China Product Prioritization & Energy Saving Potential

Based on recent MACEEP-ESP and LBNL studies

Executive Summary

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Energy consumption by appliances in Chinese homes is increasing rapidly. This is for a variety of reasons, such as the rise in consumer prosperity and the increasing number of households. The Chinese Government, through various agencies, has already begun to address this rise through a series of energy efficiency product policies, such as minimum energy performance standards (MEPS) and energy labeling on new products sold.

Two separate CLASP-funded studies have examined further potential for energy savings from improving appliance energy efficiency in China: *Potential for Further Savings from Appliance Efficiency Programs in China* by the Lawrence Berkeley National Laboratory (LBNL), hereafter referred to as "the LBNL study;" and *Market Analysis of China Energy Efficient Products* (MACEEP) by CLASP and Top10 China, which includes an energy savings potential (ESP) analysis. This will hereafter be referred to as the "MACEEP-ESP" study.

CLASP and its partners presented the MACEEP-ESP and LBNL studies, with accompanying policy recommendations, to the China National Institute of Standardization (CNIS) in 2013. Both were well-received, but CNIS raised some questions and concerns on the connections between both studies and how to reconcile the two different approaches to calculating energy savings. To avoid confusion and maximize the impact of both studies, CLASP and Kevin Lane (Oxford) initiated this study in an effort to summarize the findings of both analyses, provide an integrated overview, and provide recommendations on product prioritization and energy savings potential to Chinese policymakers.

The main objectives of this study are to:

1. Compare the MACEEP-ESP and LBNL approaches;
2. Re-run ESP analyses with scenarios to match LBNL;
3. Develop ESP models for water heaters (electric storage and gas instantaneous); and
4. Explain both sets of scenarios and summarize product prioritization and ESP from both studies.

The LBNL study

In 2012, LBNL, with support from CLASP, initiated a study of the energy savings and greenhouse gas reduction potential for six energy-intensive appliances: air conditioners, clothes washers, electric storage water heaters (ESWH), gas instantaneous water heaters (GIWH), refrigerators, and rice cookers.

The LBNL study describes and develops three scenarios using the Bottom-Up Energy Analysis System (BUENAS):

- Business-as-usual (BAU): what would happen to energy consumption with no further product policy;
- Continued improvement scenario (CIS): where the efficiency of new products improves every few years;
- Reach scenario (Reach): where all new appliances are as efficient as the best products in China or elsewhere by 2014 or 2015. This is not necessarily a realistic scenario.

The assumed efficiency values for the BAU and Reach scenarios are presented below.

Table 1: Efficiency assumptions for BUENAS BAU, CIS and Reach scenarios[1]

End use	BAU in 2015	Reach Target	CIS scenario
Air conditioners	GB-1 - 3.6 EER (market reaches GB-1 in 2012, held at 3.6)	Market Maximum EER=6.14	10% every 5 years from 2014
Clothes washers	0.0219 kWh/cycle/kg Top-Load, 0.193 Front-load - Linear trend for market shares	"GB-0 " - 0.007 kWh/kg/cycle for top-load, 0.15 for front-load	10% every 5 years from 2015
Electric storage water heaters	Efficiency 60.7 % (Linear trend from 2009-2010)	Heat Pump – 250% efficiency	10%** every 5 years starting in 2015
Gas instantaneous water heater	90% Heating Efficiency	96% Heating efficiency in 2030	6%* from 2015
Refrigerators	GB1 - 40% EEI (extrapolating 2009-2010 White Paper data leads to GB-1 in 2014)	19% EEI	4.5%, every 5 years starting in 2014
Rice cookers	82.3%	95%	4% every 5 years from 2015

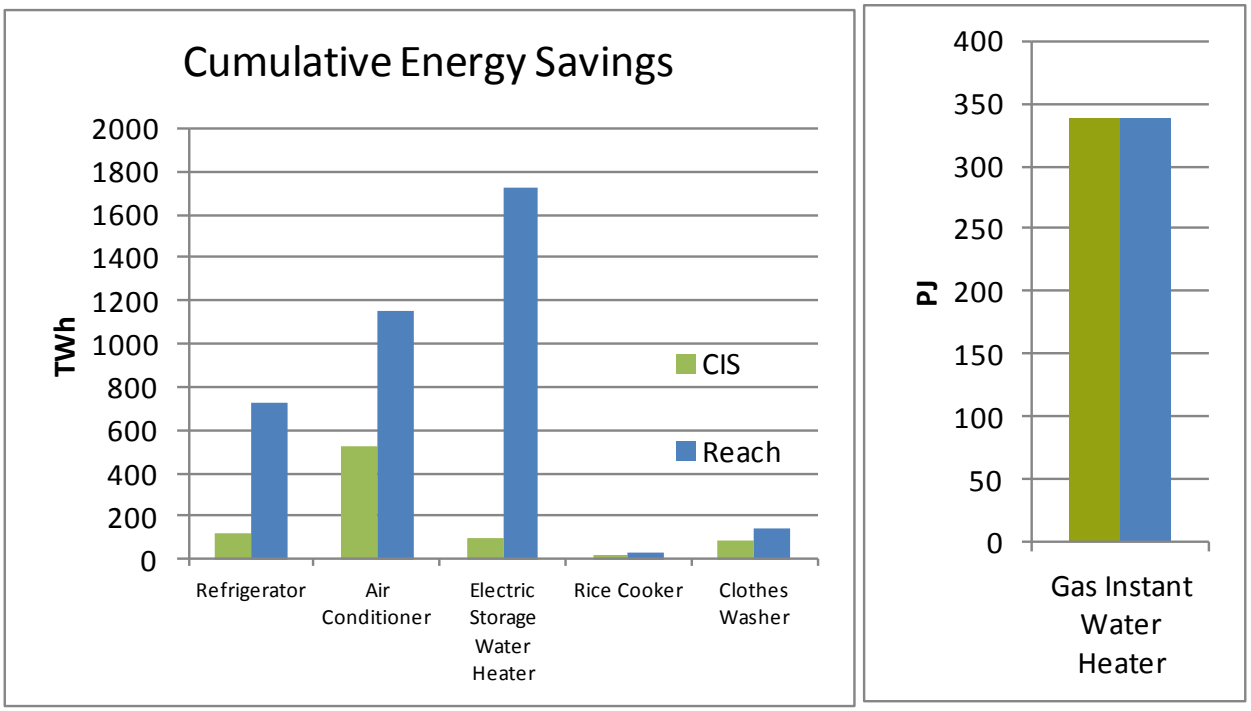
* *The change in heating efficiency from BAU, not percent relative to baseline Unit energy consumption, it is first tier of the China GB standard.*

** *This is the reduction in fixed energy efficiency, starting with 50% in 2015.*

[1] Definitions for Table1: Energy efficiency ratio (EER), seasonal energy efficiency ratio (SEER), energy efficiency index (EEI)

The estimated energy savings from these scenarios is presented in Figure 1 below. From the LBNL study the magnitude of savings ranking order is clear. ESWH, followed by air conditioners (ACs) and refrigerators, show the greatest potential in the long term. In terms of improving policy measures, both ESWH and ACs result in more savings if the current labeling schemes were made technology-neutral. That is, variable speed drive (VSD) AC products should be directly comparable to fixed speed equipment. Similarly, electric heat pump water heaters should be compared on the same basis as electric resistant water heaters in any energy labeling scheme.

Figure 1: Cumulative energy savings to 2030



Source: LBNL (2012) study

The MACEEP-ESP study

In 2012, CLASP and Top10 China jointly implemented the MACEEP project. The project used market data to analyze the energy efficiency status of major appliances in the Chinese market and the energy saving potential of different policy interventions. Based on MACEEP data and other nationally available statistics, Kevin Lane (Oxford) conducted an energy savings potential analysis for eight products: fixed speed air-conditioners, variable speed air-

conditioners, induction cookers (or hobs), display monitors, refrigerators (including freezers and combined fridge-freezers), rice cookers, flat-panel televisions, and washing machines (primarily top-loading impeller and front-loading drum types).

These products were selected due to their current and potential energy consumption levels, the potential savings that may accrue from the implementation of future policy measures, and the mandatory requirement that they all carry the China Energy Label. All are on sale in the Chinese marketplace.

The MACEEP study seeks to provide a range of national and international audiences with a transparent picture of the levels of efficiency and comparative energy consumption of a number of domestic appliances currently on sale in the Chinese market place. The research also seeks to provide suggestions on the policy interventions that could lead to improved efficiency and/or reductions in the energy consumption of these appliances in the future.

This study is centered on developing scenarios to show the expected impact from different policy measures. The three scenarios examined are:

- Business as usual (BAU): what would happen with no further product policy measures;
- Revised MEPS (MEPS2): what would happen with revised performance levels for standards and labels as recommended in the study;
- Best on Market (BOM): specifically, the most efficient on the current Chinese market. Additionally, the most efficient is weighted for all sizes so is a realistic average figure.

A summary of the market average performance levels of the two main energy-saving scenarios is presented in Table 2 below.

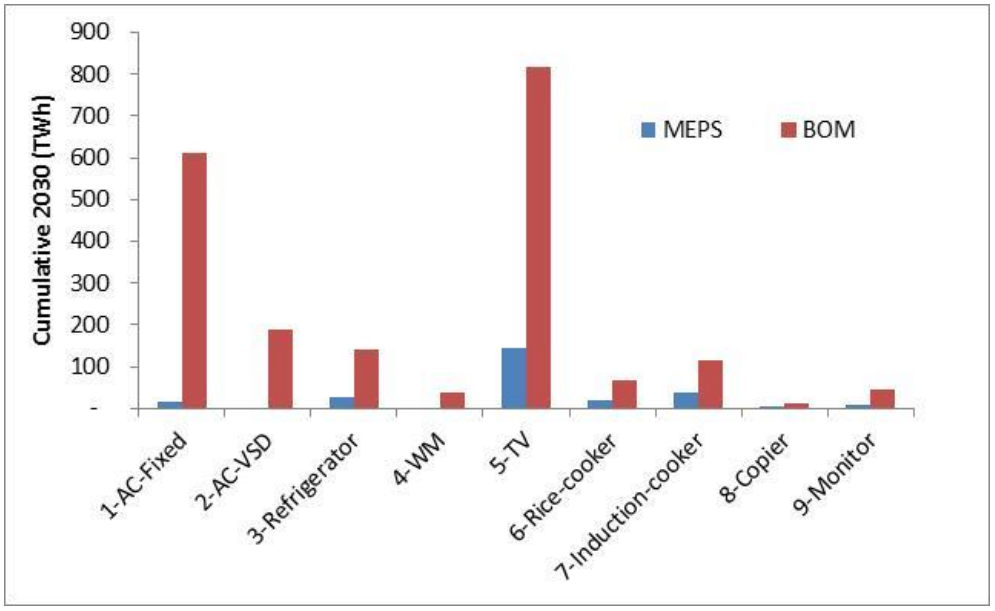
Table 2: Summary of products and scenarios (actual market average values)

Product	**BAU (2012)**	**MACEEP scenario, MEPS2 (2014)**	**BOM (2014)**
1-AC-fixed-speed	3.34 EER	3.45 EER	3.90 EER
2-AC-VSD	4.19 SEER	Na	6.45 SEER
3-Refrigerator	0.5kWh/day	0.45 kWh/day	0.3kWh/day
4-Washing-machine	Drum: 0.19 kWh/kg	-	Drum: 0.153 kWh/kg
	Impeller 0.018 kWh/kg	-	Impeller 0.011 kWh/kg
5-Television	On-mode 134 W Standby 0.5 W	On-mode 123W Standby 0.3 W	On-mode 89 W Standby 0.1 W
6-Rice-cooker	81%; 48Wh.h; 1.46W	83%, 48Wh.h; 1.5W	88%, 20Wh.h; 0.5W

7-Induction-cooker	86.2%; 2.1W	88.1%; 1W	90%; 1W
8-Copier	TEC= 5.96 kWh/week	TEC= 4.24 kWh/week	TEC= 2.43 kWh/week
9-Monitor	EEI=1.1; 0.62W	EEI=1.14, 0.5W	EEI=1.35; 0.16W

Based on the models developed, the estimated cumulative savings were identified, as shown below.

Figure 2: Cumulative energy savings to 2030, MACEEP-ESP study



From the MACEEP-ESP study the magnitude of savings ranking order is clear. However, not all of products examined were considered for further policy measures (MEPS) in this study. According to the MACEEP study, the largest theoretical potential (where all products sold from 2014 onwards reaches the best on the market) is to be found with televisions, followed by air conditioners, then refrigerators. Rice cookers and induction cookers provide less significant savings, with washing machines, monitors and copiers showing the smallest potential. When realistic next step policy options were examined by MACEEP, the achievable savings in the short term are significantly less than the theoretical BOM savings – quite understandably. In this MEPS case televisions show the largest potential, with AC equipment, refrigerators, induction and rice cookers all showing similar levels of achievable savings.

Further examination by the ESP study, provided additional important observations for policy makers:

- Incremental, single-iteration, short-term policies do not result in large amounts of energy savings, certainly not the theoretical savings from all products reaching the best on the market.

- Since the short term policy measures (MEPS) for ESWHs only realise a small potential shown by the BOM scenario, policy makers should be consider additional supporting policy measures, beyond simple ratcheting up of standards and labels, to significantly promote the efficiency in the longer term.
- Television savings are harder to realize and distinguish from multi-national policy and drivers. Efficiency improvements in televisions have been driven by the demand for slimmer televisions, which has coincided with lower energy consumption. Much of the efficiency improvement seen in televisions over recent years has been fortuitous, rather than a result of policy.
- The uptake of best practice AC-VSD could save significant amounts of energy, though care should be taken to only promote VSD technology, and not ban lower efficiency VSD products (which may be better than AC-fixed speed products still on the market).

Comparing the LBNL and MACEEP-ESP Approaches

As can be seen; the two studies were aiming to undertake similar tasks but were done on a slightly different basis. The main differences between the two studies are:

- The product coverage in each approach does not fully overlap. Two additional ESP water heater models were generated by Kevin Lane (Oxford) to ensure that the ESP models covered all the end-uses in both the MACEEP-ESP and LBNL studies.
- The LBNL and MACEEP models use different assumptions about ownership, sales, product use, etc., such that the two baselines may not match exactly (especially the water heating and refrigerator products).
- The energy-savings scenarios are conceptually different:
    - The BOM scenario represents the best (most efficient) products in China, while the Reach scenario represents the most efficient products in the world.
    - The MACEEP-ESP approach is a realistic, onetime policy analysis that is tied to practical policy suggestions, whereas the CIS scenario is designed to show continued improvement; thus, multiple iterations of policy analysis would be needed to deliver this scenario. These multiple policy iterations are not made explicit.

The scope and coverage of the products and scenarios by the two studies are shown below.

Table 3: Comparison of products and scenarios

Product	BAU (ESP)	MACEEP-ESP (ESP)	BOM (ESP)	BAU (LBNL)	CIS (LBNL)	Reach (LBNL)
1-AC-Fixed	X	X	X	X	X	X
2-AC-VSD	X		X			
3-Refrigerator	X	X	X	X	X	X
4-WM	X		X	X	X	X
5-TV	X	X	X			
6-Rice-cooker	X	X	X	X	X	X

7-Induction-cooker	X	X	X			
8-Copier	X	X	X			
9-Monitor	X	X	X			
10-ESWH	X		X	X	X	X
11-GIWH	X		X	X	X	X

Re-running savings scenarios

In order to compare all the products and scenarios on the same basis, they should be run using the same model. Where the MACEEP-ESP and LBNL products overlap, we have developed ESP models incorporating the LBNL CIS and Reach scenario values as best as possible.

The products that were identified as having the highest energy savings potential in the LBNL and MACEEP-ESP studies are evident here, though it is easier to read the savings from the equivalent table below.

Table 4: Cumulative energy savings to 2030 (TWh)

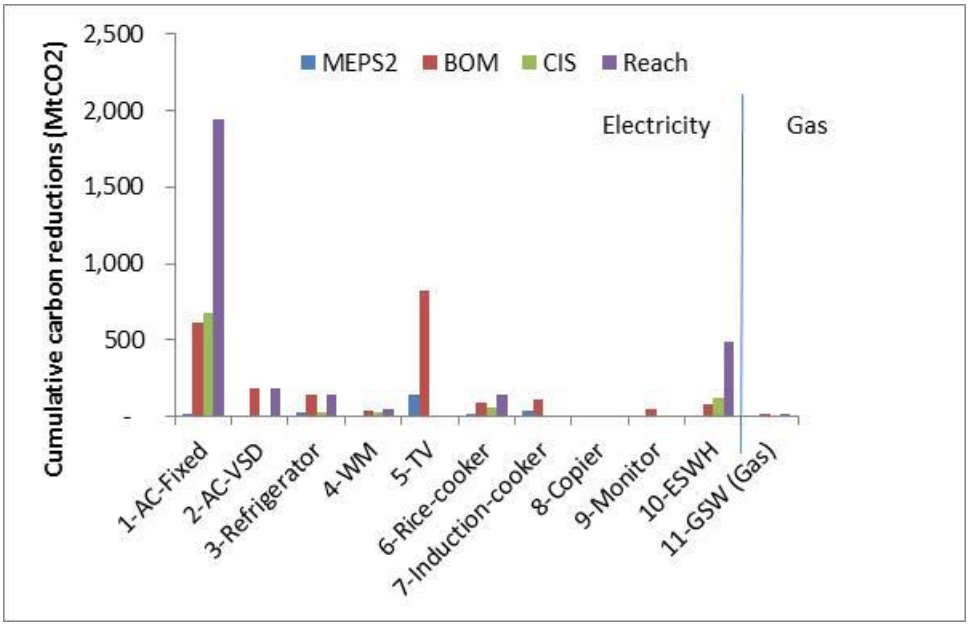
	MEPS2	BOM	CIS	Reach
1-AC-Fixed	18	610	673	1,933
2-AC-VSD	-	189	-	189
3-Refrigerator	28	142	23	142
4-WM	-	37	27	44
5-TV	147	816	-	-
6-Rice-cooker	21	89	58	148
7-Induction-cooker	40	117	-	-
8-Copier	6	11	-	-
9-Monitor	9	45	-	-
10-ESWH	-	82	120	490

SUM (ELEC)	269	2,139	901	2,946
11-GIWH (Gas)	-	95	60	95
SUM (ELEC, GAS)	269	2,234	961	3,041

Note that gas consumption by gas water heaters is also shown in TWh. The gas and electricity figures are shown as delivered or final energy consumption (not primary energy). Also, note that these scenarios are now calculated on the same basis. As a result, the AC-fixed cumulative energy savings are much larger than the LBNL approach implies, while for ESWH and GIWH, the LBNL model shows higher figures than displayed here.

Since the carbon emissions factor is higher for electricity than gas, it is useful to show the savings as CO_2 emission reductions, which is done in the chart below. Figure 3 demonstrates that the relative impact of gas is less than when comparing on a delivered energy (GWh) basis.

Figure 3: Cumulative carbon reductions to 2030



Main priorities

In theory, the three largest potential energy savers (as shown in the BOM and Reach scenarios above) are:

- ESWHs using heat pump technology;
- ACs, where the fixed speed units will be replaced by units using variable speed technology and VSD AC equipment will also be more efficient; and
- Televisions.

However, realizing many of these potential savings is challenging, and realizing the BOM or Reach target values for ESWH (especially) and the market uptake of AC-VSD will take longer. Additionally, current policy is not strongly driving improvements in the efficiency of TVs. There are other reasons (such as desirable slim-line displays coinciding with lower energy consumption) why televisions are increasing in efficiency, and they may continue to do so with less policy effort. Simply 'ratcheting up' energy performance levels by a fixed amount every few years is not the most efficient way of delivering the technology for these three products, and policy makers may need to consider other measures. These products are characterised by technology that has yet to become popular in the market, mainly due to high costs, which will fall over time, especially with policy support.

For these technology switches, other policy support measures should be considered. At a minimum, it is recommended that energy labels are made technology-neutral, so that products may be compared on the same basis. Both ESWHs and ACs would benefit from this type of change. That is, variable speed AC products are directly comparable to fixed-speed products. Similarly, electric heat pump water heaters should be compared on the same basis as electric resistant water heaters in any energy labeling scheme.

Given these considerations, we recommend that policy makers prioritize products for policy actions as shown above in Table 4, with AC and water heaters being the highest priority.

Furthermore, from this analysis, washing machines, rice cookers, copiers, and monitors do not provide many short term savings. However, if the changes to regulations are easy to make (from a policymaker perspective) then these product policies could still be considered for revision.

Note that this prioritization assessment is based on the size of energy savings and carbon emission reductions, as well as the likelihood of those savings being realized. However, policymakers may also take other factors into account in choosing to prioritize products and policy measures, which include:

- The product's impact on peak load (not just total energy consumption), since this implies additional plant for only short periods of time. In this instance air conditioners become more important for China, where there are summer peaks in load;

- Ease of the supply side (manufacturers) to meet the challenge of improved performance levels;
- Secondary benefits, which support other policy targets (such as social programmes on thermal comfort, employment in certain manufacturing industries);
- Costs to government or consumers for the raised performance levels (whether up-front costs or life-cycle); and
- Time and effort of regulators.

Finally, there is also a need for improved evidence. This is especially the case for understanding the in-home use of appliances, with the greatest emphasis on water heaters which has a large variation in likely use and significant energy savings potential.