally different meanings. To assist these audiences in understanding China's standards and labeling program, this report describes the specific meanings of standards and regulatory language used in China, as well as the terminology used within this analysis.

In most countries, the term "minimum energy performance standard" (MEPS) is a specific level of energy consumption, energy efficiency, or other performance metric that a product is required to meet in order to be placed on the market. These MEPS can be either voluntary or mandatory. In China, however, MEPS typically include four separate but interlinked items, described below.

Energy Efficiency Standard (EES)

This is the actual document in which all energy efficiency specifications, and in some cases other required specifications such as test methodology, are contained. An Energy Efficiency Standard will have an official GB standard designation[10], and a title which will normally be something like "The minimum allowable value of energy efficiency and energy efficiency grade for XXX *[product name]*."

However, as this study contains information and specifications beyond MEPS, we use the term "energy efficiency standard" (EES) throughout this analysis to describe the standard which contains energy efficiency Tiers, minimum energy performance requirements, and any additional information specific to the product being analyzed.

Energy Efficiency Tiers (EET)

Rather than simply defining a single level of performance that all products are required to meet, an EES typically specifies a range of three to five Tiers of performance that define increasing levels of efficiency, or decreasing levels of allowable energy consumption, for the specific product. The lower the Tier number, the higher the energy efficiency of the product[11]. In other words, Tier 1 identifies the most efficient products.

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[8] All products analysed in this study have energy performance Tiers, minimum energy performance requirements and are subject to the mandatory energy label.

[9] http://www.gov.cn/2011lh/content_1825838_2.htm

[10] The GB designation is drawn from the Romanized pinyin version of Chinese and standards for GuoBiao meaning National Standard.

[11] Although not necessarily lower energy consumption, for example, if the product is of larger size.

The tested performance of the particular product then defines which performance Tier the product meets.

Table 2 provides an example of the five performance Tiers applicable to Drum (Front Loading) Washing Machines in China from 1 October 2013. To qualify for a particular Energy Efficiency Tier (EET), a product must satisfy *all* the performance requirements for that specific Tier. For instance, in the 2013 EES for drum washers, a product with energy efficiency of 0.150 kWh/(cycle*kg), water efficiency of 8.5L/(cycle*kg), and wash quality of 1.05 would qualify as a Tier 3 product, whereas a unit with similar performance but an energy efficiency rating of 0.155 would be Tier 4.

Table 2: Tiers of performance and minimum energy performance standards for drum (front loading) washing machines in 2013 Energy Efficiency Standard (implemented 1 October 2013)

EET	Energy efficiency kWh/(cycle*kg)	Water efficiency L/(cycle*kg)	Wash quality
1	≤0.110	≤7	≥1.03
2	≤0.130	≤8	
3	≤0.150	≤9	
4	≤0.170	≤10	
5	≤0.190	≤12	

Throughout this analysis, the term “energy efficiency Tier” (EET) will be used in the context of these incremental steps in improving product performance.

Minimum energy performance requirements (MEPR)

Within an EES, there is also a minimum energy performance threshold that *all* products must meet. This threshold is initially set to match the required performance of the lowest EET. For example, in Table 2 the minimum energy performance threshold that all drum washing machines must meet is 0.190 kWh/(cycle*kg), water efficiency of 12L/(cycle*kg), and wash quality of 1.03. Throughout this study, the term “minimum energy performance requirement” (MEPR) will be used to describe this minimum energy performance threshold.

High efficiency products

An EES also defines the energy performance threshold that products must meet to be defined as high efficiency. This threshold is defined as the top two Tiers of performance. This threshold is important as it not only allows products to be designated as high efficiency, but is also used as the threshold for product “energy conservation” certification[12] and often as a qualifying factor for subsidy programs. Throughout this

[12] In this instance, and throughout this report, product certification refers to certification under the China Energy Conservation Certification scheme. Certification under this scheme allows products to bear the “节” mark that enables them to be eligible for government procurement and other preferential policies.

study, the term “high efficiency products” will be used to describe products that have met this premium energy performance threshold.

Comparative energy performance labeling

There are a number of different labels in use in China’s appliance market, including product certification labels and labels defining some kind of premium performance (e.g., the 6A label for washing machines). However, the primary label that impacts consumer purchasing decisions is the mandatory China Energy Label.

Figure 1: Example of the Chinese comparative Energy Label for variable speed air conditioners with both heating and cooling function

The mandatory energy label was first introduced in 2005, and at the time of publication was required to be displayed on 27 products. The label is comparative, displaying either three or five bands that represent the Tiers of performance for a specific product[13]. As with the Tiers of performance, Tier 1 identifies the best energy performing products, and Tiers 3 through 5 denote the worst performers. In addition to the performance bands, labels are also sometimes required to display additional product information, such as some physical attribute of the product (e.g., the capacity of refrigerator compartments). Figure 1 shows an example of the label for variable speed air conditioners.

Certification requires not only Tier 2 or higher energy performance, but also requires additional checks (including factory inspections) and formal registration. Authorisation to use the certification label is granted by the China Quality Certification Centre (CQC).

[13] Note that the labels on some products have three or five Tiers based on the original mandatory Tiers of performance. However, more recent revisions of the requirements have led to the reduction of the number of performance Tiers; hence, some of the lower Tiers on the label are still displayed, but products in these categories may no longer be supplied.

Throughout this analysis, we use the term “energy label” to describe the comparative label depicted above. All products analyzed in this research are required to display the energy label at the point of sale.

Other policies

Subsidy programs

The use of financial subsidy programs has had a major impact on the domestic appliance market in recent years. To date, the Chinese Government has facilitated three major subsidy programs, which are summarized below. However, where “subsidy program” appears in individual product analyses, it only refers to the Subsidy Program for Energy Efficient Products. This subsidy program has now been completed, but the program still impacted some of the products included in this analysis, and therefore it is referenced in the appropriate product sections.

Household Appliances to Rural Areas

This program was initiated by the Ministry of Finance, the Ministry of Commerce, and the Ministry of Industry and Information Technology in December 2008, and implemented on 1 January 2009[14]. The program was designed to stimulate domestic demand and consumer spending in order to combat the global financial crisis and recession that began in 2008. The program targeted consumers in rural areas in China, providing rural residents with subsidies equivalent to 13% of the retail prices when they purchased household appliances. Four product categories (TVs, refrigerators, clothes washers, and cellular phones) were included in the program from the beginning. Due to its resounding success, the program was later expanded to include more product categories, namely air conditioners (wall-mounted and free-standing), computers, induction cookers, microwave ovens, and water heaters (solar, storage-type electric, and gas types)[15]. Ultimately, by the end of 2012, the program had provided subsidies for 298 million appliances at a cost of 720.4 billion RMB ($115.7 billion USD)[16]. The program concluded in January 2013.

Subsidized Trade-in of Home Appliances (“Old to New”)

This program aimed to stimulate domestic consumer demand, improve resource and energy efficiency, reduce environmental pollution, and promote energy conservation and a circular economy. It was a national-level program implemented through seven Government ministries and agencies in 2009[17]. The program was initially piloted in nine

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[14] Circular of the Ministry of Finance, the Ministry of Commerce, the Ministry of Industry and Information Technology of the People’s Republic of China, on Work of Extending Electronic Household Appliance to Rural Areas Nationwide (In Chinese).
http://www.mofcom.gov.cn/aarticle/b/g/200901/20090105990038.html [Accessed on 8 March 2013].
[15] Circular of the Ministry of Finance, the Ministry of Commerce, the Ministry of Industry and Information Technology of the People’s Republic of China, on Further Intensifying the Implementation of the Policy for Bringing Home Appliances to the Countryside (In Chinese).
http://www.mofcom.gov.cn/aarticle/b/g/201002/20100206793004.html [Accessed on 8 March 2013].
[16] Ministry of Commerce News Release (In Chinese).
http://www.mofcom.gov.cn/article/ae/ai/201301/20130108513698.shtml [Accessed on 8 March 2013].
[17] Circular of the Ministry of Commerce, the Ministry of Finance, the National Development and Reform Commission, the Ministry of Industry and Information Technology, the Ministry of Environmental

cities/provinces between 1 June 2009 and 31 May 2010. The programs offered subsidies equivalent to 10% of the retail price of new household appliances in return for the participants' old appliances. The trade-in appliances were recycled by selected electronic recycling companies. The program covered five product categories: TVs, refrigerators (including freezers), clothes washers, air conditioners and computers. After the completion of the pilot program, it went nationwide, covering 19 additional provinces/cities[18]. According to statistics released by the Ministry of Commerce, 92.48 million appliances were purchased under the program, contributing to 342 billion RMB of direct expenditure on appliances. This program concluded in December 2011.

Subsidy Program for Energy Efficient Products

The Subsidy Program for Energy Efficient Products is the most recent nationwide subsidy program initiated by national departments and specially tailored for the promotion of energy efficient products. The program was organized and launched by the Ministry of Finance and the National Development and Reform Commission (NDRC) in 2009[19]. It was designed to subsidize highly energy efficient household appliances, typically products that achieve Tier 1 or 2 of the energy efficiency standard[20].

Room air conditioners were the only household appliance covered by the program in 2009, but the program was renewed and expanded in 2012. In 2012, the Chinese Government committed 26.5 billion RMB ($4.26 billion USD) to subsidize energy efficient televisions, refrigerators, washing machines, water heaters and desktop computers[21]. NDRC expected the market share of energy efficient products to rise from 10-20% to over 30% during the one year subsidy period, potentially resulting in 75 TWh of annual electricity savings[22]. This program will be the focus of "subsidy programs" described in this analysis, unless otherwise specified.

Protection, the State Administration for Industry and Commerce, the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, on Printing and Issuing the Measures for Implementation of the Subsidized Trade-in of Home Appliances (In Chinese). http://www.mofcom.gov.cn/aarticle/b/g/201008/20100807062260.html [Accessed on 8 March 2013].

[18] Circular of the Ministry of Commerce, the Ministry of Finance, the National Development and Reform Commission, the Ministry of Industry and Information Technology, the Ministry of Environmental Protection, the State Administration for Industry and Commerce, the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, on Printing and Issuing the Measures for Implementation of the Subsidized Trade-in of Home Appliances (Revised Edition) (In Chinese). http://www.mofcom.gov.cn/aarticle/b/g/201008/20100807062260.html [Accessed on 8 March 2013].

[19] Ministry of Finance News Release (In Chinese). http://www.mof.gov.cn/zhengwuxinxi/caizhengxinwen/200905/t20090520_159473.html [Accessed on 8 March 2013].

[20] It has to be noted that this program include not only household appliances but also automobiles, air compressors, and transformers, etc.

[21] State Council News Release (In Chinese). http://www.gov.cn/ldhd/2012-05/16/content_2138815.htm [Accessed on 8 March 2013].

[22] National Development and Reform Commission News Release (In Chinese). http://www.ndrc.gov.cn/xwfb/t20090521_280642.htm [Accessed on 8 March 2013].

Tiered electricity pricing

Until recently, domestic consumers paid a fixed rate tariff of approximately 0.5 RMB per kilowatt hour consumed[23]. However, in the last 12-18 months, tiered electricity pricing has been introduced across the country on a city or provincial basis (e.g., tiered pricing was introduced in Beijing in July 2012). The three-Tier progressive pricing system replaced the current "one price fits all" scheme with a new system wherein the more electricity a household uses, the higher the bills it will have to pay.

In this new scheme, electricity prices for first-Tier users are likely to remain the same. For example, Beijing households consuming no more than 240kWh per month are considered first Tier-users and represent about 80 % of all households. However, second-Tier users, whose monthly electricity consumption is above the first Tier threshold, will pay a slightly higher tariff on this marginal consumption. In Beijing, those households consuming over 240kWh and below 400kWh per year will pay an additional 0.05 RMB per kWh on the marginal electricity consumption. There is a third Tier for users above the 400kWh threshold. Users in this third Tier are required to pay a penalty rate on the marginal consumption above the upper second Tier threshold (in Beijing an extra 0.3 RMB per kWh, or around USD 0.05 on the marginal consumption). Table 3 shows this tiered electricity-pricing scheme for Beijing, although the specific thresholds and electricity price varies by city or region.

Table 3: Tiered electricity-pricing in Beijing (from 1 July 2012)

Tier	Monthly Electricity Consumption (kWh)	Price	
		RMB/kWh	USD/kWh[24]
1	≤ 240	0.4883	0.0800
2	241-400	0.5383	0.0882
3	> 400	0.7883	0.1292

Source: Beijing Municipal Commission of Development and Reform

Clearly this revision to the electricity pricing strategy aims to encourage consumers to use energy more rationally and efficiently, and to control their monthly electricity consumption such that it remains below the (in Beijing) 400kWh per month threshold. Consequently, the Government hopes that this action will encourage consumers to be more aware of product efficiency and/or consumption at the time of purchase of new appliances, and thus accelerate the adoption of more efficient appliances. However, enabling consumers to choose more efficient options requires that product labels clearly differentiate between more and less efficient, and higher and lower energy-consuming, appliances.

[23] Actual prices vary by region within the country.
[24] Assuming 1USD=6.1RMB, and rounded up to four digits.

Section 1: Analysis of the Market and Product Performance of Room Air Conditioners

This section of the report examines the market, product performance, and regulatory framework for room air conditioners (ACs), i.e., split system ACs. ACs can be divided into two types based on how the compressor is driven, either by Fixed Speed or Variable Speed control units. The vast majority of fixed speed air conditioners (FS AC) and variable speed drive air conditioners (VSD AC) have both cooling and heating functions, i.e., are reverse cycle. However, all types are analyzed.

ACs are of particular relevance as they are widely installed and used across China. They consume a considerable proportion of total household electricity consumption and tend to operate at periods of peak load on the electricity generation and distribution system, thereby contributing to the peak loads. The Energy Saving Potential Analysis[25] (ESP) conducted in 2013 indicated that the number of ACs installed in China will rise continuously from approximately 333 million units in 2012[26] to 470 million units in 2030[25].

1.1 Product Background

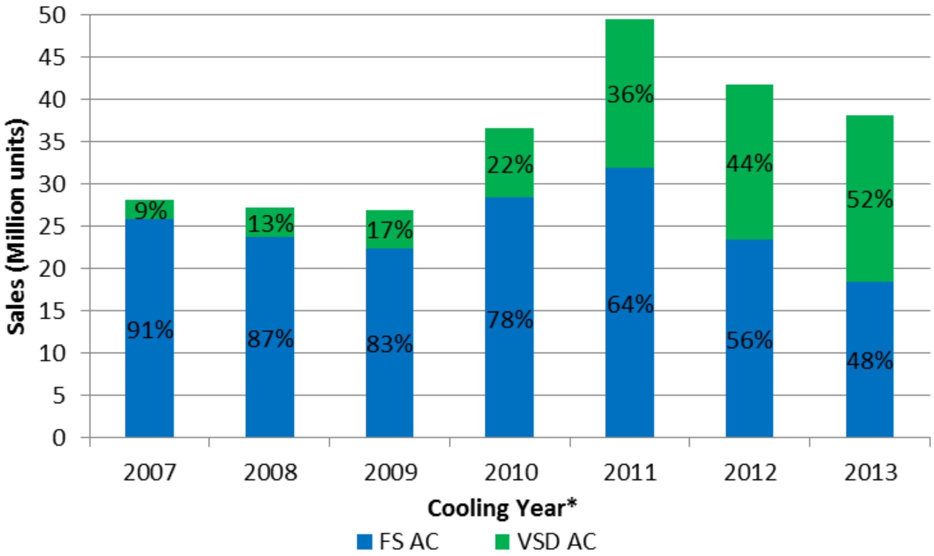
1.1.1 Domestic sales and stock level

Rapid economic development and urbanization in China has led to increasingly significant sales of AC units over the last decade. However, as shown in Figure 2, this increase in sales has been somewhat sporadic. Sales of room ACs remained steady from 2007 to 2009, but then rose rapidly in 2010 and 2011 as a result of the various subsidy programs targeting ACs during these years (refer to policy section of the introduction). In 2012, annual sales fell back following the phase-out of these incentive policies.

FS ACs dominated the market before 2009. However, VSD ACs have been rapidly penetrating the market in recent years, and between 2012 and 2013 VSD ACs received preferential subsidy in comparison with FS units as part of the Subsidy Program for Energy Efficient Products. In 2013, the market shares of the two technologies were broadly similar, with VSD AC sales just above 50% of the total (See Figure 2).

[25] Energy Saving Potential (ESP) Study for Nine Appliances in China, CLASP 2013.
[26] White paper for the energy efficiency status of China energy-use products, 2013, CNIS.

Figure 2: Annual sales of room air conditioners in China (2007-2013)



Data source: 2007 through 2012 from AVC Market Research, http://www.avc-mr.com; 2013 from http://www.cs.com.cn/
**Example: Cooling year of 2007 is From Sept 2006 through Aug 2007*

1.1.2 Usage patterns

Specific usage patterns for ACs vary significantly across China due to large variations in climate, and no detailed publicly available information on regional usage patterns has been published. However, nominal operating hours are provided in the Energy Efficiency Standard for VSD ACs. The standard suggests that on average, ACs[27] operate for 1,136 cooling hours and 433 heating hours per year, based on external ambient temperature (see Table 4 and Table 5).

Table 4: Hours of use for cooling under different environmental temperatures (taken from the energy efficiency standard for VSD ACs)

Environmental temperature/℃	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	Total
Hours of use	54	96	97	113	98	96	110	107	105	94	76	61	22	5	2	1136

Table 5: Hours of use for heating under different environmental temperatures (taken from the energy efficiency standard for VSD ACs)

Environmental temperature/℃	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Hours of use	1	1	3	7	8	21	44	26	35	46	46	38	32	30	30	21	16	9	8	4	3	3	1	433

[27] Technically these hours are defined for VSD ACs with heating and cooling functionality. However, it is reasonable to assume the operational hours are independent of technology for the heating and cooling periods.

1.2 Regulation, Labeling and Energy Efficiency Standard

1.2.1 Energy Efficiency Standard

The current energy efficiency standards (EESs) for AC units are GB12021.3-2010 and GB21455-2013 for FS AC and VSD AC, respectively. An Energy Efficiency Ratio (EER) is used as the indicator of FS AC performance. A Seasonal Energy Efficiency Ratio (SEER) is used for VSDs with cooling-only capability, and an Annual Performance Factor (APF) is used for VSD ACs with both heating and cooling functionality.

In EES GB 21455-2013,

- The APF is defined as the total heat removed from, and provided to space, divided by total energy consumed by the VSD AC:

  APF = (CSTL+HSTL)/(CSTE+HSTE) ...*Equation 1*

  Where:
  CSTL is cooling seasonal total load (under variable conditions), i.e., total heat removed from space;
  HSTL is heating seasonal total load (under variable conditions), i.e., total heat provided to space;
  CSTE is cooling seasonal total energy consumption;
  HSTE is heating seasonal total energy consumption.

- SEER is defined as:

  SEER = CSTL/CSTE ...*Equation 2*

  All parameters have the same meaning as those in Equation 1.

- HSPF (Heating Seasonal Performance Factor) is defined as:

  HSPF=HSTL/HSTE ...*Equation 3*

  All parameters have the same meaning as those in Equation 1.

In EES GB 12021.3-2010[28],

- EER is defined as the ratio of cooling capacity to input power under normal working condition of cooling, with unit of W/W.

  EER=Cooling Capacity/ Input Power ... *Equation 4*

As a consequence of these definitions, the EER, SEER and APF are not directly comparable.

The detailed energy efficiency tier (EET) requirements for the 2010 and 2013 EESs are shown in Table 6. The lower threshold of Tier 3 defines the minimum energy performance requirement (MEPR) that all types of ACs are required to meet to enter the market.

[28] Refers to GB/T 7725-2004 for EER definition

Table 6: Comparison of the requirements of the energy efficiency standard for fixed speed air conditioners (GB 12021.3-2010) and variable speed air conditioners (GB 21455-2013)

Product type	Cooling capacity range (W)	EE requirement (EER for FS AC, SEER for cooling only type of VSD AC, and APF for cooling & heating VSD AC)*		
FS AC		Tier 1 (EER)	Tier 2 (EER)	Tier 3 (EER)
	CC ≤4500	3.60	3.40	3.20
	4500< CC ≤7100	3.50	3.30	3.10
	7100< CC ≤14000	3.40	3.20	3.00
VSD AC (cooling only)		Tier 1 (SEER)	Tier 2 (SEER)	Tier 3 (SEER)
	CC ≤4500	5.40	5.00	4.30
	4500< CC ≤7100	5.10	4.40	3.90
	7100< CC ≤14000	4.70	4.00	3.50
VSD AC (both cooling and heating)		Tier 1 (APF)	Tier 2 (APF)	Tier 3 (APF)
	CC ≤4500	4.50	4.00	3.50
	4500< CC ≤7100	4.00	3.50	3.30
	7100< CC ≤14000	3.70	3.30	3.10

** Note that as the performance indicators are derived differently, the EER for FS AC and SEER and APF for VSD AC are currently not comparable.*

As the EES for VSD ACs has only recently been updated (October 2013), it is worthwhile comparing the current EES with the preceding version (GB 21455-2008). However, where the unit has both heating and cooling functionality, the 2013 EES for VSD ACs addresses both functions (through the APF), while the 2008 EES addressed only the cooling performance through use of the SEER (irrespective of whether they had heating functionality or not). Therefore, the only practical comparison of stringency between the 2008 and 2013 versions of VSD AC EESs is to compare 2008 SEER and 2013 SEER cooling requirements. On this basis, for each capacity range, Table 7 shows the SEER requirement of each tier increased by 0.20-0.50 (3.8%-11.9%). However, because nearly all VSD AC models are both cooling and heating (see Section 1.3.1), this increase in cooling stringency does not necessarily mean a similar overall performance improvement (refer to Section 1.3.6).

Table 7: Comparison of the requirements of the current energy efficiency standard for variable speed air conditioners (GB 21455-2013) and preceding standard (GB 21455-2008)

	Cooling capacity range (W)	EE requirement (SEER for cooling only models, and APF for cooling & heating models)				
GB 21455-2008, for all types but only regulating cooling performance		**Tier 1 (SEER)**	**Tier 2 (SEER)**	**Tier 3 (SEER)**	**Tier 4 (SEER)**	**Tier 5 (SEER)**
	CC ≤4500	5.20	4.50	3.90	3.40	3.00
	4500< CC ≤7100	4.70	4.10	3.60	3.20	2.90
	7100< CC ≤14000	4.20	3.70	3.30	3.00	2.80
GB 21455-2013, for cooling only models		**Tier 1 (SEER)**	**Tier 2 (SEER)**	**Tier 3 (SEER)**	**N/A**	
	CC ≤4500	5.40	5.00	4.30		
	4500< CC ≤7100	5.10	4.40	3.90		
	7100< CC ≤14000	4.70	4.00	3.50		
GB 21455-2013, for both cooling and heating models		**Tier 1 (APF)**	**Tier 2 (APF)**	**Tier 3 (APF)**		
	CC ≤4500	4.50	4.00	3.50		
	4500< CC ≤7100	4.00	3.50	3.30		
	7100< CC ≤14000	3.70	3.30	3.10		

** NOTE: APF values are **not** comparable with SEER values and are included simply for completeness.*

Cooling performance and heating performance

As Table 7 illustrates, the APF values are smaller than the SEER values. This observation, integrated with Equation 1, shows that SEER values *must be* larger than the HSPF values, and thus the VSD AC's energy efficiency requirements are set to be more stringent for cooling than heating. This is similar to the situation in the EU and the US. However, this analysis did not compare the comparative heating and cooling stringencies in these two economies, and therefore cannot conclude whether the Chinese standard is giving a similar, or excessive, allowance for heating performance.

1.2.2 Energy labeling of air conditioners

In 2005, FS ACs became one of the first products to be labeled under the China Energy Label Program. In 2009, VSD ACs were also included. Since their introduction, the energy labels for both types of ACs have been revised and rescaled once, following the update of their respective EESs; the FS AC label was revised in 2010 and the VSD AC label was revised in 2013.

The labels, shown in Figure 3, display basic product identification information; the three or five EETs as defined in the EES (the number of EETs was reduced from 5 to 3 in the more recent versions for both VSD ACs and FS ACs); an indicator showing the efficiency level achieved by the product; and other declared information like rated cooling capacity and input power. The 2008 version of the China Energy Label for VSD ACs shows values for both SEER and the Cooling Season Total Energy Consumption (CSTE, kWh). For cooling-only VSD ACs, the 2013 version reproduces this information, but for units with heating and cooling functionality, the APF, CSTE, Heating Capacity, and the Heating Season Total Energy Consumption (HSTE, kWh) are now included. In contrast, the FS AC label only presents the value of EER, and there is no information on energy consumption.

Figure 3: China energy labels for fixed speed and variable speed air conditioners (current and previous versions)

AC Type	Current version	Previous version*
FS AC		*(No image found for this historic label)*
VSD AC with cooling functionality only		
VSD AC with both cooling and heating functionality		*Note: Previously, the EES was based on five EETs. Further, the previous EES only regulated cooling performance of VSD AC and therefore the label only reflected cooling performance irrespective of whether the product was cooling only, or had both cooling and heating functions.*

** Previous label version included to provide direct comparison*

1.2.3 Test method and efficiency calculation

Calculation of cooling energy efficiency of FS AC and VSD AC

The testing method employed for all ACs is GB/T 7725 - 2004 "Room air conditioners" (as for most other economies[29], the test method element of this standard references ISO 5151:1994). However, as noted in section 1.2.1, the specific test method and metrics used to derive the energy performance for FS and VSD ACs are different.

[29] Cooling Benchmarking Study Report, 2011, CLASP

For FS ACs, the EER is expressed as the total amount of heat removed by the AC from the space divided by the amount of energy (electricity) consumed. The test is carried out at the FS AC's full load, i.e., at maximum cooling capacity. Therefore, we have

$$EER = \text{cooling capacity (W)} / \text{rated power (W)}$$

At first sight the SEER is similar, i.e., it is also the ratio of energy removed from space and energy consumed by the VSD AC. However, the SEER is derived from a more complicated function, taking account of not only full load operation, but also partial loads due to the intrinsic characteristics of VSD ACs. Therefore,

$$SEER \neq \text{cooling capacity (W)} / \text{rated power (W)}$$

and thus EER and SEER are not directly comparable.

Calculation of total energy consumption of FS AC and VSD AC

While the EES defines the operating hours (see Table 4 and Table 5) used to calculate energy consumption in cooling season (cooling only units) and whole year (heating and cooling units) for VSD ACs, these operating hours may only be referenced for FS ACs in order to understand consumers' usage behavior relative to ambient temperatures. It is not appropriate to use them to determine the energy consumption of FS ACs, as FS ACs work at full load at all times. Consequently, once the FS AC achieves the user defined target temperature it will switch off, and not operate again until the temperature has risen. Therefore, the "operational cooling time" for FS ACs will generally be less than the "operating hours" defined in Table 4.

1.3 Data Analysis

The analysis examines the performance, energy efficiency and related properties outlined in Table 8. At the time of data collection (first week of October 2013), the 2013 version of the VSD AC EES had only been issued three months previously, and the formal implementation date had only just passed (the date of implementation is three months later than the date of issue). The regulation allows a one-year transition period for manufacturers to fully transfer to the new EES following implementation[30]. Thus, it is reasonable to assume that the AC data collected will be based on values for performance and other criteria measured and declared using the 2008 EES. Therefore, ***the analysis of VSD ACs in this report is carried out in relation to the previous version of EES, GB 21455-2008, unless otherwise noted.*** The EES for FS ACs has remained unchanged since 2010, and as a result all data collected on model performance for FS AC should align with the 2010 requirements. Where applicable, the analysis also makes comparison with the research results of the Market Analysis of China Energy Efficient Products, 2013 (MACEEP 2013)[25,] completed in September 2013. Data drawn from MACEEP 2013 is referred to as "2012 (data)" in the sections below. For more detailed information on the 2012 data collection methodology and associated results, please refer to MACEEP 2013 directly.

A second data collection exercise was undertaken in March 2014 to try to establish the impact of the new EES where models had been registered under the new system. The sections of this study that report on this smaller analysis are clearly identified in the text.

[30] Notice from NDRC, AQSIQ and SAC, No. 34, 2013.

In addition to the generic cautions provided in the Approach and Methodology section of the Introduction, readers should note that not all performance and other parameters were available for all models. Whenever all products are not included in a particular analysis, this is noted in the associated text. However, where this is the case, it has not been possible to estimate the bias this has introduced into the analysis for any given parameter.

Table 8: Overview of the data used for the analysis of air conditioners (data collected October 2013)

Data type	Notes	
	FS AC	VSD AC
Total number of models	998	813
Cooling capacity (W)	2300-12000	2300-7300
Energy efficiency tier	1-3	1-5*
Energy efficiency ratio (EER)	3.00 – 3.91	N/A
Seasonal energy efficiency ratio (SEER)	N/A	3.26-6.50
Price (RMB)	1380 - 12800	1999 - 28800

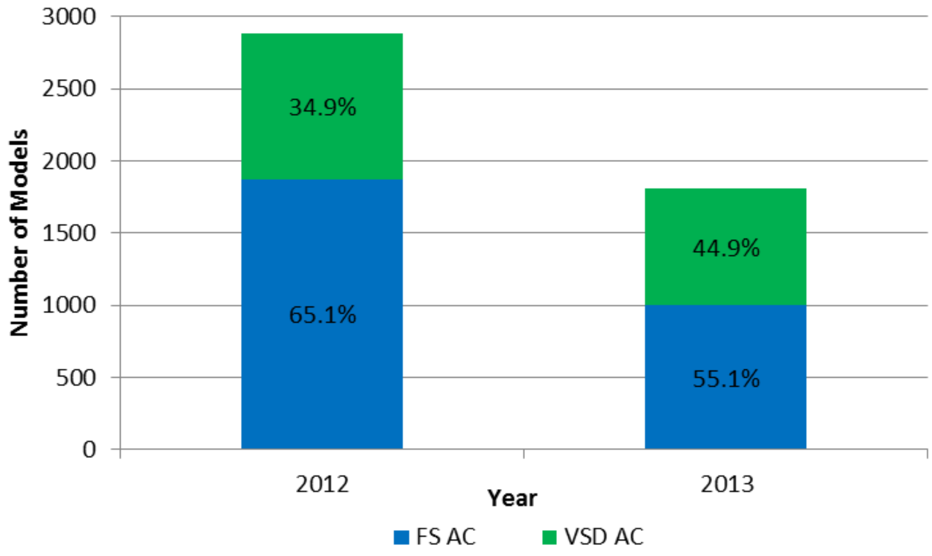
** The 2013 versions of the EES and the China Energy Label use three tiers for VSD ACs. However, it is believed that market data collected for this study is based on the 2008 EES and associated label, which had five energy efficiency tiers.*

1.3.1 Market distribution of air conditioners by compressor driven mode, installation and function

Fixed speed versus variable speed drive

As noted in the introduction, ACs can be divided into two types based on how the compressor is driven, either by Fixed Speed or Variable Speed control units. As shown in Figure 4, although the total number of models on the market fell significantly in 2013 relative to 2012 due to the withdrawal of subsidy support, the proportion of the VSD AC models relative to FS AC models rose by 10% to 44.9% in 2013 (although as noted in section 1.1.1, sales of VSD AC units were actually higher than FS ACs in 2013). This is a positive market development, as VSD ACs typically consume less energy than FS ACs when in use in households. However, the specific energy savings vary by environment and usage patterns, and a major technical study would be required to establish typical savings in the Chinese context.

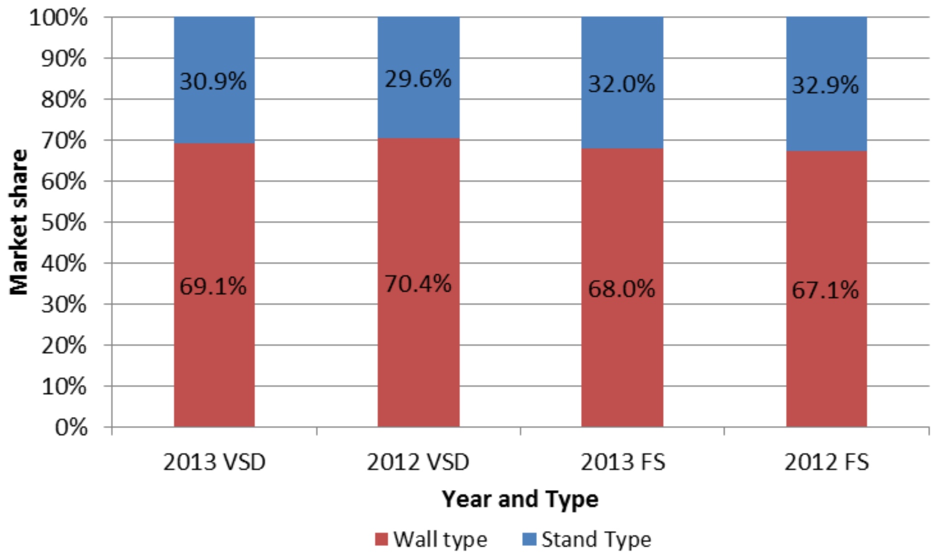
Figure 4: Market share of air conditioners by drive mode in 2012 and 2013



Wall mounted versus stand-alone

ACs can also be segmented into wall mounted and stand-alone floor units ("wall" and "stand" respectively). Wall mounted ACs are mainly used for relatively small spaces, while the stand-alone units are used for bigger spaces. The market share of the two types of ACs in 2012 and 2013 is shown in Figure 5. As can be seen, the market share of wall and floor units has remained broadly stable over the two years, at a 70:30 ratio for both FS AC and VSD AC.

Figure 5: Market share of air conditioners by installation methods in 2012 and 2013

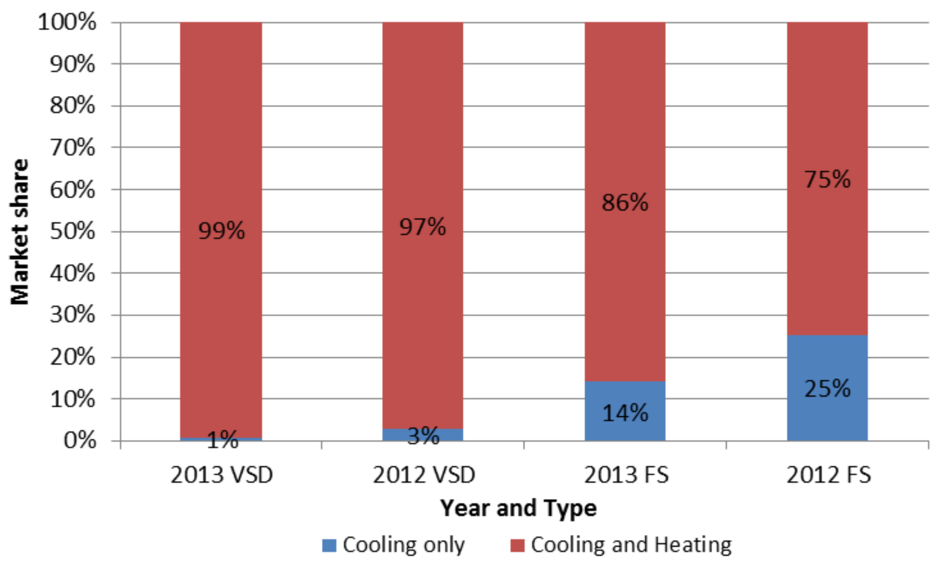


Cooling only versus cooling and heating

Given the climate in much of China, consumers in most regions find it desirable that ACs have capacity for cooling in summer and for heating in winter. Even where areas are served by district heating, this is often turned off before internal temperatures reach levels comfortable for consumers.

Figure 6 shows that, from 2012 to 2013, there was a clear market movement towards the use of units providing both heating and cooling. By 2013, only 1% of VSD AC and 14% of FS AC were cooling only units. Therefore, when next revising the EES for FS ACs, policymakers may consider including regulation of the performance of the heating function, as they have already done with VSD ACs.

Figure 6: Market share of fixed speed and variable speed drive air conditioners with cooling only and both cooling and heating functions (2012 and 2013)

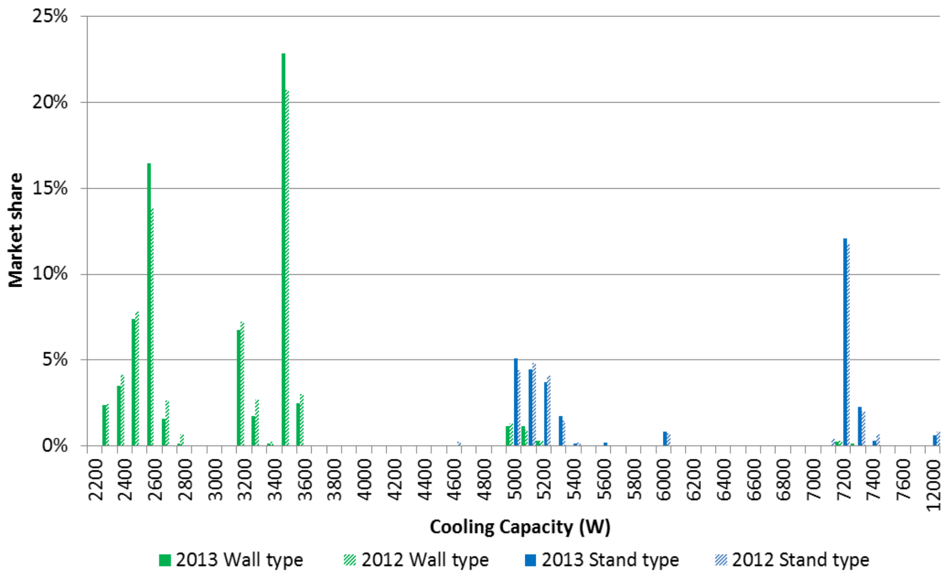


1.3.2 Market distribution of air conditioner cooling capacity

Although most AC models provide both cooling and heating functionality, cooling capacity has traditionally been the main indicator of the AC ability, as cooling was the major function. Consequently, as can be seen from Table 6 and Table 7, the EES performance requirements are set based on different cooling capacities for all AC types.

Examining the market distribution of products based on cooling capacity (Figure 7), there are four distinct market segments at cooling capacities of 2600W, 3500W, 5000W, and 7200W. Below cooling capacities of 3800W, all models are wall type and, at 5300W and above, almost all models are stand type (between these capacities, both types are available, although predominantly stand type). Overall, there was very little change in this market distribution between models available in 2012 and 2013.

Figure 7: Distribution of variable speed drive and fixed speed air conditioners by cooling capacity (2012 and 2013)



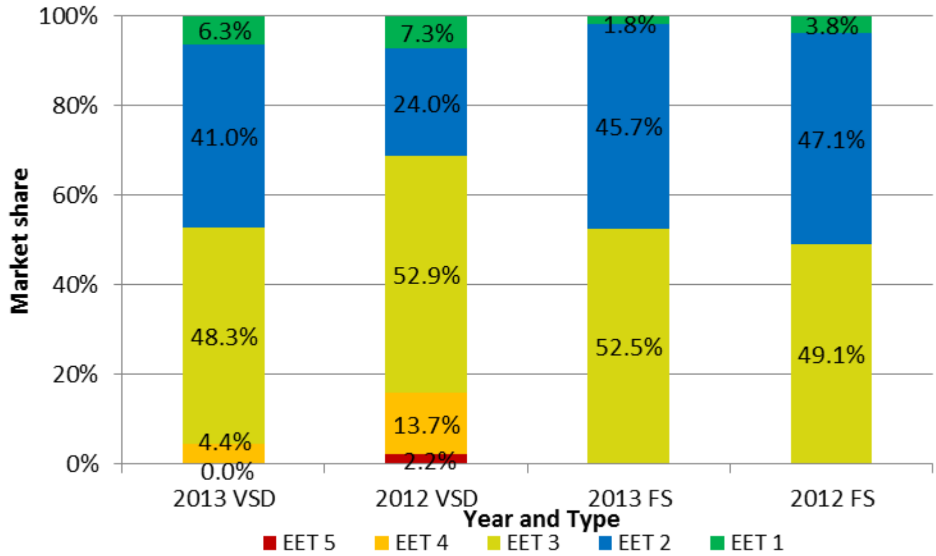
1.3.3 Market distributions related to energy efficiency

Market distribution of energy efficiency tiers (EET)

The revised FS AC label was introduced in November 2010, and therefore the label had been in effect for almost three years by the time of data collection. However, as Figure 8 shows, the market share of FS AC models in each EET remained broadly unchanged from 2012 to 2013, and the number of Tier 1 and 2 models (which are defined as "higher-efficiency" units in the Chinese categorization) actually fell slightly. Given that the penetration of fixed speed units is still high (around 50%, see Figure 2), it is likely that fixed speed units will remain in the market for a relatively long period. Hence, policymakers may wish to consider implementing measures to transform this market to higher efficiency, for example, by providing financial incentives (tax exemptions or subsidy support) to increase the penetration of Tier 1 products.

For VSD ACs, the market share of models in Tier 1 dropped by 1% from 2012 to 2013. However, the market share of Tier 2 models increased by 17%, resulting in the overall market share of efficient models increasing significantly and now constituting almost 50% of all available models. Simultaneously, the market share of models in Tier 4 dropped significantly, from almost 14% to just over 4%, and Tier 5 products disappeared. This *may* be an indication that manufacturers were preparing for the introduction of the revised standard, or it may simply be that Tier 5 products have lost their market due to the existing label. Either way, it demonstrates the effectiveness of the policy intervention.

Figure 8: Distribution of available variable speed drive and fixed speed air conditioners by energy efficiency Tier (2012 and 2013)



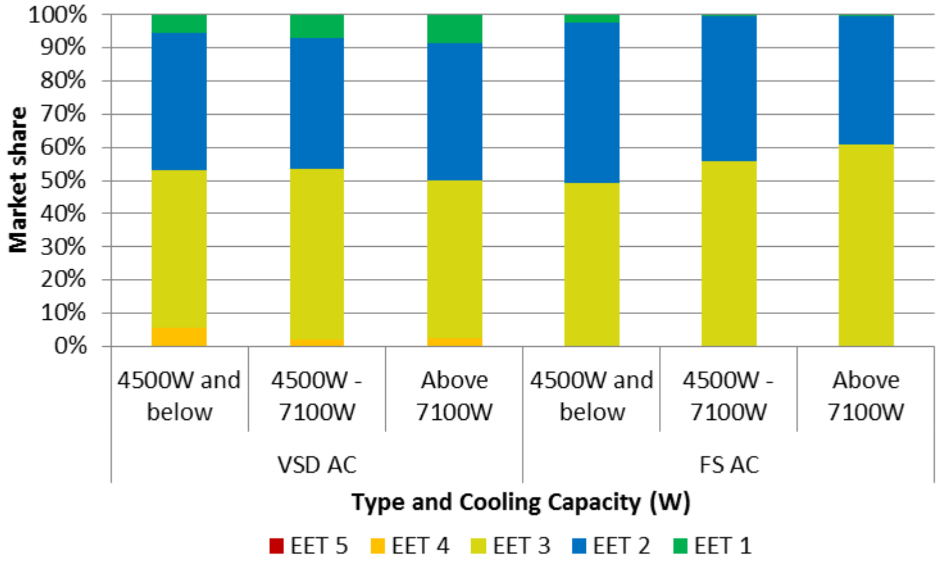
Note, as noted above, the market data collected for analysis is believed to feature FS ACs registered under the 2010 EES and VSD AC registered under the 2008 EES. Therefore, there the distribution of models is based on three EETs for FS ACs and five EETs for VSD ACs.

Market distribution of energy efficiency tiers by cooling capacity

Table 6 and Table 7 show that the required performance of the ACs decreases as the cooling capacity increases. Therefore, when studying EER/SEER of ACs on the market (and hence the distribution of products by EET), it is helpful to review these measures against cooling capacity.

Figure 9 below shows the distribution of EETs by different cooling capacities. It is clear that the proportion of models that qualify as efficient products (Tier 1 and Tier 2) stays stable across different cooling capacity ranges for VSD ACs. In contrast, for FS ACs, the share of this models that qualify as efficiency products decreases as cooling capacity gets larger. It is unclear if this is due to the technical difficulty of reaching higher efficiencies in FS ACs of higher cooling capacities, or whether there are other factors at play. Therefore, policymakers may wish to initiate a technical study on this topic, to establish the reason for this anomaly in case it is necessary to revise policy in the future to bring higher-efficiency, high-capacity FS ACs to the market, e.g., by means of an EES revision and/or incentive policies.

Figure 9: Distribution of energy efficiency Tier against cooling capacity for both variable speed drive and fixed speed air conditioners (data collected October 2013)



Market distribution of energy efficiency ratio (EER) and seasonal energy efficiency ratio (SEER)

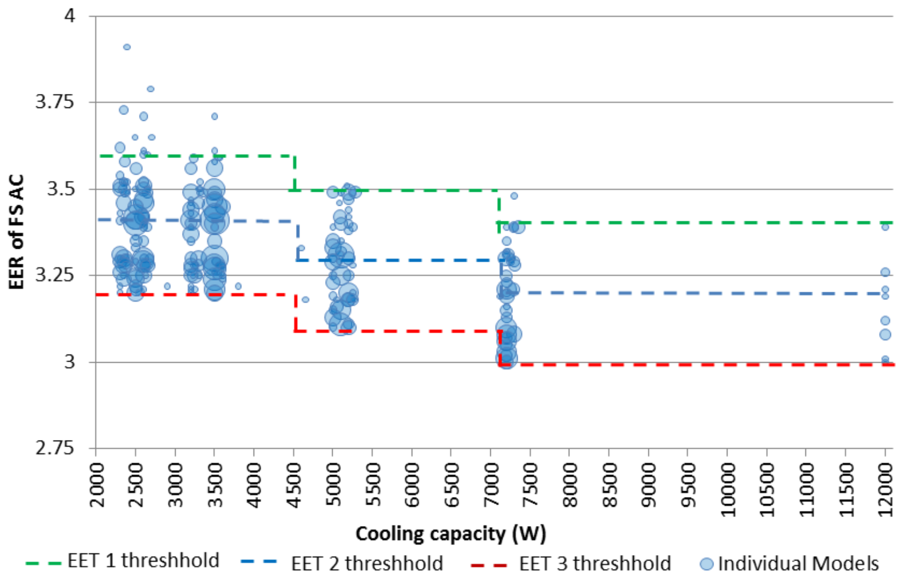
While Figure 9 shows the overall market distribution of EETs for selected cooling capacity ranges, Figure 10 and Figure 11 illustrate the composition of these distributions in more detail.

As shown, the highest efficiency models appear in the small cooling capacity range, i.e., around 2500W. The average energy efficiency level (EER or SEER) reduces quickly as cooling capacity increases from range I (cooling capacity<=4500W) to range II (4500W<cooling capacity<=7100W) and range III (cooling capacity>7100W). The efficiency of the best performing model drops even more significantly than the average efficiency, i.e., the top efficiencies of models around 2500W are as high as EER=3.91 and SEER=6.50 for FS AC and VSD AC respectively, but in cooling capacity range II, the top efficiencies are only EER=3.51 and SEER=5.24. This implies that policymakers may wish to promote high efficiency ACs with a small cooling capacity as first priority for incentive programs. This would be helpful to avoid consumers buying unnecessarily large cooling capacity products, and thereby focusing on reducing energy consumption and not just on promoting efficiency.

Further, based on the broad distribution of models shown in Figure 10, for FS ACs it appears possible for policymakers to revise the current energy efficiency standard to remove some of the worst performing products within Tier 3 from the market. This can be achieved by adopting the revised EET boundaries as proposed in Table 9.

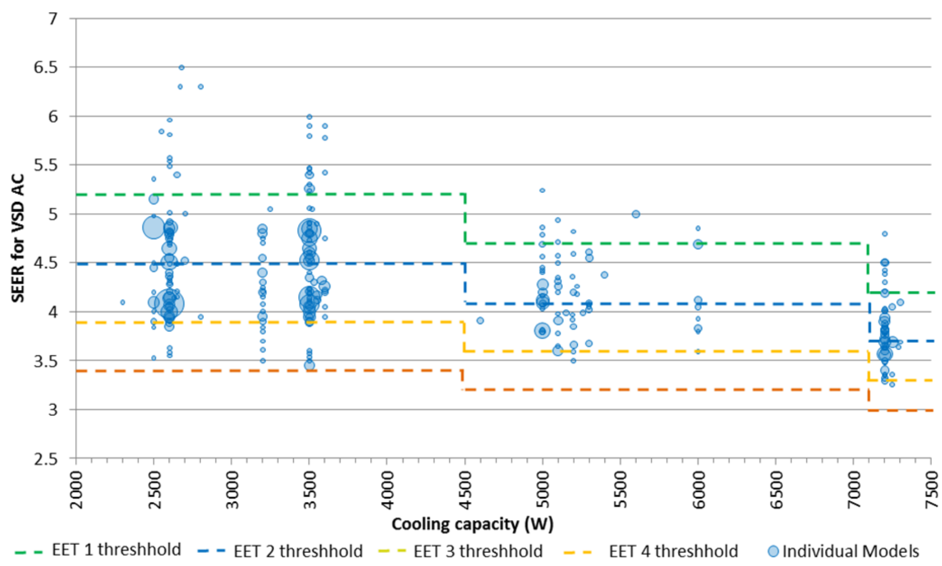
Because the new EES for VSD ACs has only recently been implemented, it would not be appropriate to revise the EES, nor make additional policy interventions, until it is clear what impact the switch to APF and the revised EETs have on the distribution of products in the market.

Figure 10: Distribution of fixed speed air conditioners by energy efficiency ratio and cooling capacity* (data collected October 2013)



**Each point represents one or more models of a specific combination of cooling capacity and EER. The size of the point reflects the number of models overlapping on that specific combination. The smallest point represents 1 model and the biggest 24.*

Figure 11: Distribution of variable speed drive air conditioners by SEER and cooling capacity* (data collected October 2013)



**Each point represents one or more models of a specific combination of cooling capacity and EER. The size of the point reflects the number of models overlapping on that specific combination. The smallest point represents 1 model and the biggest 43.*

Table 9: Potential revisions to the current minimum efficiency requirements for fixed speed air conditioners

Cooling capacity range (W)	Tier 1 EER requirement	Tier 2 EER requirement	Tier 3 EER requirement
CC ≤4500	3.7	3.5	3.3
4500< CC ≤7100	3.6	3.4	3.2
7100< CC	3.5	3.3	3.1

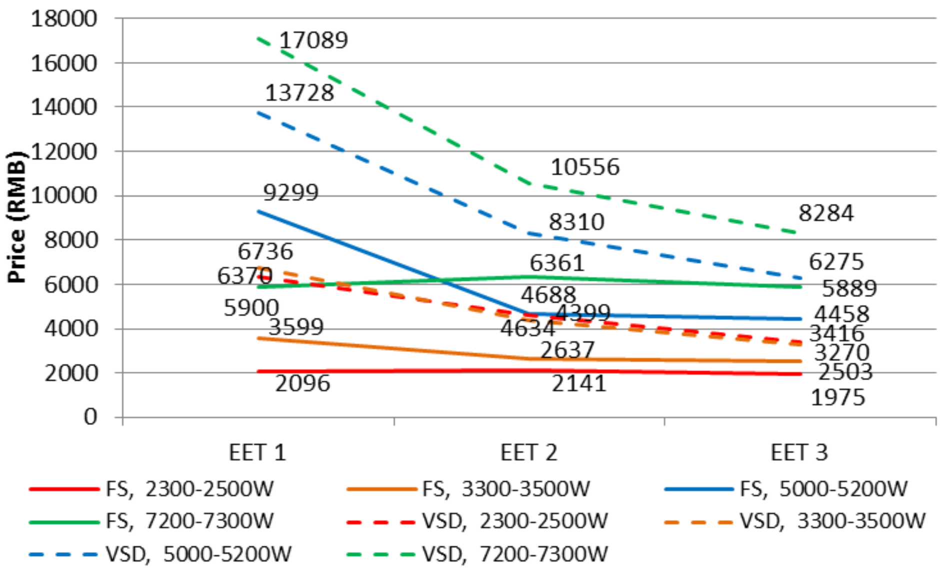
1.3.4 Relationship of price to energy efficiency tier

Figure 12 shows the relationship between the energy efficiency tier and average price[31] for some of the most popular cooling capacities.

Price relationship to capacity

In general, for all types of ACs, the price is related to the capacity, although not always significantly.

Figure 12: Comparison of average purchase price of fixed speed and variable speed drive air conditioners of different energy efficiency tiers* (data collected October 2013)



**Note that the number of models of Tier 1 ACs available on the market is very small (less than 10 models). Hence caution should be used when interpreting data related to Tier 1 products.*

Relationship of price and energy efficiency tier

There is a notable price gap between different EETs for VSD ACs, but less so for FS ACs (in each capacity range). However, it is not at all clear whether the price differentials (where they exist) are truly proportional to the costs of improved efficiency, or if they are primarily related to other factors such as brand, additional functionality, or simply lack of competition in that market segment. Therefore, it may be helpful for

[31] There are, of course, other factors that may affect price. However, as it is impossible to exclude these factors from market data, and these factors may apply across models, this analysis assumes these factors would not skew the result.

policymakers to initiate a technical study to establish the actual additional costs of improving unit efficiency of FS and VSD ACs during manufacture, to ensure that future policy addresses these costs and does not try to influence the market price should it primarily be driven by other factors.

Price differential between VSD AC and FS AC

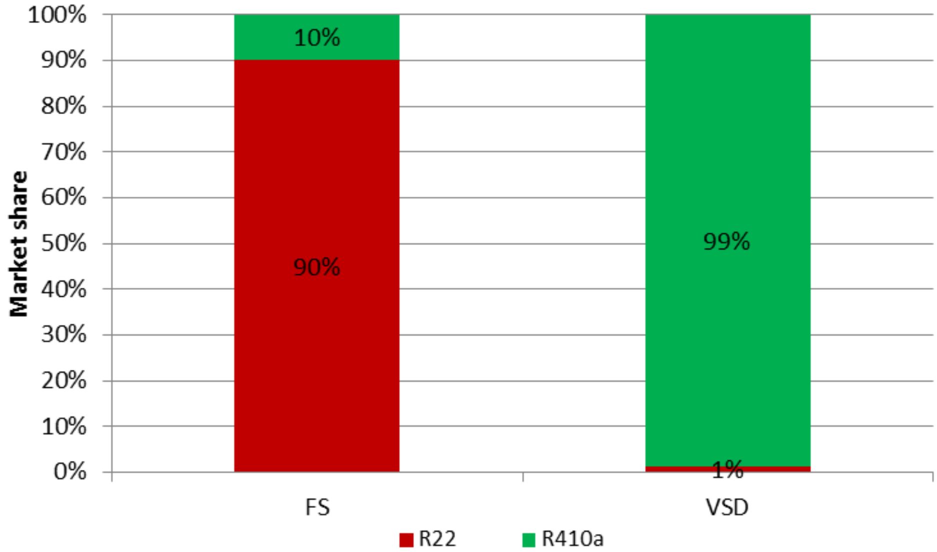
Another important observation from Figure 12 is that there is a significant price differential between VSD ACs and FS ACs of the same cooling capacities. However, the derivation of energy efficiency of these two types of AC is not directly comparable, and currently there is no defined method for measuring the annual energy consumption of FS ACs. Therefore, it is not possible for consumers or policymakers to know whether FS or VSD ACs have the lowest lifecycle cost. As this is a very important consideration for consumers in their product selection, and policymakers in their considerations on whether and how to regulate and promote each product type, it is strongly recommended that a technical study be undertaken to develop a methodology for calculating the annual energy consumption for FS ACs on the same environmental conditions defined for VSD AC units (i.e., those shown in Table 4 and Table 5). This will then allow the calculation of comparable lifetime cost to consumers, allowing more appropriate product selection and policy development.

1.3.5 Refrigerant of different AC types and relationship to efficiency

One of the main purposes of improving energy efficiency is to tackle environmental issues, i.e., preventing global warming. Unlike televisions or clothes washers, ACs use refrigerant to operate. Therefore, in addition to the impact of their energy consumption, the refrigerants currently in use in Chinese air conditioners have the potential to cause environmental problems, due to their ozone depletion potential (ODP) and global warming potential (GWP) characteristics if the refrigerant leaks during operation or the recycling process. There are currently two refrigerants used in domestic ACs in China: R22 and R410A. Relative to R22, R410A is regarded as a new and environmentally friendly product due to its zero ozone depletion potential (ODP). However, R410A's global warming potential is similar to that of R22.

As refrigerant type is not of importance to the vast majority of consumers, the type of refrigerant used is not reported for all models surveyed. 668 models did have information on refrigerant type (298 FS and 370 VSD models). Of these models, all VSD ACs used R410A as the refrigerant. However, only 29 FS AC models used R410A as the refrigerant, with the majority of FS AC models (269) using R22 as the refrigerant.

Figure 13: Type of refrigerant used by household fixed speed and variable speed drive air conditioners (data collected October 2013)

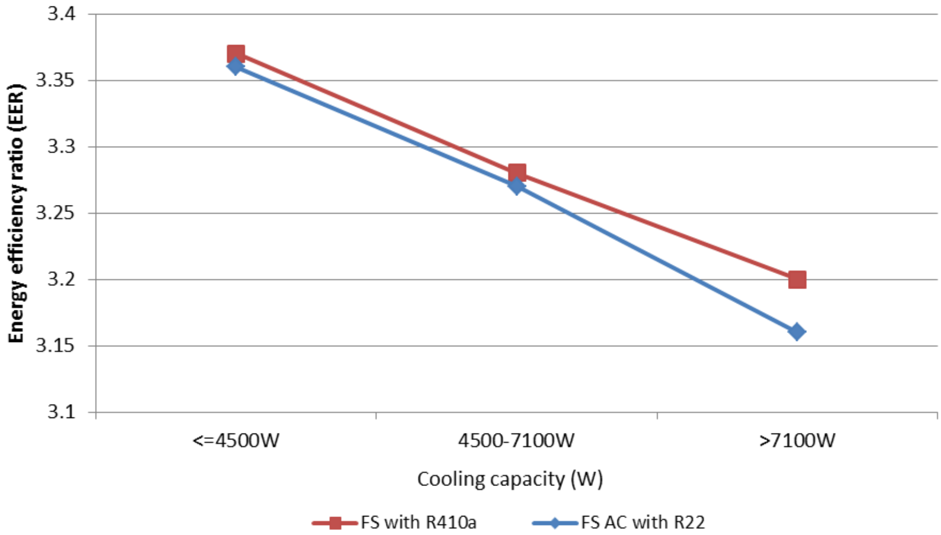


As noted above, R410A is currently considered more environmentally friendly than R22 because of its zero ODP, although both have similar GWPs. However, the efficiency of the two refrigerants is still of relevance, as this will influence the AC's energy consumption, and hence the ultimate emission of CO_2.

Figure 14 shows that FS AC models with R410A have a slight advantage in energy efficiency in every cooling capacity range. However, due to the limited number of FS AC models using R22 and the slight difference in energy efficiency, Figure 14 may not be sufficient to prove that R410A has better energy performance than R22. Therefore, a further technical study is recommended to learn the potential difference in energy efficiency between R22 and R410A[32]. If the study shows R410A has obviously higher energy efficiency in ACs than R22, the result may be used to accelerate the phase-out of R22 by setting more stringent EES for FS ACs.

[32] Although in the long term, R22 is to be banned for use in China by 2030 (except for repair and special usage), there is still more than a decade to go, and the environmental impact from its use could be huge.

Figure 14: Comparison of refrigerant type and efficiency of fixed speed air conditioners (data collected October 2013)



Further, in the future, policymakers may wish to take refrigerant characters into broader consideration when developing additional regulations or incentive policies, in order to minimize the overall impact of ACs on the environment. In the long run, there may be value in encouraging the entrance of alternate refrigerants that would have lower lifetime global warming impact when refrigerant and energy use are combined. This includes refrigerants with lower energy efficiencies but much lower GWP, or refrigerants with a reduced likelihood of leakage.

1.3.6 Analysis of the comparative stringency between the 2008 and 2013 EES and the impact of the new EES on the variable speed drive air conditioners market

To gain some insight into the impact of the 2013 EES on the market, registration data[33] was collected on all VSD ACs in March 2014 (i.e., the first five months after the 2013 EES came into effect). Data sourced for use in this analysis is summarized in

Table 10.

[33] www.energylabel.gov.cn

Table 10: Variable speed drive air conditioners registered in the first five months following the introduction of the 2013 EES (data collected March 2014)

Data type	Note
Total number of models	Total 1502: Cooling only type: 36 Both cooling and heating type: 1466
Cooling capacity (W)	Range: Cooling only type: 2300-12000 Both cooling and heating type: 2300-12800
Heating capacity (W)	Range: Both cooling and heating type: 2900-16000
Performance Tiers	Range: Cooling only type: 1-3 Both cooling and heating type: 1-3
Number of models that registered both to old and new version of EES	Totally 63: Cooling only type: 2 Both cooling and heating type: 61

This analysis seeks to establish the following:

- By changing the efficiency metric for VSD ACs with heating and cooling functionality to APF, whether the requirement has become more or less stringent than the previous SEER efficiency metric;
- What the distribution of VSD ACs within the energy efficiency tiers will potentially look like under the 2013 EES;
- As heating performance has been included in the 2013 EES, what the relationship is between cooling capacity and heating capacity based on registered product data.

Stringency change from SEER to APF

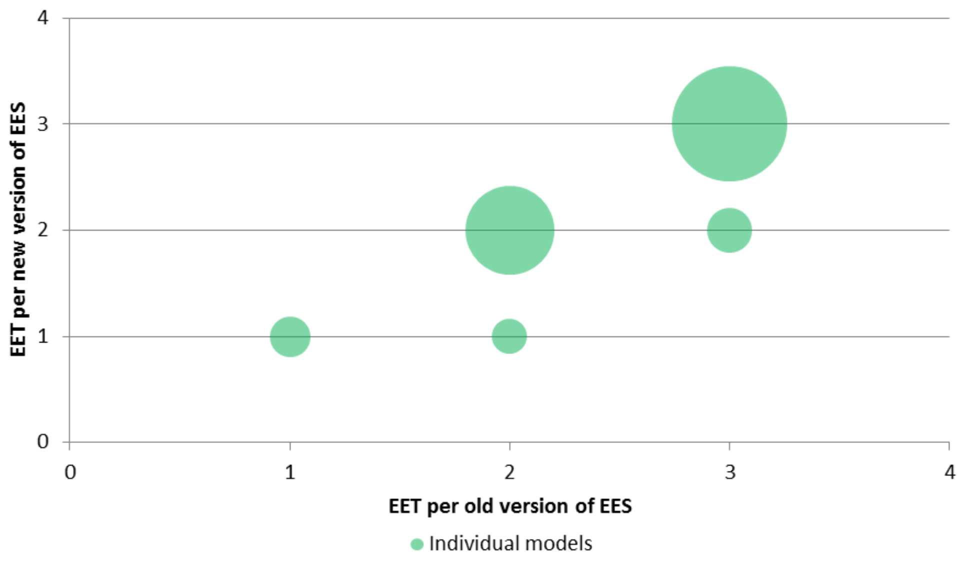
As stated above, the performance metric for VSD ACs with heating and cooling functionality was changed in the 2013 EES, with the result that the new performance requirements are not directly comparable with those used in the 2008 EES. However, as noted in

Table 10, there are 61 VSD AC models (with both heating and cooling functionality) that were originally registered under the 2008 EES and have been re-registered under the 2013 EES. Therefore it is possible to compare the EET declarations for these products based on the original SEER and the new APF, to establish if there is any relationship between the two. However, it is not possible to tell by how much the stringency of the EES requirements have been improved or lessened.

The EET distribution of the 61 VSD AC models registered under both the 2008 and 2013 EESs is shown in Figure 15. As can be seen, a number of models registered as Tier 2 and Tier 3 under the 2008 regulations have been re-registered as Tier 1 and 2 models, respectively, under the 2013 regulations. This seems to imply that the 2013 EES (including both heating and cooling) is overall less stringent than the 2008 EES with regulation of cooling functionality only. **However, it should be recognized that this sample of products registered under both the 2010 and 2013 EESs is self-selecting, i.e., only models that manufacturers have chosen to re-register are included. This is likely to bias the sample (for example, only models performing well under the 2013 EES may have been re-registered). However, the degree of bias introduced by this self-selection is unknown.**

As shown in Figure 5, when looking at the new EES' requirements for cooling only (SEER), the stringency has indeed increased in the new EES for cooling only VSD AC models. As there is no reason to assume the requirement for the cooling function is compromised for models with both cooling and heating functionality (relative to cooling only models), it appears the overall fall in stringency is due to the unnecessarily lax heating performance requirements (the other element of the APF derivation).

Figure 15: Declared energy efficiency Tier values for variable speed drive air conditioner models registered under both the 2008 and 2013 EES (data collected March 2014)

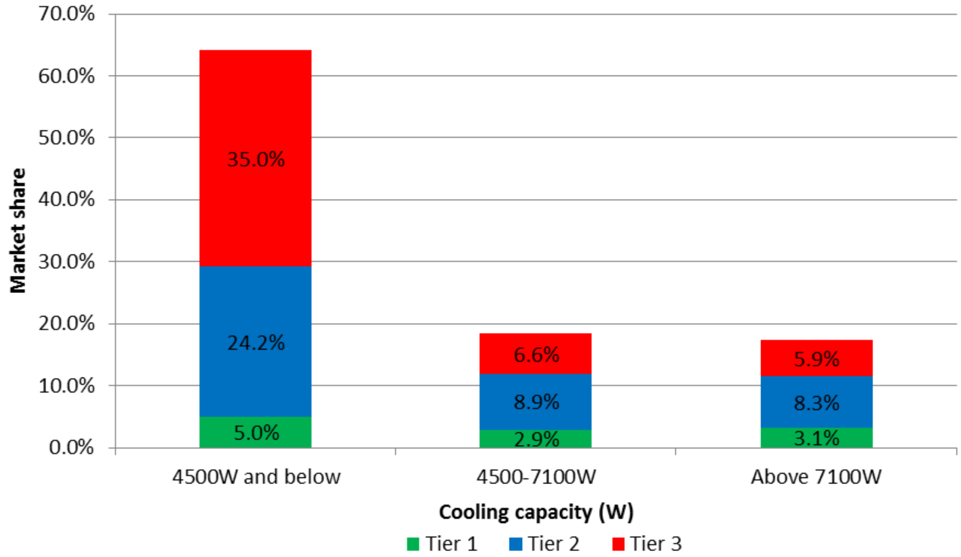


** The size of the point reflects the number of models overlapping on that specific combination.*

Potential new distribution of performance tiers of the market

Although not all registered models will necessarily become available on the market, registered models potential show what the market distribution of models will be by EET. Therefore, based on *all* models registered under the 2013 EES, the distribution of VSD AC models by EET is shown in Figure 16. This shows that, in comparison with models *available on the market* in 2013 and registered under the 2008 regulations (Figure 8), the share of Tier 1 products has increased by 6.3% and Tier 2 products decreased by 0.2%. Hence, the overall number of products that are now classified as "energy efficient" (Tiers 1 and 2 combined) has increased by 4.5%. This result echoes the conclusions that are suggested in the previous subsection: that overall stringency has degraded in the new EES (with the same caveat that newly registered models *may be* self-selecting with the best performing models being registered first). Thus, although the new EES has taken into consideration the heating performance of the units (which is very widely used and there important in terms of energy savings), it appears the energy consumption of the heating function may not have been investigated in sufficient depth prior to setting energy efficiency requirements. Consequently the new energy efficiency thresholds are based on APF values lower than may be appropriate.

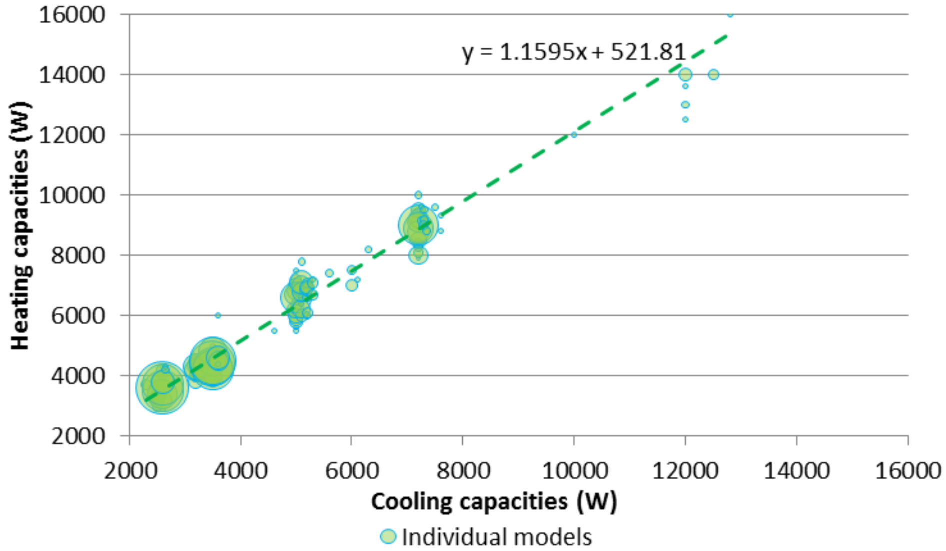
Figure 16: Distribution of energy efficiency tiers of VSD AC models registered per new version of EES (data collected March 2014)



Correlation between cooling capacity and heating capacity

Figure 17 shows the correlation between cooling capacity and heating capacity. As shown, although there is a strong correlation between heating and cooling capacity[34], the heating capacity is actually slightly greater than the cooling capacity, with an associated potential to consume more energy.

Figure 17: Correlation between cooling capacity and heating capacity of variable speed drive air conditioners (data collected March 2014)



[34] Hence, ACs with both heating and cooling capacity are normally referred to as "reverse cycle".

1.4 Conclusions and recommendations

The conclusions and recommendations drawn from the analysis of the China AC market are as follows.

Air conditioner efficiency is improving, but can be improved further

VSD ACs *typically* consume less energy than FS ACs when in use in households. Thus, it is a very positive market development that VSD ACs' share of models available in the market rose by 10% in 2013, to 44.9% of all AC models available, and that actual sales of VSD ACs are now over 50% of all models sold. Further, the efficiency of VSD ACs has improved (through labelling and/or the introduction of the 2013 EES), leading to an increase in Tier 1 and 2 models to over 50% of VSD AC models available, and to the virtual eradication of Tier 4 and 5[35] VSD models. However, there are still opportunities to further improve AC efficiency, as detailed below.

Potential revisions to the Energy Efficiency Standards and labelling information, and incorporation of wider environmental impacts

At present only the cooling function of FS ACs is regulated. However, 84% of FS AC models now have both cooling and heating functions. Further, as stated above, VSD ACs are regarded as energy saving and likely to reduce energy consumption in the typical home use. However, even with the same usage patterns, it is impossible for consumers to know exactly how much they can save by choosing variable speed models over traditional fixed speed AC models due to the difference in test methodologies and performance indices used. Therefore, policymakers may wish to:

1. Develop a test method and performance indices that can be used for both fixed speed and variable speed air conditioners with heating and cooling functions, to enable direct comparison of annual energy performance. Such an action would allow:
    a. Labeling information for all heating and cooling air conditioners to be directly comparable, thus allowing consumers to make informed purchases decisions. Such comparisons would be enhanced if heating season and cooling season energy consumption was shown on all products with both functionalities.
    b. Policymakers to make informed decisions on policies to promote the most efficient AC units regardless of technology, rather than the most efficient units of a particular type.

Further, should such a radical revision of the EES be undertaken, the opportunity arises to consider the wider environmental impacts of air conditioners. Because one of the main purposes of improving energy efficiency is to tackle environmental issues, i.e., preventing global warming, policymakers should be aware that ACs use refrigerants which themselves have global warming potential (and in some cases ozone depletion potential) characteristics, which impact the environment through leakage during operation or the recycling process. Therefore, policymakers may wish to:

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[35] Note that under the 2013 EES for VSD ACs, there are now only 3 EETs. However, the data refers to models registered under the 2008 EES as, at the time of data collection, the effects of the 2013 regulations were yet to impact the market.

2. Initiate a technical study that will help evaluate the relative impacts of energy consumption and refrigerant, thus allowing appropriate development of regulations or incentive policies that minimize the overall environmental impact of ACs. Such a policy may extend to encouraging the entrance of alternate refrigerants with lower energy efficiencies but much lower GWP (or reduced likelihood of refrigerant leakage), which could lower the lifetime global warming impact of an AC when accounting for both refrigerant and energy use.

Such a radical review of the AC EES test method and regulatory framework is likely to take some time to research and develop. Further the 2013 revision to the VSD AC has only recently come into effect and is still in the transitory stage, so the full market impact is yet to be known. However, what is clear is:

- The heating performance requirement in the 2013 EES for VSD AC appears relatively low (see Section 1.3.6).
- There is potential to remove the least efficient FS ACs from the market, particularly for FS ACs with cooling capacities where prices seem not to increase with improvements in efficiency.

Thus, during the development of a single comparative test and EES for all air conditioning units, and also while considering whether to account for the wider environmental impacts of ACs, policymakers may wish to consider the following interim actions to immediately improve efficiency:

3. Initiate a technical study of heating performance and regulation in other economies (e.g., the EU and the US) to ensure Chinese regulations are providing appropriate allowance for heating performance, as well how much additional allowance, if any, should be given to heating performance in comparison with cooling performance.
4. Eliminate the least efficient FS ACs from the market by revising the current (2010) EES to the EET thresholds proposed in Table 9.

Develop incentive policy to promote market penetration of high efficiency products

At the time of collection of the data used in this analysis, the China Energy Label for FS ACs had been in place for almost three years. However, as shown in Figure 10, only a limited number of models are able to meet Tier 1 requirements, while there are many products in Tier 2. This suggests that, without some degree of additional policy intervention, market forces alone are unlikely to move FS ACs to higher efficiency levels. Therefore, policymakers may wish to:

5. Revise EES to increase stringency of the Tier 3 MEPR and the requirements of the top two Tiers (again based on the EET thresholds proposed in Table 9) so fewer models would be categorized as energy-efficient products.
6. Provide differential levels of subsidy support to products registered under the new Tier 1 threshold, thus encouraging manufacturers to compete for both consumers and subsidy by enhancing their product’s energy efficiency. This policy intervention would need to be based on some technical analysis of production cost of FS ACs, as recommended below).

Further, for both FS and VSD AC models, the most efficient units appear to be in the smaller capacity ranges. Therefore, policymakers may wish to consider:

7. Strong policy support (through subsidy or other actions) to promote high efficiency ACs of smaller cooling capacities. This would encourage consumers not to buy unnecessarily large cooling capacity products, hence focusing on reducing energy consumption rather than only promoting efficiency.

Conduct technical study to learn how different technology and energy efficiency tiers are related to production cost

In general, VSD ACs are widely believed to be more efficient than FS ACs. However, the price differential between FS ACs and VSD ACs is significant (see Figure 12), and this is likely to be a significant barrier to the more efficient products rapidly gaining market share. Further, the price differential between energy efficiency Tiers is also significant for VSD ACs. However, the degree to which these price differentials are related to the costs of production, or whether they are simply a result of marketing strategies is unclear. Therefore, policymakers may wish to:

8. Initiate a technical study to examine the marginal cost of manufacture of FS and VSD units of different efficiencies, and the marginal cost of manufacture of FS and VSD units of similar efficiencies. Such research will assist in the formulation of future EES EET threshold levels (to ensure products remain affordable to the consumer) and would inform other potential policy intervention (e.g., appropriate levels of subsidy support to promote efficient products).

Section 2: Analysis the Market and Product Performance of Domestic Refrigerators

This section of the report examines the market, product performance, and regulatory framework for domestic refrigerated appliances.

Refrigerated appliances are of obvious importance due to their high levels of household penetration and their (typically) 24-hour running cycles. Even in rural areas, the penetration of refrigerators is rising rapidly in line with increasing incomes.

Based on the projections prepared as part of this analysis[36], approximately 340 million refrigerated appliances were installed across China by the end of 2012. This stock is expected to rise to 580 million in 2030, and under the business as usual scenario, these refrigerated appliances are estimated to consume approximately 24 TWh/yr of energy by 2030.

2.1 Product Background

This report examines refrigerator models available in the Chinese retail market. The classifications used nationally are by appliance functionality and/or by number and configuration of doors[37].

Based on functionality, refrigerators are classified in four ways:

- Fridge only for storing fresh food (abbreviated as BC);
- Freezer only for storing frozen food (BD);
- Fridge/freezer where the compartment can be switched to act as either a fridge or freezer but not both at the same time (BC/BD);
- Fridge freezer where there are two or more compartments, at least one of which is a fridge and at least one a freezer (BCD – BCDW if frost free).

The five door configurations used for classification are:

- single-door;
- double-door;
- three-door;
- side-by-side;
- multiple-door.

For stand-alone and integrated freezer units, differentiation is made between those units designed to simply store frozen food, and those capable of freezing and storing food. The Chinese regulatory framework broadly follows the IEC categorization of products, with freezer units classified in 0, 1, 2, 3 and 4 star levels. For fridge freezers, there is no regulatory difference between the configuration of upright units (i.e.,

36 Energy Saving Potential (ESP) Study for Nine Appliances in China, CLASP 2013.
37 Note that “doors” includes both doors and externally accessible drawers.

freezer at the top, bottom, or side of the fridge). There is no regulatory difference between chest and upright freezers.

2.1.1 Production, sales and stock levels

China is currently the world's largest refrigerator production base and the largest consumer market. There are more than 100 domestic refrigerator manufacturers, some of which have become the world's leading refrigerated appliance manufacturers with production capacity of four million refrigerators per year. From January to November of 2013, total output of the Chinese refrigerator industry was over 86 million units[38], an increase of 11.3% from the previous year. Over 37 million units were sold in the domestic market in 2013, an increase of 3.8% from the previous year[39].

With the rapid urbanization of China and its growing middle class population, more consumers are tending to buy larger refrigerators that consume more energy. This is evidenced by the 1.92 million multiple-door models sold in 2013, an increase of 43% from the previous year[39].

2.1.2 Usage patterns

The vast majority of refrigerated appliances in China are operated 24 hours a day throughout the year. However, there are likely to be a small number of cases where households have more than one refrigerated appliance, with the second (or third) unit only used occasionally. There are also likely to be a limited number of cases where consumers turn off refrigerated appliances, for example during long vacations.

When the market matures and a significant proportion of consumers are at the point of purchasing replacements (for reasons other than product failure), policymakers may wish to monitor whether the original units are disposed of, or whether they become secondary refrigerated appliances at home, as is the case in the US. Such a situation would clearly lead to an increase in the electricity consumption associated with refrigerated appliances.

2.2 Regulation, Labeling and Energy Efficiency Standard

2.2.1 Energy Efficiency Standard

In an effort to transform China's refrigerator market toward higher levels of energy efficiency, China first introduced an energy efficiency standard (EES) in 1989 (GB12021.2 "*The maximum allowable values of the energy consumption and energy efficiency grade for household refrigerators*"). This standard has since been revised three times, in 1999, 2003 and 2008. In September 2013, the Standardization Administration of China included refrigerators in their latest standards revision plan, indicating that the refrigerator energy efficiency standard would be soon revised again. It is hoped that this analysis will assist in the revision process.

The performance requirement thresholds within the current EES are based on an energy efficiency index (EEI) calculated as the ratio of the measured energy

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38 Source: China Industry Research Net http://www.chinairn.com/news/20140107/142132660.html
[39] Source: Tencent Digital http://digi.tech.qq.com/a/20140307/005013.htm

consumption of the appliance during the 24-hour test to the baseline energy consumption. The calculation of EEI in GB 12021.2-2008 is as follows:

$$\eta = \frac{E_{test}}{(M \times V_{adj} + N + CH) \times S_r / 365} \times 100\%$$

Where

M and N values are shown in Table 11;
CH = is 50kWh where refrigerators have a variable temperature compartment of less than 15 liters, otherwise 0;
S_r = an adjustment factor of 1.1 if the unit has through the door ice-making capability ***and/or*** *the total unit capacity is less than 100 liters or more than 400 liters;*

and

$$V_{adj} = \sum_{c=1}^{n} V_c \times F_c \times W_c \times CC$$

where:

n = number of different types of compartments;
V_c = measured storage volume of a specific type of compartment (liters);
F_c = Constant, equal to 1.4 for forced air cooling or 1.0 for non-forced air;
CC = Climate type correction coefficient, (= 1 for N or SN, =1.1 for ST and = 1.2 for climate type T);
$W_c = \left(\frac{25-T_c}{20}\right)$ where T_c is the compartment temperature.

Table 11: M and N values used in the derivation of EEI in GB 12021.2-2008

Type	Description	M value	N value
Type 1	Refrigerator without star compartment	0.221	233
Type 2	Refrigerator with 1-star compartment	0.611	181
Type 3	Refrigerator with 2-star compartment	0.428	233
Type 4	Refrigerator with 3-star compartment	0.624	223
Type 5	Refrigerator-freezer	0.697	272
Type 6	Frozen-food storage appliances	0.530	190
Type 7	Freezer	0.567	205

The EES sets five energy efficiency Tiers (EET), with Tier 1 being the most efficient refrigerated appliances. Products above the Tier 2 threshold are eligible to apply for "energy-saving product" certification[40]. The lower Tier 5 threshold defines the minimum energy performance requirement (MEPR), below which appliances are considered too inefficient to be sold.

Table 12 compares the 2003 edition of the EES with the current, more stringent, 2008 version[41].

Table 12: Energy efficiency Tier requirements for refrigerated appliances (energy efficiency standards 2003 and 2008)

EET	Energy Efficiency Index (EEI) η		
	GB 12021.2-2003	GB 12021.2-2008	
	All types	Fridge Freezer	All other types
1	η ≤55%	η ≤40%	η ≤50%
2	55%< η ≤65%	40%< η ≤50%	50%< η ≤60%
3	65%< η ≤80%	50%< η ≤60%	60%< η ≤70%
4	80%< η ≤90%	60%< η ≤70%	70%< η ≤80%
5	90%< η ≤100%	70%< η ≤80%	80%< η ≤90%

Note: the 2008 standard added the correction coefficient for different climate types, the definition and the equation for calculating base energy consumption, and the new equation for calculating energy consumption of specified refrigerator types.

The current distribution of products within these energy efficiency Tiers is investigated in section 2.3.2. However, at this point it is important to note that EES uses an EEI function, which results in Tier threshold values that are linear *and* that are based on adjusted volumes. There are two significant problems with this approach:

- While the energy consumption of a refrigerated appliance tends to increase with increases in volume, this relationship is not linear. Therefore, larger refrigerated appliances are inherently more efficient than smaller equivalents. Thus, the use of a linear function to define the energy efficiency threshold limits for the EES means either that smaller units are unnecessarily penalized, making them relatively more expensive than larger units to produce (and thus increasing price to the consumer), or that larger units are allowed more leniency and claim higher efficiency Tiers than should be the case.
- Energy consumption of a refrigerator is not actually a function of adjusted volume. The energy consumption is a function of adjusted surface area. However, over small variations in volume, the use of adjusted volumes as a proxy for adjusted surface area is acceptable, as the variation in volume

40 Energy Saving Certification is an endorsement regulation (allowing use of a label). However, in addition to the energy efficiency requirement other requirements must also be met (e.g., factory quality check, etc.) in order to register products for certification.
41 Li Tao, Dai Hong (Hefei Meiling Co.,Ltd): Analysis of GB 12021.2 – 2008, Beijing, 2010.

and surface area will be broadly similar. However, the range of product volumes is now extensive (in China unadjusted volumes of BCD products range from 150-500+ litres), and over such ranges adjusted volume ceases to be an appropriate proxy for adjusted surface area. Again, this will result in EES threshold values being unnecessarily severe for smaller appliances or lax for larger appliances, which will either increase the price of smaller units and/or make larger units appear relatively more efficient[42].

Hence, this use of linear functions and adjusted volumes is increasing the price of smaller units and/or improving the apparent efficiency of larger units. Either (or, worse, both) of these outcomes is an incentive for consumers to purchase larger appliances, which leads to higher overall energy consumption.

While the use of a linear function and adjusted volume is in line with practice in the majority of countries around the world *at present*, policymakers in China may wish to consider leading much of the world in:

- A move away from linear functions as a basis for EES performance Tier and MEPR thresholds, and a move towards a curved exponential function (Australia has already effectively done this for labeling thresholds).
- Changing the basis on which the MEPS and labeling thresholds are calculated by moving away from adjusted appliance volume and adopting adjusted surface area. Note, the suggestion is NOT that the adjusted surface area is included on the label, as this would provide no useful decision making information for consumers; the information provided to the consumer on the label should remain actual compartment volumes. *The use of adjusted appliance surface area should be for regulatory purposes only*.

Such an approach would more effectively respond to the inherent increase in efficiency as product sizes increase, and removes the potential for the perverse outcome of increased unit volumes improving apparent unit efficiency but increasing consumption.

2.2.2 Energy labeling of refrigerated appliances

The China Energy Label for household refrigerators became mandatory in March 2005, based on GB12021.2-2003. From May 2009, the label was updated to reflect the requirements laid out in GB12021.2-2008.

An example of the energy label is shown in Figure 18. The label has five Tiers, aligning with the EETs. In addition to the indicator showing the specific energy efficiency Tier of the appliance, the label also includes basic identification

42 For a full description of the relationship of adjusted volume, adjusted surface area, and the associated impact on energy consumption and regulations, refer to the IEA 4E Benchmarking report for Domestic Refrigerated Appliances at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=13

information of the model, the 24-hour energy consumption under test conditions, and the volume of the individual compartments within the appliance.

Figure 18: Example of China Energy Label for Household Refrigerators

This declared information is broadly in line with other comparative labels used internationally. However, given the desire to provide consumers with information to encourage their adoption of the lowest-energy consuming product (even if this is not necessarily the most efficient), policymakers may wish to consider amending the label declaration to include *annual*, rather than *daily*, energy consumption. The rationale for such an adjustment is, at the time of purchase, consumers are considering a range of criteria, including criteria not related to energy (e.g., price, brand, capacities, etc.). Therefore, calculating the annual energy consumption for a number of competing machines may not be at the forefront of their minds. If they do not perform the calculation, then competing machines with 0.4kWh/24hrs and 0.9kWh/24hrs may be considered to be *relatively* similar. However, over a full year, this difference would make produce approximately an 180kWh difference in consumption and 90RMB additional energy cost to the consumer (based on electricity costs of approximately 0.5RMB/kWh). Therefore, the presentation of annual consumption may have a more significant impact and increase the likelihood of consumers selecting the lower energy consumption product.

2.2.3 Test method

The Chinese test method for household refrigerators is GB/T 8059. The test method is very similar to ISO 15502 and IEC 62552, with consumption measured over 24 hours in steady state conditions (ambient temperature 25°C, average temperature in the fridge compartment 5°C, and maximum temperature in the freezer compartment -18°C).

2.3 Data Analysis

This analysis examines the performance, energy, and market-related properties outlined in Table 13. Table 13 also details the number of models for which data was available. It should be noted that it appears all types of refrigerated appliances were included in the 2013 MACEEP data collection and analysis, while only BC and BCD types were included in the data collection and analysis conducted here. However, the number of freezer units included in the MACEEP 2013 analysis was very limited (and did not reflect the total number of products on the market), so the 2013 and 2014 analyses and results should remain comparable.

Further, in addition to the generic cautions provided in the Approach and Methodology section, readers should note that not all performance and other parameters were available for all models. Where all models are not included in a particular analysis, this is noted in the text. However, it has not been possible to estimate the bias these omissions have introduced into the analysis for any given parameter.

Table 13: Summary of data captured on domestic refrigerated appliances and analyzed in this report (data collected July 2012 and October 2013)

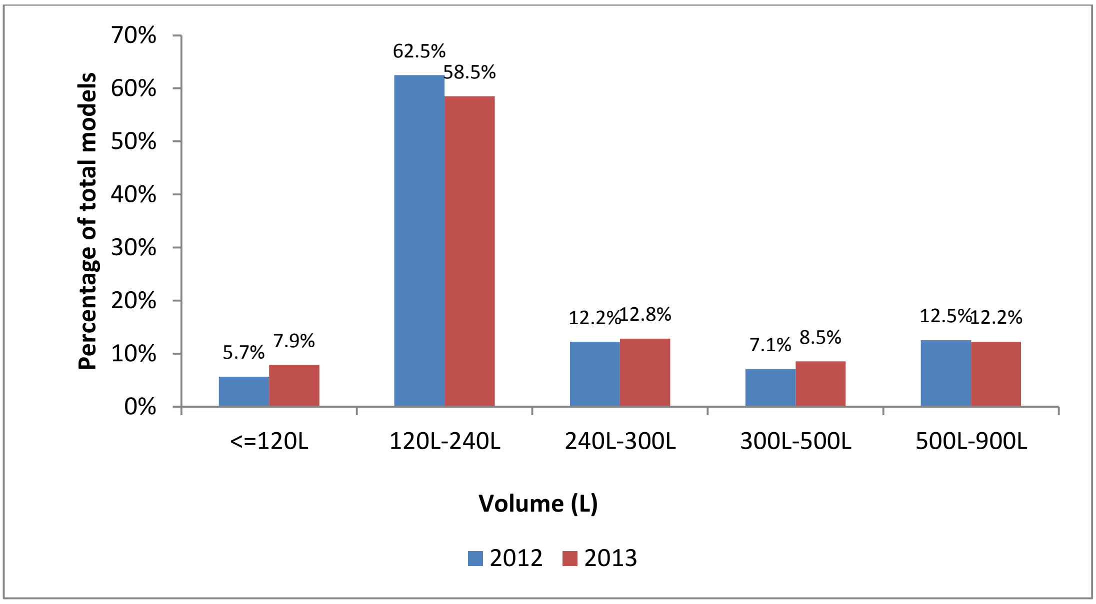
Data type	MACEEP 2013 Analysis (2012 data)	MACEEP 2014 Analysis (2013 data)
Models	1,693	1,584
Types	BC, BD, BC/BD, BCD and BCDW	BC and BCD
Number of Doors	Single, Double, Three, Side-by-Side, Multiple	Single, Double, Three, Side-by-Side, Multiple
Volume (L)	From 45 to 829	From 40 to 823
Energy Consumption (kWh/24h)	From 0.23 to 2.80	From 0.25 to 2.21
Price (RMB)	From 499 to 29999	From 469 to 32900
Energy Efficiency Tier	1, 2, 3, 4, 5	1, 2, 3, 4, 5

2.3.1 Market distribution and relationship of refrigerated appliance product type, number of doors, volume and energy consumption

2.3.1.1 Market distribution total unadjusted volume

The 2012 data used in the 2013 MACEEP study used the (unadjusted) volume ranges defined in the 2012 subsidy program as the basis for its analysis of the market distribution of products. To maintain continuity and compare reporting years, the same volume ranges are used here, with Figure 19 showing the distribution of available products by volume for the data collected in both 2012 and 2013. As can be seen, the market distribution of available models by volume in 2012 and 2013 are very similar. In 2013, there is a clear market dominance of products in the 120-240 liter range (58.5%), with smaller products taking just 8% of the market, and products having volumes of 240-300 liters and greater than 300 liters (of which 194 models have a volume of more than 500 liters) taking 13% and 21%, respectively.

Figure 19: Refrigerator model distribution by total unadjusted volume (data collected July 2012 and October 2013)

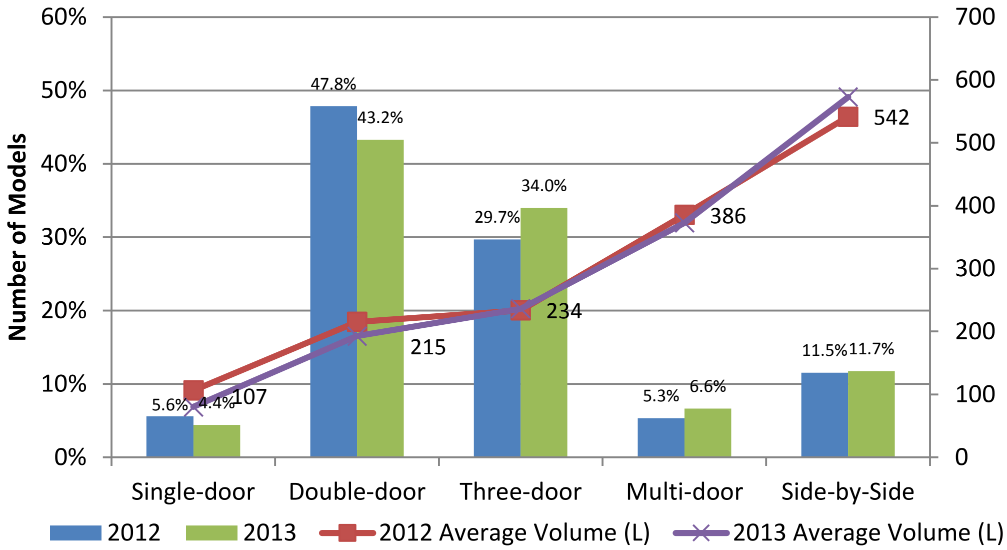


2.3.1.2 *Market distribution by number of doors and relationship to unadjusted volume*

Figure 20 shows a breakdown of available appliances by number of doors, and then combines this information with the average unadjusted volume of products for each door configuration. Similar to the trend in models available in 2012, double and three-door upright refrigerated appliances dominated the market in 2013, together accounting for 77% of all models available. Side-by-side and multi-door models account for the majority of the remaining units.

However, it is important to note that the market shares of both single-door and double-door models declined from the previous year, whereas three-door and multi-door models increased in popularity. The trend confirms the expectation put forward in the 2013 MACEEP study: that the Chinese market is moving to larger size refrigerators (as the number of doors is a reasonable proxy for the relative volume of units). This market change is highly likely to result in more energy consumption in the future, or at the very least, an offset in the reductions in energy consumption that would be expected improvements to efficiency. Consequently, policymakers may wish to monitor this movement to more door/larger volume appliances. If the trend continues as expected, policymakers may wish to consider implementing measures to limit this increase in consumption, for example, by placing substantially higher efficiency requirements on larger volume refrigerators and/or implementing financial incentives to purchase smaller units (through subsidy of smaller models or taxation of larger units).

Figure 20: Distribution of available refrigerated appliances by configuration of doors (data collected July 2012 and October 2013)



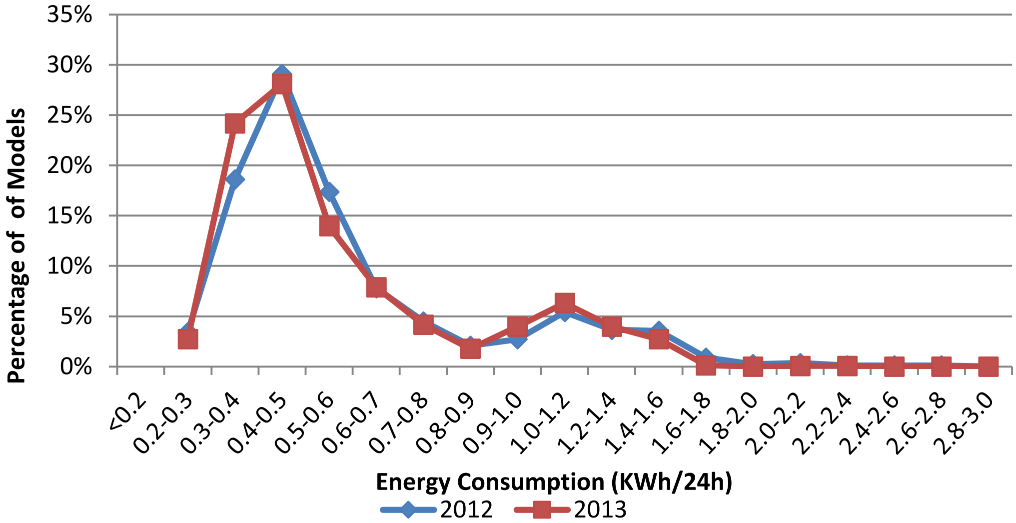
Note: Due to limitations on data available, only 1339 models analyzed for 2013.

2.3.1.3 Market distribution by energy consumption and relationship to unadjusted volume

Figure 21 examines the breakdown of refrigerated appliances by their declared energy consumption over 24 hours under test conditions. Compared to 2012, the overall refrigerator market showed a small yet visible shift towards lower energy consumption models, with more models with small energy consumption in the range of 0.2-0.3kWh/24h. The average energy consumption of all models surveyed also decreased from 0.64kWh/24h in 2012 to 0.61kWh/24h in 2013.

The majority of products are in the 0.3-0.6kWh/24 hour consumption range (equivalent to an energy consumption of 110-220kWh/year). Specifically, in 2013, 24.2% of the models have energy consumption in the range 0.3-0.4kWh/24h, 28.1% in the range 0.4-0.5kWh/24h, 14.0% in the range 0.5-0.6kWh/24h and 7.9% in the range 0.6-0.7kWh/24h. 13.3% of the models have an energy consumption of more than 1.0kWh/24h, and a small number of models have an energy consumption of more than 2.0kWh/24h (equivalent to over 720kWh/year).

Figure 21: Distribution of available refrigerated appliance by energy consumption (data collected July 2012 and October 2013)



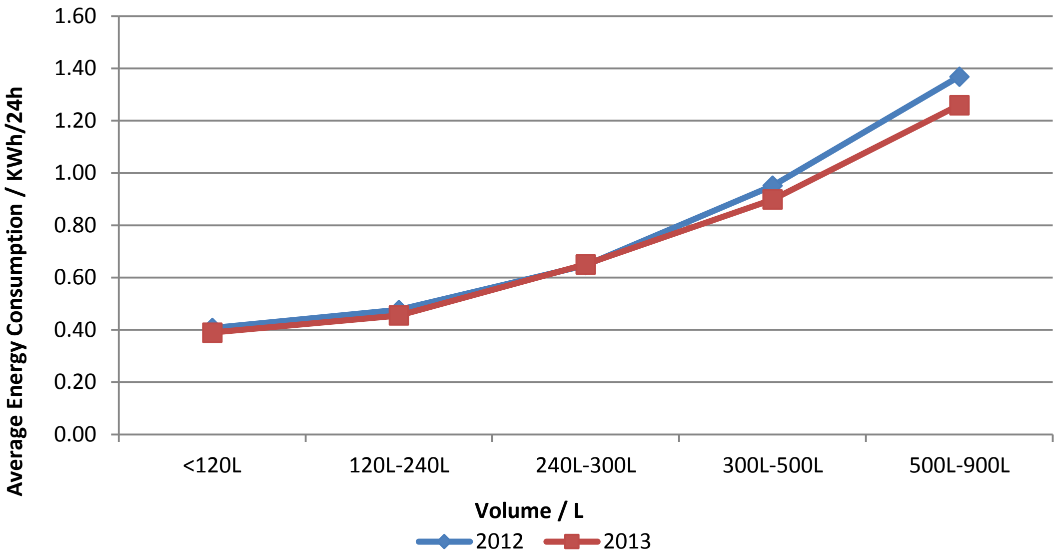
Again using the same total unadjusted volume categories used in the 2013 MACEEP study, it is possible to investigate the relationship between average unadjusted volume and average energy consumption as shown in Figure 22[43]. As would be expected, the larger the refrigerator, the more energy it consumes.

This underlines the importance of consumers selecting an appropriate size refrigerator to minimize overall energy consumption. However, it also reinforces the concern that consumers are increasingly purchasing larger products, as noted in section 2.3.1.2.

Figure 22 also suggests that, compared to models available in 2012, the average energy consumptions for all volume categories decreased in models available in 2013, with this reduction being more obvious for larger volume models. It is presumed this reduction in energy consumption was due to improvements in efficiency, for which policymakers should be congratulated. However, the energy consumption of large volumes (500L-900L) was still markedly higher than other volumes, and so the small improvements in efficiency will not be sufficient to offset the increase in consumption associated with consumers moving to these larger units.

43 Note that volume categories are based on the total (unadjusted) refrigerator compartment volumes used in the 2012 subsidy program, and are not of equal size. Therefore it appears energy consumption is increasing faster as volume increases (the curve is getting progressively steeper). This is not actually the case, and although energy consumption is increasing with volume, this increase is at a proportionately slower rate than appears to be the case in the graphic.

Figure 22: Relationship between unadjusted refrigerator appliance volume and average energy consumption (data collected July 2012 and October 2013)

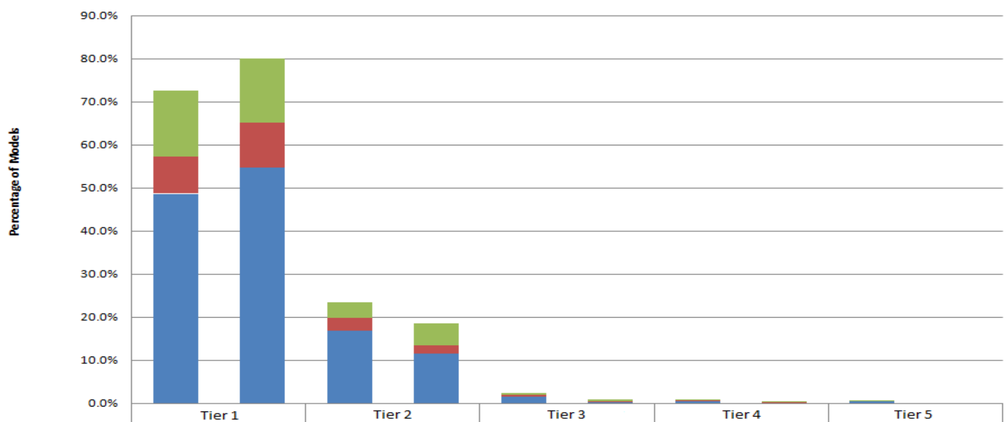


Note volume categories are based on the total (unadjusted) refrigerator compartment volumes used in the 2012 subsidy program and are not of equal size.

2.3.2 Market distribution of refrigerated appliance efficiency and energy efficiency standard Tiers

The distribution by EES Tier of refrigerated appliances available in the market is shown in Figure 23. As can be seen, the market share of Tier 1 models increased in 2013 from the previous year, to a point where 80% of models were Tier 1. Combining this with the 18.5% of available models registered as Tier 2, 98.5% of all available models can now apply to be certified as energy-efficient refrigerators. Models that qualify as Tier 3, 4 or 5 are almost non-existent.

Figure 23: Distribution of available refrigerator models by energy efficiency Tier (data collected July 2012 and October 2013)



	Tier 1		Tier 2		Tier 3		Tier 4		Tier 5	
Year	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
>300L	15.2%	14.8%	3.6%	5.1%	0.5%	0.6%	0.2%	0.3%	0.1%	0.1%
240-300L	8.6%	10.5%	3.1%	1.9%	0.5%	0.2%	0.1%	0.2%	0.0%	0.0%
<=240L	48.6%	54.7%	16.7%	11.5%	1.5%	0.3%	0.6%	0.0%	0.7%	0.0%

Note: Not all EEI values are available for all the models. EEI values are available for 1143 models in 2012 and 1116 models in 2013.

The skew towards Tier 1 and Tier 2 models was already high in 2012, but the skew towards Tier 1 models in 2013 presents policymakers with two problems:

- This skew is removing choice for the consumer. As almost all products are "high-efficiency", with the vast majority qualifying as Tier 1, it is not possible for the consumer to preferentially select the best performing products at time of purchase;
- This skew is limiting appropriate policy actions. It is not possible for policymakers to focus support (e.g., subsidy) on the best performing products, or to penalize the worst performing products, as there is very little apparent differentiation in product performance.

This suggests that the thresholds within the EES should be revised urgently. The simple solution would be to remove the current Tiers 3 through 5, and then use the current Tier 2 thresholds to establish a new lower Tier 5 threshold and MEPR limit. The remainder of the Tier 1 products could then be redistributed to new Tier levels 2 through 4.

While partially addressing the problem, typically the introduction of a revised MEPR level would aim to remove approximately 20% of the worst performing products from the market. However, setting the current Tier 2 as the new MEPR would remove only around 2% of the worst products from the market. The 2012 MACEEP study proposed that the new MEPR threshold should be set to 45%, as this would remove the desired 20% of the worst performing models. However, there appears to be value in reviewing the actual distribution of declared EEI levels of the refrigerated products available in 2013, to establish whether this proposed threshold is still appropriate.

Figure 24 compares the distribution of EEI values for refrigerated appliances in 2012 and 2013[44]. As might be expected, the movement in EEI values between models available in 2012 and those in 2013 closely reflects the moves in energy consumption seen in Figure 21 and the increases in Tier 1 products shown in Figure 23, i.e., there is a general improvement in efficiency across the EEI distribution. Thus, it appears the MEPR threshold proposed in the 2013 MACEEP report is no longer ambitious enough, as only approximately 13% of models available in 2013 will be removed if the MEPR threshold is set to an EEI of 45%.

Therefore, it is now proposed that the MEPR threshold be strengthened further to an EEI of 40%, so that the worst performing 20% of models currently on the market will be removed. Based on this MEPR value, Table 14 proposes EEI threshold values for other energy efficiency Tiers based on the 2008 EEI calculation methodology[45].

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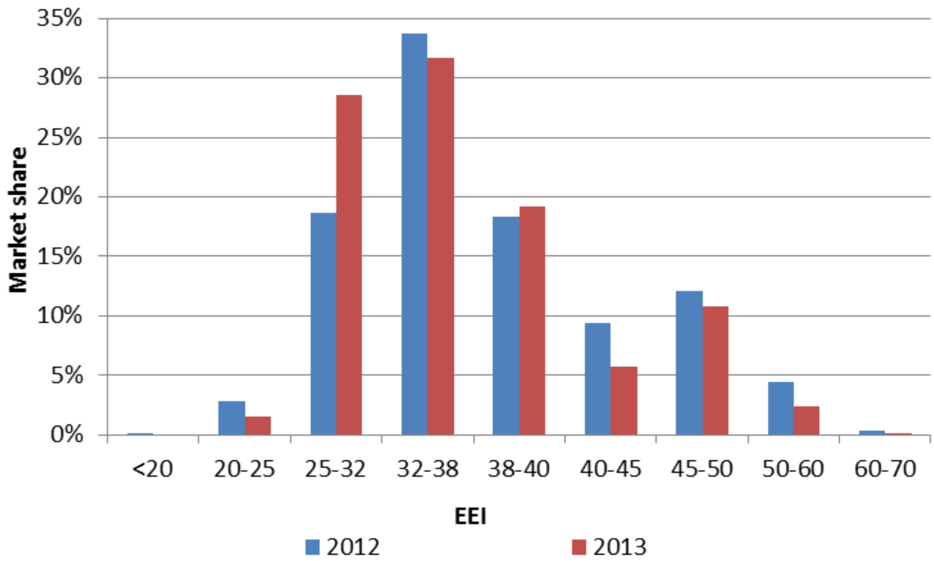
44 Not all EEI values are available for all the models. EEI values are available for 1143 models in 2012 and 1116 models in 2013.

45 Note the proposed Tier requirements are based on the analysis of BCD products and the previous approach taken by policymakers to allow 10% higher EEI allowances for other products. With limited

Figure 24: Distribution of available refrigerator freezer models by energy efficiency index (data collected July 2012 and October 2013)



Note distribution based on only 1143 BCD models for which data was available..
Also note EEI ranges on x-axis are of different sizes.

Table 14: Potential energy efficiency Tier requirements for BCD refrigerated appliances based on the 2008 EEI calculation methodology GB 12021.2-2008

EET	Energy Efficiency Index (EEI) η *(based on GB 12021.2-2008)*	
	Fridge Freezer (BCD)	**Other Products**
1	η ≤25%	η ≤35%
2	25%< η ≤31%	35%< η ≤42%
3	31%< η ≤35%	42%< η ≤48%
4	35%< η ≤38%	48%< η ≤50%
5	38%< η ≤40%	50%< η ≤55%

Such an approach would:

- Remove the very worst performing products from the market;
- Provide consumers with greater product differentiation based on the comparative efficiency of the products, allowing them to preferentially choose the more efficient units at the time of purchase;
- Incentivize manufacturers whose products have now been categorized as Tier 4 and 5 to improve their product performance, so as not to appear "inferior" compared with competitive models;

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further analysis it may be possible to revise the Tier thresholds for other products to more stringent levels.

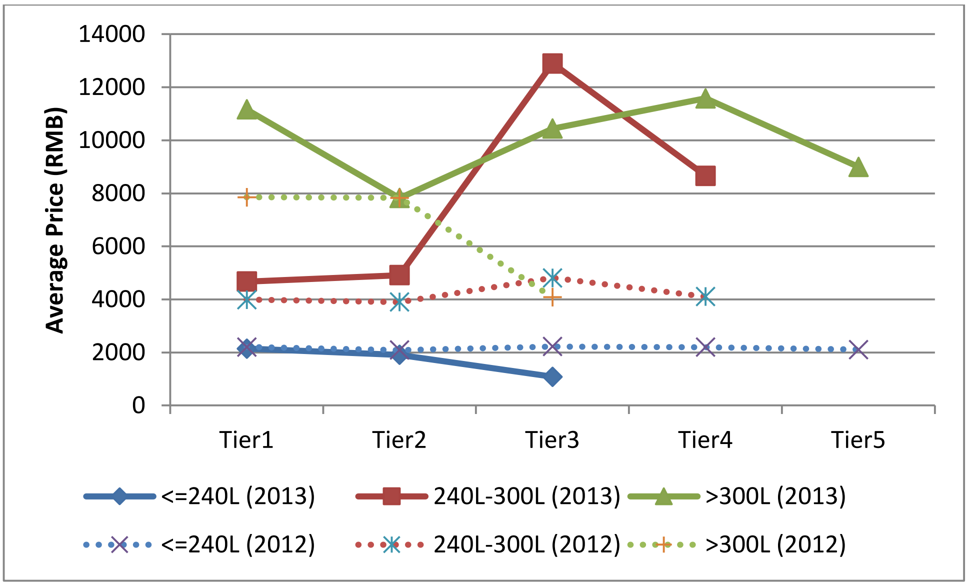
- Allow policymakers to more appropriately focus other policy support measures on only the most efficient products.

Further, it is important to note that strengthening the MEPR and Tier threshold requirements will not remove any particular product types from the market, nor will it unnecessarily limit the sizes of products available.

2.3.3 Relationship of appliance price to volume and energy efficiency Tier

There are a large number of factors that affect the price of refrigerated appliances, including brand, design, features, market position, etc. However, as Figure 25 illustrates, the average price of refrigerators of similar volumes does not seem to rise with increasing efficiency Tier[46]. If anything, the reverse is true (with the exception of products over 300 liters, which are influenced unduly by the very large spread of volumes). Hence, policymakers may be reassured that revisions to the EES that are suggested in section 2.3.2 are unlikely to result in significant price increases to the consumer, at least at present.

Figure 25: Relationship of refrigerated appliance price to energy efficiency Tier (data collected July 2012 and October 2013)

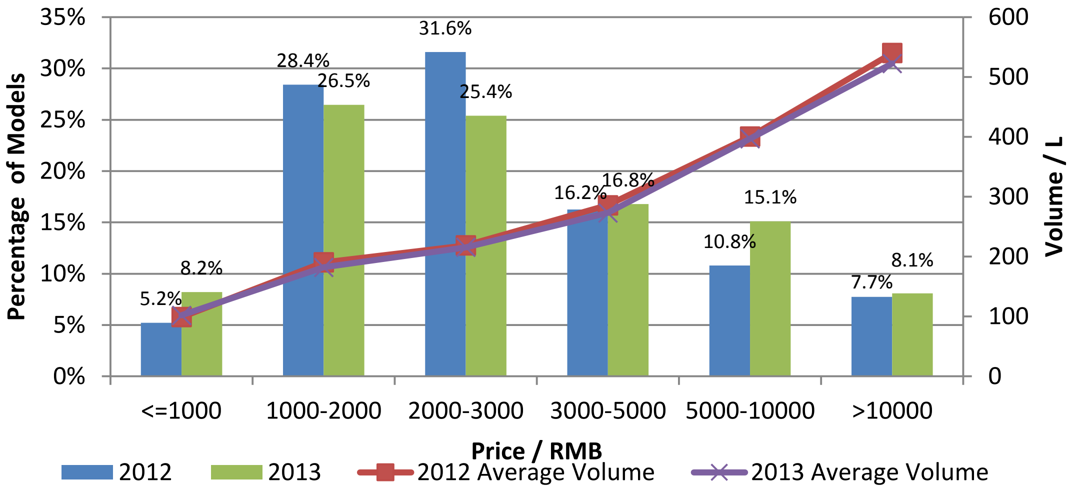


However, as might be expected, products of larger volume are on average more expensive than smaller products. Figure 26 examines the distribution of products by price range, and the average volumes in those price ranges. As can be seen, 51.9% of the refrigerator models available were in the price 1,000-3,000RMB and 16.8% in the range 3,000-5,000RMB. 23.2% of available models were in the high-end market, with prices over 5,000RMB (it is worth noting that this is over 360 models, of which 128 models have a price over 10,000RMB). Compared to 2012, the average total unadjusted refrigerator volume in each price range remained almost unchanged in 2013. However, the market share of models available in 2013 in the lower to medium price range decreased and the market share for more expensive models

46 However, it should be noted very few models are currently Tier 3 to Tier 5 products and therefore price comparisons maybe somewhat skewed.

increased (although the latter may be caused by changes in the distribution of the product volumes with an increase in particularly large feature heavy models disproportionately affecting the average price). This is in line with the observation in Section 2.3.1.2, which showed an increase in the market share of the more expensive multi-door and side-by-side models. This indicates that there are consumers in China who tend to buy larger size refrigerators as a luxury rather than for purely practical use. Such behavior comes with a significant energy penalty given the strong relationship between increased product size and energy consumption shown in section 2.3.1.3. This reinforces the recommendations made in section 2.3.1.3, that policymakers may wish to consider implementing measures to limit this increase in product size/consumption by, for example, placing substantially higher efficiency requirements on larger volume refrigerators and/or implementing financial incentives to purchase smaller units (through subsidy of smaller models or taxation of larger units).

Figure 26: Distribution of number of refrigerated appliances available and average volume by price range (data collected July 2012 and October 2013)



2.4 Conclusions and Recommendations

The conclusions and recommendations drawn from the analysis of refrigerated appliances are as follows[47]:

Proposed revisions to the energy efficiency standard and energy efficiency Tier thresholds

The current EES is based on a linear function and adjusted appliance volume to derive the energy efficiency performance Tiers and the associated MEPR. However, the use of such a linear function *and* adjusted volumes has the effect of increasing the price of smaller units and/or increasing the apparent efficiency of larger appliances. Either (or, worse, both) of these outcomes is an incentive for consumers to purchase larger appliances, which leads to higher overall energy consumption.

47 A separate study was undertaken by CLASP to benchmark Chinese refrigerator standards against a number of other countries (Benchmarking of Refrigerated Appliances, CLASP 2013). This report contains complementary recommendations, which policymakers may wish to review.

While the use of a linear function and adjusted volumes is in line with practice in the majority of countries around the world *at present*, policymakers in China may wish to consider taking a leadership position in the world and:

1. Move away from linear functions as a basis for EES performance Tier and MEPR thresholds and towards a curved exponential function (Australia has already effectively done this for labelling thresholds).
2. Change the basis on which the MEPS and labelling thresholds are calculated, by moving away from adjusted appliance volume and adopting adjusted surface area.

Such an approach would more effectively respond to the inherent increase in efficiency as product sizes increase, and removes the potential for the perverse outcome of increased unit volumes improving apparent unit efficiency yet leading to increasing energy consumption.

However, such a transition will take some time to implement, and the current distribution of refrigerated appliances is highly skewed, with 80% of the models labeled as Tier 1 and 18.5% as Tier 2 (i.e., models that can apply to be certified as energy-efficient refrigerators account for 98.5% of all available models). This skewed distribution is removing consumer choice, as almost all products are “high-efficiency” and thus it is not possible for the consumer to preferentially select the best performing products at time of purchase. The skewed distribution is also limiting appropriate policy actions (e.g., subsidy) as there is little differentiation of products within the market, thus hampering policymakers in identifying and supporting the best performing products. This suggests the threshold values within the EES should be revised urgently.

3. Specific proposals for revised EES threshold levels and a new MEPR are made in section 2.3.2. If adopted, such a revision to the EES would:
    - Remove the worst performing 20% of products from the market;
    - Provide consumers with more product differentiation based on the comparative efficiency of the products, allowing them to preferentially choose the more efficient units at the time of purchase;
    - Incentivize manufacturers whose products have now been categorized as Tier 4 and 5 to improve their product performance so as not to appear “inferior” compared with competitive models;
    - Allow policymakers to more appropriately focus other policy support measures on only the most efficient products.

Analysis suggests that policymakers may be reassured that product prices are unlikely to rise due to the proposed increases in efficiency requirements, nor will the proposed change in efficiency requirement remove any particular product group or size range from the market.

Proposed policy intervention to restrict increasing product size

There is clear evidence of a market move to the larger capacity, more expensive multi-door and side-by-side refrigerator models. This indicates that there are consumers in China who tend to buy larger size refrigerators as a luxury rather than for purely practical use. Such behavior comes with a significant energy penalty given the strong relationship between increased product size and increased energy consumption. Therefore, policymakers may wish to consider:

4. Implementing measures to limit this increase in product size/consumption by, for example, placing substantially higher efficiency requirements on larger volume refrigerators and/or implementing financial incentives to purchase smaller units (through subsidy of smaller models or taxation of larger units).

Proposed revisions to the energy efficiency label

The information declared on the Chinese refrigerated appliance label is broadly in line with other comparative labels used internationally, and in general seems highly appropriate to the market need. However:

5. Given the desire to provide consumers with information to encourage their adoption of the lowest-energy consuming product (even if this is not necessarily the most efficient), policymakers may wish to consider amending the label declaration to include *annual* rather than *daily* energy consumption. The rationale for such an adjustment is that, at the time of purchase, consumers are considering a range criteria not just related to energy (e.g., price, brand, capacities, etc). Therefore, calculating the annual energy consumption for a number of competing machines may not be at the forefront of their minds. Should they not perform the calculation, then competing machines with 0.4kWh/24hrs and 0.9kWh/24hrs may be considered to be *relatively* similar. However, over a full year, this difference would produce an approximately 180kWh difference in consumption and 90RMB in additional energy costs to the consumer (based on electricity costs of approximately 0.5RMB/kWh). Therefore, the presentation of annual consumption may have a more significant impact on consumer decisions, and increase the likelihood of consumers selecting the lower energy consumption product.

Section 3: Analysis of the Market and Product Performance of Flat Panel Televisions

This section examines the market, product performance, and regulatory framework for flat panel televisions (TVs). While there is likely to still be a small number of Cathode Ray Tube (CRT) TVs on sale on the Chinese market, the proportion of such products is now very small. Therefore, unless otherwise specified, throughout this report the term "TV" will be used to mean flat panel TVs.

Household penetration of TVs (including CRTs) in urban area of China is already high, and has remained stable since 2004 at a level of around 135 units per one hundred households. However, the ownership in rural areas is still increasing, rising from 75 units per one hundred households in 2004 to 116 units in 2011[48]. Projections[49] indicate that the total number of TVs installed in homes or similar applications will rise from approximately 579 million in 2012 to 735 million in 2030. This projected[49] stock of TVs would consume approximately 154TWh of energy per year by 2030.

3.1 Product Background

Historically, as elsewhere, the Chinese TV market was dominated by CRT TVs. More recently, however, there has been a fundamental market shift to flat panel TVs. Currently, there are two basic types of flat panel technologies that dominate the TV market, plasma display panels (PDPs) and liquid crystal displays (LCDs)[50]. LCD TVs break down further into two sub-types, differentiated by the backlighting source: cold cathode fluorescent lamps (CCFLs) or light emitting diodes (LEDs). Currently, the LCD TV market is undergoing a transition from CCFL to LED backlighting, as LEDs consume less energy, have a thinner profile, contain no mercury, and are more durable.

There are a number of technological differences between PDP and LCD TVs, and for some models this may result in differences in picture quality or other performance metrics. However, our analysis focuses solely on the comparison of energy use, assuming that, in general, TV performance between technologies is similar. Organic Light Emitting Diode (OLED) TVs are also starting to enter the market, but their market share is very small, and thus they are not included in this analysis.

3.1.1 Production, sales and stock level

As noted above, the Chinese TV market was traditionally dominated by CRT TVs. By 2006, however, about 10% of TV sales were flat panel models, rising to over 20% the following year[51]. By 2011, annual sales of flat panel TVs in China had reached 39.7

[48] Year Book of 2012, National Bureau of Statics of China.

[49] Energy Saving Potential (ESP) Study for Nine Appliances in China, CLASP 2013

[50] Organic LED (OLED) models have been in the spotlight recently but, as an emerging technology, more for demonstration than commercialization. Therefore, it is reasonable to assume LED and PDP models will remain the dominant products for at least the next decade and thus this analysis does not specifically include OLED technology.

[51] Raw data is from www.hc360.com

million, accounting for 94.8% of all color TVs sold that year[52]. In 2013, sales of all types of color TVs reached 47.8 million units[53], of which 44.4 million were flat panel TVs. Sales in 2014 are projected to fall slightly to 45.6 million, although interestingly, online sales account for 5.5 million[54] of this total.

Given current trends in the indicators, it is anticipated that ownership of flat panel TVs is likely to rise continuously in the foreseeable future, due to China's continued economic development and increasing household disposable incomes. In addition to sales driven by economic development, sales of flat panel TVs will be mainly boosted by consumers' desire to replace existing CRT units[55].

3.1.2 Usage patterns

In line with the recommendations made in the MACEEP 2013 report, CLASP initiated a consumer survey[56] on consumer usage patterns for a series of appliances, including TVs.

The survey shows that in urban areas, people watch TVs for an average of 4.0 hours per day, leaving them on standby mode[57] for an additional 13.2 hours, as shown in Table 15.

Table 15: Average usage pattern of TVs in a household in an urban area (hours/day) (data collected March 2014)

Operating mode	Time length (hours/day)
On-mode	4.0
Standby	13.2

Also, when watching TV, audiences tend to have some background light on. The survey shows that 61.1% of TV watching is accompanied with mid-levels[58] of background light, 21.4% with high-levels, and 17.5% with low-levels (including no background light).

The survey also investigated consumers' usage patterns concerning adjusting the TV's brightness and contrast. It shows that 81.7% of families use the default brightness and contrast, 15.5% would adjust them to their preferred levels, and 2.8%

[52] www.ccidthinktank.com
[53] AVC consulting.
[54] Appliance, Issue 11, 2013.
[55] Flat panel TVs did not begin to make major penetrations into the market until 2007, CRTs will remain a significant element of the stock until into the 2020s.
[56] Consumer Awareness and Comprehension of China Energy Label and Usage Pattern of Household Appliances, CLASP 2013.
[57] There is only one type of Standby Mode in the EES for flat panel TVs. It is defined as "TV is connected to the mains power, but not displaying any image or playing any sound. It can be turned OFF or ON by remote or other types of external signals."
[58] High-level of background light is defined as "with the light, people can clearly read books", middle-level means "can just read books, but not enough light to feel comfortable", and low-level (including no background light at all) means "cannot read anything at all".

occasionally adjust these parameters to meet some special needs, e.g., playing games.

3.2 Regulation, Labeling and Energy Efficiency Standard

China has both an energy efficiency standard (EES) and energy labeling program for flat panel TVs.

3.2.1 Energy Efficiency Standard and test method

The first EES for TVs (GB 24850-2010) was introduced in December 2010. This EES defined three energy efficiency tiers (EETs), a Minimum Energy Performance Requirement (MEPR), and an associated test methodology. However, due to the rapid development of TV technology and major policy incentives such as national subsidy programs (see the Policy section of the introduction), the energy efficiency of TVs in the Chinese market has improved rapidly. Consequently, the 2010 EES soon became outdated, and a revision process was initiated in 2011. A revised EES draft for comment was released in August 2012, and the finalized new version was published on 9 June 2013. This version (GB 24850-2013) came into effect on 1 October 2013, and is the current EES regulating the energy efficiency of TVs.

Table 16 details the EETs and standby power requirements of the 2010 and 2013 versions of the EES, for both PDP and LCD TVs. In both cases, the MEPR is defined by the lower boundary of Tier 3 and the maximum allowable standby power. However, it is important to note that the derivation of energy efficiency index (EEI) differs between LED and PDP TVs, and also differs between the 2010 and 2013 versions of the EES (refer to Table 17), thus the values shown in Table 16 are not directly comparable.

Table 16: The energy efficiency Tiers and standby power requirements for PDP and LCD TVs in the 2010 EES and the 2013 EES

	Energy Efficiency Index (EEI) Thresholds and Standby Power Requirements*							
	2010 Version				**2013 Version**			
TV type	**Tier 1**	**Tier 2**	**Tier 3**	**Standby**	**Tier 1**	**Tier 2**	**Tier 3**	**Standby**
LCD	1.4	1.0	0.6	<=0.5W	2.7	2.0	1.3	<=0.5W
PDP	1.2	1.0	0.6		2.0	1.6	1.2	
PDP (*normalized to LCD equivalent*) **	0.35	0.29	0.17		0.58	0.46	0.35	

**Method of EEI derivation changes between 2010 and 2013 (refer to Table 17) and differs between LCD and PDP TVs.*

*** The "PDP (normalized to LCD equivalent)" shows EEIs for PDP TVs calculated on an equivalent basis to LCD TVs (refer to Table 17).*

Test method

TVs are a globally traded product, and the test standard used to measure their performance has been harmonized in much of the world through full or partial adoption of the IEC 62087 test method. However, the test method used in China differs significantly. Therefore, it will be useful to understand the Chinese test method before looking at the calculation of EEI for LCDs and PDPs.

Test method in GB 24850-2010

The Chinese flat panel TV test method was first introduced in December 2010 as part of the EES GB 24850-2010. This standard requires TVs to be set to a standard viewing condition by adjusting brightness and contrast based on an eight-level gray pattern in a dark room. This pattern is an image consisting of different levels of brightness, with two rows of eight gray levels against a background of 50% gray level, as shown in Figure 27.

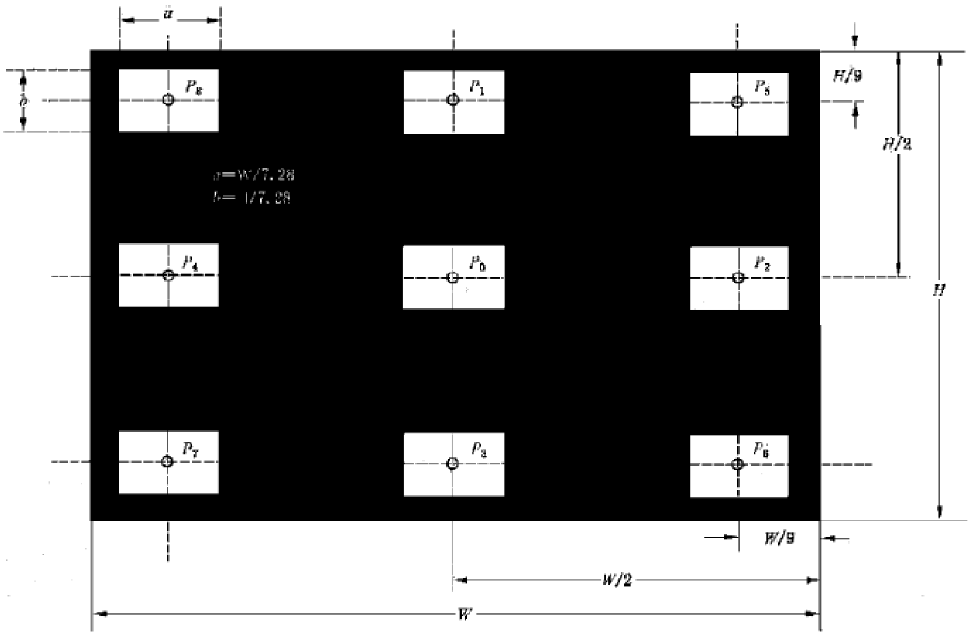
Figure 27: Eight-level gray pattern used in the Chinese TV test method

The first row consists of four levels: 0% (absolutely black), 5%, 10% and 15%. The second row contains 85%, 90%, 95%, and 100% (absolutely white). At first, brightness should be adjusted to the point when the two neighboring levels in the first row (0% and 5% gray) could be just differentiated by the test personnel. Then the contrast is adjusted from 100% to a lower level where the 95% and 100% levels in the second row could be just differentiated by the test personnel. Test personnel should repeat the adjustment procedure until both neighboring groups (0%-5% and 95%-100%) could be exactly distinguished at the same time. At that point, the brightness and contrast levels are deemed to have been set, and are used for the rest of the testing procedures. The test method also dictates that, “if such a condition cannot be achieved, adjust the image to the best quality possible and record the brightness and contrast levels.” However, there is no description of how “best quality” is defined.

Other settings need to be adjusted to achieve the standard testing condition. These settings include Color Temperature (to default mode, or to achieve best image quality, though again there is no definition of “best image quality”), Image Control (also called Quality Improvement, to default mode, or shut off), Auto Brightness Control (should be turned off), and Saturation and Hue (to default mode, or the median value). Also, other additional functions like DVD player, Internet Connection, Video Recorder, Game Center, etc. should also be turned off.

Once adjustment is complete, the luminance of the screen is calculated as the average of nine values measured at points spaced across the screen, P_0 to P_8, in a pattern dependent upon the screen size and shape, as shown in Figure 28. If the luminance is greater than 350 cd/m^2, the backlight level needs to be adjusted so that the luminance of P_0 is between 340 cd/m^2 and 360 cd/m^2. After adjustment, if the Eight-Level gray pattern can no longer be differentiated, test personnel need to adjust contrast level to make it differentiable. The IEC 62087 standard "test clip" is then played, and the power consumed by the TV is measured during the broadcast.

Figure 28: Nine-point layer used in the Chinese TV test method

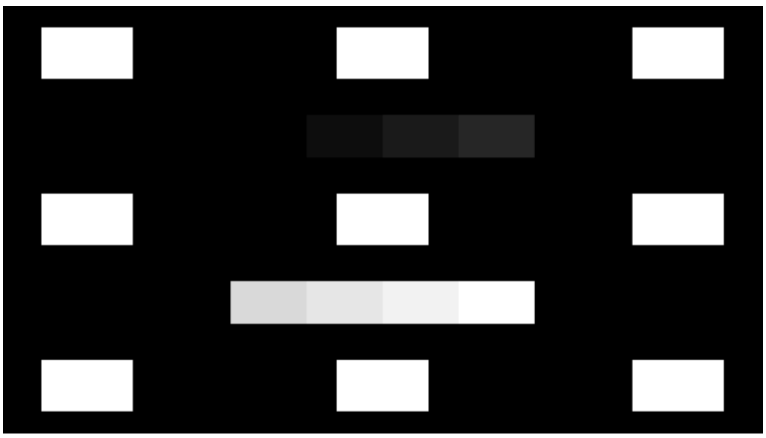


Test method in GB 24850-2013

GB 24850-2013 inherited most of the test methods from its previous version, but a number of changes were made. The main changes are detailed below:

1. The ambient testing environment temperature was changed from 15-35°C to 18-28°C;
2. The original eight-level gray pattern (see Figure 27) and the nine-point pattern (see Figure 28) are combined into one pattern, as shown in Figure 29.

Figure 29: Test pattern for TVs used in GB 24850-2013



3. If the Auto Brightness Control function cannot be turned off, apply a 300 lux at the sensor;
4. If the average luminance of nine points is greater than 250 cd/m^2, rather than 350 cd/m^2 as specified in the 2010 version, the backlight level needs to be adjusted so that the average luminance and the luminance of the central white window shall both fall into the range of 240-260 cd/m^2.

From the information available, it appears the first two points would not have any substantial impact on the final EEI value. The impact of Point 3 may differ from product to product. Point 4 may, to some extent, have a negative impact on EEI, i.e., make it harder for products to achieve high EEI value (noting a higher EEI implies higher levels of efficiency). However, in order to understand accurately what these changes could mean for the energy efficiency of TVs (i.e., will they make EEI values higher or lower), it is recommended that policymakers consider undertaking additional testing to establish a suitable baseline for comparison of the two test conditions.

In the absence of this additional testing, the analysis in this report *assumes* the changes in testing do not affect the values of EEI.

Potential problems with test method

There are three potential problems related to the 2013 test method:

Firstly, the “best viewing conditions” of the TV in the test environment are achieved through adjusting brightness and contrast in a dark room. A dark room does not reflect a typical real-life viewing environment, as most people would watch TV with a certain amount of background light[59], as described in Section 3.1.2. Consequently, the levels of brightness and contrast required in the test are likely to be insufficient to enable satisfactory viewing in a normal environment. Also, as stated in 3.1.2, most consumers do not adjust brightness or contrast from factory default settings, hence changing such parameters does not reflect normal usage pattern. Therefore, adjusting brightness and contrast in a dark environment does not result in energy consumption values reflecting normal operation.

Secondly, the test method dictates that the eight-level gray pattern may be achieved by adjusting the TV's “screen brightness”, which could be realized by either adjusting “brightness” (by changing the angle of crystals of the panel) or the “backlight level” (by changing the light output of backlighting sources). However, the two methods of adjustment will typically result in considerably different values for power consumption (and thus efficiency). Consequently the test may be “interpreted” by manufacturers/test laboratories in a way that is not typical of consumer use, but which gives the lowest energy consumption result. Although this regulation is

[59] A similar issue was identified in a recent CLASP study on background illuminance for TVs in the USA (for details refer to http://www.clasponline.org/en/Resources/Resources/PublicationLibrary/2011/Background-Illuminance-Levels.aspx)

strengthened in the 2013 version of the EES[60], there is still a degree of flexibility that may be inappropriate.

Finally, test personnel are requested to differentiate accurately between neighboring gray levels in the pattern. Such requirements may lead to considerable variation or even errors in the testing results, due to the potentially differing interpretations or perceptions of different test personnel.

Thus, to minimize these problems, policymakers may wish to consider harmonizing the Chinese test standard with IEC 62087. This would not only resolve the issues noted above, but could also contribute to improved international trade. Should this prove impractical in the short term, at the very least policymakers might consider revising the current test method to:

- Reflect more realistic viewing situations, by requiring the adjustment of brightness and contrast in the presence of a defined “typical” level of background light[61];
- Differentiate the adjustment of an LCD TV’s “brightness” and the adjustment of its “backlight level”, making sure that products are tested fairly and that no manufacturers are taking advantage of the inappropriate interchangeability of these values;
- Avoid, or at least minimize, subjective measures in the test procedure. This might be achieved by developing equipment to replace test personnel to read the eight-level gray pattern.

Derivation of the Energy Efficiency Index (EEI)

In addition to the changes in test method detailed above, the 2013 EES also changes the method of deriving the EEI (compared with the 2010 version), which has a direct impact on the reported EEI values. Table 17 describes the derivation of EEI in both the 2010 EES and the 2013 EES.

Figure 30 illustrates the comparison between EEI_{2010} and EEI_{2013}, clearly showing that EETs in the 2013 EES are significantly more stringent than the 2010 version for all EET thresholds. However, the relationship is not linear. The stringency for low power (normally smaller) TVs increases much more significantly than high power (normally larger) TVs. This has the effect that higher power consuming TVs are subject to less challenging performance requirements *relative* to smaller TVs. This outcome is particularly beneficial to PDP TVs, which typically have much higher rated/operational power.

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[60] In the 2013 EES the backlight level needs to be adjusted so that the average luminance and the luminance of the central white window shall fall into the range of 240-260cd/m^2 if the average luminance of nine points is greater than 250 cd/m^2, rather than 350 cd/m^2 as specified in the 2010 version

[61] Consumer Awareness and Comprehension of China Energy Label and Usage Pattern of Household Appliances, CLASP 2013.

This outcome (i.e., that the EET thresholds in the 2013 EES are significantly more stringent for smaller TVs than larger TVs) is also controversial. It is counter to the typical policymaker desire to minimize energy consumption. In this case, the larger energy-consuming TVs are being allowed to consume proportionately more energy than their smaller equivalents. Hence, the message potentially being sent to manufacturers is "produce higher energy-consuming TVs because it will be easier to get a higher rank in energy efficiency Tiers." This is surely counter to policymakers' intentions[62].

[62] It is recognized that there is a possibility that the 2010 EET thresholds were proportionately more stringent on larger TVs and that the 2013 thresholds have been specifically designed to redress this imbalance. However, from information available during this analysis, there is no suggestion that the 2010 EET thresholds were proportionately more stringent for larger TVs. See Section 3.3.4.

Table 17: Comparison of the derivation of EEI values for TVs in the 2010 EES and 2013 EES

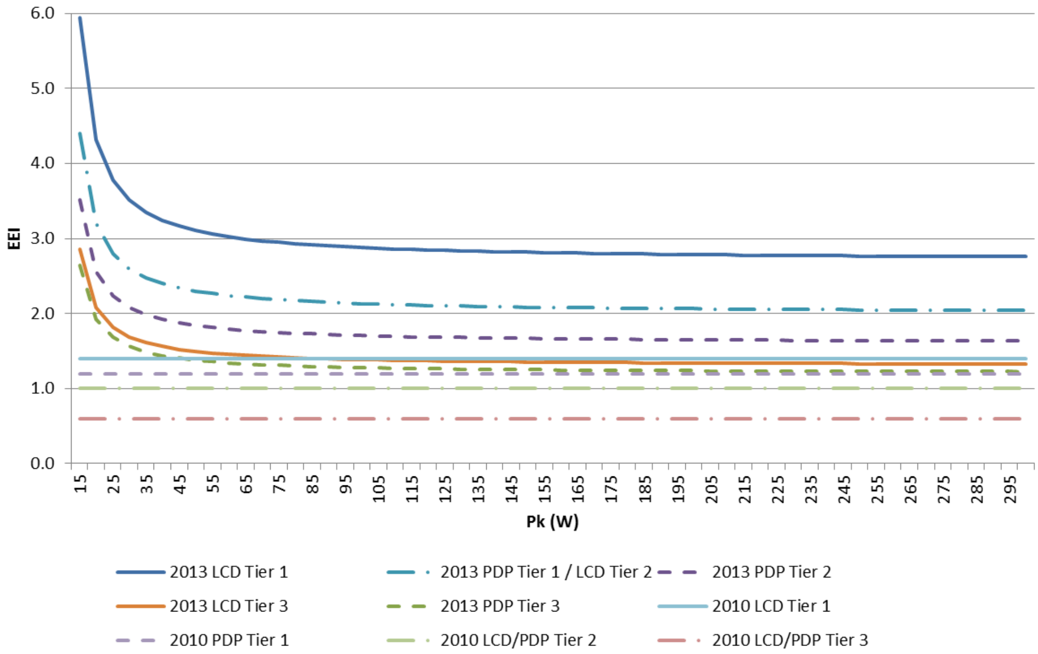
	EEI Derivation (2010 Version)		**EEI Derivation (2013 Version)**	
TV Type	**LCD**	**PDP**	**LCD**	**PDP**
EEI calculation	***$EEI_{lcd}=[L*S/(P_k-P_s)]/EEI_{lcd\ ref}$***	***$EEI_{pdp}=[L*S/(P_k-P_s)]/EEI_{pdp\ ref}$ ^***	***$EEI_{lcd}=[L*S/(P_k-P_s)]/EEI_{lcd\ ref}$***	***$EEI_{pdp}=[L*S/(P_k-P_s)]/EEI_{pdp\ ref}$ ****
	L: average screen luminance; *S: area of the screen;* *P_k: power when TV is on and dynamic image is displayed;* *P_s: power to process signal:* *P_s=6W, when YP_bP_r interface is used;* *P_s=10W, when Analog Radio Frequency interface is used;^^^* *P_s=17W, when Digital Radio Frequency interface is applied.* *$EEI_{lcd\ ref}$ = 1.1* *$EEI_{pdp\ ref}$=0.32*		*All symbols mean the same as 2010 EES, except:* *1. $P_k=P_j$, if P_d is over 30% lower than P_j, otherwise $P_k=P_d$^^.* *where:* *P_j: power when TV is on and static image is displayed;* *P_d: power when TV is on and dynamic image is displayed.* *2. Ps: power to process signal:* *Ps=4W, when Analog Radio Frequency interface is used;^^^* *Ps=8W, when Digital Radio Frequency interface is applied;* *Ps=0W, when other interface is used.*	
Conversion of EEI_{2010} to EEI_{2013}	*$EEI_{2013}=EEI_{2010}*(P_k-10W)/(P_k-4W)$*			

^ There are two $EEI_{pdp\ ref}$ values in the EES depending on the screen resolution. For PDPs with resolutions of 1920 x 1080 and higher, 0.32 is used and 0.45 is for lower resolutions. In this report, 0.32 is used because the proportion of LED and CCFL products with a resolution of 1920 x 1080 is similar to that of PDPs, and overall the market trend is increasingly towards high-resolution TVs.

^^ Because no evidence shows that P_k would necessarily change from P_d to P_j for testing samples, the analysis in this report assumes the new P_k remains as defined as the power when TV is on and dynamic image is displayed.

^^^ Analog Radio Frequency interface is the most commonly used interface in China, therefore the analysis in this report uses 10W or 4W for P_s when referring to GB 24850-2010 and GB 24850-2013 respectively.

Figure 30: Comparison of stringency levels in the 2010 and 2013 versions of TV EES* (2013 values normalized to 2010 values)



**Note: in order to compare the stringency of requirements in 2010 EES and 2013 EES, this graph is normalizing 2013 values to 2010 values.*

If stringency is viewed from the perspective of absolute energy consumption, similar conclusions are reached. According to the derivative function for the EEI in the 2013 EES (Table 17), if luminance stays unchanged when screen size (in inches) doubles (i.e., 20 inches to 40 inches), the power is allowed to increase by 4 times minus 12 watt (i.e., 50 watt to 188 watt) to achieve the same EEI. As a contrast, the requirement in the EU Eco-design regulation could be interpreted such that, when screen size is doubled, the allowable increase of power is 4 times minus 48W (i.e., 50 watt to 152 watt). The difference is as much as 36W. This comparison shows that the Chinese standard is less stringent for larger size TVs.

Therefore, policymakers may wish to consider introducing an improved derivative function for larger size TVs' EEI or power, so that, to gain the same value of EEI or EET, larger size TVs need to be *relatively* more efficient, as they are actually consuming significantly more energy.

Potential problems with derivation of EEIs

In both the 2010 EES and 2013 EES, the EEI_{ref} specified for the derivation of EEIs is not the same for LCD and PDP TVs. The specified EEI_{ref} for LCDs ($EEI_{lcd\ ref}$) is 1.1, and for PDPs ($EEI_{pdp\ ref}$) is 0.32 (refer to Table 17). Thus, if the EEI value is the same for an LCD and a PDP, the actual tested energy efficiency of the LCDs will be almost 3.5 times higher than that of the PDP[63]. The bottom row of Table 16 provides a direct

[63] Calculation: 1.1/0.32=3.4375.

comparison, showing the EEI values for PDP TVs calculated on an equivalent basis to LCD TVs.

There is no explanation within the EES for this difference in EEI_{ref} value. Thus, as presently formulated, the information delivered to the consumer is misleading, as the energy label (refer to section 3.2.2) only provides the consumer with the non-comparable EEI values of LCD and PDP TVs. This gives the consumer no indication that that a PDP TV is actually less efficient than an LCD model of equivalent size and EEI. This removes the consumer's ability to choose the fundamentally more efficient LCD TV with the associated lower energy consumption. Therefore, it is strongly recommended that policymakers consider revising the current EEI derivation for PDP TVs to be *directly comparable* with LCD TVs, i.e., by making $EEI_{lcd\ ref} = EEI_{pdp\ ref}$, or more preferably, present the power consumption for typical watching conditions. This action would create a technologically neutral energy performance benchmark to allow policymakers and consumers to source information with which to make rational policy and purchase decisions.

3.2.2 Energy labeling

Flat panel TVs were initially included in the China Energy Label scheme in March 2011. Since the implementation of the 2013 EES, all newly registered products are required to use the new version of the Energy Label, shown in Figure 31. The new label is almost identical to that used previously, except that the label now refers to "per GB 24850-2013" rather than the previous "…-2010".

The three energy performance levels shown on the label align with the EETs as specified in the EES. The specific Tier at which the product performs is clearly shown (in the two labels illustrated, both are Tier 2). Absolute values for the EEI and standby power performance of the TV are also stated. The label also includes the manufacturer's name and the product model number.

As noted in last year's MACEEP report[64], the current makeup of the TV label poses some problems. In the recent CLASP survey of consumer comprehension of the information on the energy label[61], only 8.4% of Chinese consumers understood the meaning of TV EEI. Even in those instances where consumers could correctly guess that a higher EEI means a more efficient TV, it is highly unlikely that they understand that EEIs for PDP and LCD are calculated differently (i.e., that the same EEI value or EET level does not mean the same energy performance). This eliminates the consumer's ability to choose the fundamentally more efficient, lower energy-consuming LCD TV.

Additionally, and again as noted in last year's MACEEP report[64], the label refers to energy efficiency Tier 1 as "low energy consumption" and Tier 3 as "high energy consumption", which may not actually be the case because the testing conditions do not reflect a normal viewing situation as described above. Therefore, to improve transparency to consumers, and to improve their ability to select lower energy-consuming products at the time of purchase, policymakers should consider replacing the declaration of the TV's EEI value with information on the power drawn by the

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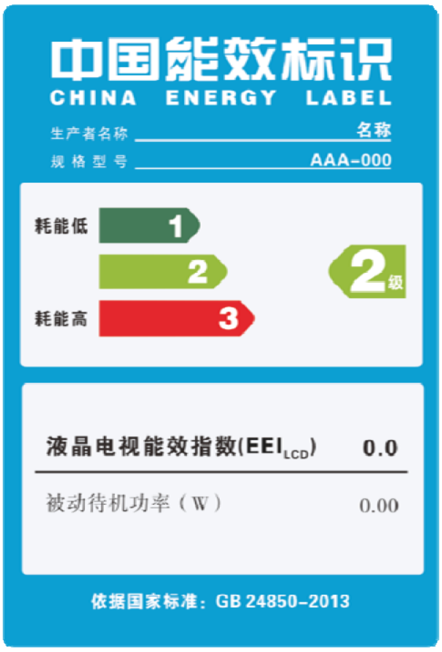
[64]Market Analysis of China Energy Efficient Products (MACEEP 2013)

product. While this will not give the consumer full information on the energy consumption of a TV, it will at least provide a measure of the comparative power (and hence typical energy) consumption of different TVs.

If policymakers take into account actual consumer usage patterns (refer to 3.1.2), this power measurement could eventually be replaced with a value for the TV's typical daily, weekly, or annual energy consumption, which is likely to be of significant value to the consumer. Such revisions would not only provide more useful decision-making information, but would more accurately reflect the real difference in power demand and energy consumption between LCD and PDP TVs.

Figure 31: China Energy Label for flat panel (LCD and PDP) TVs (current)



LCD Label

PDP Label

3.3 Data Analysis

Data analysis of flat panel TVs examines the energy performance and related properties outlined in Table 18. The table also shows some general information about the analysis, i.e., the types of TVs, the number of models for each type of TV included in the analysis, range of EEI values, standby power, size, and price. Information on all criteria were not available for all TV models (e.g., price, rated power, etc). Where this is the case, the specific sample size is indicated. However, there is no evidence indicating that bias was introduced in such circumstances.

Table 18: Overview of data used for TV analysis (data collected October 2013)

Data type	Values
Number of models	2465 in total, of which: LED backlit type: 2038 CCFL backlit type: 308 PDP type: 119
Types	LED, CCFL and PDP. When applicable and available, LEDs and CCFLs are analyzed separately. However, for some analysis and discussion, LEDs and CCFLs are integrally regarded as LCDs.
EEI (per 2010 EES)	Range: LED backlit type: 0.6 – 3.5 CCFL backlit type: 0.6 – 2.1 PDP: 0.6 – 2.0
EET (per 2010 EES)	Range: LED backlit type: 1-3 CCFL backlit type: 1-3 PDP: 1-3
Standby Power (W)	Range: LED backlit type: 0.1 – 1.0 CCFL backlit type: 0.2 – 1.0 PDP: 0.3 - 2.0
Size (inches)	Range: LED backlit type: 19'' – 65'' CCFL backlit type: 19'' – 75'' PDP: 42'' – 65'' (Models above 75 inches are excluded from the study as they are considered too large for regular domestic/commercial use and with few models in the market).

At the time of data collection (first week of October 2013), the 2013 EES had been formally issued for 3 months, and had only come into force (locally referred to as implemented) 10 days previously. The regulation allows a one-year transition period for manufacturers to fully comply with new EES after it has been implemented. Thus, it is reasonable to assume that the TV data collected in October 2013 was based on values for performance and other criteria that were measured and declared using the 2010 EES. Therefore, ***the analysis in this report was undertaken based on the previous version of the EES (GB 24850-2010), unless otherwise noted.***

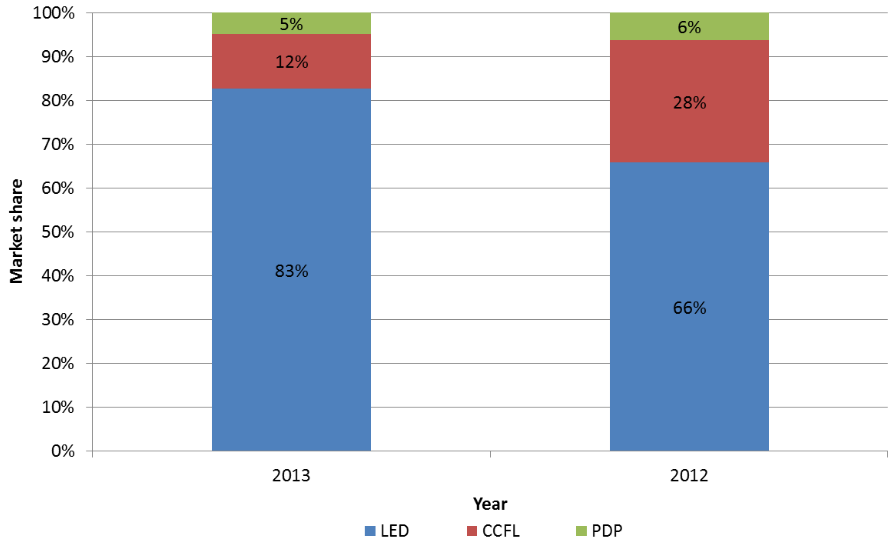
Where applicable, the data analysis also makes comparisons with the research results from the MACEEP 2013 report, completed last year. For more detailed information about last year's analysis results, however, it is recommended that readers refer to the MACEEP 2013 report directly.

3.3.1 Market distribution by product type and screen size

TV types

There are currently two basic types of flat panel technologies, PDPs and LCDs. LCD units can be further subdivided into those with CCFL backlighting, and those backlit by LEDs. Figure 32 shows the distribution of TVs available on the Chinese market in 2013, as well as the comparison with 2012.

Figure 32: Distribution of market share of different types of TVs available on the Chinese market in 2012 and 2013 (data collected October 2013)

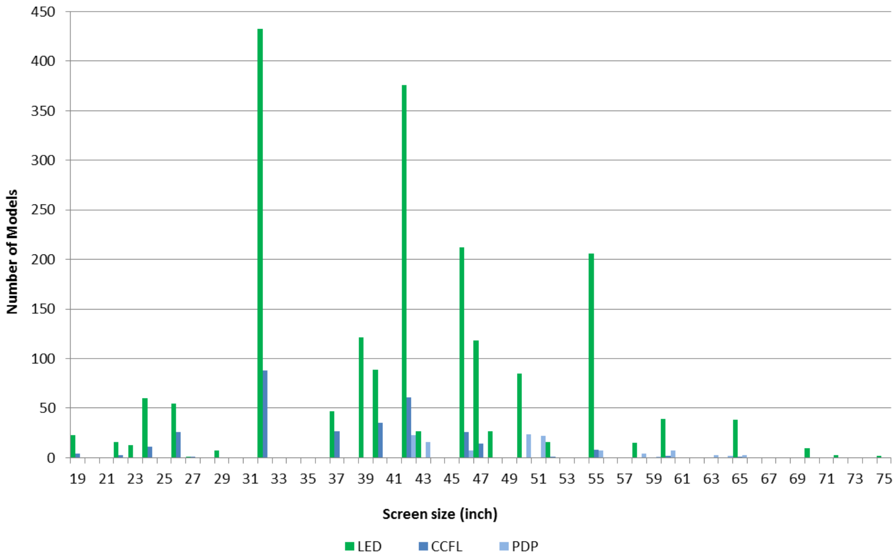


This figure illustrates that, in 2013, LED TVs had by far the biggest market share (83%) and PDPs the smallest (5%). Compared to the market distribution in 2012, it is obvious that the transition from CCFL to LED backlighting in LCD units (noted in the 2013 MACEEP report) is still ongoing, with LED units absorbing 16% of the market share of CCFLs between 2012 and 2013. The market share of PDP TVs, however, remained relatively stable over the two years.

Screen sizes

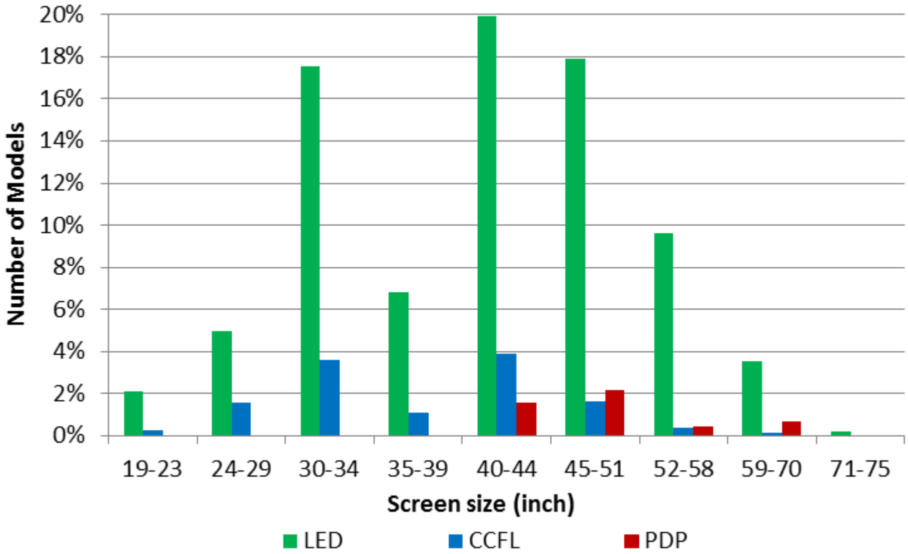
As Figure 33 shows, the most popular screen sizes for LCD TVs available on the market in 2013 are 32” and 42”. For PDPs, the most popular screen sizes are 42” and 50-51”.

Figure 33: Distribution of TVs on the Chinese market by screen size (data collected October 2013)



By grouping the screen sizes into bins, as shown in Figure 34, the broader picture of the overall distribution of the TV market becomes clearer. Figure 34 shows that models in the 30-34", 40-44", and 45-51" screen size ranges dominate the market. PDP products do not enter the market below a 40" screen size.

Figure 34: Distribution of TVs on the Chinese market by screen size range (data collected October 2013)

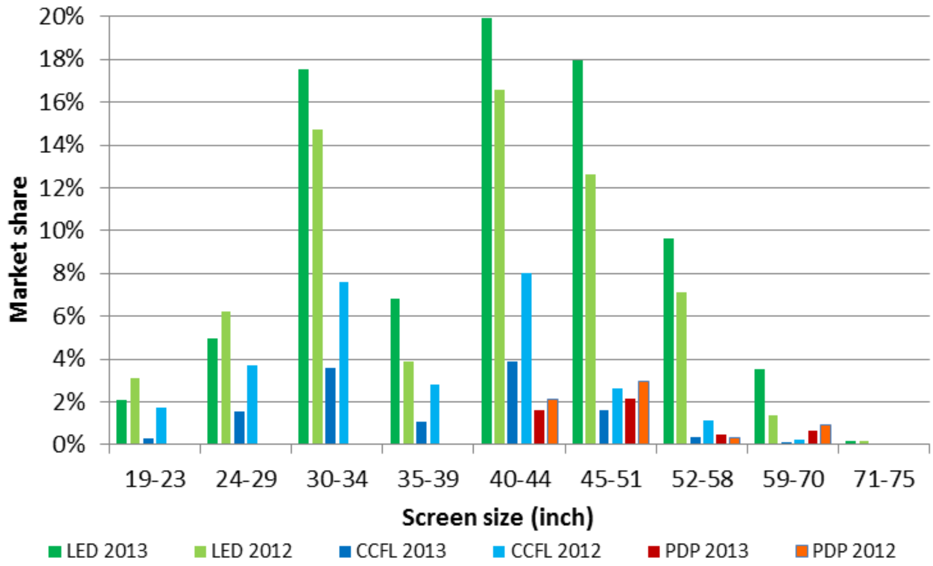


**Note: screen size bin sizes are not of equal range*

Figure 35 compares the size of available TV models in 2012 and 2013 by TV type, illustrating:

- The increase in market share of LED TVs, particularly in the popular screen sizes, i.e., 30-34'', 40-44'' and 45-51'';
- The market share of CCFL TVs has decreased in every screen size;
- There is a general migration of products from smaller to larger sizes. In particular, the availability of large screen sizes (i.e., 45-70'') is growing rapidly, while smaller sizes have fewer models. This is of concern to policymakers because, as previously noted, even highly-efficient, larger-screen TVs use more energy than less-efficient, smaller-screen models.
- The market share of PDPs in different screen sizes stays broadly stable.

Figure 35: Changes in screen size of flat panel TVs on the Chinese market from 2012 to 2013 (data collected October 2013)



3.3.2 Market distribution by Energy Efficiency Index (EEI)

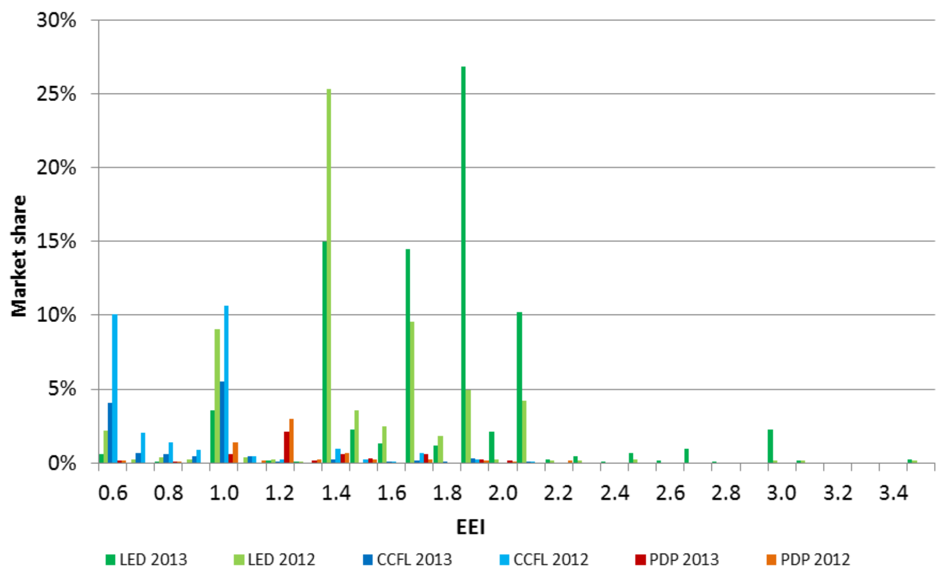
Energy Efficiency Index (EEI)

Figure 36 shows the distribution of TVs available on the market in 2012 and 2013 by the EEI declared by manufacturers[65]. Figure 36 clearly illustrates:

- The products with the highest efficiency levels are LED TVs.
- In comparison with the EEI distribution in 2012, it is obvious that in 2013 the declared efficiencies of TVs have shifted towards higher efficiency levels. This is illustrated by declines in the market share of products with EEIs of 1.4 or lower, and increases in the market share of those products with relatively high EEIs (i.e., 1.9 and 2.1). However, this may have been expected, given the draft for comment of the 2013 EES was issued in August 2012; suppliers would have been aware of the need to improve efficiency levels in time for the formal introduction of the new EES.
- Despite the majority of EEI declarations being below 2.0[66], there are TVs in the market with declared EEIs as high as 3.5. This may imply that there is significant scope for policymakers to increase performance requirements in the future to push all products towards these higher levels of efficiency.

[65] Again, note that the EEI values for LCD and PCP TVs are not comparable (refer to Table 17).
[66] An EEI of 2.0 is the 2013 EET Tier 1 threshold, albeit with a slightly different derivation (refer to Table 16).

Figure 36: Market distribution of declared EEI values for TVs on the Chinese market in 2012 and 2013 (data collected October 2013)



Nevertheless, the potential problems raised in MACEEP 2013 still exist. Comparing the declared product EEIs with the EET threshold requirements in the 2010 EES (refer to Table 16), as well as the requirements that must be met to qualify for subsidy support (See the Policy Section of the Introduction), it is clear that many models are only just achieving EEI values above the threshold requirements. This implies one or more of the following:

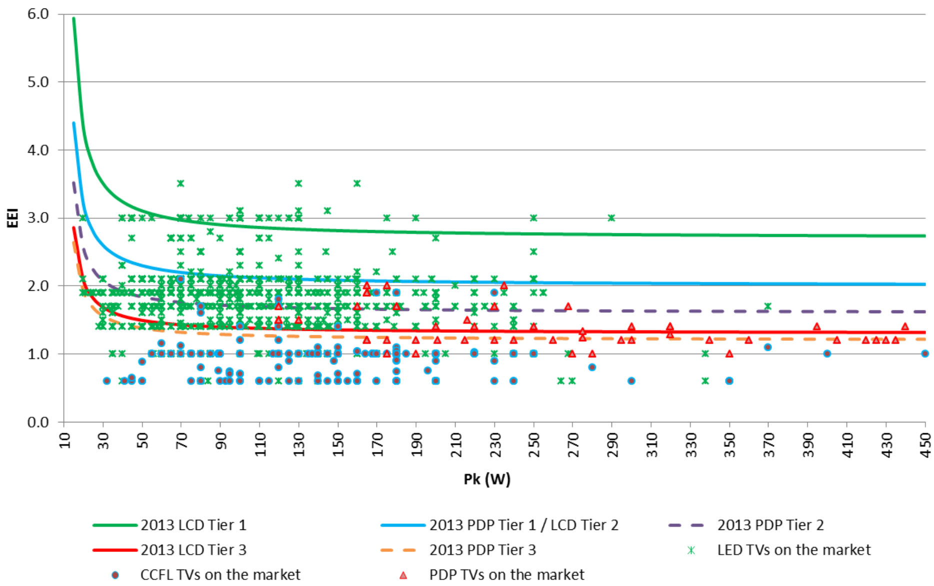
- Manufacturers may have very accurate control over the design and production of TVs, and can deliver products that are just at the boundary conditions. If this is the case, no further actions will be needed.
- Manufacturers may be exaggerating the performance of their products by using the maximum level of tolerances (e.g., testing uncertainty, which is not regulated in the EES) to appear more efficient on the label and/or to qualify for subsidy support. This may be a perfectly legitimate action if the tolerances of the declarations are sufficiently high. However, this implies that more detailed requirements should be established for the labeling tolerances. The exaggeration may also come from an abuse of the system by manufacturers, which would clearly require increasingly robust compliance actions.
- Manufacturers may be understating the performance of products. For example, declaring their products to have an EEI of 1.9, although the product may be able to achieve an EEI of 2.1. While initially counter intuitive, such declarations may be made to just achieve the first Tier, while allowing a degree of safety for manufacturing variance should any verification tests be undertaken. It appears that this type of action brings no harm to either consumers or the overall market. However, such action removes consumers' ability to choose the most efficient products, and restricts policymakers' ability to assess true data on products, which can be an obstacle for developing or revising a new EES.

To address this problem, it is recommended that policymakers require that, at the time of applying for labeling registration, manufacturers' declarations of product performance align with the actual testing report and actual product performance.

3.3.3 Impact of the 2013 EES on the TV market

As noted above, the product data available is assumed to be almost entirely drawn from products registered under the 2010 EES and sold on the market. However, to provide an idea of the potential impact of the 2013 EES on TV availability (as the revised regulation begins to take effect), Figure 37 shows the declared EEI values of flat panel TVs available on the market in 2013 in comparison to the energy efficiency requirements of the 2013 EES.

Figure 37: EEI values of available TVs, in comparison with the stringency of 2013 EES* (data collected October 2013)



** This graph normalizes 2013 EET threshold values to 2010 standard.*
Note: Sample size is 1630, of which 1399 units are LED TVs, 173 are CCFL TVs and 58 are PDP TVs. Five models with rated power higher than 500W are excluded from this analysis.

It should be noted that in Figure 37, the EET thresholds (curves) are based on power values of P_k, while the EEIs of the points representing individual models are based on the rated powers declared by manufacturers for each model, as the P_k (test values) are not available. While closely linked, these two power levels may be different, as P_k is the standard on-mode power where some of the functions (e.g., internet connection) are turned off and some settings are adjusted to the standard mode (i.e., not the most energy consuming working condition). However, the declared rated power should be no smaller than P_k. Thus in reality, the points representing individual models would move to the left on the graph (i.e., the area of greater stringency), thus rendering the impacts of the 2013 EES greater. Thus Figure 37and the related analysis show the *minimum* impact of the 2013 EES.

Figure 37 shows that, assuming manufacturers' current EEI declarations are accurate, the 2013 EES will have significant impacts on the CCFL TVs currently available on the market. There are very few CCFL models that will achieve the 2013 MEPR level. This means that, in one year's time, most CCFL TVs will disappear from the market unless new products are developed. In contrast, most LED TVs already meet the 2013 EES MEPR, although only a very limited number can reach the Tier 1 requirement. As for PDP TVs, the graph shows that some of the present models will be eliminated under the 2013 requirements. However, as the gap between their current energy performance and the new MEPR is quite minimal, manufacturers may be able to make minor improvements to their current products to make them compliant.

To summarize the potential impact of the introduction of the 2013 EES, policymakers should be applauded for boosting the transformation from CCFL TVs to more efficient LED LCD TVs, and for generally increasing the efficiency of products on the market. However, the new EES may not be as helpful in significantly improving the energy performance of PDPs and large size LCDs, due to the *relatively* low efficiency requirements for these products. Given that PDP and large screen LCD TVs are the largest energy consuming products (see section 3.3.4), policymakers may wish to re-examine this issue in the future.

3.3.4 Relationship between TV energy efficiency, power and screen size

Figure 38 shows the relationship between TV EEI, power demand, and screen size. As would be expected, power demand of a TV is strongly related to the screen size, with LED units consuming the least amount of power across all screen sizes, and PDP units consuming the most power for all screen sizes where they are available (40-44" and up)[67].

EEI in relation to screen size

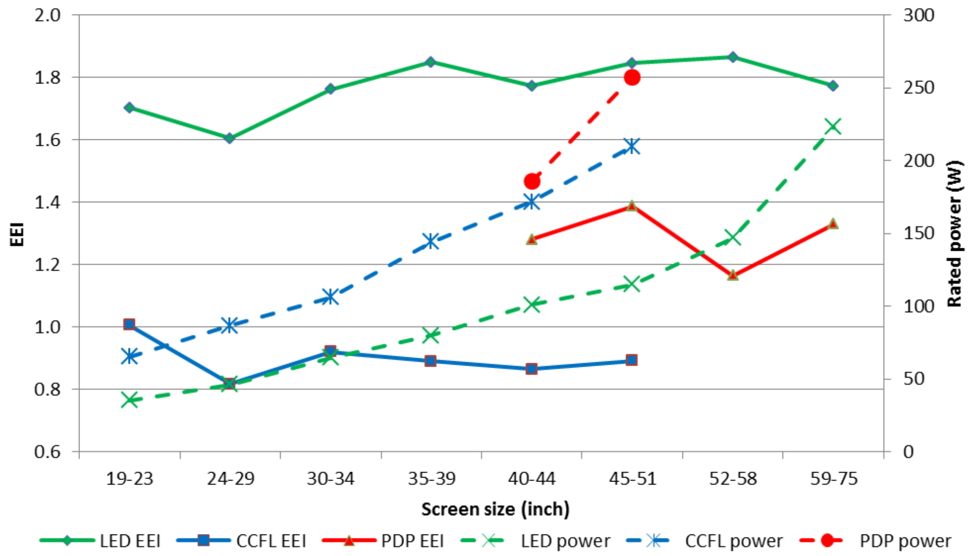
There appears to be relatively little relationship between EEI and screen size, although there is a slight tendency for EEI to increase with increasing screen size for LED units. Consequently, the revised 2013 EEI algorithm unnecessarily penalizes smaller TVs, as suggested in section 3.2.1 (shown in Figure 30). This may encourage consumers to purchase larger units that consume more energy, which is a perverse outcome for policymakers.

Power in relation to screen size

Figure 38 clearly illustrates how the energy consumption of TVs increases with increases in screen size.

[67] The power data used here are declared values. Tested value may differ, especially for PDPs, as PDPs do not consume full power under normal viewing conditions.

Figure 38: Relationship between TV EEI, power, and screen size* (data collected October 2013)



** Please note that:*
1. Sample sizes that are smaller than ten are excluded. After these exclusion, power data was available for 1,614 models, broken down by1,401 LED models, 163 CCFL models, and 50 PDP models.
2. As TVs normally do not operate at full power, i.e., lowered backlight level, the comparison of power shown in the figure above may need caution for interpretation.

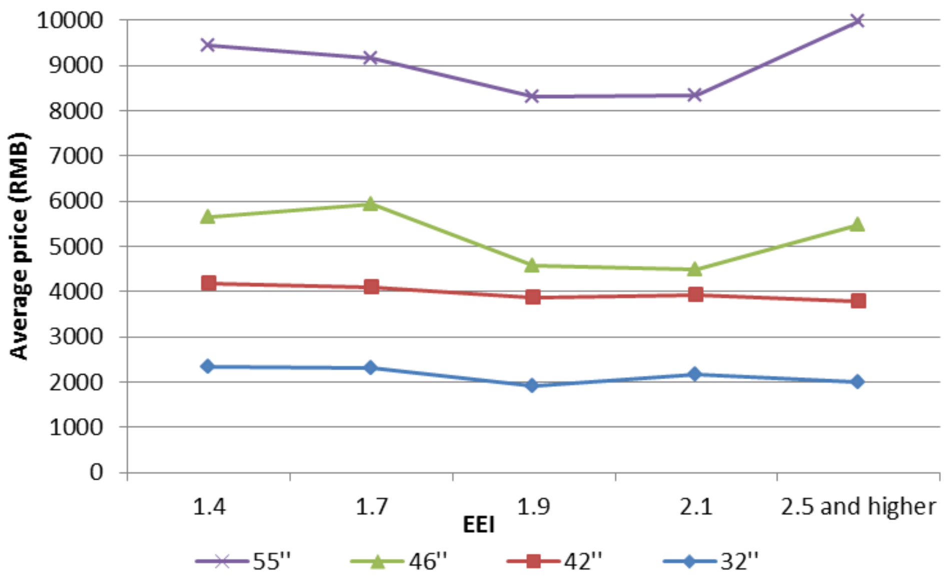
3.3.5 Relationship between TV energy efficiency and price

This section aims to investigate whether the energy efficiency of TVs is related to their price, as well as how strong the relationship is should it exist. The purpose of this analysis is to provide policymakers with information that may influence potential incentive policies in the future. As discussed above, because CCFL TVs appear to be effectively phased-out of the market, and because the actual energy efficiency of PDP TVs is significantly lower than for LEDs, the following analysis focuses on LED TVs only. LED is likely to be the only TV technology for which receiving subsidies is appropriate.

The relationship between TV screen size and price is strong. Therefore, to understand the relationship of price to EEI/EET, it is necessary to remove the influence of screen size. To this end, the relationship between energy efficiency and price is analyzed for TVs of the same screen sizes. Four representative screen sizes were chosen, 32”, 42”, 46’’ and 55”[68]. In addition, to add clarity to the analysis, only products with the four most prevalent EEI values (EEIs of 1.4, 1.7, 1.9 and 2.1 – refer to section 3.3.2), as well the most efficient products (i.e., TV with EEIs over 2.5), were selected.

68 Note: it is understood that other functions (e.g., 3D, internet connection, Auto Brightness Control, etc.,) also have an influence on price. However, the lack of available data on these functions for a number of models makes it impossible to adequately control for these factors. Further, as such functionality may exist randomly in the models of the selected sizes, the influence of these factors on price has necessarily been assumed to average across the selected sizes in broadly equal measure, and thus has been ignored.

Figure 39: Relationship between price and EEI for 32", 42", 46" and 55" LED TV models (data collected October 2013)



As can be seen from Figure 39, the price of 32'' and 42'' models stays broadly stable across all EEI levels. For 46'' and 55'' models, prices appear to fall as EEI increases from 1.4 to 2.1, but bounce back for models with EEIs of 2.5 and higher. This bounce back only raises prices to levels broadly similar to the least efficient models, however. It is therefore clear that, at efficiency levels exceeding EEIs of 2.5, there is no relationship between price and EEI. This is outcome is contrary to the common perception that more efficient products are more expensive. One of the reasons for the disconnect between price and efficiency could be that all EEI values covered here are categorized as Tier 1, and manufacturers may think that this designation should be sufficient for consumers, as few of them would care about or understand the meaning of EEI. However, equally likely is that energy efficiency is not the primary focus for TV consumers, and thus manufacturer and retailer pricing strategies focus more on brand and/or other functionalities.

Whatever the underlying cause of this lack of relationship between efficiency and price, analysis of the market based on the 2013 data and EEI values proves that there is no (or at most a very limited) extra cost for manufacturers to produce high efficiency TVs with EEI values in excess of 2.5. Should this remain the case when the market has responded to the revised EES and associated EEI requirements, policymakers may wish to focus subsidies at only the most efficient models, so that these models become among the cheapest models available at all screen sizes. Doing so would stimulate manufacturers to supply these products, which would then provide the potential for increasing the EET thresholds in the future.

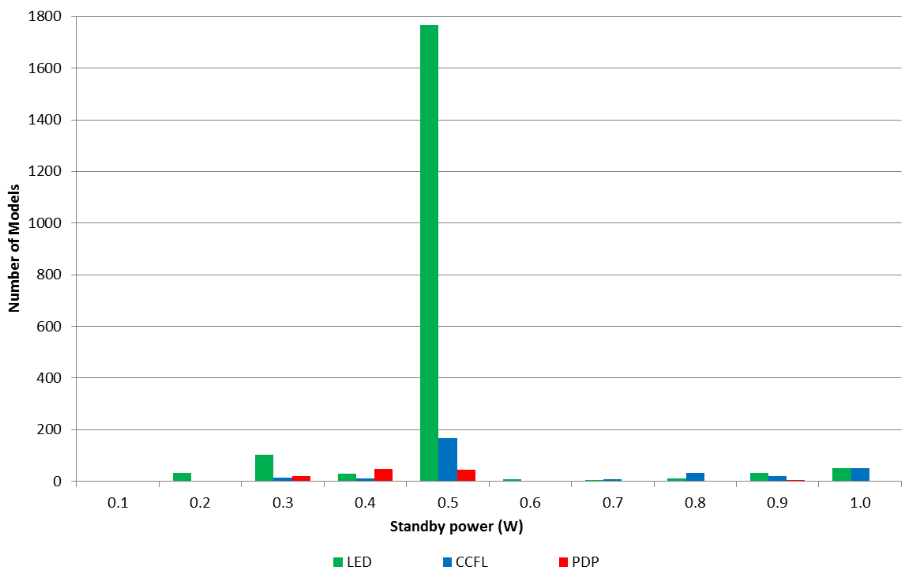
3.3.6 Market distribution of TVs by standby power

The mandatory MEPR for standby power was 1.0W at the introduction of the 2010 EES, moving to 0.5W as of January 1 2012. The 2013 version of EES adopted this 0.5W requirement.

Figure 40 illustrates the market distribution of standby power (as declared by manufacturers) of models available in the market in 2013. As shown, the standby powers of the majority of the models are declared to be 0.5W, exactly the minimum requirement in the EES. It is rather unlikely that such a high proportion of models would comply exactly with the boundary level, and it is more likely that manufacturers are declaring values above or below the actual standby performance of the TVs. This potentiality is similar to the observation made about EEI declarations aligning very closely with EET thresholds, as noted in section 3.3.2. Thus, policymakers may wish to address this issue by requiring manufacturers to ensure that declarations of product performance (at the time of product registration) align with actual testing reports and actual product performance.

It is also worth noting that there are still models with standby power higher than 0.5W, and these products should formally be eliminated from the market once the one-year transition period between the 2010 EES and 2013 EES is complete. Policymakers should consider strengthening market surveillance to ensure these products are actually removed from the market.

Figure 40: Distribution of declared TV standby power (data collected October 2013)



Finally, it is worth noting that both EU Eco-design and US ENERGY STAR regulate several types of standby modes, for example: passive standby, off mode, standby-active, low mode, etc. Due to the rapid technological development of TVs on the Chinese market (e.g., models now include functions such as internet connection/ communication, fast wake-up, etc.), policymakers may need to consider including more detailed regulations around standby mode and related conditions in the next revision of the EES, similar to the EU/US approach.

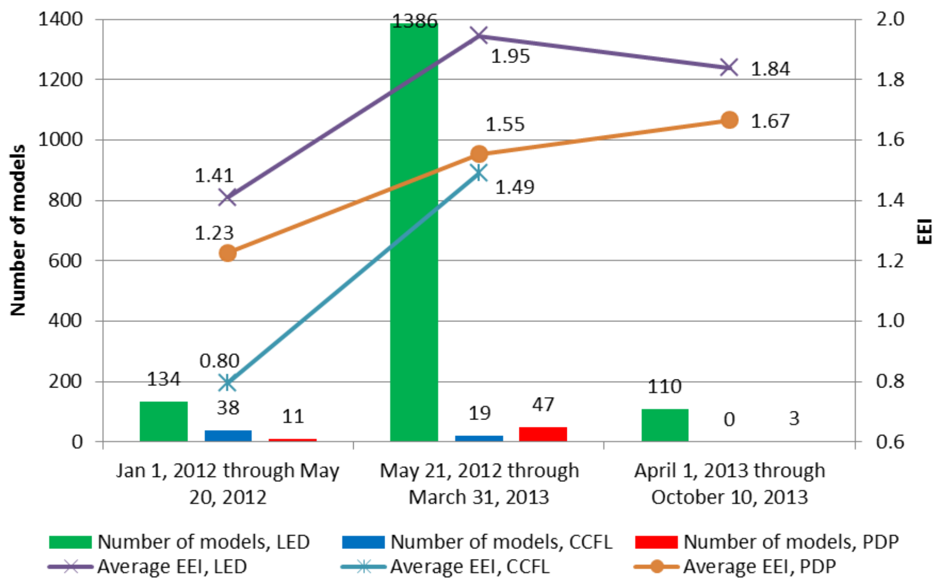
3.3.7 Impact of subsidy program and overall transformation of the TV market since 2012

This section seeks to investigate how the TV market has evolved over time since the start of 2012, and how the subsidy program and the EES working together have impacted product efficiency.

Figure 41 shows the number of models registered during different time periods, as well as their average energy efficiency index (EEI). While not of equal lengths, the time points referenced in Figure 41 correspond to:

- 1 January 2012, the selected starting time point;
- 20 May 2012, when public announcement of subsidy threshold levels was made;
- 31 March 2013, three months prior to closure of the subsidy program. Instead of choosing the exact closing date of subsidy, this time point was selected because it is likely that, for the final three months, manufacturers would focus on promoting sales of previously registered models, rather than registering new models for the subsidy;
- 10 October 2013, when the most recent collection of market data included in this study was completed.

Figure 41: Trends in the average TV EEI declared at registration over various time periods*



**Note that analysis is limited to the registration date of products still on the market when data was collected in 2013. This may skew outcomes, as some products may have entered and then left the market over the period, while others remained in the market. However, as the total period is only 20 months, it is likely that the influence of products being phased out is limited.*

Figure 41 clearly shows that introduction of the subsidy program had a significant stimulus effect on the market, increasing both the number of models registered and the average energy efficiency of those models. The number of LED models registered skyrocketed[69]. This increased the overall efficiency of non-PDP units, allowing the 2013 EES to set MEPR values which effectively phased-out the less efficient CCFL products (no CCFL registrations were made after the end of the subsidy program).

[69] PDPs also benefited, with the number of registrations more than doubling.

As the subsidy program approached its end, manufacturers seemed to slow the introduction of new products (and higher efficiency models), and the number of registrations fell back to the level seen before the subsidy program.

However, the subsidy program's significant contribution to market transformation to higher efficiency TVs highlights an important issue for policymakers. The speed with which products were registered after the announcement of subsidy is surprising. It is unlikely that so many new products could be developed, and so many manufacturing processes changed to deliver products to the market, in this limited timeframe. This suggests one or more of the following possibilities:

- Manufacturers already had products of this specification, but had no incentive to bring them into the market. If this is the case, then the subsidy brought already-designed products into the market more quickly than would have occurred without the subsidy. This is a highly desirable outcome.
- Manufacturers were already producing products of this specification, but were previously understating product performance. When the new subsidy and/or EES requirements were announced, these products were simply re-registered with more accurate performance data. If this was the case, policymaker adoption of the requirement that manufacturers register products with actual test results—thus verifying their declarations—will help prevent such a situation from occurring in the future.
- Manufacturers were over-declaring the performance of products registered after the subsidy announcement simply to qualify for the subsidy. Policymakers are encouraged to conduct check-testing on subsidized models to ensure that such market manipulation is avoided and product declarations comply with EES requirements.

As noted earlier in this section, the subsidy program initiated market transformation by effectively removing the vast majority of CCFLs from the market, and this transformation enabled the development and implementation of the 2013 EES.

The process to develop the 2013 EES was initiated before the subsidy program was announced. It is reasonable to assume that during deliberations over how the new energy efficiency requirements in the 2013 EES should be set, there were differing opinions among different stakeholders. Some manufacturers likely insisted that a new requirement would be too high, and therefore difficult for the industry to reach, while others may have desired very high thresholds. When the subsidy program was announced, however, manufacturers appear to have actively transferred production to more efficient products that could meet the subsidy criteria. Consequently, the whole market moved forward, and the new EES set requirements accordingly. The 2013 EES was issued on 9 June 2013, right after the subsidy program ended. However, because of the higher efficiency requirements of the new EES, manufacturers could not go back to producing TVs at previous efficiency levels. That is why even after the subsidy, as shown in Figure 41 the average EEI remained high.

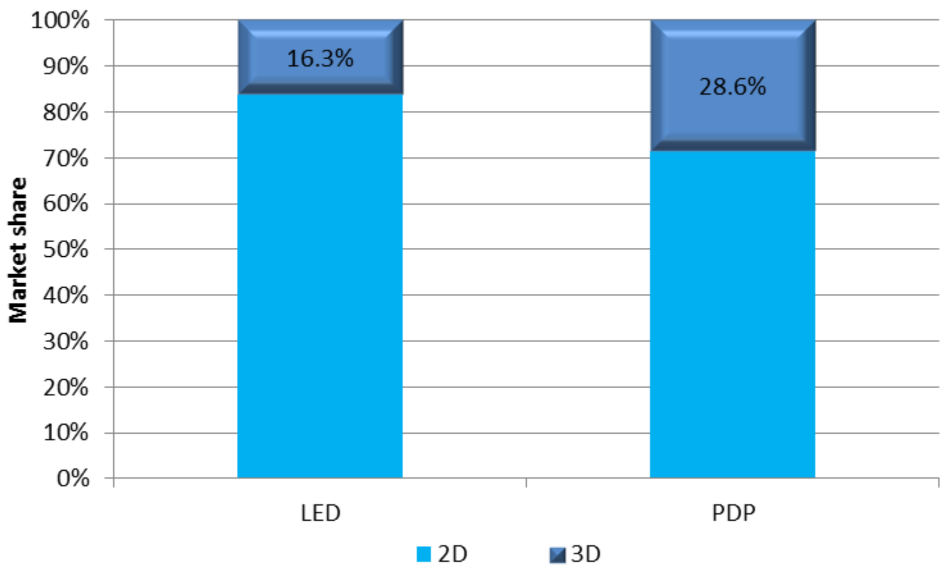
Although the subsidy program may not have brought about the creation of any new technology, it definitely stimulated the TV industry to bring their best reserves to the market as well as eliminate out-of-date technologies.

3.3.8 Three-dimensional (3D) TVs

3D technology is becoming popular with consumers, and an increasing number of manufacturers have begun to deliver 3D TVs to the market. Consequently, the question of whether 3D TVs consume more energy than traditional 2D TVs has attracted policymakers' attention, and a number of groups have conducted research on the issue[70]. However, since there is not yet any universally recognized test standard for 3D TVs, the research and tests that have been completed to date may not allow consistent comparisons of 2D to 3D results, nor comparison of inter-3D results.

Due to the limited availability of reliable data, this analysis looks only at the market share of 3D TVs, and performs a simple comparison of the rated power[71] of 2D and 3D TVs on the market at the time of data collection.

Figure 42: Market share of 2D and 3D TVs (data collected October 2013)



**Because CCFL is disappearing from the market, Figure 42 does not include it.*

As shown in Figure 42, 3D TVs have a market share of 16.3% of the LED segment and a 28.6% share of the PDP segment, and thus 3D TVs already take up a significant proportion of the market. Considering the rapid development and penetration of this technology, it is recommended that policymakers should start drafting energy performance regulations for 3D technology immediately.

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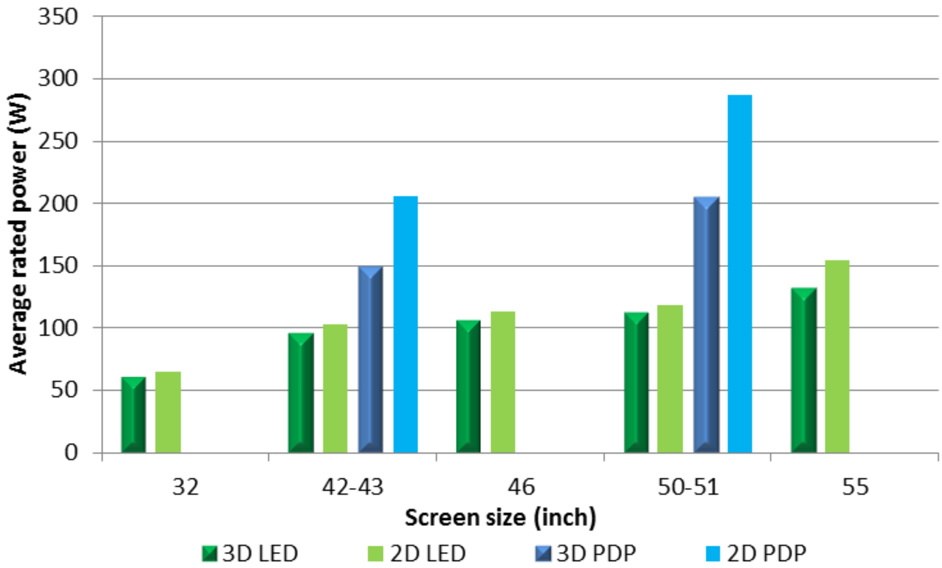
[70] Examples are: SEAD, 3D TV Sets Research Report, 2013; U.S. Department of Energy, "TV 3D Mode Data," 2012; and CEA, "Investigation of 3D TV Technology and Energy Consumption," 2012.

[71] It should be noted that the comparison of power is based on rated power rather than any standard mode power. Therefore, the result may not accurately reflect which technology consumes least energy during typical use.

Figure 43: Comparison of average rated power of 2D and 3D TVs by screen size (data collected October 2013)



For those screen sizes where both 2D and 3D TVs were available on the market at the time of data collection, Figure 43 provides a comparison of the average rated power consumption of models employing the two technologies. Contrary to the expectation of most people, 3D TVs in each screen size show a lower power consumption than 2D TVs, and in the case of PDPs models, the lower power levels of 3D models are significant. However, once again it should be noted that the comparison is based on rated power, rather than standard tested power.

3.3.9 Analysis of TV models registered under the 2013 EES

In order to gain some insight into the market impact of the 2013 version of the TV EES, registration data[72] was collected on TVs in March 2014 (i.e., five months after the 2013 EES came into effect). Data sourced for use in this analysis is summarized in

Table 10.

[72] www.energylabel.gov.cn

Table 19: Data for flat panel TVs registered in the first five months following the introduction of the 2013 version of EES (data collected March 2014)

Data type	Note
Total number of models registered to new version of EES	Total: 3199 LCD* : 3074 PDP: 125
Screen size (inch)	Range: 15-85** LCD: 15-85 PDP: 42-85
Energy efficiency tiers	Range: 1-3 LCD: 1-3 PDP: 1-3
Number of models that registered both to old and new version of EES	Total:1363 LCD: 1260 PDP: 103

Note:

**In this section, all LCD models are assumed to be LED backlit types.*

*** Unlike the analysis of models available in 2013 where models were limited to screen sizes no larger than 75 inches, in this section, screen size are extended to 85 inches to better reflect the impact of the new EES on more products. While there are several models bigger than 85 inches, they are excluded due to the very limited number and potentially special usage condition.*

This analysis seeks to establish:

- What would the distribution of TVs within the energy efficiency tiers potentially look like under the new EES?
- Whether the new requirement will have tremendous impacts on small-size TVs, as appeared likely from the analysis shown in Figure 30.

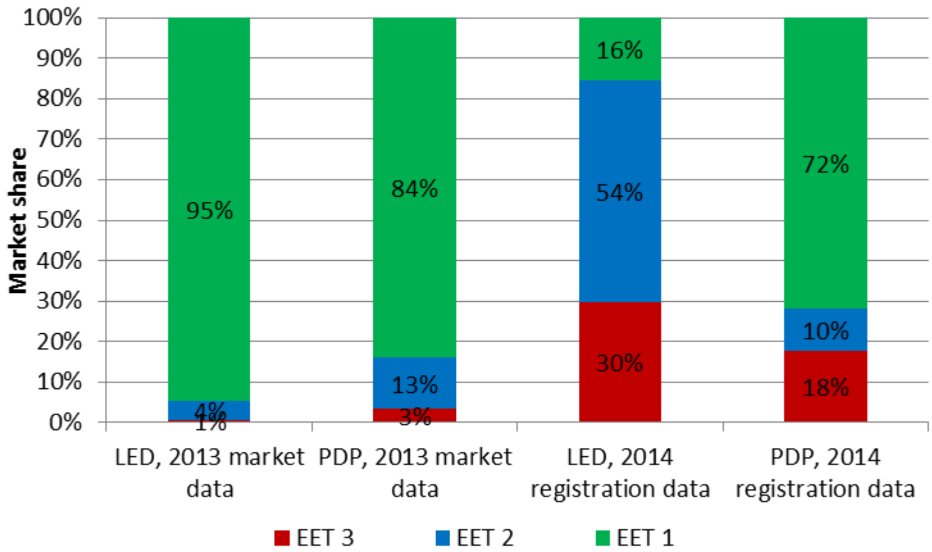
Overall change in energy efficiency Tier distribution

As stated above, the 2013 EES has greatly increased the stringency of requirements on LCDs. Consequently, because the MEPR level has been raised significantly, it is assumed that all registered LCD models are LED-type. However, from the publicly available registration data, it is not possible to tell whether a registered model is backlit by CCFLs or by LEDs.

Figure 44 shows that, compared with the energy efficiency Tier distribution of 2013, the 2014 distribution of LED TVs under the new EES changed significantly. The proportion of Tier 1 products shrank to 16%, down from 95% in 2013, and Tier 3 rose to 30%, up from 1% in 2013. In contrast, the change in energy efficiency Tier registrations for PDPs is much less profound, with the proportion of Tier 1 models falling by 12% and Tier 3 models increasing by 15%. From this analysis, two conclusions can be drawn:

1. The new version of the EES has a much greater impact on LCD models than PDP models, due to the *relatively* greater increase in stringency for LCD models. Consequently, the true difference in energy efficiency/consumption between PDPs and LCDs will grow, i.e., PDPs will consume *relatively* more energy than LCDs in the future.
2. "Efficient" products, defined as all Tier 1 and Tier 2 models, are still a major proportion of the market. This could potentially mean that, in the near future, the market may again become filled with Tier 1 products, thereby eliminating consumers' ability to differentiate products.

Figure 44: Comparison of TV energy efficiency Tier distribution in 2013 (market data) and 2014 (registration data under 2013 version of EES) (data collected March 2014)

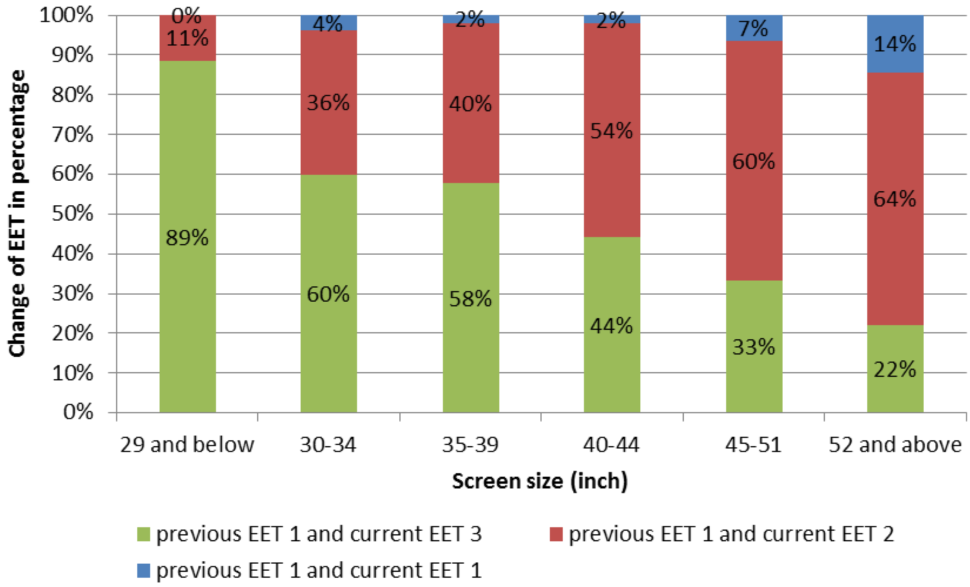


Changes in energy efficiency Tier distribution across different screen sizes

The analysis above, based on Figure 30, indicates that the new EET requirements in the 2013 EES increased the stringency requirements for all TVs, but also that this increase in stringency was greater for small screen TVs than for larger screen models. As there are a number of TV models which were originally registered under the 2010 EES and have been reregistered under the 2013 EES, this provides the opportunity to compare the two performance requirements directly. **However, it should be recognized that this sample of products registered under both the 2010 and 2013 EES is self-selecting, i.e., only models that manufacturers have chosen to re-register are included. This is likely to bias the sample (e.g., only models performing well under the 2013 EES may have been re-registered). However, the degree of bias introduced by this self-selection is unknown.**

From Figure 45, it is clear that a significantly higher proportion of smaller screen products (compared to larger screen units) that registered as Tier 1 under the 2010 EES were re-registered as Tier 3 products under the 2013 EES requirements. Conversely, Figure 45 shows that a higher proportion of the larger screen machines, particularly those above 45", managed to retain their Tier 1 status.

Figure 45: Change in energy efficiency Tier of TVs that registered to both the 2010 and 2013 versions of EES (data collected March 2014)

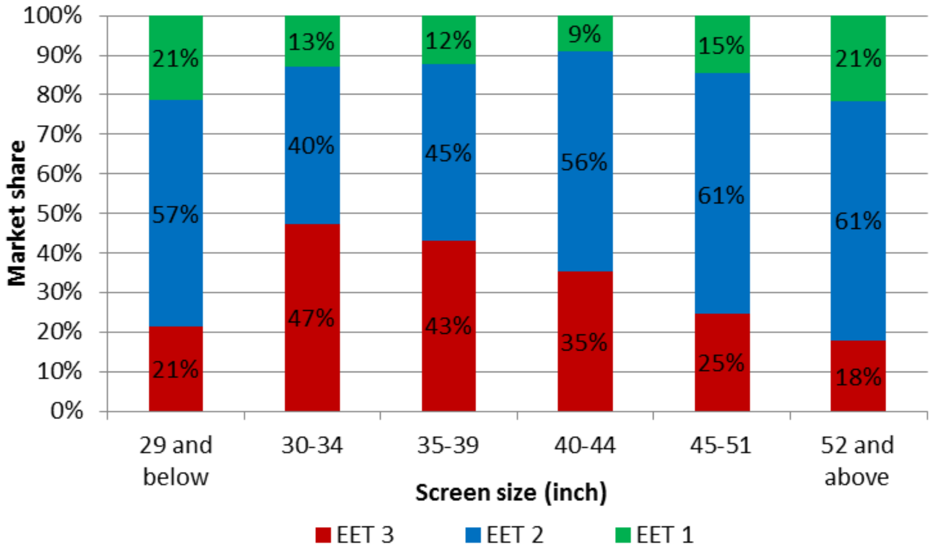


NOTE: In order to make the graph look clearer, Figure 45 uses only LCD models that were previously registered as Tier 1. The basis for this selection is:

1. *The increase of stringency is greater for LCDs than PDPs, as illustrated in Figure 30, and;*
2. *LCDs have much more market share than PDPs, as illustrated in Figure 32, and;*
3. *Previously, almost all LCD models were Tier 1 products and they represent 92.9% of all LCD models (1171 models out of 1363).*

Figure 46, which illustrates the EET distribution of all TV models that have been registered since the introduction of the 2013 EES, shows that manufacturers appear to have responded to changes made to the EES in 2013 by modifying their product designs/production methods to more evenly distribute products among the three EETs for all screen sizes. With the exception of 29” and smaller units, there is still a higher proportion of energy efficient (Tier 1 and 2) products among larger screen sizes, but there is a much greater balance of Tier 1, 2 and 3 products among all screen sizes. This distribution may represent the likely market state in the near future, as these recently registered products are brought to market.

Figure 46: EET distribution of all models of TV that have been registered to 2013 version of EES (data collected March 2014)



3.4 Conclusions and Recommendations

The conclusions and recommendations drawn from this analysis of the TV market are as follows:

Revise energy efficiency test method

A number of issues have been identified that may potentially lead to manipulation of TV testing outcomes, or to varying interpretations of the testing requirement:

- Currently the test method adjusts the TV to its best viewing condition in a dark room. However, evidence presented from a study by CLASP of normal consumer usage suggests 78% of users watch TV with background light of varying intensity. Hence, TVs set to the current test method performance levels would provide insufficient light output to be viewed clearly under normal viewing conditions. Consequently, tests using the current test method result in comparatively low energy consumption values.
- The adjustment requires test personnel to judge if the test pattern meets the specified criteria. This introduces significant levels of subjectivity into the process, and is likely to lead to a lack of repeatability in test results from different testing personnel. This subjectivity would remain even if the test method were revised so that TV adjustments were made under normal viewing conditions.

Therefore, policymakers may wish to consider:

1. Harmonizing the Chinese test standard with IEC 62087. This would not only resolve the issues noted above, but could also contribute to improved international trade, as Chinese manufacturers would be using the same test methodology for products distributed within China and to the majority of other countries around the world.

Should this prove impractical in the short term, then at the very least policymakers should consider:

2. Revising the current test method to
   - Reflect more realistic viewing situations, by requiring the adjustment of brightness and contrast in the presence of a defined “typical” level of background light;
   - Differentiate the adjustment of an LCD TV’s screen brightness from backlight brightness, to make sure that products are tested fairly and no manufacturers are taking advantage of the inappropriate interchangeability of these values;
   - Avoid, or at least minimize, subjective measures in the test procedure. This might be achieved by developing some equipment to replace test personnel to read the eight-level gray pattern.

Modify energy efficiency requirements

Policymakers should be applauded for introducing a new energy efficiency standard in 2013, which has clearly led to an increase in the efficiency of registered TVs.

However, the EEI’s in the 2013 EES for LCD and PDP TVs are still not based on the same EEI derivation, and are thus not comparable. Using the current calculation method, PDPs’ apparent EEI is manipulated to a point where PDP energy consumption can be over three times that of the equivalent size LED TV, yet still achieve the same EEI value. This approach is not technology-neutral, and distorts the product comparisons necessary for policy analysis and appropriate regulation. But of at least equal importance, consumers are completely unaware of this difference. Therefore, it is probable that consumers are directly comparing the efficiency (EEI index of label category) of PDP and LED models when there is no basis for such direct comparison, and may well lead to consumers unwittingly selecting higher energy consuming PDP units by mistake.

Therefore, policymakers are strongly encouraged to:

3. Make the derivation of the EEI for PDP and LED televisions identical, to create a technologically neutral energy performance benchmark that will allow policymakers and consumers to source information on which to make rational policy and purchasing decisions.

Further, by implementing the 2013 EES in the current form, policymakers may be inadvertently signaling to the market that “larger screen TVs can be proportionately less efficient than smaller screen TVs”. This is because:

- In comparison with the 2010 EES, the increase in stringency in energy efficiency requirements for lower power (typically smaller screen size TVs) was significantly higher than the increase in stringency for larger screen size TVs. While manufacturers have responded by registering new, higher efficiency small screen products, the relative increase in stringency for smaller screen products is still potentially controversial.

- In comparison with the EU Eco-design and US ENERGY STAR requirements, the EEI derivation has very large incremental power allowances as screen size increases. As the size of Chinese TVs are increasing relatively rapidly, it is important for policymakers to rigorously regulate this increasing power consumption.

As larger screen TVs typically use substantially more energy than small screen TVs, these market signals seem counter to the typical policymakers' desire to minimize energy consumption. Thus, to clearly indicate to the market that management of energy consumption is the primary goal of policy intervention in TVs, policymakers may wish to consider:

4. Further strengthening the energy efficiency requirements on large screen, higher energy-consuming TVs to make them relatively more stringent than, or at least as stringent as, those for the lower energy-consuming small screen TVs.
5. In the EEI algorithm, consider adopting the EU and US approach to incremental power allowances.

Finally, TVs on the Chinese market have recently introduced new, much extended functionality, e.g., internet connection/communication, fast wake-up, etc. Almost all these additional functions have an energy penalty that is not currently included in the EES regulations. In addition, 3D technology has already begun to take a substantive share of the Chinese TV market, yet the question of whether 3D TVs consume more energy than traditional 2D TVs has not been answered due to lack of a standardized test method. Therefore, policymakers may wish to consider:

6. Revising the EES to account for the energy used in some TVs for a range of standby states and additional functionality. The EU Eco-design and US ENERGY STAR requirements would serve as a good basis for the development of such additional regulatory requirements.
7. Initiating processes to develop a standardized test method for 3D TVs as soon as possible, and including it in the next revision of the EES. Current evidence *suggests* that 3D TVs have the potential to use substantially less energy than 2D equivalents.

Improve clarity and transparency of information on labeling

The goal of the China Energy Label for TVs is to give consumers the information they need to choose more efficient, lower energy-consuming TVs. However, the CLASP survey on consumer comprehension of the China Energy Label established that only 8.4% of Chinese consumers understand EEI, even to the very limited extent that they know that a higher EEI indicates a more efficient TV. Therefore, policymakers may consider:

8. To enhance consumers' ability to select lower energy-consuming-products at the time of purchase, replace the EEI value reported on the energy label with the daily/monthly/annual energy consumption of the TV (based on typical watching hours). This would enable consumers to directly compare the energy consumption of competing TV models, and may partly solve the problem caused by the fact that EETs for PDPs and LCDs are not based on the same EEI derivative.

Should this be impractical in the short term, at the very least policymakers should consider:

9. Replacing the EEI value reported on the TV Energy Label with the more understandable and useful (to consumers) value of power consumption for the TV.

Policy support for higher efficiency products

There appears to be very little relationship between the efficiency of TVs and the price charged in the Chinese market, with products of very different efficiencies retailing at similar prices. Other factors such as functionality and brand seem to be of much greater importance to the pricing strategy of manufacturers. Therefore, policymakers may wish to take this as an opportunity to:

10. Provide significant subsidy support to products with the very highest efficiencies (there are already a number of products in the market with EEI in excess of 2.5, and in some cases as high as 3.5). Such subsidy support should clearly differentiate these products from those of less efficient competitors, and thus encourage cost conscious consumers to preferentially select the more efficient products. In turn this should stimulate more manufacturers to produce premium efficiency products, which will allow policymakers the opportunity to further strengthen the EES in the future.

Revisions to the registration requirement to assist in future policy development and market surveillance

At present, manufacturers register their products based on derived EEI values. However, policymakers may wish to consider:

11. Revising the registration system for TVs to require the declaration of tested energy consumption values. This will allow policymakers to better understand the development of the TV market with respect to overall energy consumption rather than just efficiency, and will assist in market surveillance, as enforcement agencies will be able to directly compare market check-test results with actual declarations from manufacturers.
12. Requiring manufacturers to also declare all allowances and tolerances applied to test results, again enabling enhanced market surveillance activities.

Section 4: Analysis of the Market and Product Performance of Washing Machines

Washing machines are considered a necessity by most Chinese households. As income levels rise, particularly in rural areas, the total stock of installed washing machines continues to rise. Based on the limited data available from the China National Bureau of Statistics[73], it is estimated that approximately 351 million washing machines were installed across China by the end of 2012, with penetration levels of 98.0% 67.2% in urban and rural areas, respectively.

4.1 Product Background

There are three main types of washing machine on the Chinese market:

- Drum (front load) units;
- Impeller (top load) units; and
- Twin tubs (top loading units with two tubs, one for washing and one for spin drying).

Although currently accounting for approximately 10% of models available on the market (see Section A.5.3.1), the popularity of twin tub washing machines is rapidly waning. This is especially true in cities and towns due to the increasing availability of drum and impeller washing machines, which are both fashionable and have extended functionality. Therefore, this analysis refers only to drum and impeller units, unless otherwise stated.

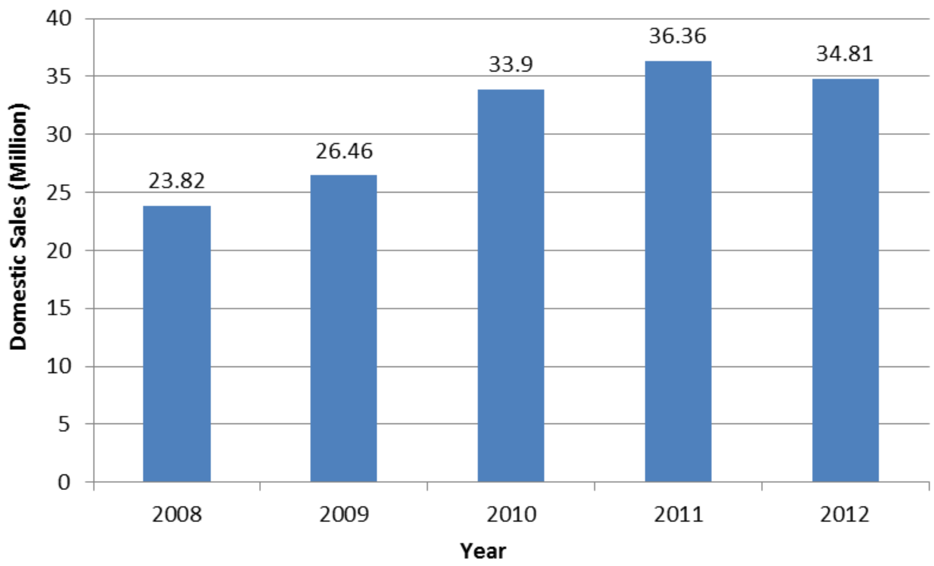
4.1.1 Production, sales, and stock level

As shown in Figure 47, annual sales of washing machines (all types) within China in 2012 were 34.8 million units, a slight fall of 4.0% from the preceding year. The estimated number of washing machines installed in Chinese households is 351 million, and this is projected to grow to 443 million by 2020[1]. This stock is expected to rise further to 484 million in 2030, and, under a business-as-usual scenario, washing machines are expected to consume approximately 17TWh of energy per year in 2030[74].

[73] www.stats.gov.cn

[74] Energy Saving Potential (ESP) Study for Nine Appliances in China, CLASP 2013.

Figure 47: Annual sales of washing machines in China (2008-2012)



** Data source: data for 2008 through 2011 from MACEEP 2013; data for 2012 from http://www.askci.com*

4.1.2 Usage patterns

Historically, washing machines in China were all impeller or twin tub types. Neither type had an integral heating function. However, it appears that consumers have become accustomed to using the cold wash so, although washing machines with heating functions are now available (i.e., almost all drum units and a small number of impeller unit have heating functionality), most users still prefer to wash clothes on a cold cycle. A CLASP study[75] shows that among the families owning drum washers, only 30% of them use the heating function to wash with warm/hot water, while all washes by impellers are done in unheated mains feed water.

The same CLASP study also investigated the volume for each wash. The result shows that only 11.6% washes used the full capacity of the washer. 42.3% washes were about three quarters full and 42.8% of half-loaded. For the remainder, only half or less of the full capacity was utilized.

The survey also found that about 30% of consumers do not unplug the washing machine or turn off the mains supply to the washer after washing tasks are completed. As washing machines have increasing levels of electronic control, this suggests that policymakers may wish to consider introducing regulations to manage the likely increasing standby power energy consumption of washing machines.

[75] Consumer Awareness and Comprehension of China Energy Label and Usage Pattern of Household Appliances, CLASP 2013

4.2 Regulation, Labeling and Energy Efficiency Standard

4.2.1 Energy Efficiency Standard

Requirements in the 2004 and 2013 versions of EES

The current version of the energy efficiency standard (EES) for washing machines is GB 12021.4-2013, which replaced the 2004 version. The 2013 EES became effective on 1 October 2013, but allows for a one year period for manufacturers to convert all declarations to the new requirements[76]. The EES inherits the same three performance indicators from the previous version for measurement and declaration of performance, i.e., energy efficiency, water efficiency, and wash quality. However, there are two main changes in the new version. These are:

- A change of test method, to measure the unit's energy efficiency, water efficiency, and wash quality under a half-load test condition;
- A change in stringency of different performance tiers (see Section 4.3.6).

Originally, in the 2004 performance calculations, all three performance indicators were based on full-load tests. However, the 2013 performance calculations also take into consideration half-load test condition. Further, the 2013 EES gives the half-load test a higher weighting factor for the energy and water efficiency calculations. This aligns with the usage study[75], which found that most washes are done under half load or three quarters of full load (See Section 4.1.2). The differences in the calculation of unit performance between the 2004 and 2013 EESs are summarized in Table 20.

Table 20: Summary of changes in calculation of performance indicators between the 2004 and 2013 Energy Efficiency Standards for washing machines

Performance indicator	Calculation in *current* (2013) version	Calculation in *previous* (2004) version
Energy efficiency	I.e.,*$(E_1+2E_2)/2m$	E/m;
Water efficiency	I_w*$(W_1+2W_2)/2m$	W/m
Wash quality	$(C_1+C_2)/2$	C

Where:

I.e.,: energy efficiency correction factor: 0.85 for drum washer and 0.75 for fully automatic impeller washer;
I_w: water efficiency correction factor: 0.7 for both types of washers;
E and E_1: total energy consumption during one full cycle of washing at full load, kWh/cycle;
E_2: total energy consumption during one full cycle of washing at half load, kWh/cycle;
m: capacity of washing machine, kg;
W and W_1: total water consumption during one full cycle of washing at full load, L/cycle;
W_2: total water consumption during one full cycle of washing at half load, L/cycle;
C and C_1: wash quality tested at full load condition;
C_2: wash quality tested at half load condition.

[76] www.energylabel.gov.cn

The performance requirements in the 2004 and 2013 EESs are shown in Table 21 through Table 24[77]. To qualify for a particular Energy Efficiency Tier (EET), a product must satisfy *all* the performance requirements for that specific Tier. For example, in the 2013 EES for drum washers, a product with energy efficiency of 0.150kWh/(cycle*kg), water efficiency of 8.5 L/(cycle*kg), and wash quality of 1.05 would qualify as a Tier 3 product, whereas a unit with similar performance but an energy efficiency rating of 0.155 would be Tier 4.

It should be noted that in each case the lower threshold of Tier 5 denotes the Minimum Energy Performance Requirement (MEPR), below which a product cannot be sold on the market.

Table 21: Performance requirements for impeller washing machines in 2004 Energy Efficiency Standard

EET	Energy efficiency kWh/(cycle*kg)	Water efficiency L/(cycle*kg)	Wash quality
1	≤0.012	≤20	≥0.90
2	≤0.017	≤24	≥0.80
3	≤0.022	≤28	
4	≤0.027	≤32	≥0.70
5/MEPR	≤0.032	≤36	

Table 22: Performance requirements for drum washing machines in 2004 Energy Efficiency Standard

EET	Energy efficiency kWh/(cycle*kg)	Water efficiency L/(cycle*kg)	Wash quality
1	≤0.19	≤12	≥1.03
2	≤0.23	≤14	≥0.94
3	≤0.27	≤16	
4	≤0.31	≤18	≥0.70
5/MEPR	≤0.35	≤20	

Table 23: Performance requirements for impeller washing machines in 2013 Energy Efficiency Standard

EET	Energy efficiency kWh/(cycle*kg)	Water efficiency L/(cycle*kg)	Wash quality
1	≤0.011	≤14	≥0.90
2	≤0.012	≤16	≥0.80
3	≤0.015	≤20	
4	≤0.017	≤24	
5/MEPR	≤0.022	≤28	

[77] Due to changes in the test method and derivation of performance parameters, and the non-comparability of drum and impeller performance declarations, neither Table 21 and Table 23 nor Table 22 and
Table 24 are integrated, to ensure no direct comparisons are inadvertently made by the reader. However, certain comparisons of performance between the 2004 and 2013 performance standards have been made in Section 4.3.6, showing the stringency of the 2013 EES has increased.

Table 24: Performance requirements for drum washing machines in 2013 Energy Efficiency Standard

EET	Energy efficiency kWh/(cycle*kg)	Water efficiency L/(cycle*kg)	Wash quality
1	≤0.110	≤7	≥1.03
2	≤0.130	≤8	
3	≤0.150	≤9	
4	≤0.170	≤10	
5/MEPR	≤0.190	≤12	

4.2.2 Test methods comparison between drum and impeller

The test method for both impeller and drum washing machines is GB/T 4288. This test method measures the same performance variables for both types of machines, including energy consumption/efficiency, water consumption/efficiency, and wash quality. However, the testing conditions for energy consumption/efficiency are very different for the two types of machine:

- Impeller washing machines are tested using water at 30 ± 2°C. Water is heated from ambient temperatures to the test temperature externally, and the energy used to heat the water is not regarded as part of the energy consumption for washing;
- Drum washing machines are tested using hot water, which is heated inside the washer, and therefore the energy for heating is regarded as part of the energy consumption, which actually forms the biggest part of the total energy consumption. Drum washing machines are fed by cold water at 15 ± 2°C and run at the default standard hot washing setting[78].

Clearly these different test methods create substantially differing results. The tested energy consumption of the impeller units comprises only the mechanical energy needed to agitate and spin the laundry, plus the energy used for water pumping. In contrast, the energy consumption of the drum machines includes the mechanical energy in addition to the energy to heat the water. Consequently, when such test results are reflected on energy labels, it may be misleading, as consumers would not know that the performance values were based on different testing conditions.

Therefore, it is recommended that policymakers:

- Introduce a technology-neutral test for both types of washers. This would allow consumers to truly compare declarations of energy consumption, water consumption, and wash quality between machines types. Such a direct comparability of test results would also allow policymakers to more accurately develop energy efficiency standards and projections of national energy consumption, as well as identify the "most efficient" products for labeling and other policy purposes such as subsidy support.

[78] The test condition for drum machines without heating function is different. However, given the very high proportion of drum machines that contain integrated heating elements, we refer to this type of drum machine all through the report, unless otherwise stated.

- Develop a hybrid test that combines differing washing temperatures for drum units based on the consumer usage patterns (see Section 4.1.2). There could be two separate tests for cold washes and warm washes that are both reflected on the same label (such an approach is adopted in other countries, such as Australia, albeit with the warm and cold washes on separate labels). This could help consumers of different washing patterns to better choose the products that best fit their needs.

- Examine the issue of standby power. As described in Section 4.1.2, a significant amount of users do not unplug washing machines after use. Therefore, it could be of importance to regulate standby power of washing machines.

4.2.3 Energy labeling of washing machines

Although the EES for washing machines came into effect in 2004, the China Energy Label for washing machines was not introduced until 2007, with a revision occurring in 2013 to coincide with the 2013 revision to the EES.

Figure 48 shows both the 2007 and 2013 versions of the energy labels for washing machines. Both labels have five Tiers aligning with the EETs defined in the EES. In addition to the colored bars indicating the specific energy efficiency Tier of the washing machine, the labels also include basic identification information on the model, energy consumption per washing cycle, water consumption per washing cycle, wash quality, and the (rated) capacity.

However, the 2013 label has been slightly re-designed to reflect the revision of the EES. The main change is that the new label includes information on accessing the official website of the China Energy Label (the bottom row in the white box), so that, if needed, consumers are able to immediately verify the authenticity of the label and the associated declarations (provided internet access is available). This is the first time that this kind of information has been included on a China Energy Label, and is designed to improve consumer confidence in the label.

Figure 48: China energy label for washing machines (2007 version and 2013 version)

2007 Version **2013 Version**

4.3 Data Analysis

Data analysis of washing machines was conducted to examine the energy performance and related properties as outlined in Table 30. Analysis was undertaken on a number of performance and other parameters. However, because not all models have all types of data (e.g., price, type of motor, etc.), not all models were included in all analyses. When this is the case, a note is included indicating the specific sample size. It has not been possible to evaluate the degree of skew this may have introduced to the analysis.

The majority of data collection for this analysis was undertaken between the end of September 2013 and the beginning of October 2013, when the 2013 version of EES had just been implemented. As noted above, the regulation allows a one-year transition period for manufacturers to fully transfer to the new EES after the date of implementation[79]. Thus, for the majority of the analysis, it is assumed that the market had yet to be affected by the new EES and that ***the majority of the analysis in this report is based on comparisons against the previous version of the EES (GB 12021.4-2004), unless otherwise noted.*** Where applicable, the analysis also makes comparison with the research results from the similar MACEEP analysis from 2013[80]. However, for more detailed information on the MACEEP 2013 analysis results, readers are recommended to refer to that report directly.

A second round of data collection was undertaken in March 2014 to try to establish the impact of the new EES on models that were registered under the new system. The sections reporting on this smaller analysis are clearly identified in the text.

Table 25: Overview of the data used for the analysis of washing machines (data collected October 2013)

Data type	Note
Number of models	Totally 1381, breaking down to: Drum type: 500 Impeller type: 760 Twin Tub type: 121
Rated wash capacity (Kg)	Range: Drum type: 3-13 Impeller type: 2-13
Energy efficiency Tier	Range: Drum type: 1-2 Impeller type: 1-5
Energy efficiency (kWh/cycle/Kg)	Range: Drum type: 0.111-0.190 Impeller type: 0.011-0.029
Water efficiency (L/cycle/Kg)	Range: Drum type: 6.4-12 Impeller type: 12-32
Price (RMB)	Range: Drum type: 999-18800

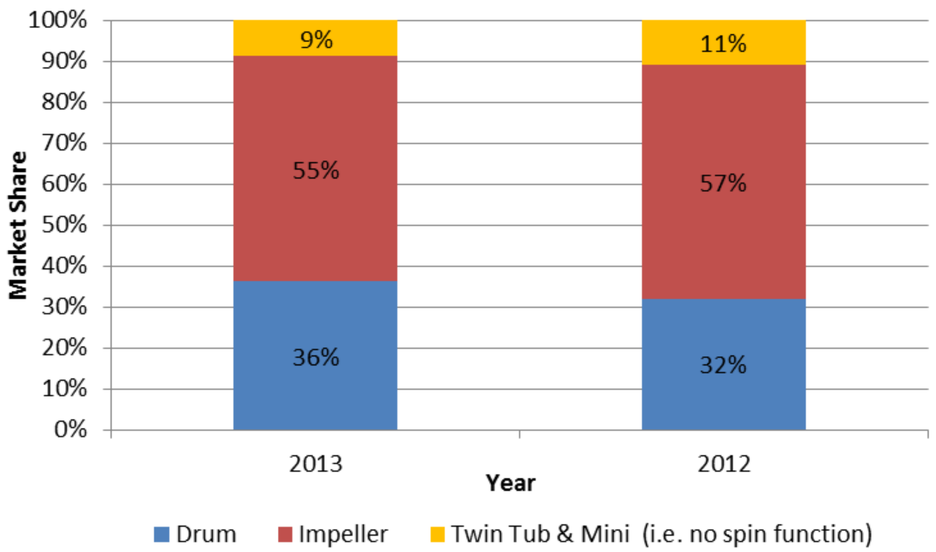
[79] Notice from the National Development and Reform Commission (NDRC), the Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) and the Standardization Administration of China (SAC), No. 34, 2013.
[80] CLASP 2013: Market Analysis of China Energy Efficient Products, 2013

	Impeller type: 587-6510

4.3.1 Market distribution by washing machine type

Impeller washing machines have traditionally dominated the Chinese market. As Figure 49 illustrates, impeller units still accounted for 55% of the market in 2013, although this represents of decline of 2% from 2012. Twin tub units are gradually being removed from the market altogether, with their market share dropping to 9% in 2013, also a decline of 2% from the year before. In contrast, the market share of drum washing machines has increased to 36%, absorbing the losses from both impeller and twin tub machines. This indicates that the Chinese clothes washer market is gradually transitioning towards drum machines, although at a relatively slow rate.

Figure 49: Market share of washing machines by product type (2012 and 2013)



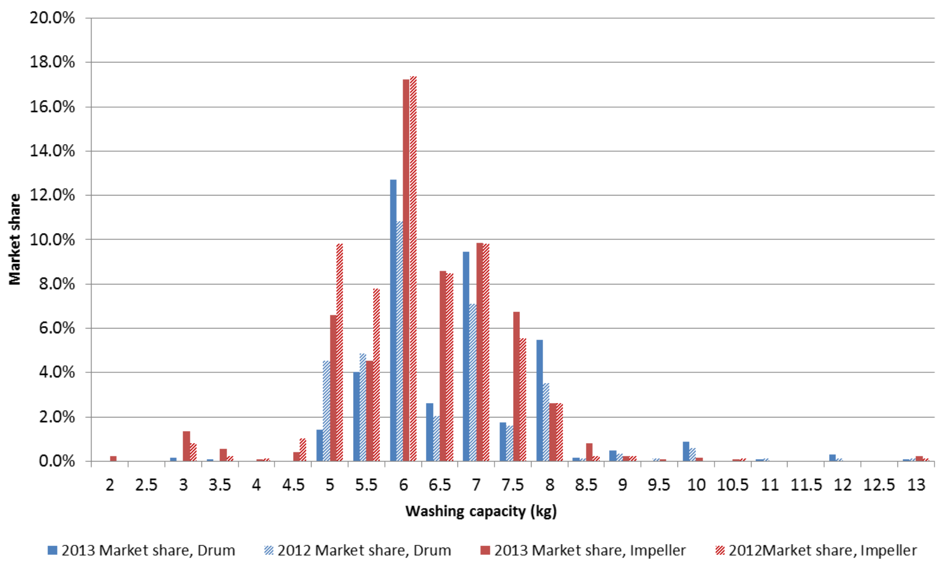
4.3.2 Market distribution by washing machine rated wash capacity

As shown in Figure 50, drum and impeller washing machines have similar rated wash capacity distributions, with the vast majority of both product types falling in the 5 to 8 kilogram range, with 6 kilograms being the most popular.

What differs from 2012 is that:

- A very limited number of drum washers has started to appear with capacities smaller than 5kg, although the total number of models of all types with capacities below 5Kg remains very small;
- There has been a major shift in the market from capacities of 5kg and 5.5kg towards the bigger 7kg and 8kg capacities.

Figure 50: Impeller and drum washing machine rated capacity distribution (2012 and 2013)



4.3.3 Relationship between wash capacity, energy and water efficiency, and wash quality

As noted in the previous section, there are a very limited number of models in the capacity ranges below 5kg and above 8kg. Therefore, the analyses in this section of the relationship between key performance parameters focus only on models in the 5kg to 8kg range, which is a popular size range in China and offers a large number of units of both drum and impeller type models for analysis[81].

Wash capacity and efficiency

The average energy efficiency of drum and impeller washing machines across the range of wash capacities is shown in Figure 51 and Figure 52. Drums and impellers are presented in separate graphs because the efficiencies of these two types of machines are derived differently and are not directly comparable. Also, please note that the scales of energy efficiency of these two types differ by a factor of 10.

The two figures show that:

- For both drum and impeller washing machines, average energy efficiency has improved across all washing capacities from 2012 to 2013, with only two minor exceptions in 5kg drum and 5.5kg impeller machines;
- The most efficient models for drum machines appear in capacities of 6.5kg and 7kg, while for impellers greater efficiency is attained with bigger capacities,.

[81] Hence the resulting sample size for the analysis in this section is 1224 (497 drum and 727 impeller models).

Figure 51: Average energy efficiency of drum washing machines by capacity (2012 and 2013)

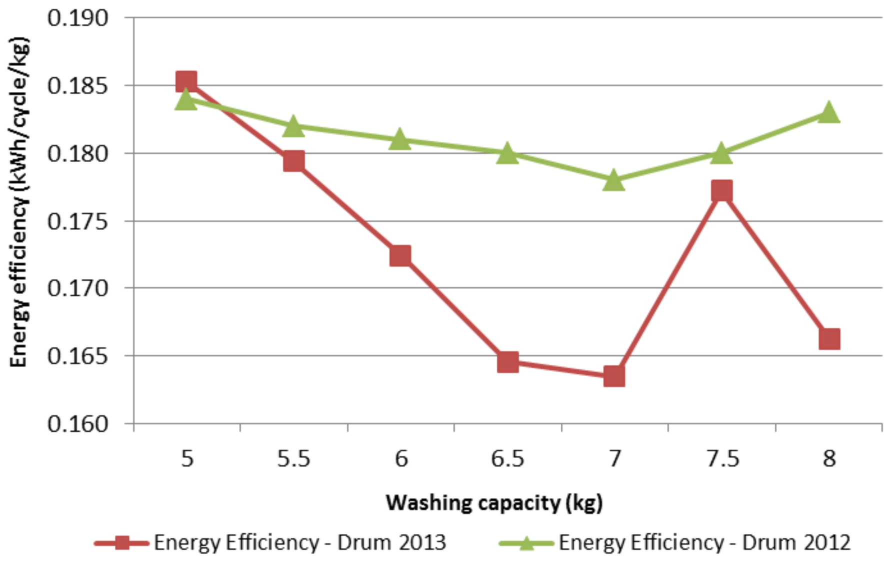
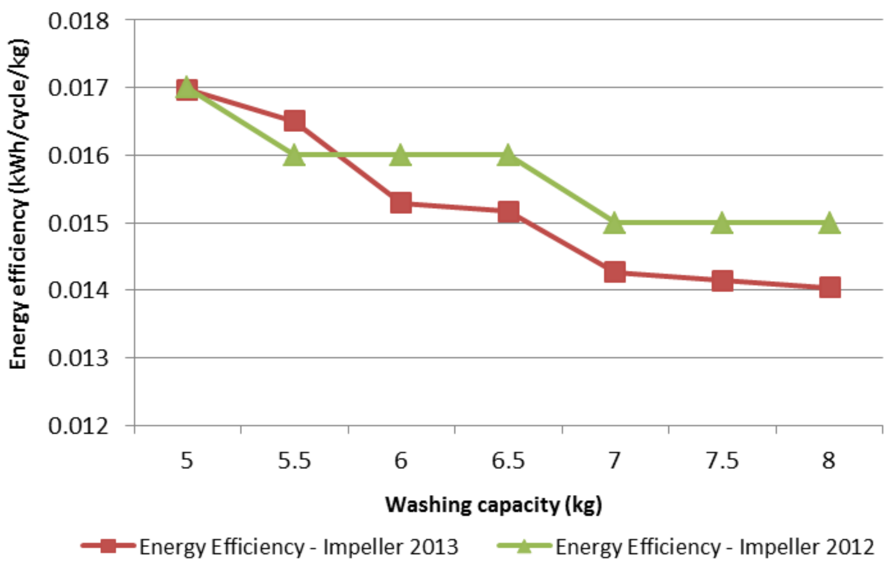


Figure 52: Average energy efficiency of impeller washing machines by capacity (2012 and 2013)



The average water efficiency of both impeller and drum washing machines across wash capacity is shown in Figure 53. Impeller machines show an improvement in water efficiency as wash capacities increase (although total water consumption increases with capacity). For drum washing machines, there is no observable change in average water efficiency with the wash capacity of the unit. For both machine types, there is a small improvement in water efficiency between 2012 and 2013 for most volumes.

Figure 53: Average water efficiency of impeller and drum washing machines by capacity (2012 and 2013)

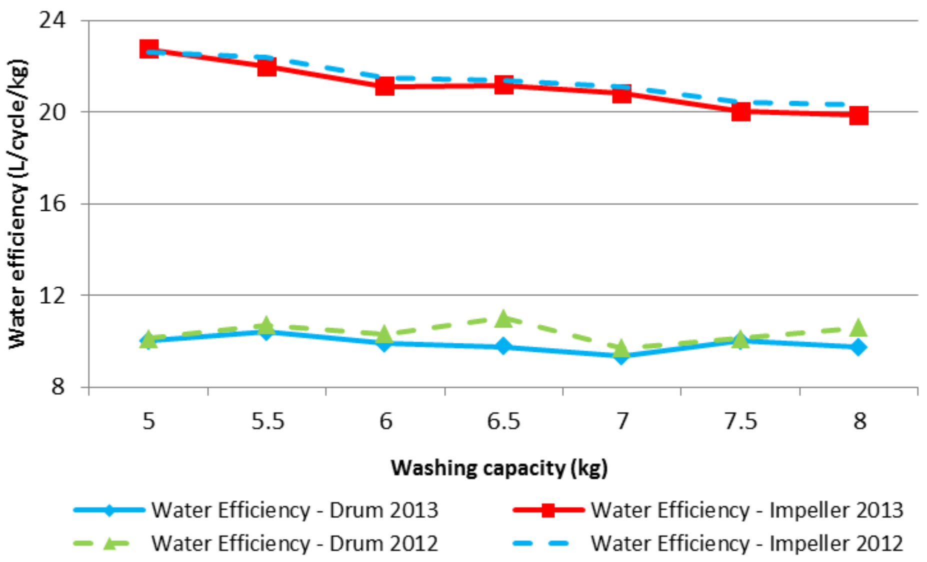
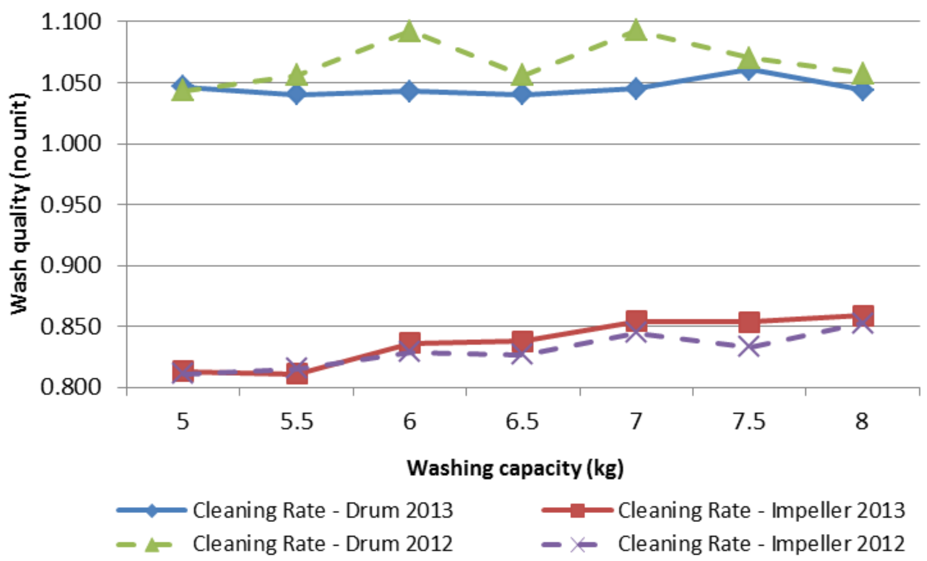


Figure 54 shows the average wash quality of the two types of washers across wash capacity. Impeller machines demonstrate increasing average wash quality as capacity increases, while for drum machines the average wash quality is somewhat variable over capacity range (albeit less so in 2013). While the average wash quality of impeller washing machines increases noticeably at most capacities from 2012 to 2013, drum washing machines experience falls in wash quality, especially in the 6kg and 7.5kg range. This may be linked to the improvement in energy and water efficiency, i.e., the reduced energy and water consumption has resulted in slight reductions in wash quality. However, overall, the wash quality of drum machines is significantly better than that of impellers at all capacity ranges.

Figure 54: Average wash quality of impeller and drum washing machines by capacity (2012 and 2013)



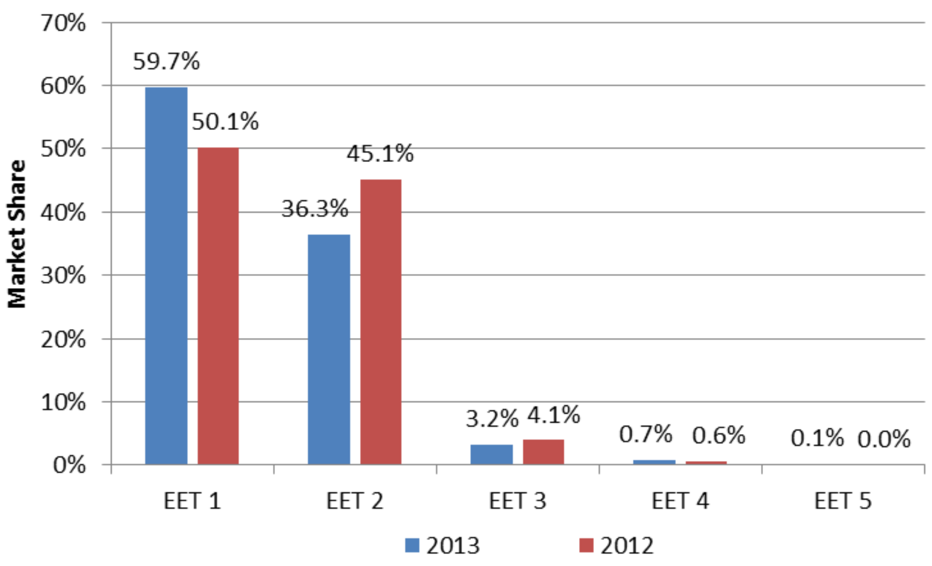
As demonstrated in Figure 51 through Figure 54 collectively, it is clear that impeller washing machines become more efficient in all aspects (energy, water use, and wash quality) when wash capacity increases. Therefore, in order to minimize energy consumption and maximize the service received by the consumer, when next revising the EES for impeller washing machines, policymakers may wish to consider setting tiered energy, water, and washing quality requirements based on unit capacity.

4.3.4 Distribution of washing machines by performance tiers

The washing machine EES contains five performance Tiers. As shown in Figure 55, Tier 1 and Tier 2 products accounted for 96% of market share in 2013, while there were almost no Tier 4 and 5 products available.

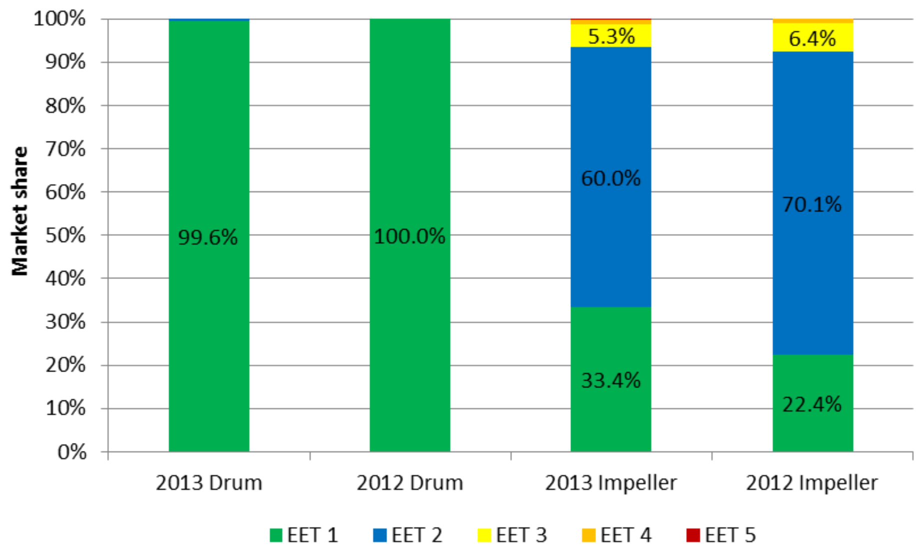
In comparison to 2012, the market share of Tier 1 product increased by 9% in 2013, mainly through model migration from Tier 2. The percentage of the market in the other three performance Tiers stayed relatively stable, albeit at very low proportions of the overall market.

Figure 55: Distribution of washing machine of all product types by energy efficiency Tier (2012 and 2013)



However, when breaking the market down by product type (Figure 56), it is clear that in 2013 almost all drum machines were Tier 1. This market share actually dropped from 100% in 2012 to 99.6% because two Tier 2 machines appeared on the market in 2013. 93% of impeller machines in 2013 were energy efficient products (Tier 1 and Tier 2), with Tier 1 products increasing from 22.4% to 33.4% of the market, mainly at the expense of Tier 2. Tier 2 products made up 60.0% of the market in 2013, down from 70.1% in 2012. Note that performance Tiers with market share of less than 2% are not presented with a data label.

Figure 56: Distribution of washing machine energy efficiency Tiers by product type (2012 and 2013)



Energy efficiency and water efficiency distribution of individual models on the market

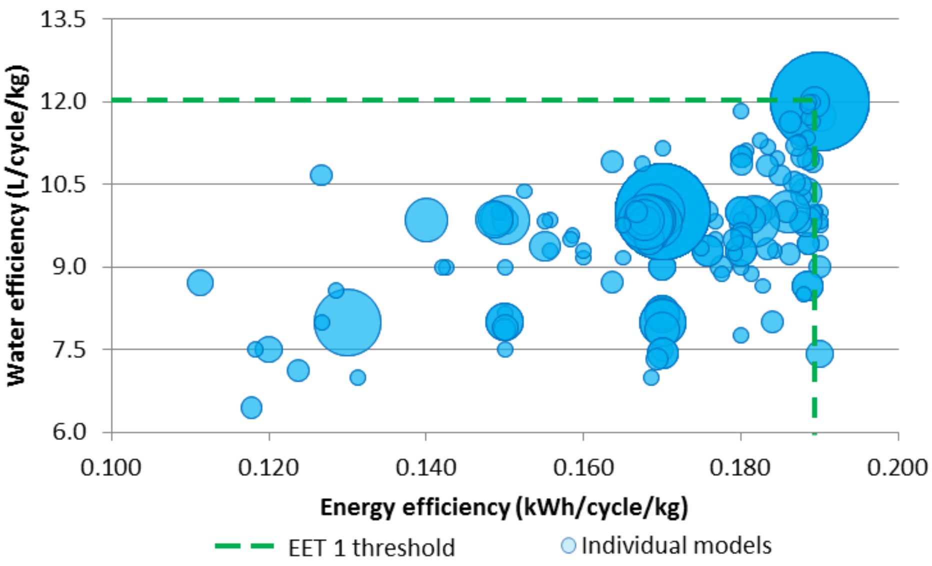
This sub-section presents the energy efficiency and water efficiency distribution of individual models on the market for drum washers (Figure 57) and impeller washers (Figure 58). As shown in Table 21 and Table 23, there are three parameters determining which performance tier a washing machine fits in. However, as the two figures in this sub-section are flat 2-dimensional graphs, one of the parameters has to be excluded. Wash ability (cleaning rate) is chosen to be the parameter excluded, because it has minimal impact on performance tier determination. For example, in almost all cases in 2013, if both energy efficiency and water efficiency of a model met Tier 1 requirements, wash ability also met the Tier 1 requirement[82].

Drum machine models

Although nearly all drum models were Tier 1, there was significant variation in energy and water efficiency, as shown in Figure 57. The most efficient models consumed about 30%-40% less energy and water than the least efficient models. This wide-spread distribution provides a sound foundation for resetting the EET boundary levels to give a spread of products across the efficiency Tiers, thus allowing consumers to more easily select the more efficient models. From the analysis of products registered under the 2013 EES in section 4.3.6, it appears that policymakers have partially achieved this goal.

[82] There are several exceptions though: two models out of 500 for drum machines and four out of 760 for impeller machines. These six models are NOT included in Figure 57 and Figure 58.

Figure 57: Energy efficiency and water efficiency distribution of individual drum models (data collected October 2013)



**Each "bubble" represents one or more models of a specific combination of energy efficiency and water efficiency. The size of the bubble reflects the number of models overlapping on that specific combination. The smallest bubble represents 1 model and the biggest 42.*

Impeller machine models

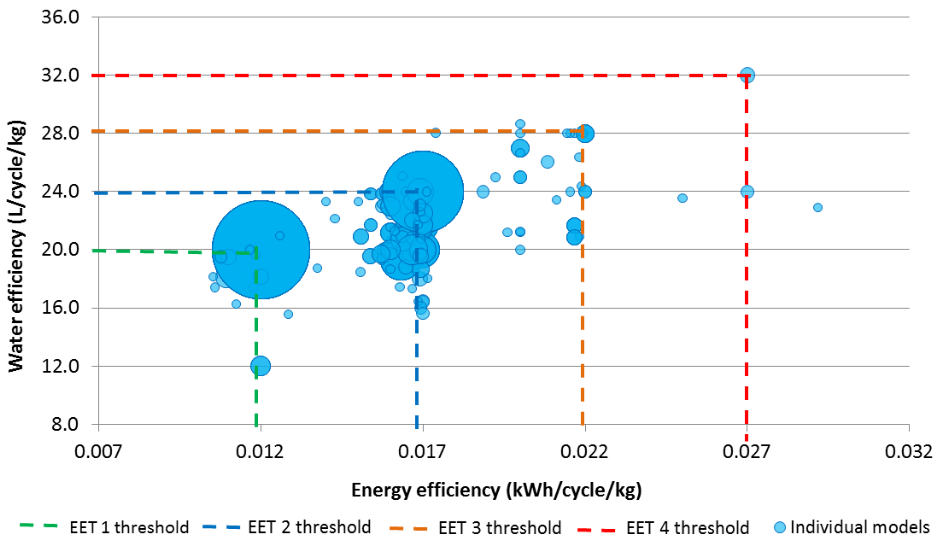
Figure 58 presents a different picture from Figure 57. Unlike drum machines, nearly all of which fell *within* Tier 1, impeller models were dispersed across all five performance Tiers in 2013 (although primarily concentrated in Tier 1 and 2). However, it is clear the majority of models have declared performance right at the threshold of Tier requirements. This phenomenon was noted in the 2013 MACEEP report and implies that either:

- Manufacturers have very accurate control of the design and production of washing machines, and can deliver products that are just at the boundary conditions. If this is the case, any tolerances allowed for MEPR and labeling compliance are not required and can be removed (although test laboratory tolerances will still be required).
- Manufacturers are over-reporting the performance of products (e.g., declaring the lowest value of the EET tier above that which their products qualify, either to appear more efficient on the label and/or to qualify for subsidy support). This may be a perfectly legitimate action if the tolerances of the declarations are sufficiently high, but again this implies that the tolerances for labeling declarations should be removed.
- Manufacturers are under-reporting the performance of products (e.g., declaring the lowest value within the EET tier to which their products qualify, to ensure their products pass any verification testing undertaken by the regulator). On one level there is no problem with this situation, as manufacturers are acting cautiously and protecting their reputations, while delivering products to the consumer that perform *better* than stated. However, from the policymaker point of view this situation is problematic, as

knowledge of the true performance of products is important when developing future EES and subsidy requirements, as well as when analyzing the potential impact of differing threshold levels.

At present there is no evidence to suggest which of the hypotheticals above may be causing so many performance declarations to fall just above EET threshold levels, and there is certainly no evidence of manufacturer malpractice. However, there is sufficient evidence to recommend insistence by policymakers that claims made on product registration and labeling *must* align with actual testing reports that are submitted to support the applications, and that these test reports must be from a unit with representative performance. Once declarations are accurate, further research can then be undertaken to establish whether tolerances (other than those required by test laboratories) may be tightened.

Figure 58: Energy efficiency and water efficiency distribution of individual impeller models (data collected October 2013)



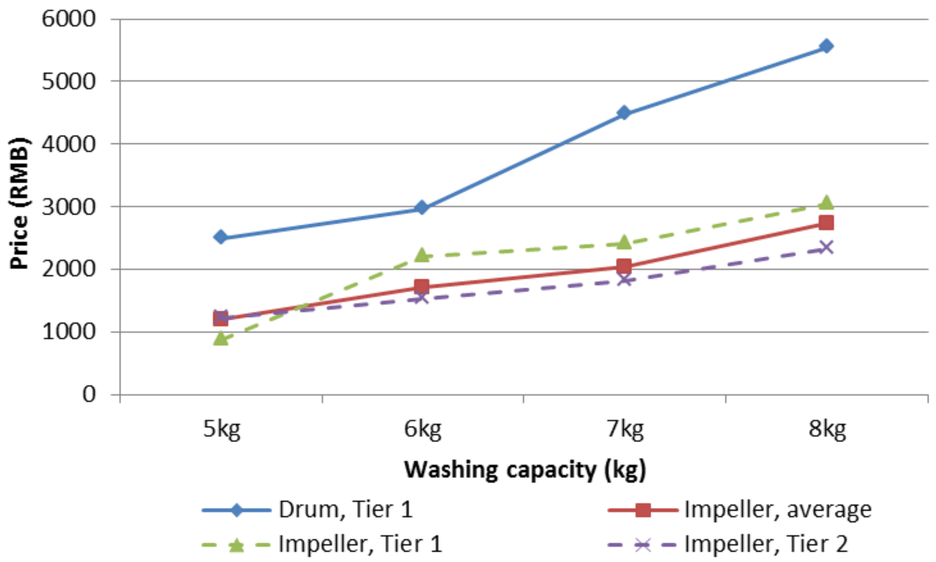
** Each "bubble" represents one or more models of a specific combination of energy efficiency and water efficiency. The size of the bubble reflects the number of models overlapping on that specific combination. The smallest bubble represents 1 model and the biggest 123.*

4.3.5 Relationships of price to product type, wash capacity and EETs

The type of product (drum or impeller) has a significant impact on price. As Figure 59 illustrates, on average drum machines are approximately twice as expensive as impeller machines of equivalent wash capacity. Within a product type, there is a close relationship between average price and wash capacity.

It is not possible to evaluate the relationship between price and the current performance Tiers for drum units, as effectively all models are Tier 1. For impeller washing machines, the price increases with higher performance Tiers, except for 5kg units (although the number of Tier 1 models is small, so this finding may not be representative of a general condition).

Figure 59: Average drum and impeller washing machine price across wash capacities (data collected October 2013)



**Washing capacity of 5kg means 4kg to 5kg. Same for other wash capacities.*

4.3.6 Impact of the new EES

In order to gain some insight into the market impact of the 2013 version of the washing machine EES, registration data[83] was collected on washing machines in March 2014 (i.e., five months after the 2013 EES came into effect). Data sourced for use in the analysis is summarized in

Table 10.

Table 26: Registration data of washing machines per 2013 version of EES after five months since implementation (data collected March 2014)

Data type	Note
Total number of models	Totally 2137, breaking down to: Drum type: 753 Impeller type: 1384
Performance Tier	Range: Drum type: 1-5 Impeller type: 1-5
Number of models registered both to	Totally 524, breaking down to:

[83] www.energylabel.gov.cn

old and new version of EES	Drum type: 229 Impeller type: 295

This analysis seeks to establish:

- By changing the metric for efficiency for washing machines, what the distribution of washing machines within the energy efficiency Tiers would potentially look like with the new EES.
- What the likely market distribution will be of product performance under the 2013 EES Tiers.

Stringency improvement

As stated in Section 4.2.2, the performance test method changed in the 2013 EES, and therefore the performance requirements of the 2013 EES are not directly comparable with those from the 2004 EES. However, as there are a number of models on the market which were originally registered under the 2004 EES, and have been tested and re-registered under the 2013 EES, this provides the opportunity to compare the two performance requirements. **However, it should be recognized that this sample of products registered under both the 2004 and 2013 EES is self-selecting, i.e., only models that manufacturers have chosen to re-register are included. This is likely to bias the sample (for example, only models performing well under the 2013 EES may have been re-registered. However, the degree of bias introduced by this self-selection is unknown.**

Of the 229 drum washers registered under both the old and new EES, all were Tier 1 under the 2004 EES, and 113 of them remain Tier 1 under the 2013 EES. The rest are distributed among Tier 2 through Tier 4, as shown in Figure 60. Of the 295 impeller machines registered to both the old and new EES, the changes to their performance Tiers under new EES are shown in Figure 61.

It is clear from these two Figures that the stringency of the performance Tiers has been strengthened, as a high proportion of models have experienced a fall in performance Tiers, i.e., many models that were originally Tier 1 are now Tier 2, Tier 3, or even Tier 4. However, the precise correlation (or quantitative improvement) of stringency between the two versions cannot be derived[84].

[84] One interesting observation from Figure 61 is that there is one model that was originally classified as Tier 3 per the old standard, but upgraded to Tier 2 under the new standard. This could be because of the under-declaration of product performance. For example, if this model performed the best in Tier 3, and thus was very close to Tier 2 but was only declared at the lower threshold, it may be able to jump to Tier 2 under the new EES.

Figure 60: Stringency comparison between 2004 and 2013 versions of EES for drum washing machines (data collected March 2014)

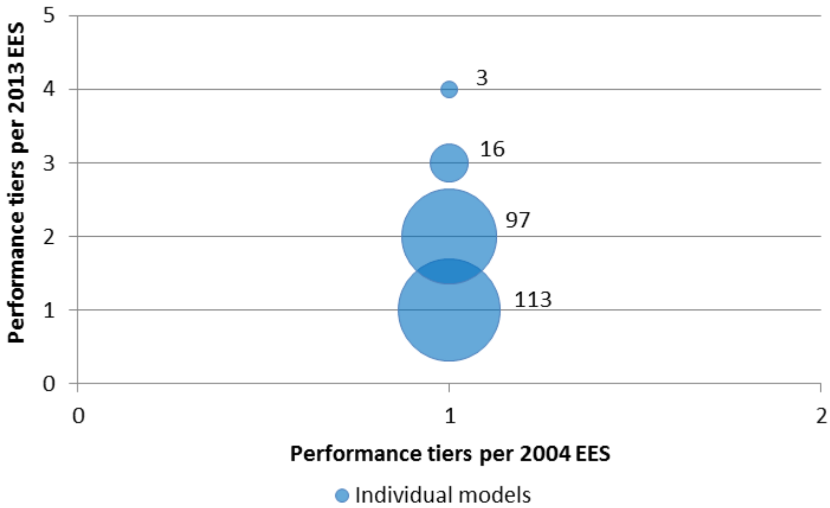
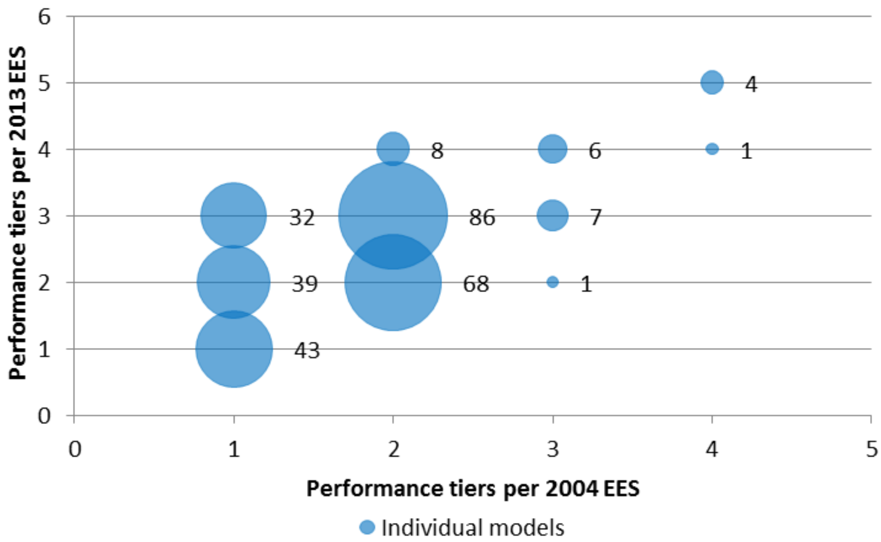


Figure 61: Stringency comparison between 2004 and 2013 versions of EES for impeller washing machines (data collected March 2014)



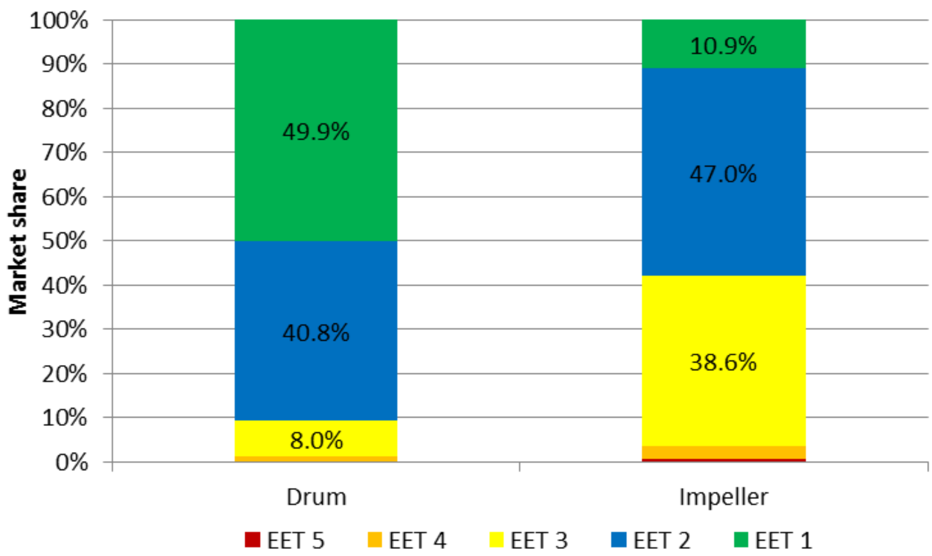
Potential new distribution of performance tiers of the market

The distribution of performance Tiers of *all* models registered under the 2013 EES is shown in Figure 62. Although not all models are necessarily available on the market, it is assumed that these models could reflect the likely performance Tiers distribution of models in the market.

In comparison with the 2013 market, the share of Tier 1 drum machines dropped significantly in 2014, from 99.6% to 49.9%. Impellers machines also experienced a sharp drop: Tier 1 impeller products dropped by 22.5%, Tier 2 by 13%, and in total the "efficient group" dropped by about 35%.

Nevertheless, the new EES may still be considered insufficiently stringent, according to the principle raised last year[85] that market share of Tier 1 and Tier 2 (which are together regarded as efficient products) should not exceed 15% by the time the new EES is implemented. Although the data was collected five months after the implementation of the new EES, already 90% of drum washers and 58% of impellers are qualified as either Tier 1 or Tier 2 products. This current distribution implies that in a short time the washing machine market will again be occupied by only "efficient" or even Tier 1 products, and at that time policymakers would need to initiate another round of EES revision. This situation could be avoided if future revisions of the washing machine EES focus on models currently available and aim to reduce the Tier 1 and Tier 2 products to levels significantly below 15% market penetration levels.

Figure 62: Distribution of performance tiers of drum and impeller washing machine models registered per new version of EES (data collected March 2014)



4.4 Conclusions and Recommendations

The conclusions and recommendations drawn from this analysis of the Chinese washing machine market are as follows:

Develop technology-neutral test method and account for true user behavior

The current test conditions for energy consumption/efficiency for drum and impeller washing machines are very different. Consequently, when such test results are reflected on the energy label, it may be misleading to consumers, as they would not know that performance values were based on different testing conditions. Further, consumer research conducted by CLASP established that consumers have a very varied pattern of usage including:

- Variations in the overall size of the load washed (which has been taken into account by the full load/part-load requirements of the 2013 EES);

[85] Market Analysis of China Energy Efficient Products, 2013.

- Only 30% of users of drum washing machines use the unit's water heating function, with the remainder continuing to wash in cold water. This makes the requirement that all drum machines be tested on "hot wash" somewhat misleading for consumers in terms of reported energy consumption, and makes predicting overall energy consumption challenging for policymakers.
- Approximately 30% of users do not unplug their washing machines from the electricity supply between uses. As washing machines have increasing levels of electronic control, which use power even when the machine is not washing, a significant power use is not currently accounted for under the regulations.

Therefore, policymakers may wish to consider:

1. Introducing a technology-neutral test for both types of washers. This would allow consumers to truly compare declarations of energy consumption, water consumption, and wash quality between machines. Such a direct comparability of test results would also allow policymakers to more accurately develop energy efficiency standards and projections of national energy consumption, as well as identify the "most efficient" products for labeling and other policy purposes, such as subsidy support.
2. Develop a hybrid test, combining differing washing temperatures for drum units based on the consumer usage patterns. Consequently, there could be two separate tests, and the results reflected on the same label for cold washes and warm washes (such an approach is adopted in other countries, e.g., Australia). This could help consumers of different washing patterns to better choose the products that best fit their needs.
3. Examine the issue of standby power and possibly include it in the algorithm for total washing machine energy consumption.

Performance requirements in the 2013 version energy efficiency standard and associated market distribution

The performance test method changed in the 2013 EES, and therefore the performance requirements of the 2013 EES are not directly comparable with those in the 2004 EES. However, analysis of a number of models on the market that were originally registered under the 2004 EES, and which have been tested and reregistered under the 2013 EES, indicates that the stringency of the performance Tiers has been strengthened, as a high proportion of models have experienced a fall in performance Tiers, i.e., many models that were originally Tier 1 are now Tier 2, Tier 3, or even Tier 4. For this, policymakers should be applauded.

However, when looking at *all* products registered since the introduction of the 2013 EES, within 5 months already 90% of drum washers and 58% of impellers have qualified as either Tier 1 or Tier 2 products. This current distribution implies that, in a short time, the washing machine market will again be occupied by only "efficient" or even Tier 1 products, and policymakers would need to initiate another round of EES revision. Policymakers could avoid this situation if:

4. Future revisions of EES focus on models currently available, and aim to reduce the Tier 1 and 2 products to levels significantly below 15% market penetration levels.

Potential revision of EES performance and registration requirements

Impeller washing machines become more efficient in all aspects (energy, water use, and wash quality) when wash capacity increases. Therefore, in order to minimize energy consumption and maximize the service received by the consumer, policymakers may wish to consider:

5. When next revising the EES for impeller washing machines, establish tiered energy, water, and washing quality requirements based on unit capacity.

Further, analysis of the impeller washing machine performance declarations indicates that the vast majority of models have performance declarations that sit very close to the EES Tier thresholds. This indicates that:

- Manufacturers have very accurate control of the design and production of washing machines, and can thus deliver products that are just at the boundary conditions; or
- Manufacturers are over-reporting the performance of products, e.g., declaring the lowest value of the EET Tier above that which their products qualify, either to appear more efficient on the label and/or to qualify for subsidy support; or
- Manufacturers are under-reporting the performance of products, e.g., declaring the lowest value within the EET Tier to which their products qualify, to ensure that their products pass any verification testing undertaken by the regulator.

At present there is no evidence to suggest which of the above reasons may be causing performance declarations to fall just above EET threshold levels, and there is certainly no evidence of manufacturer malpractice. However, there is sufficient evidence to recommend that policymakers:

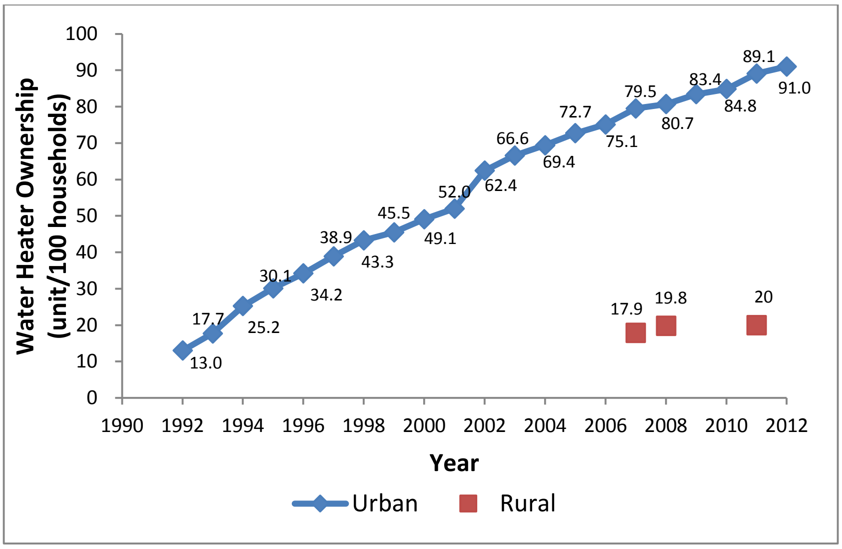
6. Insist that claims made on product registration and labeling must align with actual testing reports that are submitted to support the applications, and these test reports must be from a unit with representative performance. This will ensure fair reporting of product performance to consumers, and provide policymakers with higher quality information for future regulatory purposes.

Section 5: Introduction to the Analysis of Water Heaters

Water heaters are both a very popular appliance in many Chinese households and a significant energy consumer. They are used for general domestic hot water duties, e.g., dish washing, showering, etc., although not generally clothes washing, which is typically performed with cold water.

Due to increasing incomes and generally improving living standards in urban areas, water heaters are more commonplace in urban China. The urban ownership of water heaters has been increasing steadily for the past decades, from 13.0 units/100 households in 1992 to 91.0 units/100 households in 2012 (Figure 63). Ownership of water heaters in rural areas is much lower, reaching only 20 units/100 households in 2011. However, as urbanization accelerates and personal income increases, the total ownership of water heaters in China is very likely to also increase in the near future, especially in rural areas.

Figure 63: Urban and rural water heater ownership in China (1992-2012)[86]



There are four major types of water heaters for domestic use in China:

- Electrical storage water heaters;
- Gas instantaneous water heaters;
- Solar water heaters;

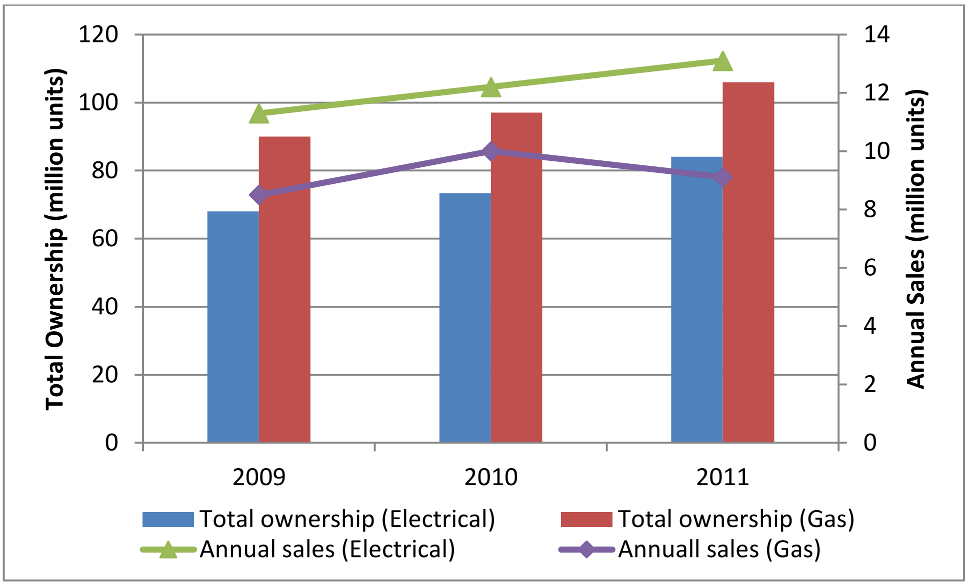
[86] Data source: National Bureau of Statistics of China (for all urban ownership data); http://www.china.com.cn/aboutchina/data/ncjj/2008-12/12/content_16940684.htm (Rural ownership data for 2007, date accessed March 18, 2014); http://www.china.com.cn/economic/txt/2009-05/05/content_17724319.htm (Rural ownership data for 2008, date accessed March 18, 2014); http://news.51xiaoguo.com/viewnews-115918.html (Rural ownership data for 2011, date accessed March 18, 2014).

- Heat pump water heaters.

5.1 Electrical and Gas Water Heaters

Electrical storage water heaters and gas instantaneous water heaters are the most popular water heaters on the Chinese market, together accounting for approximately 2/3 of all water heaters installed in the country[87]. Gas water heaters have higher levels of ownership, but in recent years they have seen lower annual sales than electrical water heaters (Figure 64).

Figure 64: Ownership and annual sales for electrical and gas water heaters (2009-2011)[88]



While direct comparisons of efficiency are challenging due to the differences in operational modality and test methods, from a primary energy perspective, gas instantaneous water heaters are usually more efficient than electrical storage water heaters. There are no electrical distribution losses with gas instantaneous water heaters, and no energy is required to repeatedly reheat the water to offset energy lost while the water is stored. However, gas instantaneous units typically cost 1.5 to 2 times more than electrical storage water heaters (refer to section A.5.3.6)

5.1.1 Electrical storage water heaters

Electric water heaters are typically storage rather than instantaneous heaters. They are cylindrical in shape and work on the principle of Joule (resistance) heating, which converts electrical energy into heat energy. Stored water is preheated by the heating elements in the water heater, with the temperature controlled and maintained by way of an electrical, electronic, or mechanically controlled thermostat.

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[87] Qin, Li. (2012). *Gas water heaters: market cooling while industry returns to rational upgrade*. Appliance. June issue. [In Chinese]. Estimate of types of installed water heaters in article attributed to Mr. Tang Jianrong, the president of Bosch and Siemens Home Appliances Group China.

[88] Data source: *White paper for the energy efficiency status of China energy-use products (2010)(2011)(2012)*, by China National Institute of Standardization.

Electrical storage water heaters are normally installed in bathrooms (Figure 65) and provide hot water for the entire household.

The capacities of the electric storage water heaters range from 10L to 100L, but 40L to 60L are most common. Only a very limited number of manufacturers are capable of producing electrical water heaters with capacities over 100L.

Figure 65: Example of electrical storage water heater installation[89]

Small models with rated volumes less than 10L are unable to provide a continuous hot water supply for a long period of time, but are sufficient for intermittent hot water use. They are often installed in the kitchen to provide hot water for dishwashing, cooking, and cleaning (Figure 66).

Figure 66: Example of small electrical storage water heater installation[90]

[89] Picture adapted from internet. http://img1n.soufun.com/homebbs/2010_05/11/taiyuan/1273510444017_000.jpg [Date accessed: Nov. 18th, 2013].

[90] Picture adapted from internet. http://img2.qeeka.com/attachments/month_0912/09122122250a009d76348a1cb2.jpg [Date accessed: Nov. 18th, 2013].

5.1.2 Gas instantaneous water heaters

There are two types of gas water heater, combination (combi) and instantaneous water heating only units. The combi-water heaters supply heat to both a central heating system and to heat water for domestic use, while the water heater only units simply heat water for domestic use. Due to the apparent low market prevalence of combi units, and challenges in accessing data on the types and volumes of such combis currently available, this report focuses primarily on instantaneous water heater only units.

Gas instantaneous water heaters use natural gas or liquefied natural gas to heat water as it flows continuously through the device; the water heater itself does not store any hot water. A hydraulically-controlled ignition device is triggered when the faucet is opened, and the water heater starts heating.

Typically gas instantaneous water heaters are installed in the kitchen, where easier installation of the exhaust duct makes them safer to use (Figure 67).

The hot water output capacities of domestic gas instantaneous water heaters normally range from 6L/minute to 20L/minute.

Figure 67: Example of gas instantaneous water heater installation[91]

5.2 Solar Water Heaters

Solar water heaters entered the Chinese market much later than electrical and gas water heaters, but they quickly gained popularity and now have a stable share of the water heater market. However, 90% of the total sales of solar water heaters are in rural areas[92] because:

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[91] Picture adapted from internet. http://img2.jc001.cn/img/508/1154508/1225205022624.jpg [Date accessed: Dec. 26th, 2013].

[92] Mao, Junting. (2013). *Difficulties in market transformation of solar water heaters: urban sales account for only 10%*. http://jd.zol.com.cn/349/3493014.html. Estimate of types of the proportion of

1) The government's "Appliance to rural areas" program began in 2009, which subsidized household appliance purchases in rural areas. As one of the 9 subsidized products, solar water heaters benefited greatly from a 13% subsidy, and rapidly gained significant popularity in rural areas[93].
2) Compared to electrical and gas water heaters, the operational costs for solar water heaters are minimal, as they do not use, or use very little, other energy sources such as gas or electricity. The unavailability of natural gas supply in rural areas contributed to the increase in popularity of solar water heaters in rural settings.
3) It is more difficult for urban families, who live in apartment buildings, to install individual solar water heaters on rooftops (see Figure 68).

Solar water heaters convert solar energy to thermal energy to raise the water temperature. A solar water heater typically consists of solar thermal collectors, which heat the water by absorption of solar energy, connected to a horizontally mounted storage tank where the hot water is stored; a single frame supports both the solar collectors and storage tank (Figure 68).

There are two primary types of solar collectors: evacuated tube and flat plate. Solar water heaters with evacuated tube collectors are the dominant model in the Chinese market, with over 95% of the market share[94]. The number of evacuated tube collectors used in a solar water heater is often used as a proxy for that unit's hot water capacity. Units on the Chinese market typically have 14 to 36 evacuated tube collectors, corresponding to 140L to 360L of hot water storage.

Figure 68: Example of solar water heater installation

rural sales from, the president of Hi-Min Solar Group (one of the leading companies in the Chinese solar industry).

[93] The various incentive policies greatly boosted the solar water heater market, but they also caused the market to rely heavily on subsidies. As soon as all the subsidy programs concluded in the second half of 2013, the sales of solar water heaters started to slow. Solar water heater production in 2013 has only increased by 11%, the lowest increase for the industry since 2008[93].

[94] http://zx.meilele.com/chuwei/rsq/article-30490.html [Date accessed: March 19, 2014]

5.3 Heat Pump Water Heaters

Although air-source heat pump water heaters are seen as the future of the water heater industry in China, currently they only account for 3% of the water heater market in terms of annual sales[95]. Their high price is the major barrier to the expansion of the market, although sales are growing.

5.4 Report Focus

Although solar water heaters now have a stable share of the market, and the market for air-source heat pump water heaters is growing fast, electrical and gas water heaters still dominate the Chinese market. Further, gas and electrical water heaters are the products types that consume the most energy in operation, and hence need to be the focus of policymakers to ensure that this energy use is managed appropriately. Therefore, the focus of the analysis in this report is on these electrical and gas water heaters. However, as noted earlier, due to the differences in operational modality and test methods, direct comparisons of gas and electrical units is challenging. Further, the current regulatory structure within China considers gas and electrical water heaters as completely separate products. Consequently, the analysis presented in this review considers the two product types independently.

[95] Yu, Hao. (2013). *Heat pump water heaters: major problems remain outstanding for the industry*. Appliance. October issue. [In Chinese]

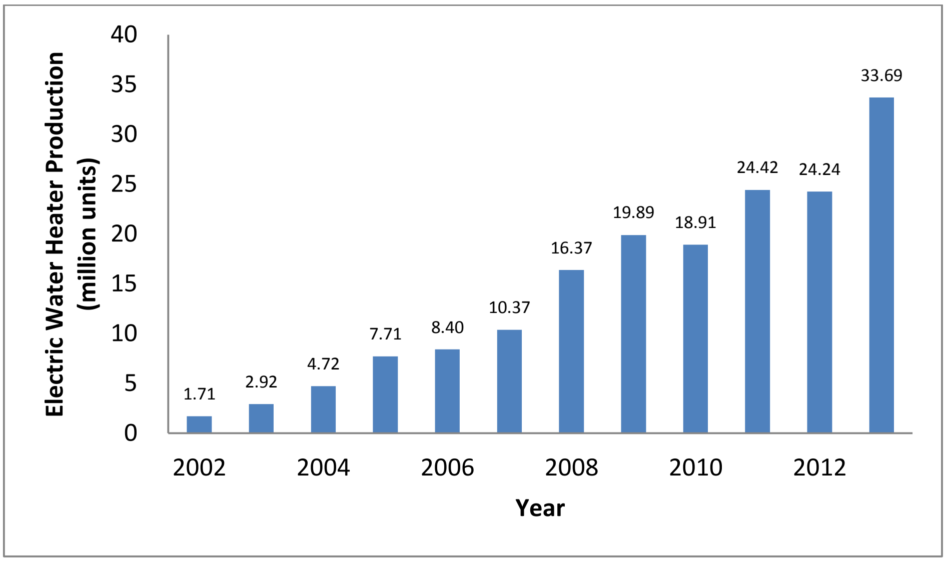
Section 5A: Analysis of the Market and Product Performance of Electrical Storage Water Heaters

A.5.1 Background

A.5.1.1 Production, sales, and stock level

Production of electrical storage water heaters increased dramatically over the past decade (Figure 69). Production peaked temporarily in 2011, fell slightly in 2012, but resumed its long-term growth trajectory in 2013, reaching an annual production level of 33.69 million units.

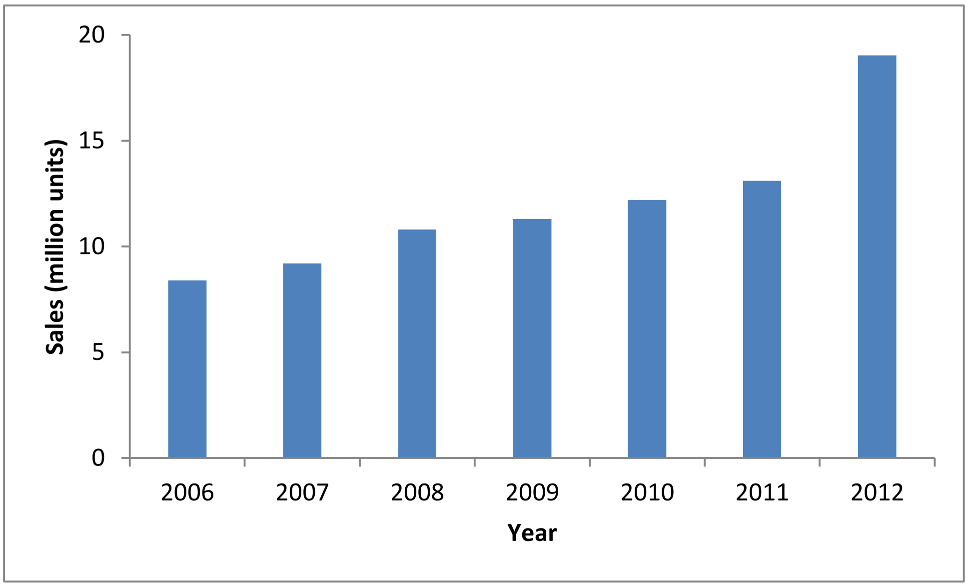
Figure 69: Electrical storage water heater production in China 2002-2013[96]



Sales of electrical storage water heaters slowed in 2011 (Figure 70). This slowdown was possibly due to the reduced growth rate of the Chinese economy, increased competition from other technologies, or policy support for competing products. In 2012, however, sales of electrical storage water heaters noticeably increased, growing by more than 45% to reach over 19 million units.

[96] Data source: China Industry Information. http://data.chyxx.com

Figure 70: Electrical storage water heater sales in China 2006-2012[97]



A.5.1.2 Usage patterns

Electrical storage water heaters are usually installed in bathrooms. They supply hot water not only for showering, but also for other domestic uses such as cooking, dishwashing, cleaning, etc., via a hot water circuit. Normally electrical storage water heaters remain in standby mode at all times, in order to maintain the water temperature and supply hot water at any time of the day. However, a recent CLASP study found that 38% of 81 families who owned electrical water heaters chose to only turn them on prior to use and then turn them off after use.

A.5.2 Regulation, Labeling and Energy Efficiency Standard

A.5.2.1 Energy Efficiency Standard

The most recent energy efficiency standard (EES) for electrical storage water heaters is GB 21519-2008. This EES was issued in 2008, and became mandatory on 1 November of the same year. The scope of this EES includes all domestic or similar-purpose electrical storage water heaters, but does not include gas, solar, or heat pump water heaters.

The EES metrics used to define energy efficiency Tiers are *24-hour standby energy loss index* (ε) and *hot water output rate* (μ). Note there is no metric for the actual water heating efficiency, as this is direct electrical resistance heating and can be assumed to be 100% efficient in all cases.

24-hour standby energy loss index (ε)

The 24-hour standby energy loss index measures how much energy is lost in 24 hours while maintaining the temperature of hot water once the water heater

[97] Source: White paper for the energy efficiency status of China energy-use products (2010, 2011, 2012 and 2013).

reaches steady state. The 24-hour standby energy loss index is defined by the following equation:

Equation 5: 24-hour standby energy loss index

$$\varepsilon = \frac{Q_{pr}}{Q}$$

Where:
ε = *24-hour standby energy loss index;*
Q_{pr} = *24-hour standby energy loss after the fully filled water heater reaches steady state, without water being drawn (kWh);*
Q = *Baseline 24-hour standby energy loss, which is calculated from Table 27 (kWh).*

Table 27: Baseline 24-hour standby energy loss of electrical storage water heaters

Rated volume (C_R) in L	Baseline 24-hour standby energy loss (kWh)
$0<C_R\leq30$	$Q=0.024C+0.6$
$30<C_R\leq100$	$Q=0.015C+0.8$
$100<C_R\leq200$	$Q=0.008C+1.5$
$C_R>200$	$Q=0.006C+2.0$
Where C_R is the rated volume and C is the measured volume.	

The current standby energy loss index is a unit-less value that is the ratio between the measured standby energy loss and a pre-defined baseline energy loss value for different rated volume bands (as shown in Table 27).

The use of a 24-hour standby energy loss is a common practice to define the efficiency of electrical storage water heaters in many economies, including the EU, Australia, Canada, New Zealand, and Hong Kong. However, these economies all express the 24-hour standby energy loss as a pure watts or kilowatts per hour value. Such an approach is completely transparent to consumers, as they are able to *directly* compare the energy lost in standby by products of the same and differing capacities. Conversely, Chinese policymakers have adopted a unit-less index value for 24-hour standby loss. This Chinese approach is less transparent and has less inherent meaning to consumers. Consumers do not intuitively understand whether a higher or lower value represents a better product to purchase. In a CLASP study of consumer comprehension of the China Energy Label[98], consumers were able to understand simple technical parameters related to energy consumption such as “24 hour energy consumption” or “input power” much better than unit-less index parameters. By adopting the simple watt or kilowatt loss value, it will be more transparent to consumers how much energy is actually being lost by the unit, which will allow for a more informed purchase decision. Therefore, Chinese policymakers may wish to consider adopting the international practice of defining and labelling 24-hour standby energy loss as a simple kilowatt hour or watt value.

Should Chinese policymakers wish to retain the current index system, they may at least consider a revision of the rated volume (C_R) categories, shown in Table 27. At

[98] Consumer Awareness and Comprehension of China Energy Label and Usage Pattern of Household Appliances, CLASP 2013.

present, 90% of all products available in the market fall into the single 30-100L capacity range (refer to Section A.5.3.1). Therefore, the regulatory Tier and Minimum Energy Performance Requirements (refer to section A.5.2.2) for this 30-100L volume range are unnecessarily strict on products at lower capacities, and unnecessarily lax on products with larger capacities. Therefore, in order to maximize the efficiency of all products within this range (and to better align with the existing flow rate categorization used in the test method, refer to Table 29), policymakers may wish to consider introducing additional volume bands into the regulatory structure, possibly 30-50L, 50-70L, and 70-200L, as proposed in Section A.5.3.1. Such a revision would also capture the majority of the 1% of products in the current two bands above 100L, leaving only a single band to address specialist products above 200L.

Hot water output rate (μ)

The hot-water output rate measures the water heater's capability to continuously produce hot water. It is a measure of the unit's ability to "deliver a quality of hot water" rather than a measure of efficiency. The hot water output rate (μ) is calculated as the ratio between the actual volume of hot water produced and the rated volume of the unit defined by the following equation:

Equation 6: Hot water output rate

$$\mu = 10^3 m_p \times \frac{\theta_p - \theta_c}{(\theta_{A1} - \theta_c) \times \rho \times C_R} \times 100\%$$

Where:

μ = *Hot-water output rate; (%);*
θ_p = *Average output water temperature; (°C);*
θ_c = *Average input water temperature; (°C);*
ρ = *Density of water at the temperature of qp; (kg/cm^3);*
m_p = *Hot water output mass; (kg);*
θ_{A1} = *Initial temperature when the power is first cut-off in the hot-water output rate test; (°C);*
C_R = *rated volume of the water heater. (L).*

However, similar to 24-hour standby energy loss, consumers do not appear to understand the "hot water production rate". Hot water production rate essentially measures the amount of hot water that can be supplied on a continuous basis. Unfortunately, consumers are unable to visualize how much water they will actually receive when the value is expressed as a percentage. Therefore, policymakers may wish to consider changing the hot water production rate to terms that can carry more physical meanings to the consumers, in particular by using the total volume of hot water delivered (m_p) as the value reported on the label.

Energy Efficiency Tiers and Minimum Energy Performance Requirements

Table 28 shows the five energy efficiency tiers (EET) set in the 2008 EES, with Tier 1 being the most efficient. A water heater must satisfy both parameters (ε and μ) in order to qualify for a specific tier. Water heaters with Tier 1 or Tier 2 efficiencies are deemed to be energy efficient products according to the EES.

The EES also specifies a minimum energy performance requirement (MEPR) that all electrical storage water heaters must satisfy, which initially aligned with the lower threshold value of Tier 5. However, the EES also specified that the MEPR would be automatically upgraded to Tier 4 two years after the implementation of the EES, meaning electrical storage water heaters with Tier 5 efficiencies have not been permitted in the market since 1 November 2010.

Table 28: Energy efficiency Tier requirements for electrical storage water heaters (2008 EES)

Energy Efficiency Tier	24-hour standby energy loss index (ε)	Hot-water output rate (μ)
1	≤0.6	≥70%
2	≤0.7	≥60%
3	≤0.8	≥55%
4	≤0.9	≥55%
5 / MEPR	≤1.0	≥50%

A.5.2.2 Energy labeling of electrical storage water heaters

The application of the China Energy Label to electrical storage water heaters became mandatory on 1 March, 2009[99]. Figure 71 illustrates the energy label and Figure 72 shows the application of the label on a typical water heater at point of sale.

Figure 71: China energy label for electrical storage water heaters (current)

The label has five colored bars indicating the specific energy efficiency Tier of the water heater. Each colored bar aligns with the original EETs defined in the EES (noting that only the top four Tiers are currently in use, as Tier 5 products fall below the current MEPR, as stated in section A.5.2.1). The specific registered Tier for an individual model is highlighted on the label. In addition to indicating the EETs, the

[99] China Energy Label website, http://www.energylabel.gov.cn/NewsDetail.aspx?Title=&CID=83&ID=1001

label also includes basic identification information, including the model number, manufacturer, the 24-hour standby energy loss index, and hot water output rate. However, as noted in section A.5.2.1, the 24-hour standby energy loss index and the hot water output rate have little meaning for consumers in their current form, and policymakers may wish to consider changing the declarations to values that have more meaning for consumers. This would enable consumers to select the lowest-energy consuming product that meets their hot water needs.

Figure 72: Current 5-tiered China energy label[100]

A.5.2.3 Test method

The test method for electrical storage water heaters is included in the EES GB 21519-2008. Test procedures for the two primary parameters are described as follows:

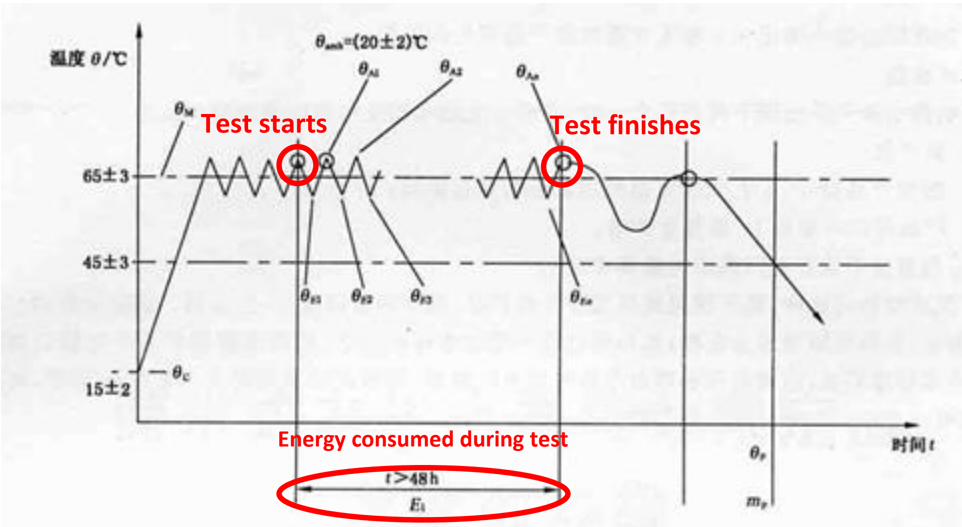
24-hour standby energy loss

The water heater is fully filled and the water heated until it reaches a steady-state with an average temperature (θ_m) of 65±3°C. Once the water heater reaches the steady-state, the measurement of standby energy loss can begin at any point immediately after the water heater has finished a re-heating cycle. The water heater is required to maintain its steady-state for more than 48 hours after the test starts.

Figure 73 illustrates the starting point, end point and the duration of the standby energy loss test. A kilowatt meter is used to measure the total standby energy loss (E_1) during the test period (t_1).

[100] Picture adapted from Gome. http://www.gome.com.cn/product/A0003857754.html [Date accessed: Nov. 18th, 2013].

Figure 73: Measurement of standby energy loss for electrical storage water heaters (2008 EES)



E_1 is then adjusted to 24 hour energy loss by the following equation:

Equation 7: Energy loss in 24 hours

$$E = 24 \times \frac{E_1}{t_1}$$

Where:
E = energy loss in 24 hours (kWh);
E_1 = total energy loss measured during the test (kWh);
t_1 = total time elapsed during the test (t_1>48h) (h).

E is then adjusted to account for the ambient temperature during the test to obtain the 24-hour standby energy loss, Q_{pr}, which is used to calculate the 24-hour standby energy loss index (ε), refer to section A.5.2.1.

Equation 8: 24-hour standby energy loss

$$Q_{pr} = E \times \frac{45}{\theta_M - \theta_{amb}}$$

Where:
Q_{pr} = 24-hour standby energy loss (kWh);
E = energy loss in 24 hours (kWh);
θ_M = Average water temperature at steady-state (°C);
θ_{amb} = Average ambient temperature during test; (°C).

Hot water output rate

The hot water output rate test simulates the use of water heaters under real conditions, where hot water is being used continuously while cold water is entering the storage tank. Before the test, the water heater needs to be installed with an inlet valve control so that inlet flow rates satisfy the requirements shown in Table 29.

Table 29: Energy efficiency Tier requirements for electrical storage water heaters (2008 EES)

Rated Volume (liters)	Flow Rate
C_R<10L	2L/min
10L≤C_R≤70L	5L/min
70L<C_R≤200L	10L/min
200L<C_R	C_R*5%/min

Initially, the water heater is filled with cold water to half its rated volume, thus activating the thermostat to initiate water heating. If the thermostat does not turn on when the water heater is filled to half of its rated volume, cold water is added to the point where the thermostat is activated and water heating begins. As soon as the initial temperature (A_1) reaches the required 65±3°C, and the thermostat turns off for the first time, the hot water output rate test starts immediately. The procedures are as follows:

Hot water is continuously drained from the water heater while cold water is filled at the above specified flow rate during the test. Inlet temperature (q_{ci}) and outlet temperature (q_{pi}) are recorded in 5s intervals, beginning 15s after the test starts. The maximum outlet temperature (q_{MAX}) is recorded. Hot water is continuously drained until the outlet temperature drops to (q_{MAX} -20)°C. The total mass of the hot water drained during the test m_p is measured. Hot water output rate is then calculated using Equation 6 (see Section A.5.2.1).

A.5.3 Data analysis

Data on the 595 distinct electric storage water heater models was collected from three major Chinese online appliance retailers: Suning[101], Gome[102] and Jing Dong[103]. Data regarding energy efficiency tiers, 24-hour standby energy loss, and hot water output rate was acquired by cross-referencing model numbers with the China Energy Label website[104].

Data acquired during the research phase was based on the availability of individual models in the market (i.e., model-based). However, it is recognized that model availability is not always representative of the actual products consumers are purchasing, and often sales-based analysis provides a better picture of the market.

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[101] http://www.suning.com
[102] http://www.gome.com.cn
[103] http://www.jd.com
[104] http://www.energylabel.gov.cn/NewsMore.aspx?para=uncc_bagg

However, the acquisition of sales-based data is challenging. Therefore, to complement the model-based analysis, the online data sources used were also interrogated to produce a “rank-by-sales”. While not providing a true sales weighted average, this approach gives a broad proxy for sales-weighting by identifying the subset of products purchased most frequently by the consumer (albeit not the absolute quantity of each model purchase). By comparing all surveyed models (product-based) and the 57 distinct models listed in the “rank-by-sales” search (proxy sales-based), the analysis provides a better understanding of the true market picture.

In addition to the generic cautions provided in the Approach and Methodology section of the Introduction, readers should note that not all performance and other parameters were available for all electrical storage water heater models identified. The specific number of models where each product property was known, and hence included in the analysis, is indicated in Table 30. However, it has not been possible to estimate the bias this has introduced into the analysis for any given parameter.

Table 30: Overview of the data used for the analysis of electrical storage water heaters

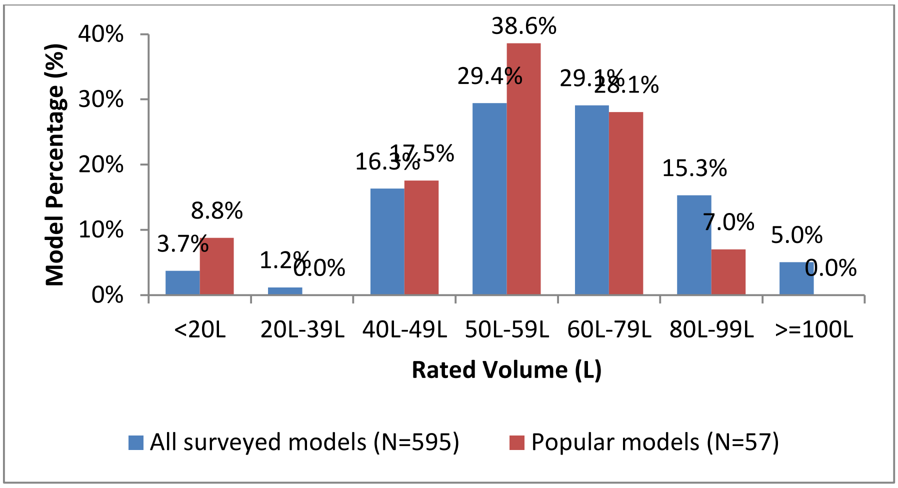
Data type	All surveyed models	Popular models
Number of models	595	57
Energy efficiency Tier	Range: 1 – 4	Range: 1 – 4
Rated volume (L)	Range: 5 – 300	Range: 5 – 80
Maximum rated power (W)	Range: 1000 – 5500	Range: 1500 – 3000
24-hour standby energy loss index (ε)	Range: 0.5 – 0. 9	Range: 0.6 – 0. 9
Hot-water output rate (μ)	Range: 55% – 94%	Range: 55% – 90%
Price (RMB)	Range: 439 – 8558	Range: 439 – 4818

A.5.3.1 Market distribution by electrical storage water heater rated volumes

The distribution of rated volume for all surveyed and popular models shown in Figure 74 indicates a likely close relationship between the “most popular” market distribution of models and the model-based analysis.

Models with medium rated volumes (40L - 60L) dominated the market, whereas models with rated volumes over 100L were rare. This is to be expected, as the volume of the water heaters is very much dependent on the size of the family. In the 2010 nationwide census, the average Chinese household size was reported to be 3.10[96]. This explains why medium volume water heaters are the most popular model, as they are the most suitable for typical households with 2 or 3 members.

Figure 74: Distribution of electrical storage water heaters by rated volumes for all surveyed models and popular models (data collected October 2013)



As noted in the *24-hour standby energy loss index* discussion in Section A.5.2.1, the actual market distribution of rated volumes is quite different from the categorization of rated volumes (C_R) for the calculation of baseline 24-hour standby energy loss (Table 27). Over 90% of the models available on the market fall into the second category 30-100L capacity range. Therefore, the regulatory Tier and Minimum Energy Performance Requirements (refer to Section A.5.2.2) for this 30-100L volume range are unnecessarily strict on products at the lower capacities and unnecessarily lax on products with larger capacities (refer to Section A.5.3.2). Further, only 1% of models are in the *two* categories above 100L, and none of the popular models are in these volume ranges. Therefore, policymakers may wish to consider:

- Introducing additional capacity ranges into the regulatory structure (possibly 30-50L, 50-70L and 70-200L), thus distributing products more evenly across capacity ranges to highlight the difference in efficiency (and ideally the actual energy consumption) of units. Such an action would allow policymakers to set threshold values for the EETs and MEPR that are more appropriate for the smaller capacity ranges, and thus provide consumers with greater opportunity to select higher efficiency, lower energy consuming models.
- Whether it is necessary to have two separate categories for models with rated volumes beyond 100L, or whether a single category would be sufficient to capture the 1% of products available in these capacities.

A.5.3.2 Market distribution by energy efficiency tiers

Chinese policymakers first considered the energy efficiency status of the electrical storage water heater market when the EES was developed and implemented in 2008. The most efficient 5% and 20% of the models on the market were used as the benchmark for setting the Tier 1 and Tier 2 efficiencies[105]. However, as Figure 75 demonstrates, five years after the implementation of this EES, the efficiency status of the electrical storage water heater has changed dramatically (again noting that the MEPR was raised in 2010 so no models are allowed to be supplied in the Tier 5 category).

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[105] Chen, Haihong. (2008, May). Explanation and analysis of the national energy efficiency standards for electrical storage water heaters. *Appliance*, 62-63. [In Chinese].

Figure 76 shows the breakdown of tier distributions for different volume categories. It can be observed that larger models tend to be more efficient than smaller models (as would be expected given the current use of an energy efficiency index which naturally favors larger products within a particular volume range). No Tier 1 products were observed for models with a rated volume smaller than 30L, whereas almost all models with rated volumes between 81 and 100L were Tier 1 products.

Figure 75: Distribution of electrical storage water heaters by energy efficiency tiers for all surveyed models and popular models (data collected October 2013)

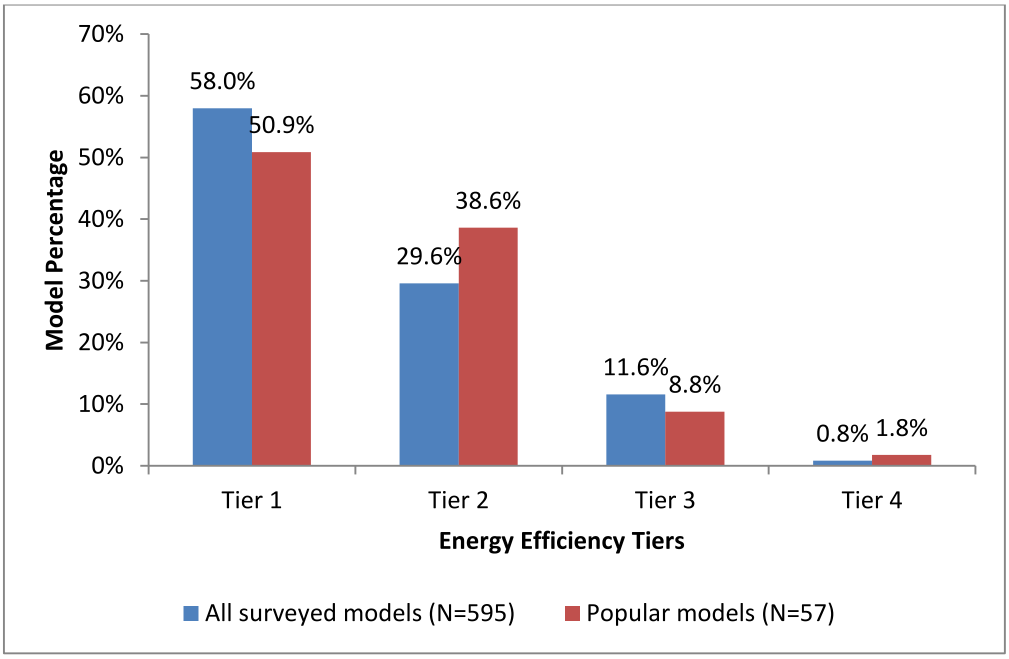
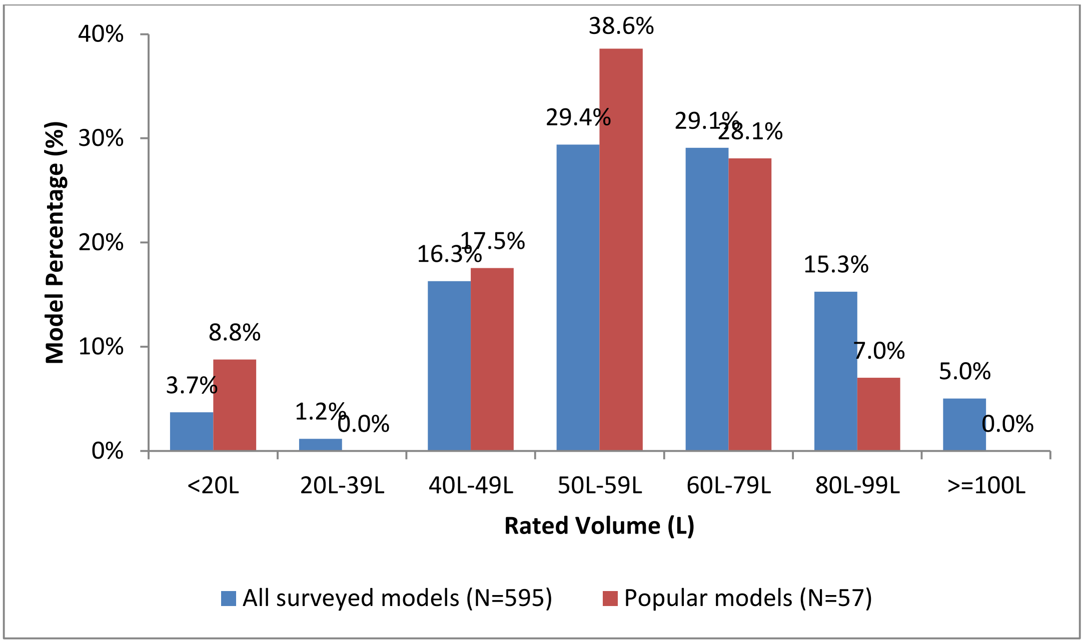


Figure 76: Distribution of electrical storage water heaters by energy efficiency tiers and rated volumes, all surveyed models and popular models (data collected October 2013)



Over half of all surveyed models are now Tier 1 products, and 30% of models are Tier 2 products. Similar patterns are also observed for the "most popular" models. Thus, under the definition of "energy efficient products", as defined in GB 21519-2008 (i.e., Tier 1 and 2 products), the current electrical storage water heater market is saturated with such products. This indicates that implementation of the EES has effectively induced a market transformation towards higher efficiency electric water heaters, and as such, policymakers should be congratulated. However, as over 90% of products on the market are now Tier 2 or better, it is clear that the current EES threshold levels have become outdated as:

- Consumers can no longer use energy efficiency tiers as a reference to make purchase decisions;
- Products with higher efficiencies are not being merited or acknowledged by the current EES;
- There is no encouragement for manufacturers to improve the efficiencies of their products.

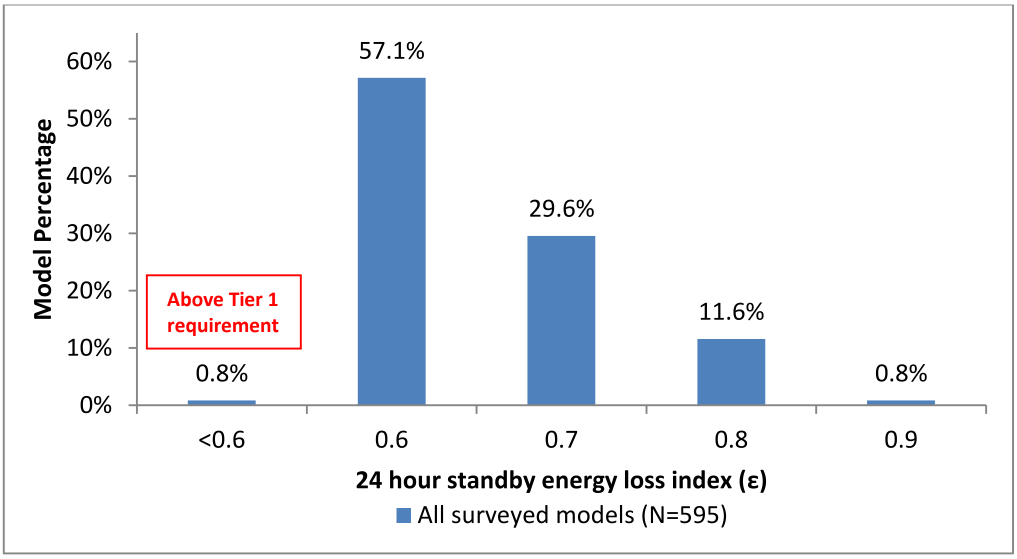
Therefore, it is strongly recommended that policymakers consider revising the current EES Tier performance requirements to more effectively distribute models according to their relative performance levels, thus giving consumers greater levels of choice in selecting the most efficient, lowest-energy consuming products and providing manufacturers with an incentive to improve product performance. Simultaneously, the MEPR level should be raised to remove the worst performing products from the market. Proposals for revised thresholds for EES Tiers and the MEPR are made in Table 29, Section A.5.3.3.

A.5.3.3 Market distribution by 24-hour standby energy loss index and hot water output rate

The model distribution by 24-hour standby energy loss index (ε) and hot water output rate (μ) are shown in Figure 77 and Figure 78.

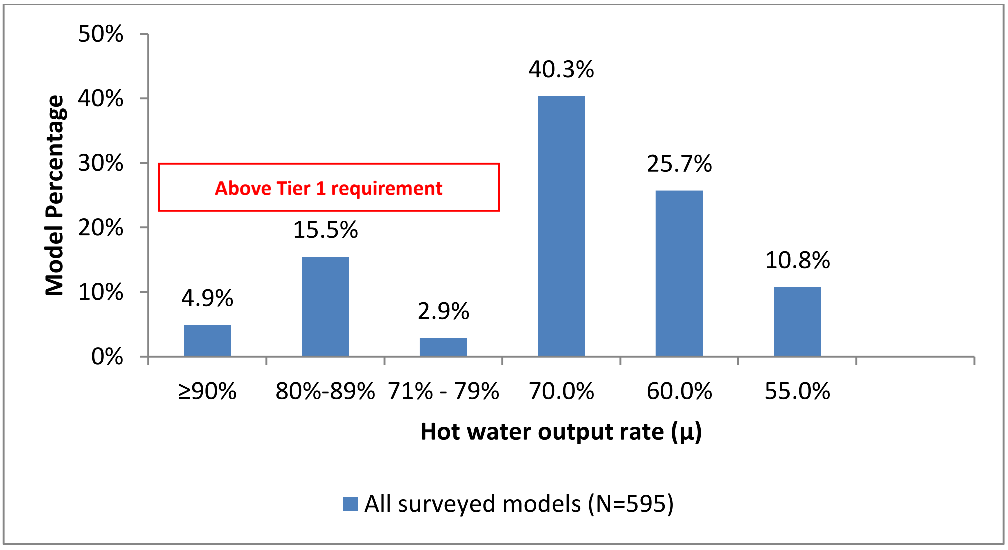
Among all Tier 1 products (58% of all surveyed models), almost all have standby loss index values of 0.6, i.e., at the threshold value of the Tier 1 requirement. Almost 30% of models achieve the Tier 2 requirement and 12% the Tier 3 requirement. Currently only a few premium brand models (less than 1%) have standby index values values above the Tier 1 requirement.

Figure 77: Distribution of electrical storage water heater models by 24-hour standby energy loss index (ε) (data collected October 2013)



In terms of hot water output rate (i.e., the measure of service provided according to the quantity of hot water that can be delivered on a continuous basis), the required 70% threshold value for Tier 1 is no longer difficult for manufacturers to achieve, as more than 63% of all surveyed models satisfy this requirement. Moreover, 23% of models are now able to deliver hot water in quantities significantly above the Tier 1 requirement. However, again only a small number of from premium brands are able to supply hot water above the 90% rate.

Figure 78: Distribution of electrical storage water heater models by hot water output rate (μ) (data collected October 2013)



Thus, as suggested in Section A.5.3.2, it is possible for policymakers to revise the EES Tier thresholds and MEPR requirements to remove the worst performing products from the market, while still providing consumers with more information they can use to choose the best performing products and incentivizing manufacturers to develop better products. As suggested in section A.5.2.1, the ideal scenario would be to introduce different volume ranges for the calculation of standby power (or even better, adopt the international standard watt or kilowatt loss metric). However, as an interim measure, the current test, metrics, and volume categories can be used with Tier values similar to those proposed in Table 31.

Table 31: Proposed revised thresholds for energy efficiency Tier requirements for electrical storage water heaters

Energy Efficiency Tier	24-hour standby energy loss index (ε)	Hot-water output rate (μ)
1	≤0.50	≥90%
2	≤0.55	≥80%
3	≤0.60	≥75%
4	≤0.65	≥70%
5	≤0.70	≥65%

Based on the current product performance declaration levels available for this analysis, it is not possible to be *absolutely* certain what proportion of products would be removed from the market by the new MEPR requirements (the lower threshold of Tier 5), nor the exact proportion of existing models that would fall into each revised energy efficiency Tier. However, it is *estimated* that 20% of the worst performing models would be removed from the market, and Tier 1 products would be restricted to the best 1% of products available, hence identifying the “top runner” products. The remaining products would be spread across the other efficiency tiers, thus giving consumers a clear choice of product performance levels, and providing manufacturers with incentives to improve (or withdraw) their worse performing products and introduce higher performing models.

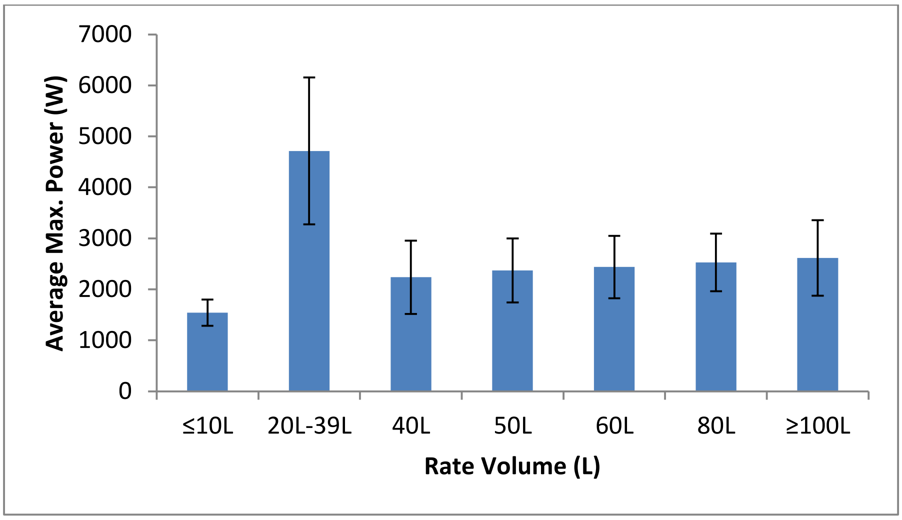
A.5.3.4 Relationship of rated volume and maximum power

In general, most electrical storage water heaters have maximum powers between 1000W to 3000W. On average, it appears that the rated volume follows a positive linear relationship with maximum power (Figure 79). This would be expected, as a larger capacity water heater requires more power to heat the greater volume of water within a reasonable period.

However, it has to be noted that many factors other than volume may affect the maximum power of a water heater, such as the water heating rate, computerized control system, insulation, etc. In particular, for models with rated volumes between 20L and 39L, the average maximum power is much higher than the rest of the models, at approximately 5000W. This newer generation of water heaters is considered a hybrid of electrical instantaneous water heaters (also known as tank-less, or on-demand water heater) and electrical storage water heaters, combining the advantages of both types. Their small volume (smaller physical size) allows them to be installed more conveniently in limited spaces, while the stored preheated water can be used immediately without any delay. However, their high power allows inlet cold water to be heated rapidly, and they can thus handle large hot water demands.

At the time the current EES was developed, these hybrid models had not entered the market. They are currently regulated as a storage water heater. However, because these hybrid models have features from both instantaneous and storage electrical water heaters, and do not entirely belong to either categorization, policymakers may consider setting a new standard specifically targeted at this type of product, once its market share rises.

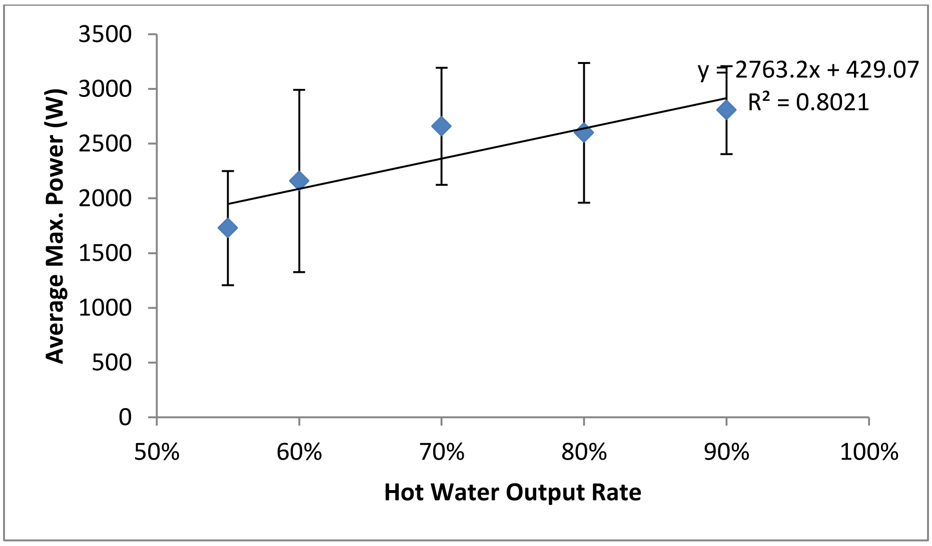
Figure 79: Relationship of rated volume and maximum power for electrical storage water heaters (data collected October 2013)



A.5.3.5 Relationship of hot water output rate and maximum power

As would be expected, the relationship between the hot water output rate and maximum power is again broadly a positive linear relationship in line with the relationship of maximum power and rated volume above. As described in Section A.5.2.3, the hot water output test measures the ability of water heaters to supply hot water continuously. Hence, it is not surprising that higher power would yield a higher hot water output rate. But again, this relationship is not absolute. For example, one brand boasts its technology of "double thermal conductivity wing", which allows their product to achieve a hot water output rate of 90% with 2000W of maximum power. Therefore, other factors such as the number of heating elements, placement of heating elements, or the use of other fast heating technologies may also affect the hot water output rate.

Figure 80: Relationship of hot water output rate and maximum power for electrical storage water heaters (data collected October 2013)



A.5.3.6 Relationship of energy efficiency tiers, rated volume and price

Figure 81 and Figure 82 illustrate the relationships between energy efficiency Tiers, rated volume, and price.

Figure 81: Relationship of rated volume and price for electrical storage water heaters (data collected October 2013)

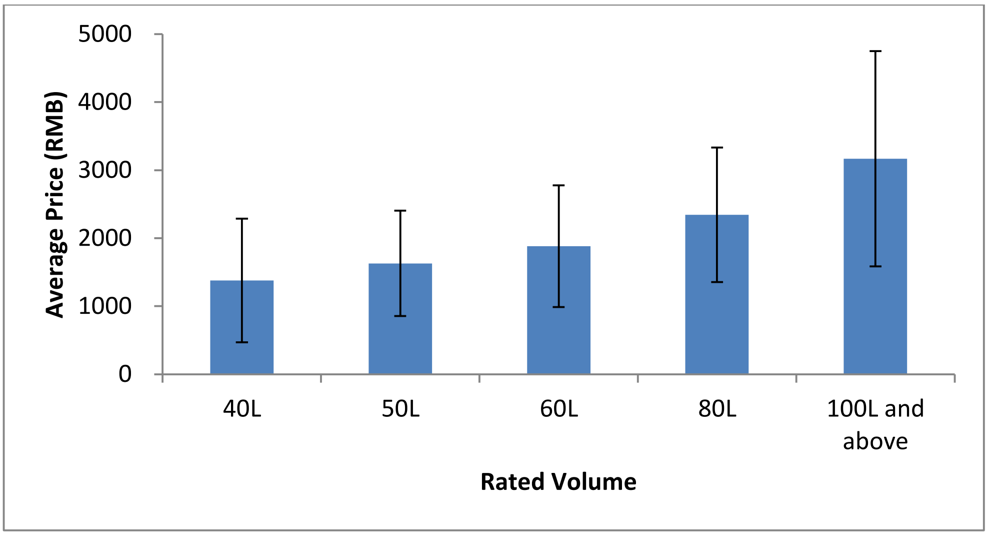
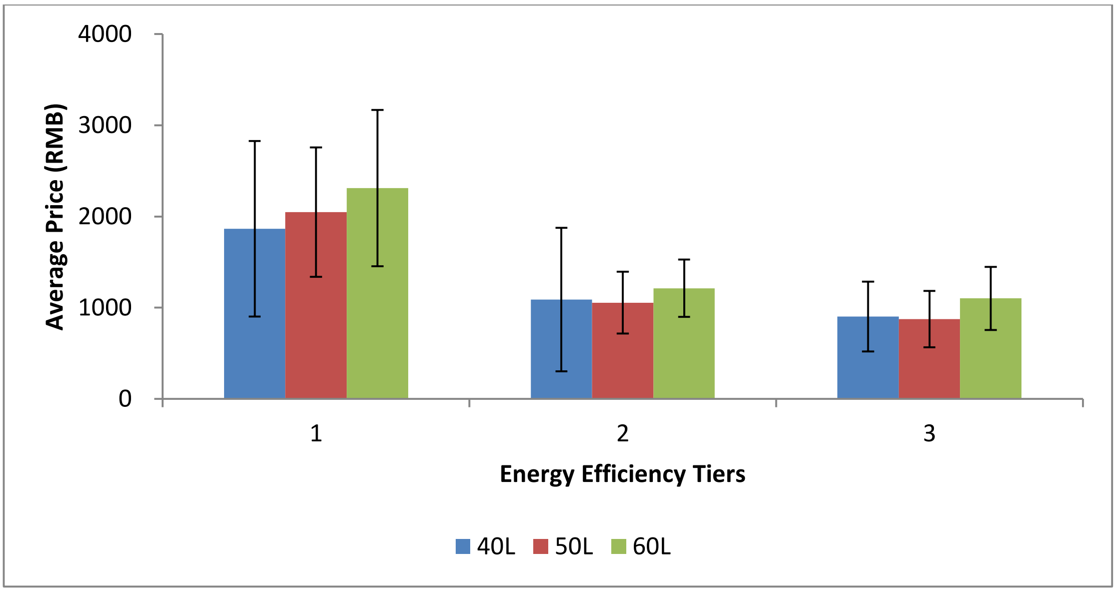


Figure 82: Relationship of energy efficiency Tiers and price for electrical storage water heaters (data collected October 2013)



On average, it appears that the price of electrical storage water heaters increases with both capacity and energy efficiency Tier, i.e., consumers have to pay more for efficient products with large capacities. However, such a conclusion should be used with *extreme* caution, because prices of electrical water heaters are affected by many factors. Models with computerized control and display panels are often more expensive than traditional mechanically controlled models. Materials used for surface, inner container, insulation, or sacrificial anode rod all contribute to the overall pricing of the water heaters. There are also high-end water heaters with intelligent control, which can record the users' hot-water-using habits and adjust heating patterns to allow for off-peak heating, which adds to the price, as does the large power requirements of the hybrid models mentioned previously. Such additional functionality and differences in materials lead to the broad spread of prices around the average in both Tier and capacity. Thus, policymakers should not be concerned that raising performance requirements of the energy efficiency Tiers would significantly increase the price of electrical storage water heaters, as it is likely that lower cost products would remain available in each capacity and efficiency Tier.

A.5.4 Conclusions and recommendations

The conclusions and recommendations drawn from this analysis of electrical storage water heaters are as follows:

Revisions to metrics and capacity ranges used for the current Energy Efficiency Standard and declared on the Energy Label

The use of a 24-hour standby energy loss is a common practice to define the efficiency of electrical storage water heaters in many economies. However, these economies all express the 24-hour standby energy loss as simple watts or kilowatts per hour values. Such an approach is completely transparent to consumers, as they are able to directly compare the energy lost in standby by products of the same and differing capacities. Conversely, Chinese policymakers have adopted a unit-less index value for 24-hour standby loss. This approach is less transparent and has less inherent meaning to consumers, as evidenced by a CLASP study of consumer comprehension of the China Energy Label[106].

Similarly, consumers did not appear to understand the "hot water production rate". The hot water production rate essentially measures the amount of hot water that can be supplied on a continuous basis, but consumers are unable to visualize how much hot water they will actually receive when this value is expressed as a percentage.

Therefore, Chinese policymakers may wish to consider:

1. Adopting the international practice of defining and labelling 24-hour standby energy loss as a simple watt or kilowatt hour value, thus providing consumers with more transparent information on how much energy is actually being lost by each water heater model, allowing consumers to make a more informed purchase decision.
2. Changing the hot water production rate to terms that carry more physical meaning to the consumers. An appropriate value to report to the consumer on the label may be the "total volume of hot water delivered" (*mp*), which is the quantity of water measured in the test before the water is considered to be insufficiently warm for consumer service.

[106] Market research report on consumer comprehension of China Energy Labels and household appliance-using habits in China.

However, should policymakers wish to retain the current standby index and hot water production rate as indices in the long term or during a transitional phase, they may at least consider revision of the rated volume (C_R) categories used for defining baseline 24-hour standby energy loss (Table 27). At present, 90% of all products available in the market fall into the single 30-100L capacity range, and thus the energy efficiency Tier and Minimum Energy Performance Requirements for this 30-100L volume range are unnecessarily strict on products with lower capacities and unnecessarily lax on products with larger capacities. Therefore, policymakers may wish to consider:

3. Introducing revised rated volume bands used for defining baseline 24-hour standby energy loss. Possible revised bands may be 30-50L, 50-70L and 70-200L. The use of such revised bands would better align with the existing flow rate categorization used in the test method and provide policymakers with the opportunity to set threshold values for the EETs and MEPR that are more appropriate for each capacity range. This would provide consumers with greater opportunity to select higher efficiency, lower energy-consuming models.

Revisions to the Energy Efficiency Tiers and Minimum Energy Performance Requirements

Policymakers should be applauded for their interventions in the electrical storage heater market to date. From a starting point in 2008 where only 20% of available models qualified as “energy efficient products” (i.e., Tier 1 and 2 products), by 2013 over half of all surveyed models were Tier 1 qualified products and 30% models were Tier 2. However, as over 90% of products on the market are now Tier 2 or better, it is clear that the current EES threshold levels have become outdated, meaning:

- Consumers can no longer use energy efficiency tiers as a reference to make purchase decisions as the majority of products are undifferentiated;
- Products with higher efficiencies are not being merited or acknowledged by the current EES;
- There is no encouragement for manufacturers to improve efficiencies of their products.

Therefore, it is strongly recommended that policymakers consider:

4. Revising the current EES Tier performance requirements to more effectively distribute models according to their relative performance levels, thus giving consumers greater levels of choice in selecting the most efficient, lowest-energy consuming products and providing manufacturers with incentive to improve product performance. Simultaneously, the MEPR level should be raised to remove the worst performing products from the market. Specific proposals for revised thresholds for EES Tiers and the MEPR are made in Table 29, Section A.5.3.3.

Based on the product performance declaration levels available to this analysis, it is not possible to be absolutely certain what proportion of products would be removed from the market by the proposed MEPR requirement, nor the exact proportion of existing models that would fall into each revised energy efficiency Tier. However, it is estimated that 20% of the worst performing models would be removed from the market, and Tier 1 products would be restricted to the best 1% of products available, hence identifying the “top runner” products. The remaining products would be spread across the other efficiency Tiers, thus giving consumers clear choices of product performance levels, and manufacturers incentives to improve (or withdraw) their worse performing products and introduce higher performing models.

Revisions to the scope of the Energy Efficiency Standard

This analysis shows that a new generation of hybrid electrical water heaters is emerging in the market. These newer models feature a smaller storage volume but a high power, and combine the functions of storage and instantaneous water heaters. As these hybrid units have such unique combinations of performance attributes, policymakers may wish to consider:

5. Whether hybrid water heaters should be formally included in the scope of EES for electrical storage water heaters, or whether a separate EES categorization is required.

Policy intervention to limit the adoption of electrical storage water heaters

From a primary energy perspective, electrical water heating technology is the least efficient technology available when compared with the alternative gas, solar, and heat pump technologies. It appears policymakers have already recognized this issue, as subsidy support was provided in 2012 to all water heaters with the exception of electrically-heated units. Despite the structure of this subsidy support, however, growth in sales of electrically heated units in 2012 actually increased, as indicated in Figure 70 above. Therefore policymakers may wish to consider:

6. Continuing to offer subsidy support for the alternative gas, solar, and heat pump technologies, or placing a punitive tax on the electrically-heated units.

Section 5B: Analysis of the Market and Product Performance of Instantaneous Gas Water Heater

B.5.1 Background

B.5.1.1 Production, sales, and stock level

Over the past decade, the market for gas instantaneous water heaters expanded tremendously. Production increased steadily from 2.4 million units/year in 2002 to 11.6 million units/year in 2009. Production peaked in 2010, reaching 16.9 million units/year, but was followed by sharp declines in 2011 and 2012 (Figure 69).

Gas water heaters are a relatively new entrant to Chinese households, and their installation is directly linked to new build as they are obviously challenging to retrofit to existing houses, even in the rare instance where mains gas is supplied without gas water heaters already being installed. Hence, the new-build real estate market is thought to be a primary driver for any gas water heater market fluctuations. The real estate market in China experienced an abrupt boom in late 2009 and early 2010. Many gas water heater manufacturers saw this booming real estate market as an opportunity to expand their business, and they were eager to increase their production capacities. As a result, the production of gas water heaters boomed in 2010.

However, in subsequent years, the government implemented several strong policies aimed at stabilizing housing prices, which resulted in a significant reduction in housing development in 2011, directly reducing the demand for gas water heaters (and indeed other products that are closely tied to the real estate market). The reduced sales in 2011 and 2012 (Figure 84) led directly to sharp declines in production[107]. However, in mid-2012, the government initiated a massive subsidy program for energy-efficient appliances, including gas instantaneous water heaters (refer to section Policy section of the Introduction). This subsidy, combined with the resurgence in housing development, is thought to have resulted in the pickup in both the production and sales of instantaneous gas water heaters in 2013.

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[107] Qin, Li. (2012). *Gas water heaters: market cooling while industry returns to rational upgrade*. Appliance. June issue. [In Chinese].

Figure 83: Gas instantaneous water heater production 2002-2013[108]

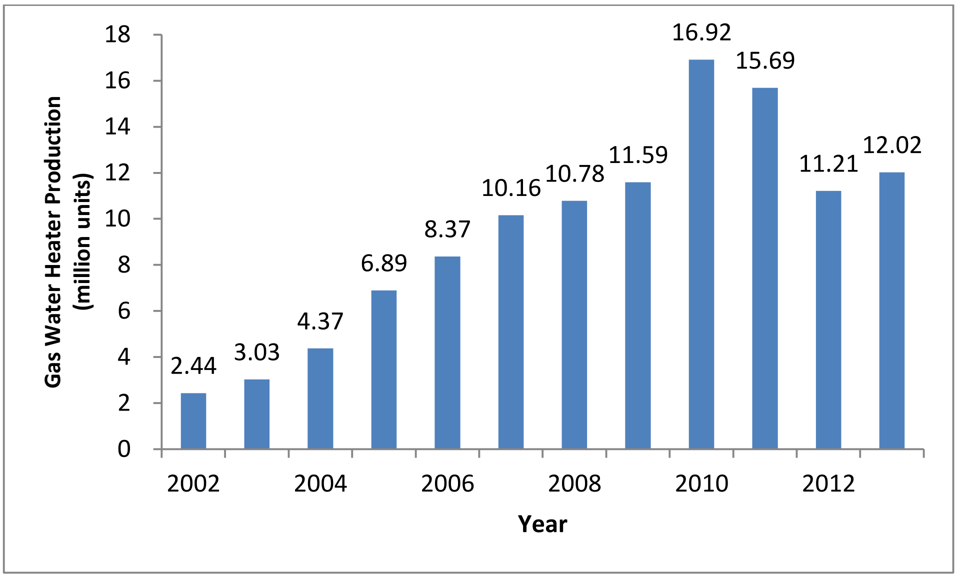
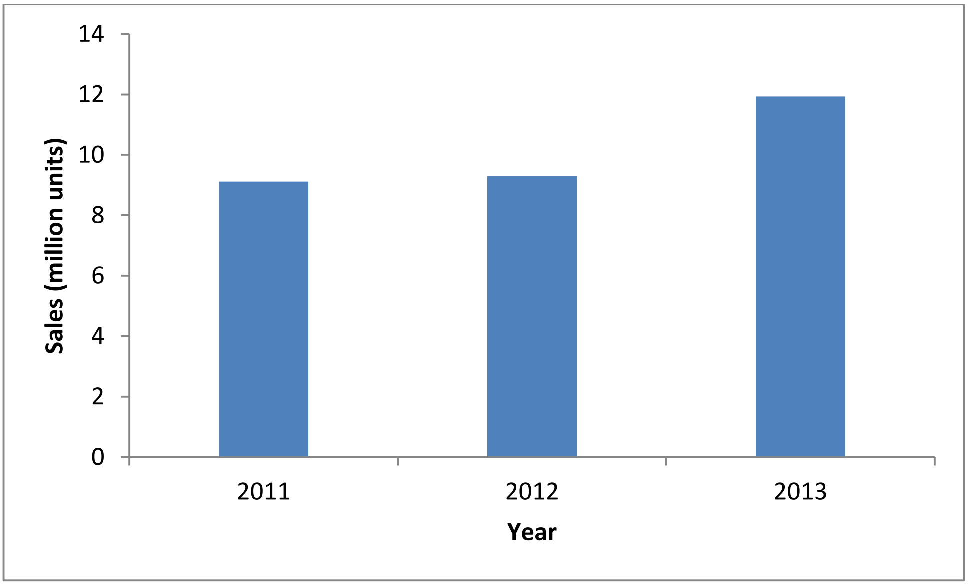


Figure 84: Gas instantaneous water heater sales 2011-2013[109]



B.5.1.2 Usage patterns

Instantaneous gas water heaters are usually installed in kitchens. They typically supply hot water throughout a dwelling for all domestic purposes (showering, dish washing, cleaning, etc.) via a hot water circuit. As the name suggests, water is heated instantly on demand, with only very limited storage capacity within the unit itself.

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[108]Data source: China Industry Information. http://data.chyxx.com

[109] Figure 84 modified from Gao, Min. (2013). *Rapid increase of water heater market with new focus on efficient fast-heating water heaters*. Appliance. October issue. [In Chinese].

B.5.2 Regulation, Labeling and Energy Efficiency Standard

B.5.2.1 Energy Efficiency Tiers and Minimum Energy Performance Requirements

At the time of writing, the most recent energy efficiency standard (EES) for gas instantaneous water heaters was GB 20665-2006. This EES was issued in 2006 and came into effect on 1 July, 2007. The scope of the EES covers domestic gas instantaneous water heaters (including those with condensing water heaters[110]), boilers for room heating only, and combination boilers, which are used for both room heating and hot water (combi-boilers). The EES only applies to products with rated heat input lower than 70kW. The EES does not apply to gas-fired storage water heaters that are not labelled nor subject to minimum energy performance requirements (MEPR).

Again at the time of writing, the EES was being revised by the Standardization Administration of China, and the revised version was pending final approval with release expected in late 2014.

However, as the 2014 EES is yet to be formally adopted, and all the model data analyzed has performance declarations made against the current GB 20665-2006, except where specifically stated, all analysis undertaken in this section of the report relates to product performance declarations under, and comparisons with the energy efficiency requirements of, GB 20665-2006, *NOT* the 2014 revision.

Further, due to the much lower market penetration of combi-boilers in comparison to instantaneous water heaters, and the associated limited availability of data, this analysis focuses primarily on gas instantaneous water heaters. However, where possible, information is also provided on other gas water and heating appliances, for example in discussions on the EES and energy labels.

B.5.2.2 Current EES (GB 20665-2006)

In GB 20665-2006 EES, thermal efficiency (η) is used to define the energy efficiency Tiers (EETs). The thermal efficiency is essentially the ratio of energy absorbed by the water relative to the amount of energy released by burning the natural gas in the heating process.

Table 28 shows the classification of EETs and required thermal efficiencies for the types of product covered by the scope of the standard. The thermal efficiency is measured firstly using the rated heat capacity[111], and again using 50% of the rated heat capacity. In order for a product to qualify for one particular efficiency Tier, the product has to satisfy both requirements under that Tier (noting there is no efficiency requirement for 50% capacity tests for Tier 3 products). For example an instantaneous water heater with measured thermal efficiencies of 96% using the rated heat input, and 93% using 50% of the rated heat input, can only be classified as a Tier 2 product. It is worth noting that while the EES is technology-neutral, it is

[110]A condensing water heater or boiler uses waste heat in the flue gases by condensing the water vapor produced during combustion to heat the cold water entering the water heater or boiler. Typically condensing units are of high thermal efficiencies (usually above 90%).

[111] Rated heat input refers to the rated maximum heating capacity of the unit in kWh.

almost impossible for a non-condensing boiler of any type to achieve Tier 1 performance.

The EES also specifies a minimum energy performance requirement (MEPR) that all gas water heaters must satisfy. The MEPR aligns with the lower threshold value of Tier 3. The EES deems water heaters with Tier 1 or Tier 2 efficiencies to be "energy efficient products".

Table 32: Energy efficiency Tier requirements for gas instantaneous water heaters (2006 EES)

Type		Heat input	Minimum thermal efficiency (%)		
			Energy Efficiency Tiers		
			1	2	3
Water heater		Rated heat input	96	88	84
		≤ 50% rated heat input	94	84	-
Boiler (for heating only)		Rated heat input	94	88	84
		≤ 50% rated heat input	92	84	-
Combi-boiler	For heating	Rated heat input	94	88	84
		≤ 50% rated heat input	92	84	-
	For hot water	Rated heat input	96	88	84
		≤ 50% rated heat input	94	84	-

B.5.2.3 Energy labeling of gas instantaneous water heater

The labeling of gas instantaneous water heaters and combi-boilers became mandatory on 1 June 2008 as part of the China Energy Labelling program. The labels for gas water heater and combi-boilers are very similar (Figure 85 and Figure 86). They are both categorical labels with three Tiers aligning with the EETs defined in the EES. In addition to colored bars indicating the specific energy efficiency Tier, the labels also include basic identification information of the model number, manufacturer, rated heat input, and thermal efficiency for water heating. The label for combi-boilers has additional parameters on rated heat input and thermal efficiency for heating.

Figure 85: China Energy Label for gas instantaneous water heaters (current)

Figure 86: China energy label for combi-boilers (current)

B.5.2.4 Test method

As noted earlier, due to the limited penetration of combi-boilers in the market to date, and the associated limitation on data availability, this analysis primarily focuses on gas instantaneous water heaters. Therefore, only the test methods related to instantaneous water heaters (conventional and condensing) are discussed. The EES cites *GB 6932-2001: Domestic Gas Instantaneous Water Heater* as the test method to be used in evaluating the performance of gas water heaters.

Thermal efficiency

The testing conditions specified by GB20665-2006 and GB 6932-2001 are:

- Ambient temperature should be set to 20°C±5°C;
- Inlet cold water temperature should be set to 20°C±2°C;
- For tests using the rated heat input, the water temperature increase should be 40 °C±1°C; and for tests using 50% of the rate heat input, the water temperature increase should be 30 °C±1°C;
- The pressure of the gas should be the rated pressure;
- The test should be carried out using reference gas. The error of the Wobbe number and combustion potential of the reference gas should be within ±2% and ±3% respectively of the required values in *GB/T 13611: Classification and essential properties of city gas*.

During the test the instantaneous water heater is initially operated for 15 minutes to allow the hot water output temperature to reach a steady state. The energy consumption test is then conducted by measuring the total amount of hot water output during a period over which the gas flow meter finishes one or more complete cycles.

The thermal efficiency is then calculated using Equation 9:

Equation 9: Thermal efficiency for gas water heaters (GB 6932-2001)

$$\eta_1 = \frac{M \times C(t_{w2} - t_{w1})}{V \times Q_1} \times \frac{273 + t_g}{273} \times \frac{101.3}{p_{amb} + p_g - S} \times 100$$

Where:

η_1	*= thermal efficiency when the temperature increase is t (=tw_2–tw_1)K;(%);*
C	*= specific heat capacity of water, use 4.19 x 10-3 MJ/kg·K;*
M	*= mass of hot water output; (kg/min);*
tw_2	*= output water temperature; (°C);*
tw_1	*= Inlet water temperature; (°C);*
Q_1	*= measured gas net calorific value; (MJ/Nm^3);*
V	*= measured gas flowrate; (m^3/min);*
t_g	*= gas temperature in the gas flowmeter; (°C);*
p_{amb}	*= atmospheric pressure during the test; (kPa);*
P_g	*= gas pressure of the water heater during the test; (kPa);*
S	*= pressure of saturated steam at temperature tg (kPa).*

B.5.2.5 Revised 2014 draft EES

The revision of GB 20665 is at the final stage of approval, and is expected to be released in 2014. Heating-only boilers were removed from the scope, and now the revised 2014 EES only covers water heaters and combi-boilers[112].

Similar to current (2006) EES, there are three Tiers of performance, with the MEPR being the lower boundary of Tier 3 (refer to Table 33). The EET requirements are more stringent for every Tier in terms of numerical values, but it should to be noted that many changes have been made to the test methods, making the actual comparison of stringency between the revised (2014) and current (2006) standards impossible. Further, in the current 2006 EES, the products are required to be tested under both rated heat input and 50% (or less) rated heat input, and the respective thermal efficiency obtained must satisfy the requirement for each test in order to qualify for a particular energy efficiency Tier. However, in the revised 2014 EES, thermal efficiency must still be tested under the same two heat input conditions specified in the 2006 EES, but the results of the two tests may be used differently. Under the 2014 EES, irrespective of whether tested under rated heat input conditions or 50% of rated heat input, the higher value of the two thermal efficiencies obtained in the tests will be η_1 and the lower value will be η_2. Again, the product must satisfy both the η_1 and η_2 requirements to qualify for a particular Tier.

[112] It is unclear why heating-only boilers have been removed from the standard, but it is *likely* that such units now have very low sales in the rated boiler sizes covered by the standard, and hence regulation has been removed.

Table 33: Energy efficiency tier requirements for gas instantaneous water heaters (revised 2014)

Type			Minimum thermal efficiency (%)		
			Energy Efficiency Tiers		
			1	2	3
Water heater		η_1	98	89	86
		η_2	94	85	82
Combi-boiler	For hot water	η_1	96	89	86
		η_2	92	85	82
	For heating	η_1	99	89	86
		η_2	95	85	82

In some respects, the option for the supplier to design their products to perform optimally under full load or at 50% load is a positive development. This should give consumers the choice of selecting a water heater that is optimal for their needs, i.e., either a water heater that is generally to be operated at full load or, alternatively, generally operated at part load. However, this requires:

- The consumer to know under which conditions the η_1 and η_2 values reported on the label were obtained. Under the current label design, it would be impossible to know, and therefore consumers would be unsure whether they are purchasing a gas water heater that is optimized for full- or part-load operation;
- The consumer to know under which load condition the water heater is most likely to operate. This is problematical as, in the majority of cases, the water heater is selected by the builder who will have only an outline idea of the likely usage patterns of the ultimate occupier of the property.

Therefore, policymakers may wish to consider:

- Revising the Energy Label to make clear whether the unit is optimized for full-load or part-load operation;
- Commissioning a full technical study to establish the typical (or typical range of) operating load conditions of gas water heaters in Chinese households. This study should be completed before the next revision to the EES, to allow policymakers to consider whether full-load or part-load should be the primary operating condition under which performance should be measured, or whether some combined value of the two thermal efficiency results would be most representative of Chinese operating conditions (in a similar way to the current washing machines standard, which uses an algorithm to combine the energy consumption of full and part load washes to give an average performance for the washing machine under typical Chinese operating conditions). By doing so, the onus is no longer placed on the purchaser to understand their particular load conditions (or the load conditions likely by the ultimate purchaser of the property), and the unit will be optimized for typical operation in the market. While this will result in water heaters not

being optimized for all consumers, it will remove the requirement for consumers to understand their particular load conditions, thus removing the risk of purchasing a water heater that is completely unsuitable for their purposes.

One final note on the EET thresholds proposed under the 2014 EES: from the values given in Table 33, once again only condensing boilers will be able to attain Tier 1 product status. However, non-condensing boilers should still be able to attain Tier 2 or Tier 3 status. This is somewhat at odds with many international actions (particularly in the EU where *only* the higher efficiency condensing water heaters are allowed to be sold in the market). While further revisions to the proposed 2014 EES thresholds are unlikely to be possible at this stage, policymakers may wish to take the opportunity to signal to suppliers that during the next revision to the EES, it is likely China will follow the international trend and require all water heaters to be condensing units. This will give suppliers sufficient notice to develop compliant products in time for the next EES revision.

B.5.2.6 Test methods for revised EES

The revised EES uses different test methods for conventional water heaters and condensing water heaters. Table 34 summarizes the test standards used for different types of products.

Table 34: Test methods for different types of gas instantaneous water heaters (revised 2014)

Product type	Test standards
Conventional water heater	GB 6932 (revised)
Condensing water heater	CJ/T 336-2010[113]

Conventional water heaters

The revised test methods for conventional water heaters are broadly the same as the current (2006) test methods, as described in Section A.5.2.3. However, the equation used for thermal efficiency calculation has changed slightly, to take account of the temperature adjustment of thermal efficiency for reference gas (highlighted in red in Equation 10). However, this adjustment has not been made to the condensing water heater calculation, possibly due to the fact that the test method for condensing water heaters had not been revised.

Equation 10: Thermal efficiency for gas water heaters (GB 6932 revised)

$$\eta_1 = \frac{M \times C(t_{w2} - t_{w1})}{V \times Q_1} \times \frac{273 + t_g}{288} \times \frac{101.3}{p_{amb} + p_g - S} \times 100$$

[113] CJ/T 336-2010: Condensing domestic gas instantaneous water heaters

Condensing water heaters

The test methods for condensing water heaters in the revised EES are also similar to the methods described in Section B.5.2.4, but some of the parameters vary (refer to Table 35 for details).

Table 35: Overview of the data used for the analysis of gas instantaneous and condensing water heaters (data collected October 2013)

	Instantaneous water heater	Condensing water heater
Test standards	GB 6932 (revised)	CJ/T 336-2010
Heat input used in the tests	1. Rated heat input 2. 50% rated heat input	1. Rated heat input 2. 50% rated heat input
Gas composition/ type	0-2	0-2
Water supply pressure	0.1MPa	0.1MPa
Ambient Temp.	20±5°C	20±5°C
Inlet temp.	20±2°C	20±2°C
Output water temperature	40±1°C higher than inlet water temp; set to closest value if this temp. requirement cannot be met.	35±2°C higher than inlet water temp; set to closest value if this temp. requirement cannot be met.
Formula for η_1	Equation 2	Equation 1
Other considerations	—	Add 2.4% to η_1 when LNG is used.

B.5.3 Data Analysis

As stated earlier, due to the limited penetration of combi-boilers in the market to date, and the associated limited availability of data, data collection and analysis has been restricted to gas instantaneous water heaters. Further, as the 2014 EES has yet to be formally adopted, and all the model data analyzed has performance declarations made against the current GB 20665-2006, the following analysis relates to product performance declarations under, and comparisons with the energy efficiency requirements of GB 20665-2006, *NOT* the 2014 revision.

Data on a total of 361 distinct instantaneous water heater models were collected from three major Chinese online appliance retailers: Suning[114], Gome[115] and Jing Dong[116]. Some models were available from more than one retailer, and some models were essentially the same but available for different energy sources (natural gas and liquefied natural gas). Duplicate data were removed in these cases.

In addition to the generic cautions provided in the Approach and Methodology section of the Introduction, readers should note that

- Data has been sourced from three online retailers as detailed above. However, it is not clear whether this data set is representative of the market

[114] http://www.suning.com
[115] http://www.gome.com.cn
[116] http://www.jd.com

as a whole, as online distribution may not be a primary retail channel for gas water heaters. For example, housing developers would bulk purchase gas water heaters and pre-install them in newly-developed apartment buildings. However, at present this is the best data available, and is presumed to be broadly representative of the models available on the market. However, it is recognized that model availability is not always representative of the actual products consumers are purchasing, and often sales-based analysis provides a better picture of the market. However, the acquisition of sales-based data is challenging. Therefore, to complement the model-based analysis, the online data sources used were also interrogated to produce a "rank-by-sales". While not providing a true sales weighted average, this approach gives a broad proxy for sales-weighted data by identifying the subset of products most purchased by the consumer (albeit not the absolute quantity of each model purchased). By comparing all surveyed models (product-based) and the 57 distinct models listed in the "rank-by-sales" search (proxy-sales based, called "popular models" from now on), the analysis provides a better understanding of the true market picture.

- Not all performance and other parameters were available for all gas instantaneous water heater models identified. The specific number of models where each product property was known, and hence included in the analysis, is indicated in Table 30.

It has proved impractical to provide a numerical value describing the degree to which the data set is skewed by online availability, and the degree of bias introduced where not all parameters are known.

Table 36: Overview of the data used for the analysis of gas instantaneous water heaters, all surveyed models and popular models (data collected October 2013)

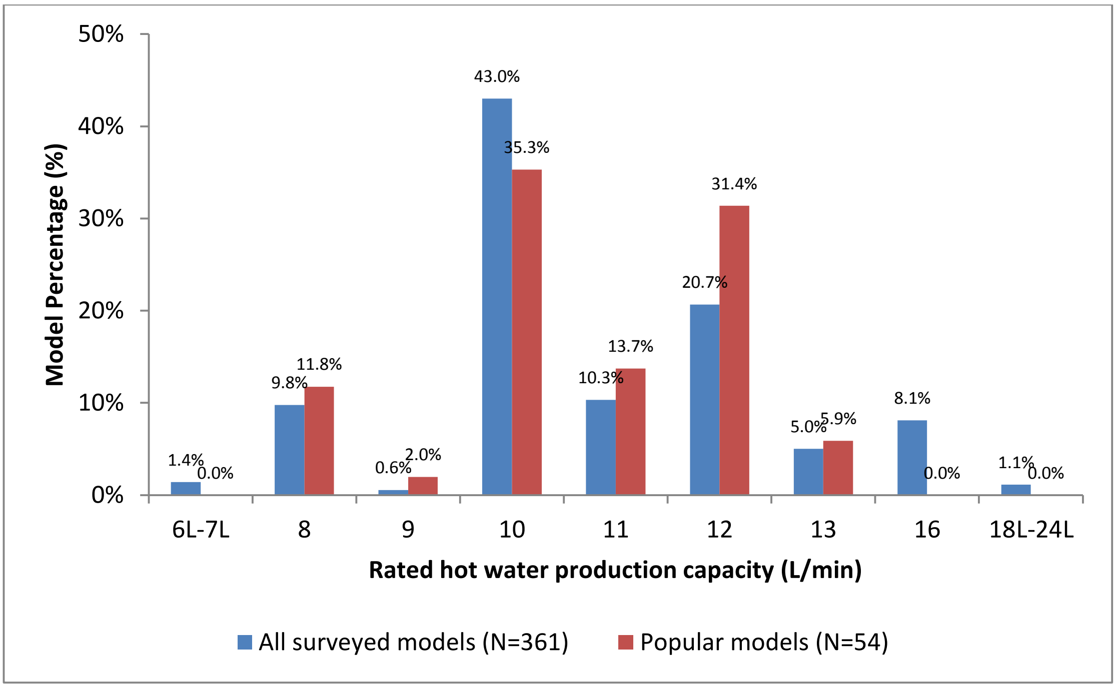
Data type	All surveyed models	Popular models
Number of models	361	54
Energy efficiency Tier	Range: 1 – 3	Range: 1 – 2
Hot water production capacity(L/min)	Range: 6 – 18	Range: 8 – 16
Rated heat input (kW)	Range: 12 – 33	Range: 16 – 33
Price (RMB)	Range: 269 – 8329	Range: 699 – 6098

B.5.3.1 Market distribution by gas instantaneous water heater rated hot water production capacities

The hot water production capacity is defined as the amount of hot water produced (25°C higher than inlet water temperature) per minute when the water heater is at its maximum heat input. The distribution of rated hot water production capacity for all available and popular models is shown in Figure 87. This Figure shows a broad similarity between the real market distribution (as defined by popular models) and the model-based analysis, which gives a degree of confidence in this approach. This confidence is further enhanced, as Figure 87 shows that gas instantaneous water heaters with a rated hot water production capacity of 10L/min have the highest market availability (43% of all models available in the market) and are also the most popular models (35%). Analysis elsewhere suggests 10L/min models are the most popular purchase, accounting for 31% of the total sales[117].

The 12L/min and 11L/min models are the next most available and most popular models. However, China is experiencing a period of increasing disposable incomes and living standards, with an associated tendency to have bigger homes that require more hot water at a faster rate. Therefore, models with 12L/min rated hot water production capacity are an increasingly important market segment and also a main battlefield for manufacturers. Policymakers may wish to monitor changes in the capacity of products being sold, as, even if efficiency is increasing, the increase in capacity of units is likely to lead to an increase in overall energy consumption.

Figure 87: Distribution of available and most popular models of gas instantaneous water heaters by rated hot water production capacity (data collected October 2013)

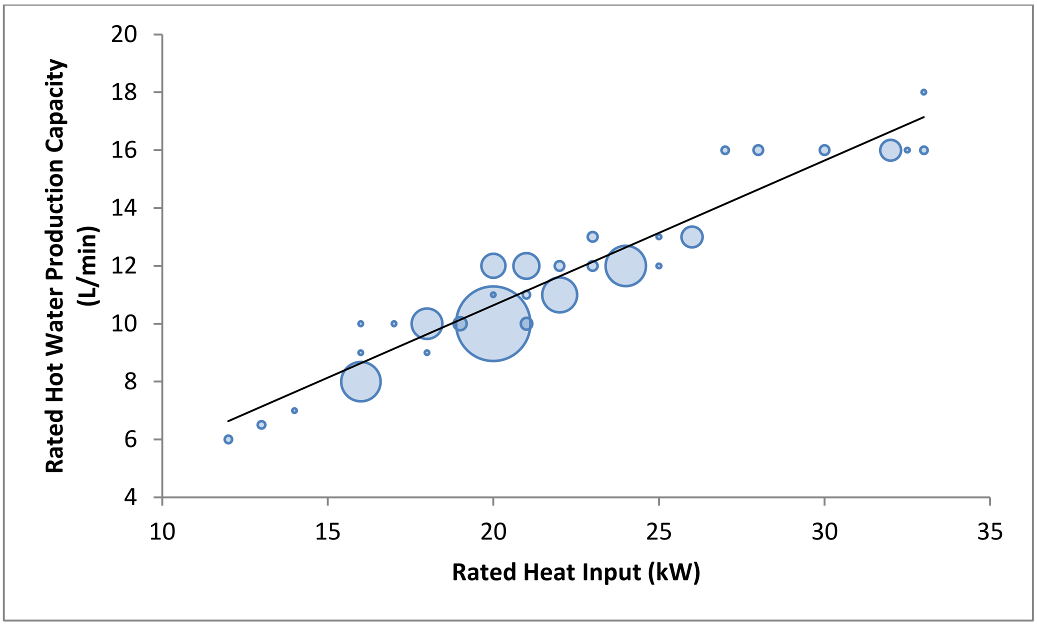


B.5.3.2 Relationship of rated heat input and rated hot water production capacity

Heat input is the amount of heat released by burning the fuel per unit of time. It is the product of the gas net calorific value and volume flow rate. Obviously on a theoretical level, the water should be heated more quickly when the rated heat input of the water heater is higher. This is confirmed by Figure 88, which shows a strong positive linear relationship between rated heat input and hot water production capacity of models available in the market. Figure 88 also shows that, with a small number of exceptions, models with the same rated heat input have the same rated hot water production capacity.

[117]Gao, Min. (2013). *Rapid increase of water heater market with new focus on efficient fast-heating water heaters*. Appliance. October issue. [In Chinese].

Figure 88: Relationship of rated heat input and rated hot water production capacity of gas instantaneous water heater models available on the market (data collected October 2013)

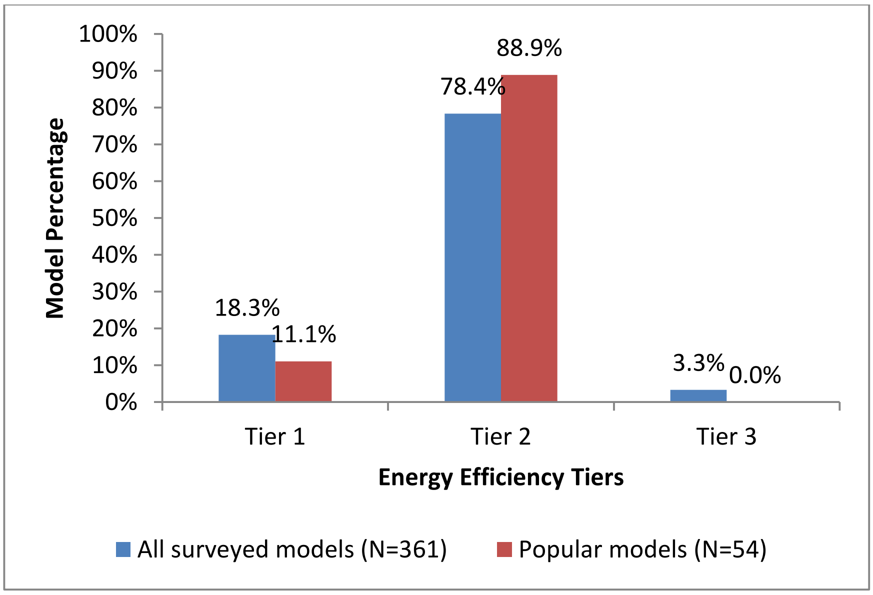


Note, the size of the circle indicates the relative number of models available at center-point of the circle.

B.5.3.3 Market distribution by energy efficiency tiers

The distribution of models by EET is shown in Figure 89.

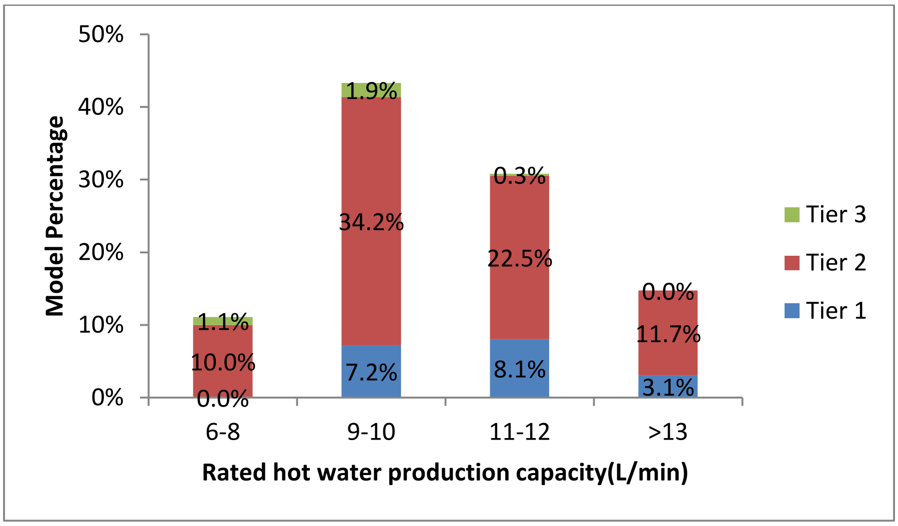
Figure 89: Distribution of gas instantaneous water heaters by energy efficiency tiers, all surveyed models and popular models[118] (data collected October 2013)



[118] Only condensing gas water heaters can achieve Tier 1 energy efficiency requirements, and so Tier 1 and condensing water heaters are used interchangeably.

A total of 18% of available models, and 11% of popular models are Tier 1 (condensing gas instantaneous water heaters are the only type that can achieve the Tier 1 efficiency requirements[119]), with almost all other products being Tier 2. Figure 90 illustrates a similar pattern across capacity ranges (with the exception of the smallest models, where no Tier 1 products are available). This result is in line with a recent article in which the current (2013) market share of condensing water heaters was reported to be 14%.

Figure 90: EET distribution of gas instantaneous water heaters by rated hot water production capacity (data collected October 2013)



However, the same article also noted that the 2012 market share of condensing water heaters was only 4%. Hence, despite the current (2006) EES coming into force in 2007, and the label being introduced to water heaters in 2008, there was a very slow initial take up of condensing water heater technology, despite the label demonstrating the obvious efficiency benefits. This is in line with the European experience where, despite the presence of the label, uptake of more efficient condensing water heaters was very slow. In Europe, the reason for the slow uptake was that the majority of boilers were purchased by either developers (i.e., house builders) or by professional plumbers renovating the hot water/heating system. In both cases, the actual purchaser of the water heater was not the home owner responsible for the cost of operation, and hence the efficiency of the water heater was of little importance; rather it was the purchase price which was the prime driver for water heater selection. Eventually initial adoption of condensing technology was stimulated through additional interventionist policies, in particularly subsidies (for example those provided by the UK's Energy Saving Trust). However, even such additional policy intervention failed to make the more expensive condensing units mainstream, and ultimately Europe has revised their MEPS level for water heaters/boilers such that condensing models are now mandatory. Such a situation

[119] Only condensing gas water heaters can achieve Tier 1 energy efficiency requirements, and so Tier 1 and condensing water heaters are used interchangeably.

appears to be the case in China, with bulk-purchase from housing developers making a large proportion of the total gas water heater sales. These purchasers are very likely to choose the lowest cost models, not necessarily the most efficient models. The situation further mirrors the European example, as the sudden acceleration of take up of condensing models in 2013 appears to have been a result of the 2012 incentive program (which started late in 2012 and ran into much of 2013), providing a major subsidy for the Tier 1 (condensing) instantaneous water heaters. From this we may deduce the current (2014) revision of the EET requirements (and the associated reclassification of label EETs) for gas water heaters is unlikely to be sufficient to significantly move the market to more efficient units. Hence, to realize widespread adoption of condensing technology, policymakers may wish to consider additional policy intervention such as:

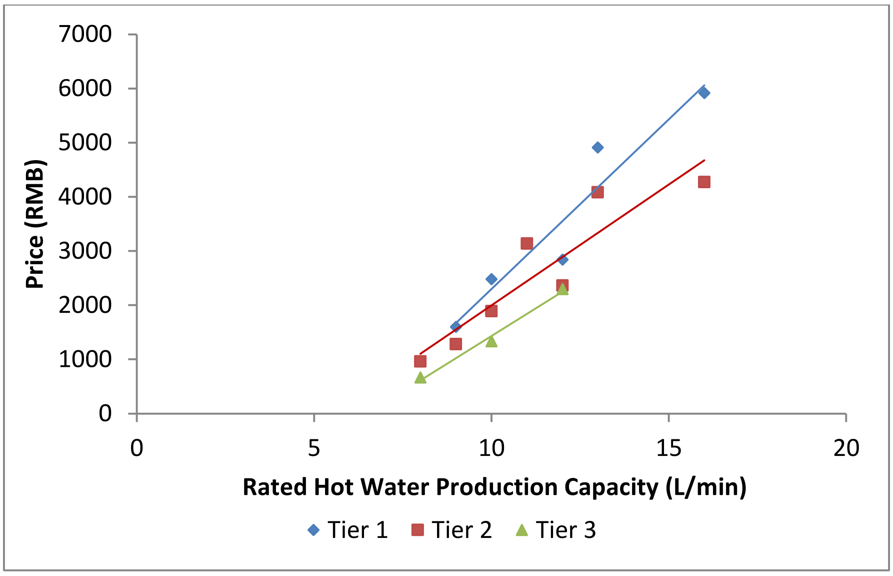
- Continued provision of significant subsidies to cover the additional cost of condensing models (refer to Section B.5.3.4) and/or support manufacturers to further develop condensing water heater technology to lower the price differential;
- Implementing overall energy consumption requirements for the hot water/heating supply for entire buildings. Such a practice has already been enforced for lighting, where maximum energy consumptions are prescribed for certain building types;
- Signal that the next revision of the EES will make condensing water heaters mandatory by increasing the MEPR level.

However, in the shorter term, currently over 95% of all models are deemed “energy efficient”, i.e., are Tier 1 or Tier 2 products. As a consequence, consumer choice is limited where they wish to make a choice based on model efficiency, and manufacturers of higher efficiency products are not recognized and rewarded. Further, it is not possible for policymakers to easily focus support (e.g., subsidy) on the best performing products, as there is very little product differentiation. The EET thresholds under the proposed 2014 EES have all been raised, and thus policymakers should be applauded for attempting to remove the least efficient products from the market and appropriately distribute the remaining models across the three EETs. However, as the 2014 EES has slightly modified the test methods and the changed the basis for evaluating the efficiency of units (i.e., the η_1 and η_2 values can be at full or half load), there is insufficient data available to this analysis to establish whether the revised thresholds will achieve the goal of appropriately distributing models across the EETs. Therefore, policymakers may wish to carefully monitor the registration of products under the EES, to establish if the models registered are appropriately distributed across the EETs (with the goal of only 20% of products achieving Tier 1 or 2 status).

B.5.3.4 Relationship of energy efficiency tiers, rated hot water production capacity, and price

Brand, appearance and intelligent functionality can all contribute to price differences between gas water heaters, but price is also influenced by both rated hot water production capacity and energy efficiency Tiers, as illustrated in Figure 91.

Figure 91: Relationship of rated energy efficiency tiers, hot water production capacity and price of gas instantaneous water heater models available on the market (data collected October 2013)



Water heaters with larger hot water production capacities are generally more expensive than smaller ones. Water heaters with higher efficiency Tiers are more expensive than those with lower efficiency Tiers. In particular, Tier 1 (condensing models) are more expensive due to a number of reasons:

- The construction of condensing water heaters is very different from conventional gas water heaters, particularly the heat exchanger. In order to adequately absorb heat from high temperature flue gas, a two-stage heat exchange process is normally required rather than the single heat exchanger present in standard units.
- Secondly, condensing water heaters have to tackle two key problems associated with vapor condensation. The first problem is that by recycling waste heat from flue gas, the temperature of the gas is lowered, and therefore water condensation will form on the main heat exchanger, leading to significant corrosion problems. The second problem is the collection of the acidic condensing water, which if not treated properly will cause corrosion problems in the pipeline and other environmental problems. In order to solve these two problems, better anti-corrosion materials must be used for condensing water heaters, and a neutralization collector for condensing water must be installed.

B.5.4 Conclusions and Recommendations

The conclusions and recommendations drawn from this analysis of gas instantaneous water heaters are as follows:

The revised (2014) Energy Efficiency Standard: benefits and risks

Currently over 95% of all models are deemed “energy efficient”, i.e., are Tier 1 or Tier 2 products. As a consequence, where consumers may wish to select a gas instantaneous water heater based on model efficiency, choice is limited, and manufacturers of higher efficiency products are not recognized and rewarded.

The EET thresholds under the proposed 2014 EES have all been raised, and thus policymakers should be applauded for attempting to remove the least efficient products from the market and appropriately distribute the remaining models across the three EETs. However, as the 2014 EES has slightly modified the test methods and changed the basis for evaluating the efficiency of units (i.e., the η_1 and η_2 values can be at full- or half-load) there is insufficient data available to this analysis to establish whether the revised thresholds will achieve the goal of distributing models across the EETs. Therefore, policymakers may wish to:

1. Carefully monitor the registration of products under the revised 2014 EES, to establish whether the models registered are appropriately distributed across the EETs (with the goal of only 20% of products achieving Tier 1 or 2 status).

Further, under the 2014 EES, suppliers have the option to design their products to perform optimally under full load or at 50% load. In many ways this is a positive development, as it *should* give consumers the choice of selecting a water heater that is optimal for their needs, i.e., either a water heater that is generally to be operated at full load or, alternatively, generally operated at part load. However, this requires:

- The consumer to know under which conditions the η_1 and η_2 values reported on the label were obtained. Under the current label design, it would be impossible to know, and therefore consumers would be uncertain whether they are purchasing a gas water heater that is optimized for full- or part-load operation;
- The consumer to know under which load condition the water heater is most likely to operate. This is problematical as, in the majority of cases, the water heater is selected by the builder (see below), who will only have an outline idea of the likely usage patterns of the ultimate occupier of the property.

Therefore, policymakers may wish to consider:

2. Revising the Energy Label to make clear whether the instantaneous water heater is optimized for full-load or part-load operation;
3. Commission a full technical study to establish the typical (or typical range of) operating load conditions of gas water heaters in Chinese households. This study should be completed before the next revision to the EES, to allow policymakers time to consider whether full load or part load should be the primary operating condition under which performance should be measured, or whether some combined value of the two thermal efficiency results would be most representative of Chinese operating conditions. By doing so, the onus is no longer placed on the purchaser to understand their particular load conditions (or the load conditions likely to be used by the ultimate purchaser of the property), and the unit will be optimized for typical operation in the market.

Additional policy action required to stimulate the uptake of the most efficient condensing units

The 2012 market share of condensing water heaters was only 4%. Hence, despite the current EES coming into force in 2007 and the label being introduced to water heaters in 2008, there was a very slow initial take up of condensing water heater technology, despite the label demonstrating the obvious efficiency benefits. This is in line with the European experience where, despite the presence of the label, uptake of more efficient condensing water heaters was very slow. In Europe, the reason for the slow uptake was that the majority of boilers were purchased either by house builders or by professionals renovating the hot water/heating system. In both cases, the actual purchaser of the water heater was not the home owner responsible for the cost of operation, and hence the efficiency of the water heater was of little importance; rather it was the purchase price which was the prime driver for water heater selection. Eventually initial adoption of condensing technology was stimulated through additional interventionist policies, in particularly subsidy. However, even such additional policy intervention failed to make the more expensive condensing units mainstream, and ultimately Europe has revised their Minimum Energy Performance Standards for water heaters/boilers such that condensing models are now mandatory.

Such a situation appears to be the case in China with bulk-purchase from housing developers making up a large proportion of the total gas water heater sales. These purchasers are very likely to choose the lowest cost, not necessarily the most efficient models. The situation further mirrors the European example, as the sudden acceleration of take up of condensing models to 14% of the market in 2013 appears to have been a result of the 2012 incentive program (which started late in 2012 and ran into much of 2013) providing a major subsidy for the condensing instantaneous water heaters.

From this we may deduce that the 2014 revision of the EET requirements (and the associated reclassification of label EETs) for gas water heaters is unlikely to be sufficient to significantly move the market to more efficient units. Hence, to realize widespread adoption of condensing technology, policymakers may wish to consider additional policy intervention such as:

4. Continued provision of significant subsidies to cover the additional cost of condensing models and/or support manufacturers to further develop condensing water heater technology to lower the price differential;
5. Implementing overall energy consumption requirements for the hot water/heating supply for entire buildings. Such practice has already been enforced for lighting, where maximum energy consumptions are prescribed for certain building types;
6. Signaling that the next revision of the EES will make condensing water heaters mandatory by increasing the MEPR level. This would mirror the international trend, but still provide suppliers with sufficient notice to develop compliant products in time for the next EES revision.

Increases in water heating sizes risk offsetting improvements in model efficiency

China is experiencing a period of increasing disposable incomes and living standards, with an associated tendency to have bigger homes that require more hot water at a faster rate. Clearly this leads to the potential that the increased energy consumption of the larger water heating products will more than outweigh the benefit of marginal improvements in model energy efficiency. Therefore policymakers may wish to:

7. Monitor the changes in the capacity of products being sold. Should average capacities continue to rise, consider policy actions that may offset the increase in energy consumption (e.g., a mandatory requirement for condensing boilers above a certain capacity).

Conclusions and Recommendations

The MACEEP 2014 analysis of six domestic appliances clearly demonstrates that the actions taken by Chinese policymakers to date (including the development and implementation of minimum energy efficiency standards, product labeling, and other interventions) have resulted in substantial improvements in the energy efficiency of these products. However, the analysis also shows that there are considerable additional opportunities for energy and cost savings that could result from further actions by policymakers.

Within the six appliance analyses presented in MACEEP 2014, a total of 43 recommendations have been made for improving energy efficiency policy, ranging from refining the energy label to technical revision of standards. In each case these recommendations are specific to the appliance and justified on the evidence presented in the individual analysis of that appliance. However, when reviewing the individual appliance conclusions and recommendations together, there are a number of overarching themes that may be of significant interest to policymakers. These summary conclusions and recommendations are as follows.

Immediate energy saving opportunities

Significant energy saving opportunities are immediately available through relatively simple revisions to the minimum energy performance requirements for fixed and variable speed air conditioners, refrigerators, and water heaters. Potentially appropriate minimum energy performance requirements are proposed in the relevant appliance analyses above. Policymakers should be reassured that, in general, there is little evidence to suggest such revisions would have an adverse impact on product price. However, it may be necessary to support some manufacturers in adapting to higher performance requirements if a change in production is necessary.

Revise current strategy for developing energy efficiency Tiers

The strategy currently being pursued by Chinese policymakers when developing energy efficiency standards has resulted in the situation where, for most types of appliances, a large proportion of models are qualified at higher efficiency levels, or "Tier 1" and "Tier 2". As there has been a clear and sustained improvement in the efficiency of many products, there is evidence that this strategy is working. This is possibly because there is no incentive for manufacturers to apply premium pricing to Tier 1 products, and thus there is no price barrier preventing consumers from selecting efficient products. This may be leading to less efficient products only accounting for a limited market share, making it easy for policymakers to eliminate these products when revising/updating energy efficiency standards.

However, the current strategy means that consumers do not have the opportunity to preferentially select the most efficient products at the point of purchase, i.e., if Tier 1 products only count for less than 5% of available models on the market, consumers would be able to differentiate them from other regular or less efficient models. Moreover, there is limited incentive for manufacturers to develop new products of higher efficiency, since they will not be distinguished in the market. Therefore, policymakers may wish to consider an alternative strategy, whereby future revisions to the energy efficiency Tiers for all appliances will introduce new performance requirements such that:

- Tier 1 requirements are set at the efficiency level of the best performing appliance in the market at that time (thus creating the equivalent of a "Top Runner" target – i.e., the top 5% of products in terms of energy efficiency – to encourage the development of new high performance products), or at some other similarly-ambitious efficiency level that satisfies the desires of Chinese policymakers;
- The Tier 2 requirements dictate that only the top 10% of efficient appliances are eligible for qualification at the time the standard is introduced; and
- The remaining products are evenly distributed across the remaining labeling categories.

Furthermore, an automatic revision of the Tier requirements should be initiated when 10% of products in the market achieve Tier 1 performance, or 25% of products achieve Tier 2 performance. This would ensure that higher efficiency products are continually differentiated from other appliances on the market.

Such a strategy would allow consumers to choose higher-efficiency products and allow policymakers to more effectively pursue other policy support measures that target the best performing products. This strategy is also in line with current (or likely) developments in other countries, such as Australia, Canada, Korea, and Japan – where premium products are effectively identified in the market, or automatic standards revisions are undertaken when approximately 25% of products reach a level considered to define premium efficiency.

A more detailed review will be conducted in future MACEEP studies to learn which of the two strategies mentioned above is more suitable for China's situation.

Make efficiency requirements technology neutral

Currently, a number of appliances with the same functionality qualify for differing energy efficiency tiers and minimum performance requirements based on different technologies. For example, variable and fixed speed air conditions (and air conditioners with and without heating functionality), impeller and drum washing machines, LED TVs and PDP TVs, and various types of water heater[120] have differing test procedures and energy performance requirements. This is very likely to mislead consumers in the relative performance of the various appliance types, and is likely to lead to inadvertent purchases of products that consume more energy than necessary.

Therefore, this study strongly recommends that policymakers attempt to ensure that all appliance standards are based on technology-neutral test methods and performance requirements. It should again be noted that some manufacturers may require additional policy support to shift production where their existing product range is adversely affected by the switch to a technology-neutral standard.

Consider the wider environmental implications of products when developing energy efficiency standards

The primary purpose of the current energy efficiency standards regime is to save energy. However, energy saving in itself is not the primary goal, but simply a mechanism through which other goals are achieved, for example reduction in the use of natural resources, reductions in the emissions that accelerate global warming, and reductions in consumer expenditure on energy. Thus the focus on energy savings alone in the development of energy efficiency standards may not yield the optimal outcome. For example, it *may* be appropriate to make the efficiency requirements for air conditioners less stringent should they use refrigerants with lower global warming impact. Hence, when developing energy efficiency standards, a switch to a wider remit encapsulating the overall environmental impact of the product (as is the case in the EU) may be appropriate.

Research consumer usage patterns

Real life use of products by consumers in their homes directly impacts several factors in the development of energy efficiency standards. It affects projections of energy consumption and saving potentials, the accuracy and relevance of test methods, and determines the actual energy used by the consumer in their household. Despite this, very little public information appears to be available on current consumer usage patterns for the majority of appliances in China. A separate study conducted by CLASP[121] provides the basis for this understanding of consumer usage patterns for a number of products, and it is recommended that this study be extended to capture usage patterns

[120] For water heaters there is increasing overlap in functionality between storage water heaters and instantaneous units and hence the historical differentiation of products based on technology no longer seems appropriate.
[121] Consumer Awareness and Comprehension of China Energy Label and Usage Pattern of Household Appliances, CLASP 2013.

for a wider group of products and, if possible, to undertake nationwide in-household monitoring of actual product usage and energy consumption.

Revise labels to be more understandable to the purchaser

Currently, a number of the criteria displayed on energy labels are not assisting consumers in selecting the most efficient or lowest energy-consuming appliance. For example, the declared energy efficiency index (EEI) of televisions, "hot water production rate" of electrical storage water heaters, and the thermal efficiency (η) of gas water heaters have little meaning to consumers[122] and are unlikely to impact their purchasing decisions.

Further, using efficiency as a measure of comparative performance is not always beneficial. For example, a 50" TV of Tier 1 will probably use *more energy* than a 45" TV of Tier 2, but that information is not communicated effectively on the label. A consumer aiming to purchase efficient products may purchase the 50" unit due to its apparent higher efficiency, but ultimately that unit will consume more energy.

Therefore, the study recommends that a typical daily, monthly, or (ideally) annual energy consumption figure be included on the label for most products, similar to that which is used for refrigerators. Actually, this is already a nominal requirement of the energy labeling management rules.[123] In the longer term, the calculation of energy consumption should be based on typical usage patterns that are established by research into consumer usage patterns.

Require energy labels to reflect typical product performance, and review allowable testing and labeling tolerances

There is evidence to suggest that some manufacturers are reporting energy performance values on appliance energy labels that are higher or lower than the typical performance of the model. This has the potential to lead to the development of inappropriate revisions to the affiliated energy efficiency standard or hamper the development of a more appropriate one. It can also lead consumers to select an appliance that is not appropriate for their needs or that fails to meet their expectations of energy consumption.

Therefore, the study strongly recommends that policymakers require declarations of energy efficiency and other performance indicators on an energy label in order to

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[122] Consumer Awareness and Comprehension of China Energy Label and Usage Pattern of Household Appliances, CLASP 2013

[123] Clause 8 of the "energy label management rules" states "the label should include information of energy consumption."
http://energylabel.gov.cn/NewsDetail.aspx?Title=%e6%94%bf%e7%ad%96%e6%b3%95%e8%a7%84&CID=31&ID=137

accurately reflect the true performance values reported in the test certificate submitted with the label application. This test certificate must represent the *typical* performance of the model under production conditions. Furthermore, once clarity is achieved in product claims, policymakers may wish to re-examine the tolerances, or allowable level of variance between test results, in test methods and labeling claims to ensure they are appropriate for each appliance type.

Revise some test methodologies and thresholds for performance

A number of potential shortcomings have been identified in existing test methodologies, particularly for TVs and water heaters. Policymakers may wish to encourage revision of these test procedures, possibly through the adoption of existing and accepted international methodologies, to ensure that the performance of the appliance is represented accurately. This information is essential for consumer decision-making and for the development of appropriate policy measures.

Similarly, an issue has been identified in the use of linear functions and adjusted volumes as the basis for regulation of refrigerated appliances. The current Energy Efficiency Standard is based on a linear function and adjusted appliance volume to derive the energy efficiency performance Tiers and the associated minimum energy performance levels. However, the use of such a linear function *and* adjusted volumes has the effect of increasing the price of smaller units and/or improving the apparent efficiency of larger appliances. Either (or, worse, both) of these outcomes is giving an incentive for consumers to purchase larger appliances, which leads to higher overall energy consumption. The approach used in China is in line with current practice in the majority of countries around the world. However, Chinese policymakers may wish to consider a move to curved exponential functions based on adjusted appliance surface area as a basis for minimum performance and Tier thresholds. Such an approach would more effectively respond to the inherent increase in efficiency as product sizes increase, and removes the potential for the perverse outcome of increased unit volumes improving apparent unit efficiency but increasing consumption.

Consider a technical study to assist in future energy efficiency standards development

In general, existing energy efficiency standards have some Tier or minimum performance requirement related to the "standby" of the appliance. Typically these standards refer to a single standby mode; for example, "off-mode power" where a unit is plugged into the main power supply but the appliance is switched off. However, with the advent of microprocessor control and additional appliance functionality, an increasing number of appliances have varying standby modes. For example, televisions have "fully off", "standby with no activity", instant "on" functionality, internet connectivity, and so on – all of which have varying levels of energy consumption that are not currently captured by existing Chinese test methodologies. Therefore, policymakers may wish to conduct a technical study examining appropriate appliances to establish the type and extent of standby modes currently available. This study, in combination with consumer research on typical usage patterns, should identify any additional standby modes that result in significant energy consumption and are commonly used by consumers.

Similar technical studies are also recommended to consider:

- How heating performance should be better regulated, the comparative real life energy consumption of variable speed versus fixed speed, and the impact of refrigerants on air conditioners.
- Typical range of operating loads of gas water heaters in Chinese households, to allow consideration of whether full load or part load should be the primary operating condition under which performance should be measured, or whether some combined value of the two thermal efficiency results would be most representative of Chinese operating conditions.
- Developing a standardized test method for 3D TVs as soon as possible, and including it in the next revision of the EES. Current evidence *suggests* 3D TVs have the potential to use substantially less energy than 2D equivalents.

The results can then be integrated into the testing and energy efficiency standards for that appliance. Similar research is under way in other parts of the world and there is potential for Chinese policymakers to collaborate with, or learn from, these studies.

Improve the collection of sales data

The majority of analysis in this report was conducted on a product basis rather than a sales weighted basis due to limited access to sales data. This study found that although the results of sales and models analysis are often similar, this is not always the case, and the difference has the potential to distort findings as, for example, particularly efficient or inefficient products may sell in significantly larger quantities than an average product on the market. If policymakers are similarly limited in their access to sales figures for products, it may lead to similar potential distortions in the analyses conducted for the development of energy efficiency standards and associated energy saving projections.

Therefore, policymakers may wish to require suppliers of registered appliances to supply annual sales figures for those appliances as part of the registration requirement. While this may sound impractical, policymakers may wish to know such a requirement is part of the registration requirement in Australia, Canada, and Korea (and as part of the USA ENERGY STAR program), where, if suppliers do not provide annual sales data, the registration of the product is cancelled. Nevertheless, it should be recognized that implementation of such an approach can face initial barriers from industry, who perceive such data to be commercially sensitive. However, the experience from elsewhere indicates that policymakers can secure the data *and* benefit from improved market knowledge and resulting improved policy making.

Reorient the focus of future subsidy programs

There is little doubt that the use of subsidies in preceding years in support of efficient appliances has achieved the primary goal of stimulating national demand for high efficiency appliances and increasing their penetration into rural areas. However, in some cases, the subsidies have been supporting products that are highly efficient, yet still consume very high levels of energy. For example, LED-backlit televisions with very large screens may be highly efficient, but will still consume over twice as much power as a television of half the screen size.

Therefore, if policymakers wish to consider the use of subsidies in the future to promote energy efficient products, they may wish to consider:

- Only providing subsidy support for Tier 1 or higher products, ideally with the best in market ("Top Runner");
- Setting a maximum cap on total energy that can be consumed by the appliance. This introduces the concept of sufficiency in addition to efficiency – i.e., not subsidizing expensive products of large size or volume, and/or those containing sophisticated but energy-consuming functions.