China Product Prioritization & Energy Saving Potential

31 November 2013

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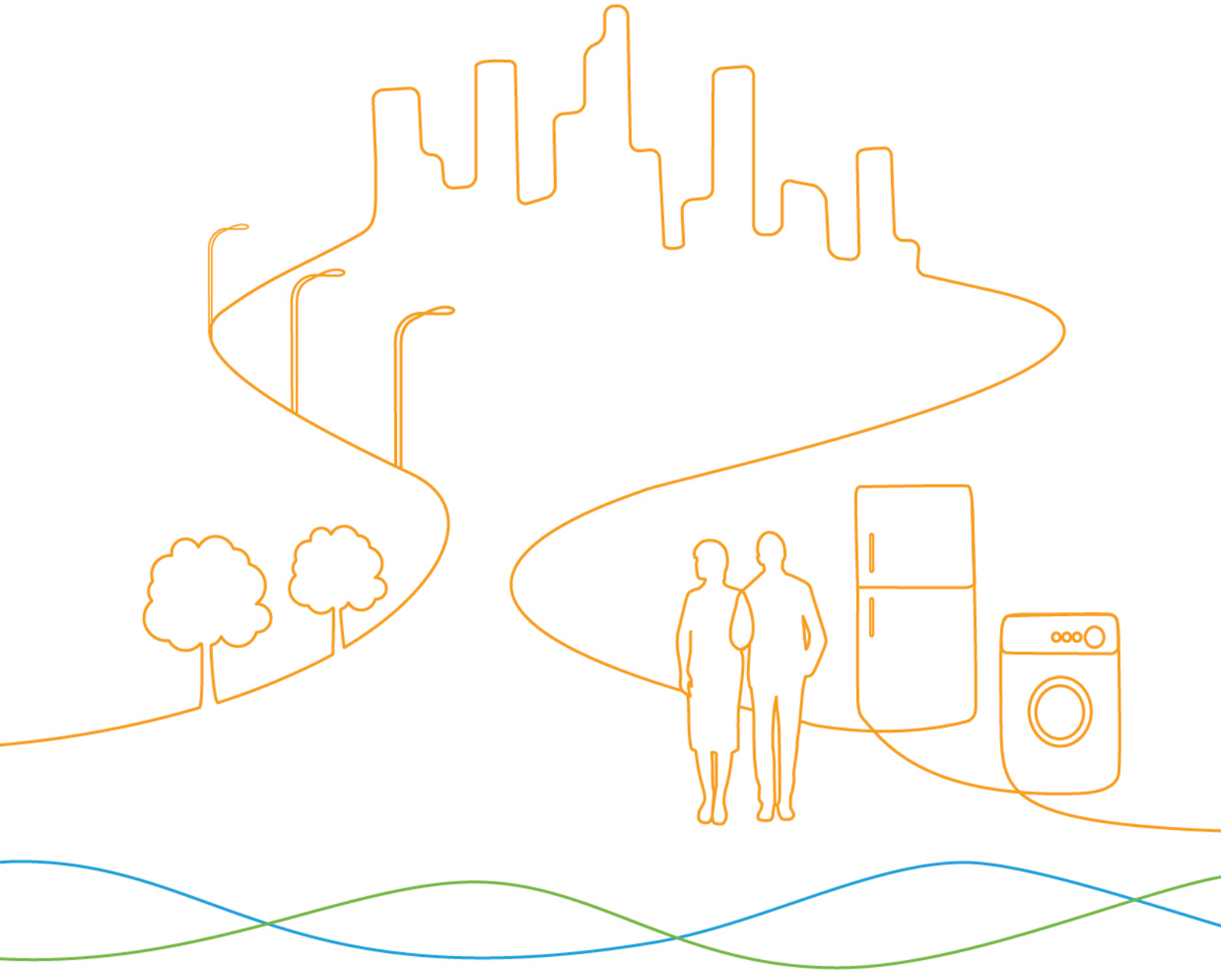

Summarizing Product Prioritization and Energy Saving Potential (ESP). *Based on recent MACEEP-ESP and LBNL studies*

Date: 31 November 2013

Disclaimer

Acknowledgements

This report is prepared by Kevin Lane (Oxford) Ltd. The primary author of this report is Kevin Lane.

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Executive Summary

Energy consumption by appliances in homes in China is increasing rapidly 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 a program of policies to address this rise through a series of product policy energy efficiency measures, such as minimum energy performance standards and energy labelling on new products sold.

Two separate CLASP-funded studies have examined the further potential for energy savings from improving the efficiency of products: the LBNL study and the MACEEP-ESP study.

ES.1 The LBNL study

In 2012, the Lawrence Berkeley National Laboratory (LBNL), with support from CLASP, initiated a study (referred to as the LBNL study hereafter) 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, refrigerators, and rice cookers.

The LBNL study described and developed **three scenarios,** which are:

- Business-as-usual (BAU): what would happen to energy consumption with no further product policy;
- Continued improvement scenario (CIS): where 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 BAU and Reach scenarios are presented below.

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

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 6.14 EER (CLASP 2011)	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 UEC. It is GB-1.
** This is the reduction in fixed energy efficiency, starting with 50% in 2015.

The estimated energy savings from these scenarios is presented below. From the LBNL study the magnitude of savings ranking order is clear. ESWH, followed by air conditioners and refrigerators show the greatest potential in the long term. In terms of improving policy measure both ESWH and AC would benefit from the current labelling scheme being technology neutral. That is, that 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 resistance water heaters in any energy labelling scheme.

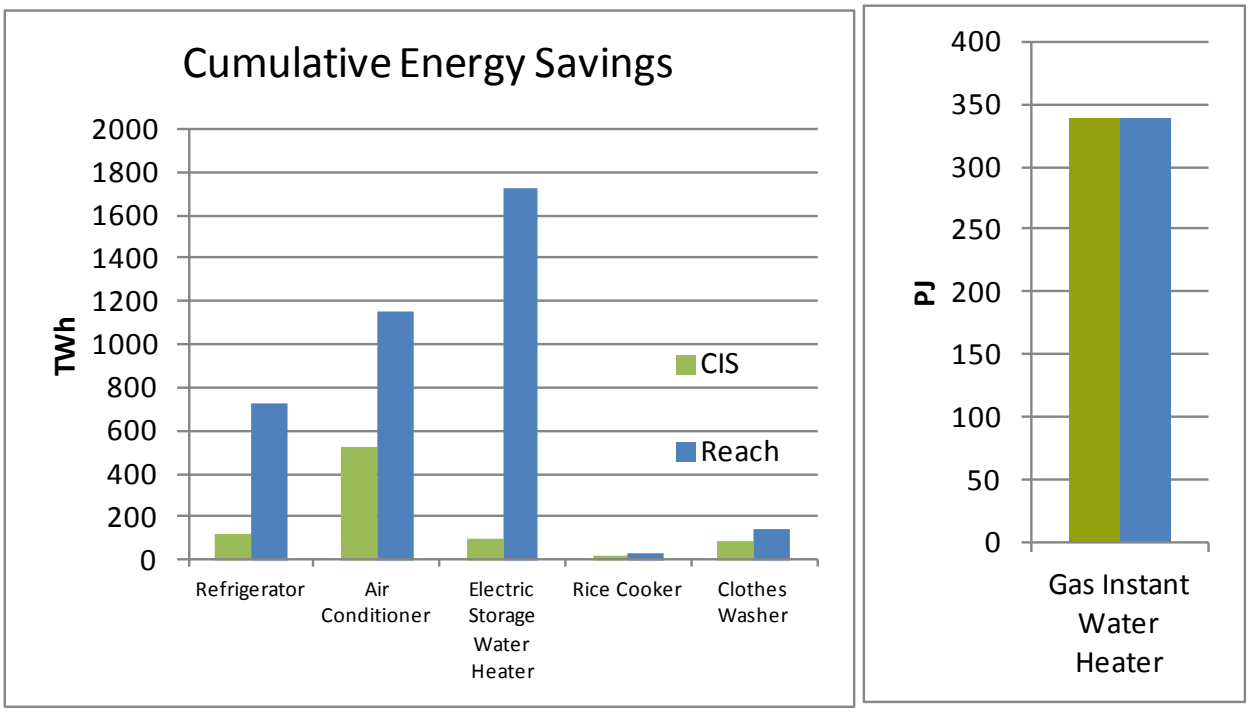


Figure 1: Cumulative energy savings to 2030, LBNL study

Source: LBNL study

ES.2 The MACEEP-ESP study

In 2012, CLASP China Program and Top10 China jointly implemented a project named Market Analysis of China Energy Efficient Products (MACEEP). The project used market data to analyze the status of energy efficiency 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 (referred to as MACEEP ESP thereafter) 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, televisions (primarily flat panel), and washing machines (primarily top-loading impeller and front-loading drum types).

All of these products are on sale in the Chinese market place. 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 actions, and the mandatory requirement that they all carry the Chinese Energy Label.

The Market Analysis of China Energy Efficient Appliances (MACEEP) research 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 centred on developing scenarios, to show the expected impact from different actions. 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 aligned with the MACEEP proposal;
- Best on Market (BOM): specifically, the best on the current Chinese market.

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	0.25kWh/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

Where the following units are used in the above table:

EER is the energy efficiency ratio; the higher the value, the more efficient.
SEER is the seasonal energy efficiency ratio; the higher value, the more efficient
TEC is a total energy consumption figure for a standard use pattern over one week.
EEI is the energy efficiency index; the lower the value the more efficient.

Based on the models developed, the estimated cumulated savings were identified, as seen in Figure 2.

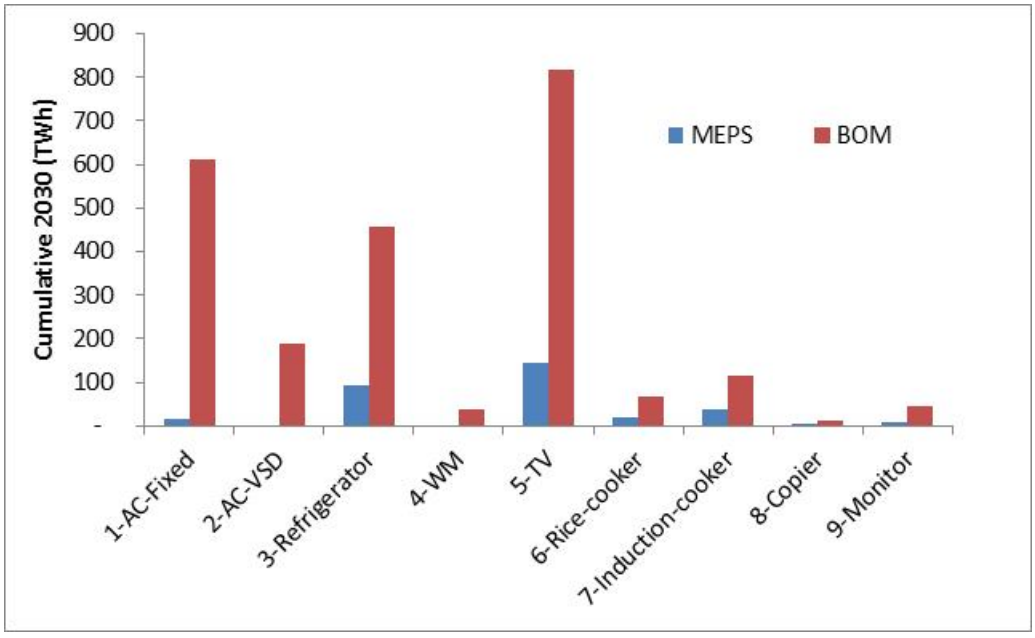


Figure 2: Cumulative energy savings to 2030, MACEEP-ESP study

From the MACEEP-ESP study the magnitude of savings ranking order is clear. However, noting that not all products have MACEEP proposal scenarios. Some findings are:

- Incremental single-iteration short term policies do not realise large amounts of energy.
- ESWH should be long term targets for policy makers.
- Television savings are harder to realise and disentangle from multi-national policy and drivers.
- Uptake of best practice AC-VSD could save significant amounts of energy, though care should be taken to only promote VSD, and not ban lower efficiency VSD products (which may be more efficient than AC-fixed speed AC equipment)

ES.3 Comparison of LBNL and MACEEP-ESP projects

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 does not overlap exactly. Two additional ESP water heater models were generated to ensure that the ESP models covered all the end-uses, though the use is different.
- The underlying models have different assumptions on ownership, sales, use, etc., so that the two baselines may not match exactly (especially the water heating products).
- The energy-savings scenarios are conceptually different:
    - The BOM is for the best in China, whilst the Reach is for the best in the world.
    - The MACEEP-ESP is a realistic one-iteration policy proposal (tied to practical policy suggestions), whereas the CIS scenario is to show continued improvement, so multiple iterations of policy would be needed to deliver this scenario.

The scope and coverage of the products and scenarios by the two studies is 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-GWH	X		X	X	X	X

ES.4 Re-running savings scenarios

In order to cross-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, the ESP models have been used with the LBNL CIS and Reach scenario values (as best as possible).

The three products that were identified 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	92	458	72	458
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)	**332**	**2,454**	**949**	**3,262**
11-GWH (Gas)	-	95	60	95

SUM (ELEC, GAS)	**332**	**2,550**	**1,010**	**3,357**

Note – gas consumption by gas water heaters is also shown in TWh, i.e. both show the delivered or final energy consumption figure. Also, note these scenarios are now done on the same basis. Due to this the AC-fixed is much larger than LBNL would imply, whilst for ESWH and GWH the LBNL model would show higher figures.

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. This shows that the relative impact of gas is less than when comparing on a delivered energy (GWh) basis.

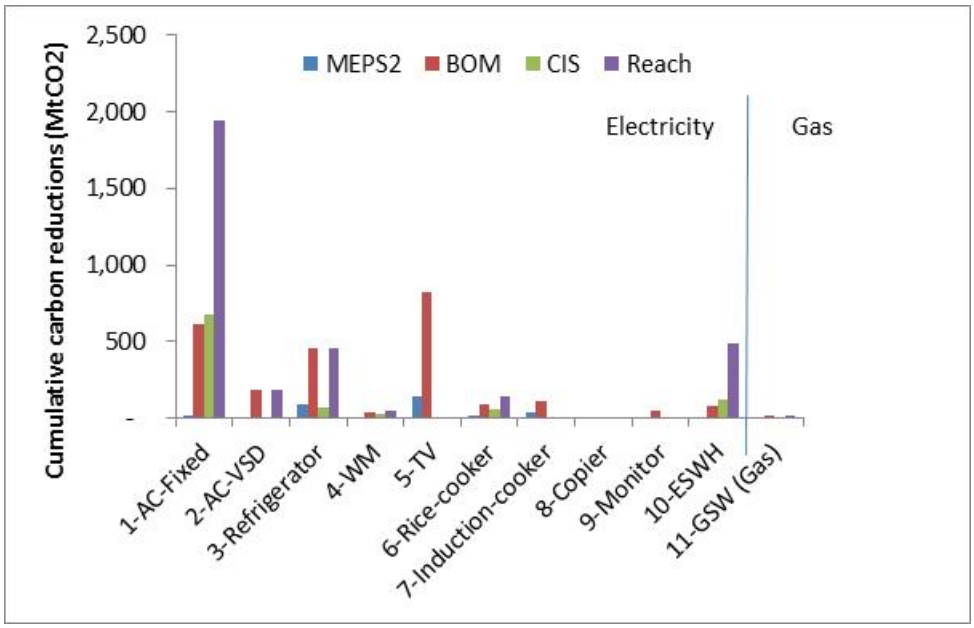


Figure 3: Cumulative potential carbon reductions to 2030

ES.5 Main priorities

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

- ESWH using heat pump technology
- AC using variable speed technology
- Televisions.

However, realising many of these savings is challenging, and realising the BOM or Reach target values for ESWH (especially) and the uptake of AC-VSD will take longer. Improvements in the efficiency of TVs are not being driven strongly by policy. There are other reasons why televisions are increasing in efficiency and they may continue to do so with less policy effort. Simply 'ratcheting up' the levels by a fixed amount every few years is not the most efficient way of delivering the technology (for these three products). For these technology switches other policy support measures should be considered. At a minimum, it is recommended that energy labels are made neutral, so that they may be compared on the same basis.

From this analysis, washing machines, rice cookers, copiers and monitor do not provide many short term savings. However, if the changes to regulations are easy (from a policy-makers point of view), then they could still be considered.

Note the above prioritisation is based on the size of energy savings and carbon emission reductions, and the likeliness of them being realised. However, other aspects may also be taken into account by policy makers choosing to prioritise products and policy measures, which include:

- Impact on load (not just total energy consumption). In this instance air conditioners become more important for China.
- Ease of supply side to meet the challenge of improved performance levels.
- Secondary benefits, which support other policy targets.
- Cost to government or consumers for the raised performance levels (whether up-front costs or life-cycle).
- Time and effort of regulators.

Additionally, there is also the need for improved evidence. This is especially the case for understanding the in-home use of appliances, with the greatest importance for water heaters.

In terms of improving policy measures, both ESWH and AC would benefit from the current labelling scheme being technology neutral. 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 resistance water heaters in any energy labelling scheme.

1 Introduction

1.1 Background to summarization study

In 2012, CLASP China Program and Top10 China jointly implemented a project named Market Analysis of China Energy Efficient Products (MACEEP). The project used market data to analyze the status of energy efficiency of major appliances in Chinese market, and the energy saving potential of different policy interventions. Based on MACEEP data, and other nationally available statistics, Kevin Lane conducted an energy savings potential analysis (refer as MACEEP ESP thereafter) for eight products: AC (fixed speed and VSD), televisions (TV), refrigerator, electric rice cooker, induction cooker, PC monitor, washer, and copier.

In 2012, the Lawrence Berkeley National Laboratory (LBNL), with support from CLASP, initiated a study(refer as LBNL study thereafter) of the energy savings and greenhouse gas reduction potential for six energy intensive appliances: air conditioners, clothes washers, electric storage water heaters, refrigerators, rice cookers, and gas instantaneous water heaters. This study used the BUENAS model developed by LBNL and CLASP as analysis tool. Based on the findings of both studies, on May 2nd, 2013, CLASP organized a policy workshop at CNIS and presented both studies to the Chinese policy researchers. The findings were highly acknowledged by the audience. In general, the CNIS audience regarded both studies useful as each of them provided a different perspective on energy saving potential under different assumptions and scenarios. Nevertheless, some CNIS audiences raised questions and concerns on the connections between both studies and how to present both to the policy makers who may feel confused about which one is better to use. To avoid the confusion and maximize the impact of both studies, the China Program and Global Research team initiated this study in a hope that, through the support of Kevin Lane, we can summarize the findings of both studies, and provide an integrated overview and policy recommendations on product prioritization and energy saving potential to Chinese policy makers.

The four main tasks for the current summarization project are:

1. Compare MACEEP/ESP and LBNL approach
2. Re-run ESP with scenarios to match LBNL
3. Develop ESP models for water heaters (electric storage and gas instantaneous)
4. Explain both sets of scenarios, summarise product prioritisation and potential from both studies.

A fuller description of the scope of work is given in Appendix A.

This report provides a record of the work underdone for this project, whilst Section 7 and/or the Executive summary this report can be used for further prioritisation work within CLASP.

2 Background - summary of MACEEP ESP analysis (Task 1, Task 4)

In 2012, CLASP China Program and Top10 China jointly implemented a project named Market Analysis of China Energy Efficient Products (MACEEP). The project used market data to analyze the status of energy efficiency of major appliances in Chinese market, and the energy saving potential of different policy interventions. Based on MACEEP data and other nationally available statistics, Kevin Lane conducted an energy savings potential analysis (refer as MACEEP ESP thereafter) 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,
- televisions (primarily flat panel),
- washing machines (primarily top-loading impeller and front-loading drum types).

All of these products are on sale in the Chinese market place. 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 actions, and the mandatory requirement that they all carry the Chinese Energy Label.

The current analysis and report was done in conjunction with a separate, but related, MACEEP study. Separate detailed reports are available that describe the analysis undertaken.

The Market Analysis of China Energy Efficient Appliances (MACEEP) research 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 centred on developing scenarios, to show the expected impact from different actions. The three scenarios examined are:

- Business as usual (BAU), what would happen if no further product policy measures are undertaken;
- Revised performance levels for MEPS (standards and labels) aligned with the MACEEP proposal (labelled MEPS2 in this report);
- Best on Market (BOM), specifically, the best on the current Chinese market.

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

Table 5: Summary of products and scenarios (actual market average values in the year, market average)

Product	BAU (2012)	MACEEP scenario, MEPS2 (2014)	BOM (2014)

1-AC-fixed	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	0.25kWh/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-TV	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

Noting that these levels are the impact on the market, not the performance levels for MEPS or label thresholds.

2.1 The MACEEP-ESP (MEPS2) scenario

Using the MACEEP-ESP end-use model, the annual energy savings for the MESP2 scenario through to 2030 (relative to the BAU) is shown below in Figure 4.

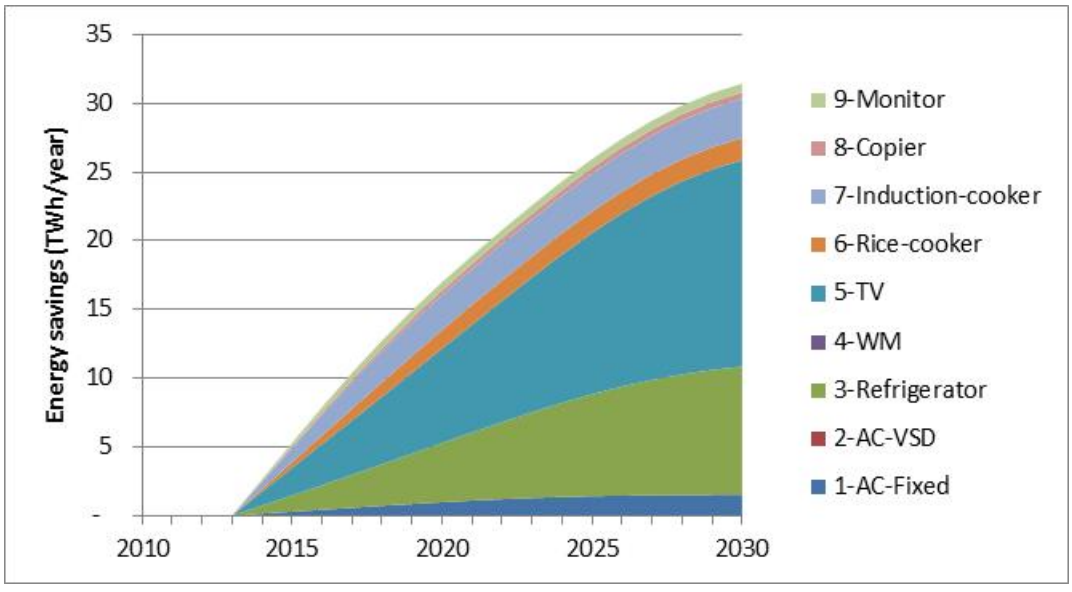


Figure 4: Energy savings from MEPS2 scenario

The underlying data for the energy savings in each 5-year interval is given in the table below (Table 6).

Table 6: Summary of energy savings under MEPS2 by product in 2020, 2025, 2030 (TWh/year)

	2020	2025	2030
1-AC-Fixed	0.98	1.42	1.5
2-AC-VSD	-	-	-
3-Refrigerator	4.30	7.43	9.3
4-WM	-	-	-
5-TV	6.87	11.74	15.0
6-Rice-cooker	1.35	1.57	1.6
7-Induction-cooker	2.54	2.76	2.9
8-Copier	0.34	0.42	0.4
9-Monitor	0.59	0.63	0.6
SUM	17	26	31

Note – no MACEEP proposals were made for washing machines or variable-speed air conditioners, so no energy savings are presented for these products.

This table can also be shown graphically, which is useful to visualise the relative savings from the different products (Figure 5). Based on the efficiency assumptions, televisions show the largest potential.

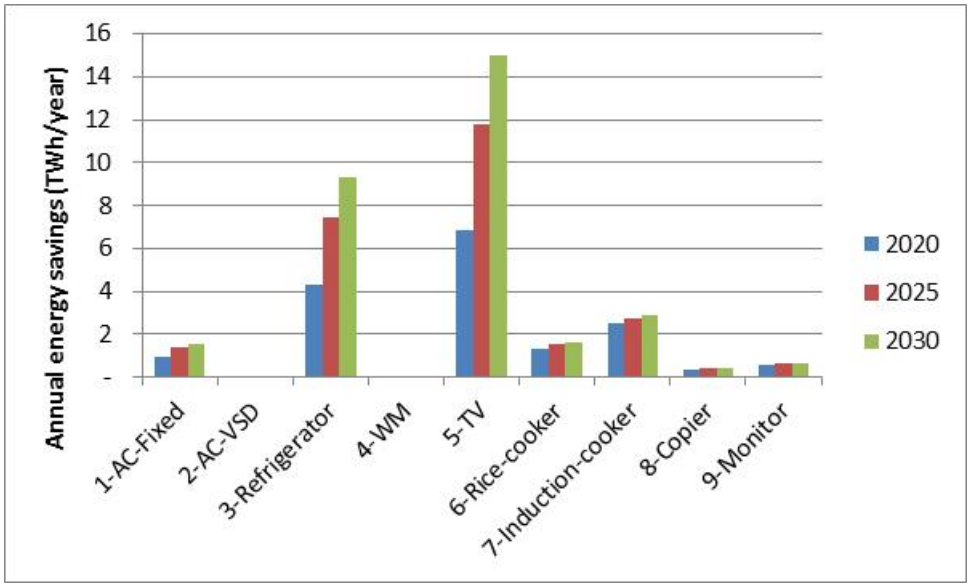


Figure 5: Energy savings from MEPS2 scenario

Based on the savings estimated a summary of the energy, financial and carbon savings from these measures is given in Table 7.

Table 7: Summary of energy, financial and carbon savings for the MEPS2 scenario (nine products)

	2020	2025	2030
Annual electricity savings (TWh/yr)	17.0	26.0	31.5
Annual financial savings (RMB billion)	8.0	12.2	14.8
Annual carbon reductions ($MtCO_2$)	17.0	26.0	31.5
Cumulative electricity savings (TWh)	70.9	183.5	331.8
Cumulative financial savings (RMB billion)	8.0	24.5	38.1

Cumulative carbon reductions ($MtCO_2$)	17	81	230

2.2 The Best on Market (BOM) scenario

A similar savings analysis is done for the scenario where future products which are being sold reach the current best on the Chinese market (labelled BOM in the study). The annual electricity savings are shown in Figure 6.

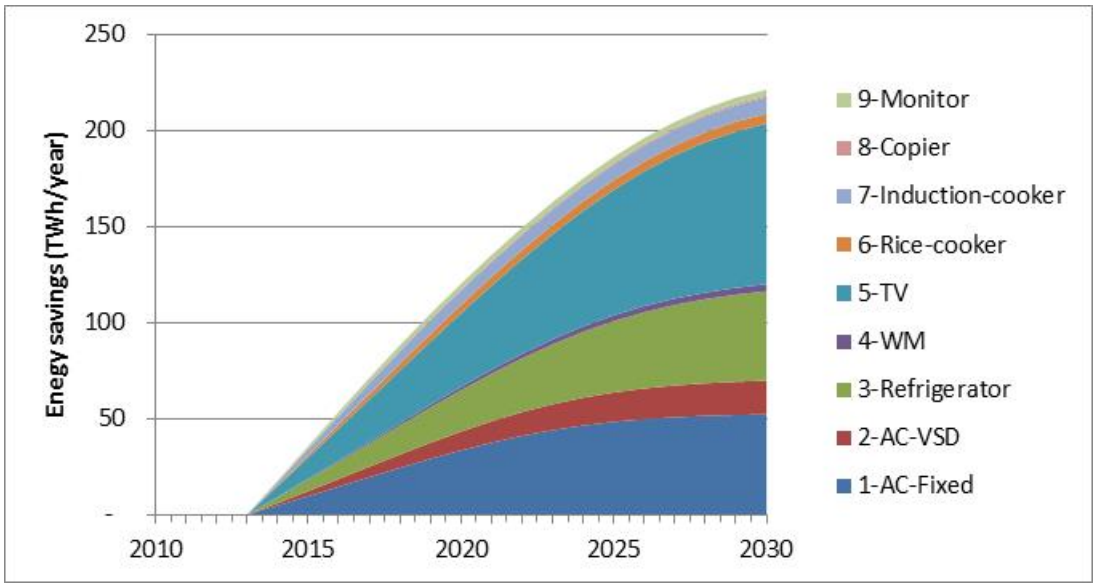


Figure 6: Energy savings from BOM scenario

The 5-year interval values for the savings are given in Table 8.

Table 8: Summary of energy savings under BOM by product in 2020, 2025, 2030 (TWh/year)

	2020	2025	2030
1-AC-Fixed	33.6	48.4	52.3
2-AC-VSD	9.8	15.3	17.5
3-Refrigerator	21.5	37.1	46.6
4-WM	1.8	3.0	3.6
5-TV	38.3	65.4	83.7
6-Rice-cooker	4.4	5.1	5.2
7-Induction-cooker	7.4	8.1	8.4
8-Copier	0.7	0.9	0.9
9-Monitor	2.9	3.1	3.2
SUM	**120**	**186**	**221**

This table can be more easily viewed graphically, as shown below in Figure 7.

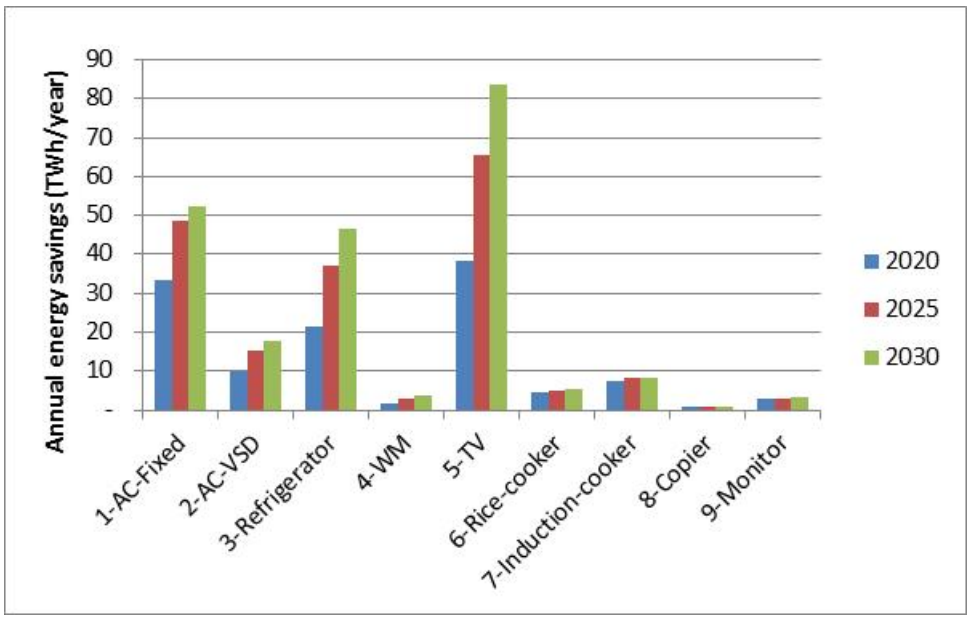


Figure 7: Energy savings from BOM scenario

Note: the energy-savings for AC-fixed-speed and televisions do not show their full savings on the chart, since the y-axis is restricted.

These energy savings can be converted to financial benefits to consumers and carbon benefits to the environment, shown in Table 9.

Table 9: Summary of energy, financial and carbon savings for the BOM scenario (nine products)

	2020	2025	2030
Annual electricity savings (TWh/yr)	120	186	221
Annual financial savings (RMB billion)	57	88	104
Annual carbon reductions ($MtCO_2$)	121	187	222
Cumulative electricity savings (TWh)	120	365	1,226
Cumulative financial savings (RMB billion)	57	171	576
Cumulative carbon reductions ($MtCO_2$)	121	366	1,229

2.3 Main conclusions from the MACEEP-ESP summary

Following the detailed MACEEP-ESP study the following conclusions were drawn:

- Significant energy savings are available, both theoretically (based on BOM scenario) and realistically from relatively simple short term measures (MEPS2 scenario).
- These savings are all from existing technology on the market, and not overly ambitious.
- Various policy recommendations followed. Including improved standards and labels will provide additional differentiation to products on the market due to efficiency, and enable consumers and policy makers to identify more efficient products. These included suggestions to make labels more adaptive and clearer on their role and, in addition, to sharpen the focus of the large subsidy programmes currently being used.
- The study was hampered by poor information and lack of evidence on usage patterns and model-weighted analysis and the MACEEP study made some recommendations to help rectify this.

2.4 Commentary of MACEEP ESP analysis

The current project is not to provide a detailed critique of the MACEEP ESP report. However, while reading the main MACEEP and MACEEP ESP documents, the following aspects were noticed and noted here:

- The MACEEP ESP scenario is fully realistic, and not overly ambitious.
- The MACEEP ESP scenario ambition level is not based on an engineering analysis, nor does it include a detailed cost analysis for improved efficiency. As such, it may be lacking ambition.
- The "best on the market" (BOM) scenarios only quote what is currently on the Chinese market. There may be technologies beyond China which are available and are feasible for the Chinese market, perhaps even at a cost-effective level.

3 Background - summary of LBNL analysis (Task 1, Task 4)

In 2012, the Lawrence Berkeley National Laboratory (LBNL), with support from CLASP, initiated a study (referred to as the LBNL study hereafter) of the energy savings and greenhouse gas reduction potential for six energy intensive appliances. The main LBNL document reviewed and used for comparison with ESP figures in this report was: "China Potential Update -Mar 21.doc".

The LBNL study shows **three scenarios,** which are:

- Business-as-usual (BAU), what would happen to consumption with no further product policy;
- Continued improvement scenario (CIS), where 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. Not necessarily a realistic scenario.

The LBNL analysis was done for six products:

- Air conditioners, though appears to be just fixed-speed versions,
- Clothes washers (top loader and front loader merged into one),
- Electric storage water heaters,
- Refrigerators (and freezers and combinations),
- Rice cookers,
- Gas instantaneous water heaters.

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

Table 10: Assumptions for BUENAS BAU and Reach scenarios

End use	BAU in 2015	Reach Target
Air Conditioners	GB-1 - 3.6 EER (market reaches GB-1 in 2012, which is held at 3.6)	Market Maximum 6.14 EER (CLASP 2011)
Clothes Washers	0.0219 kWh/cycle/kg Top-Load, 0.193 Front-load - Linear trend of recent year level market shares from White Paper	"GB-0 " - 0.007 kWh/kg/cycle for top-load, 0.15 for front-load
Electric Storage Water Heaters	Efficiency 60.7 % (Linear trend from 2009-2010 values from White Paper)	Heat Pump – 250% efficiency
Gas Instantaneous Water Heater	90% Heating Efficiency	96% Heating efficiency in 2030
Refrigerators	GB1 - 40% EEI (extrapolating 2009-2010 White Paper data leads to GB-1 in 2014)	19% EEI
Rice Cookers	82.3% (White Paper for average efficiency in each power class, Korean EELSP shipments for power class weighting, Japanese retail data for average model's UEC with efficiency)	95%

The assumed efficiency values for the LBNL Reach scenario are showed below.

Table 11: Assumptions for LBNL CIS scenario

End Use	Schedule	Percent Improvement
Refrigerator	Every 5 years starting in 2014	4.5%
Air Conditioner	Every 5 years starting in 2014	10%
Gas Instant Water Heater	2015	6%*
Electric Storage Water Heater	Every 5 years starting in 2015	10%**
Clothes Washer	Every 5 years starting in 2015	10%
Rice Cooker	Every 5 years starting in 2015	4%

*This is the change in heating efficiency from BAU, not percent relative to baseline UEC. It is GB-1

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

Coupling these assumptions with the sales, lifespan, and using the BUENAS model, the energy savings by scenario were estimated.

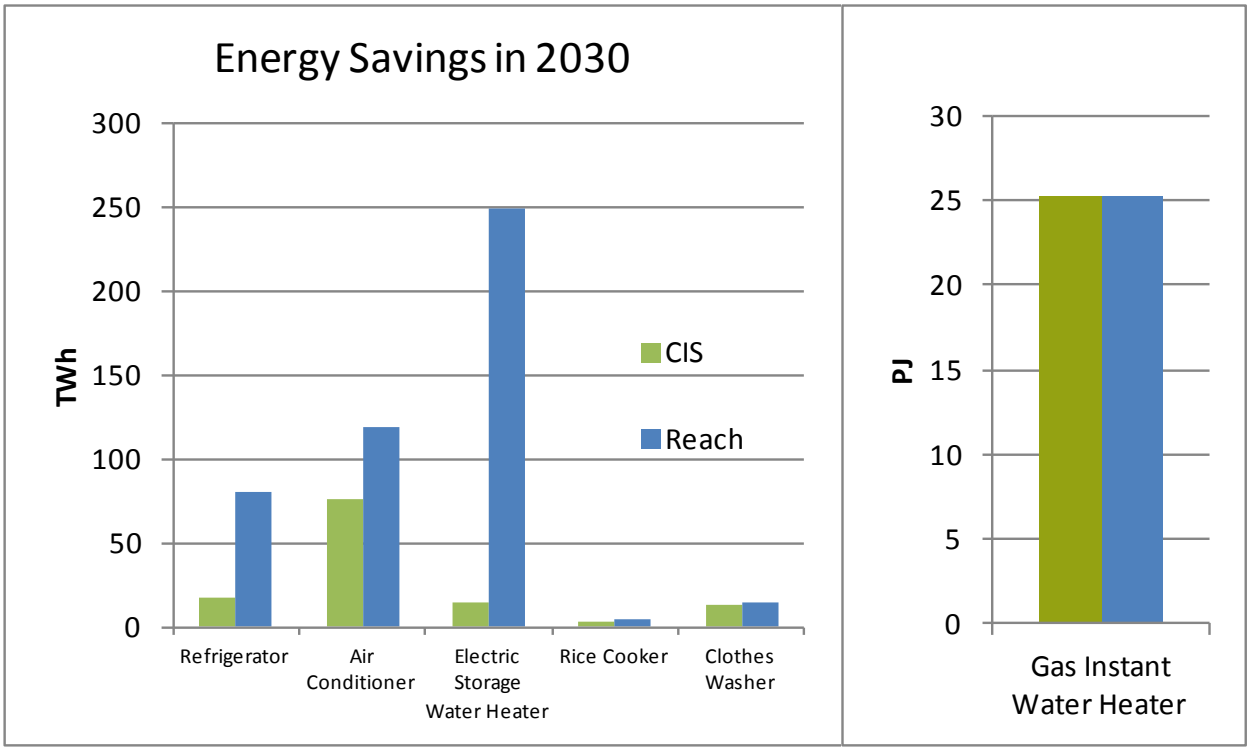


Figure 8: Energy savings in 2030 from CIS and Reach scenarios, LBNL analysis

3.1 Main conclusions from the LBNL study

A summary of the savings from the two main scenarios (CIS and Reach) are presented in the table below.

Table 12: LBNL energy savings potential

	Scenario	Air Cond.	Clothes Washers	Elec. Storage WH	Refrig.	Rice Cookers	Gas Instant. WH	**Total**
Annual Energy Savings in 2030 (TWh)	CIS	76	14	15	17	2.6	7	**131**
	Reach	119	14	250	80	4.3	7	**474**
Cumulative Energy Savings 2015-2030 (TWh)	CIS	529	89	97	116	15	94	**939**
	Reach	1153	137	1724	721	32	94	**3862**
Cumulative CO_2 2015-2030 (Mt)	CIS	520	87	95	114	15	19	**850**
	Reach	1140	136	1696	712	32	19	**3734**

The general conclusions can be summarized as follows (direct quote below):"

- The 'traditional' large footprint products of refrigerators, air conditioners and water heaters still show a large opportunity for improvement, particularly in the reach scenario.
- Refrigerators may show 2030 savings of 80 TWh in the reach scenario at 19 EEI over 6 times as much as could be expected from a continuous improvement scenario. The cumulative CO_2 emissions opportunity is over 700 Mt from this target.
- Air conditioner savings in the incremental scenario are significant, but could be more than doubled, to almost 120 TWh in 2030, with a cumulative CO_2 emissions mitigation of 1,140 Mt. Achievement of this savings might require that VSD technologies be included for direct comparison in the labelling program, and might require harmonization of test procedures between VSD and non-VSD air conditioners, which are currently defined as separate product classes.
- Electric storage water heaters represent the largest opportunity if the Chinese market were transformed to heat pump water heaters. Potential electricity savings from this transformation could be as high as 250 TWh in 2030 and a cumulative CO_2 emissions mitigation of over 1700 Mt. Similar to air conditioners, market transformation through the current labeling program to heat pump water heaters might require that this technology be included in the same scheme as electric resistance water heaters.
- Gas water heaters could see moderate annual savings in the incremental scenario. Further savings are challenging from a technical perspective.
- Rice cookers do not show a large potential for savings compared to the other products since the efficiency of the process of heating and warming water/rice is already relatively efficient.
- Clothes Washers show a moderate savings potential because of the relatively low footprint of this product and the absence of super-efficient or 'disruptive' technologies."

3.2 Commentary of LBNL analysis

The current project was not to provide a detailed critique of the LBNL report. However, while reading the main LBNL document, the following items were noticed and are noted:

- The modelling approach is fine and similar to the ESP approach.
- The charts of sales, efficiency, UEC data are useful to include, the actual numbers would be better.
- Reference to underlying source data (evidence) could be improved, as such is not very transparent.
- The BAU scenario description is better than LBNL's previous use of a frozen efficiency scenario, since it is a more realistic baseline. Furthermore, it assumes all sales will eventually become GB1. Should probably look at a case by case basis to see if this is likely (e.g. rice cookers probably not if this implies all have to be induction technology). Also, there may be further autonomous improvement due to other effects.

- BAU should also specify the regulation cut-off date, so it is clear which labels (other measures) have already been included in the BAU (we may be able to infer from the charts, and the CIS revision dates)
- The CIS scenario only includes upgraded labels in the assessment (at least in the definition, p2). In practice this could include the impact of changing MEPS (MEPR).
- Refrigerator average new UEC is 450kWh/year in the text (p3), though in the chart (p16) it is much lower. Refrigerator UEC figures were previously too high in LBNL reports (usually starting from more than 500kWh/year). The figures in the chart are much more realistic and in line with ESP and other data available.
- The Reach scenario as described (p2) implies it may be achievable, thus realistic. The levels appear achievable for refrigerators and clothes washers. The levels appear unrealistic in the near future for the rice cookers (nothing on the market yet that reaches 95%) and water heaters and air conditioners (which would require a significant change in manufacturing the required volumes within two years).
- The projections of water heater national sales volume is unusual, in that it does not match national statistics and the projections are exponentially upwards (this effect not seen with projected sales for other products). It is based on BSRIA, though the full source is not given, so we cannot check the rationale for this.
- Figure 6 needs fixing, BAU should be the top line, rather than the bottom one.
- The title of Figure 5 should be corrected to show emission reductions, rather than emissions (and could then change Figure 6 title).

4 New ESP water heater models (Task 3)

In order to make a comparison between the two studies two additional simple energy-savings models were developed. ESP model for two types of water heaters:

- Electric storage water heaters
- Gas instantaneous water heaters

Two separate detailed working reports have been generated which show the workings of these new models. A summary of the two models, undertaken to be similar to ESP is given in the next two sub-sections.

4.1 Electric storage water heaters

These models were undertaken after the MACEEP analysis, so the level of information on the current efficiency is less than the other products. Additionally, there are no MACEEP-ESP scenarios. Since it is possible to obtain a best on the market figure a BOM scenario can be derived.

4.1.1 Household ownership

Some stock data are available from the latest CNIS white paper (Table 13).

Table 13: Available stock/implied household ownership data for electric storage water heaters

Year	2006	2007	2008	2009	2010	2011
Stock (million)	38	48	59	69	73.37	84.09
Other notes (from text)					• 11.8% increase on 2009 • 11.2% less than 2011	

Source: stock based on CNIS (2012)
[Chart read error about up to 5%]

These data have been used to generate a time series, with projections to 2030 (Figure 9).

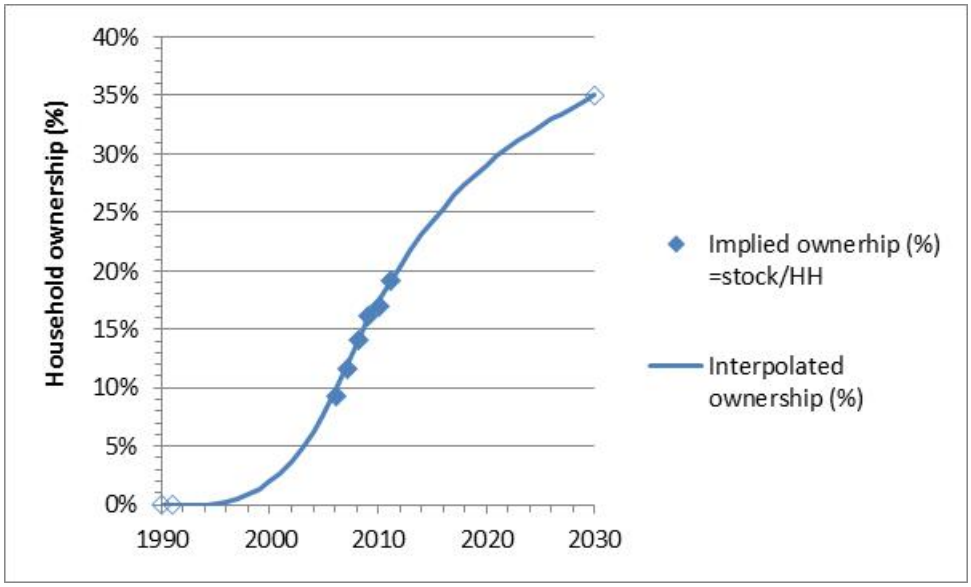


Figure 9: Household ownership of ESWH (%)

4.1.2 Sales volume

Like the household ownership data, there are only sales volume data published in CNIS (2012), which have been read from a chart and shown in the table below.

Table 14: Annual sales of residential electric storage water heaters in China

Year	2006	2007	2008	2009	2010	2011
Sales (million)	8	9.5	10.9		12.2	13.1
Text					7.6% more than 2009	

Source: CNIS (2012)

Using the available sales and ownership data an expected lifespan figure is estimated to be around nine years. It may be slightly higher if number of sales has been significantly boosted by any rebate programmes. Using the stock values and this average lifespan figure an estimate of future sales can be made, which is shown in Figure 10.

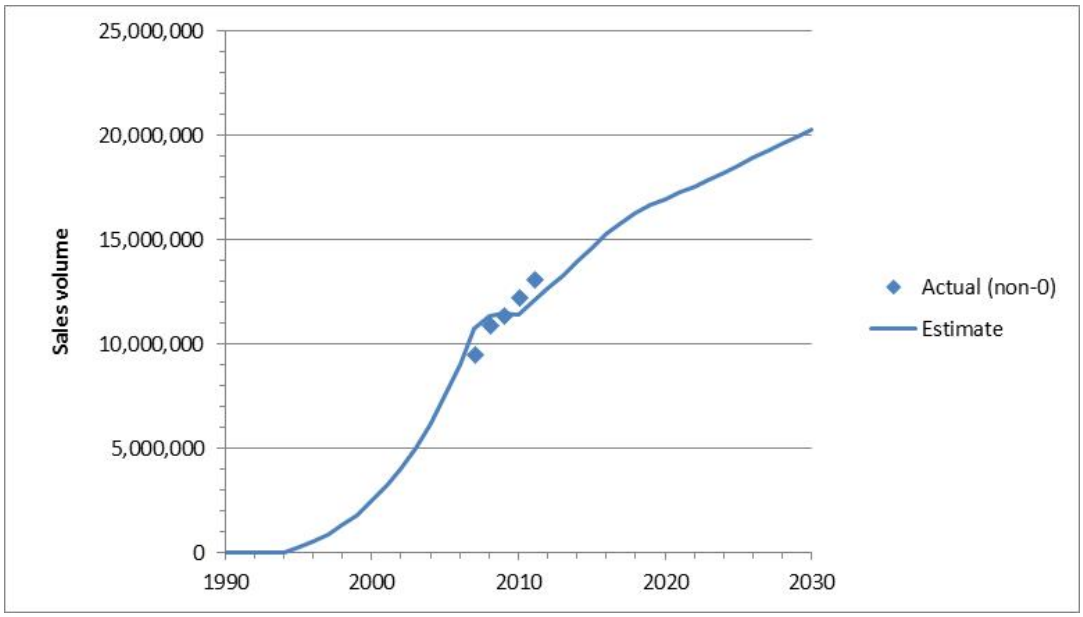


Figure 10: Sales of electric storage water heaters

4.1.3 Lifespan

Use sales and stock to estimate lifespan, the figure is around nine year, which is not too dissimilar to an ex-ante expectation of 8 years or so.

4.1.4 Scenarios

Since there are no proposals for MACEEP, only a best on market has been undertaken for the current project. However, there are certainly opportunities to ratchet the current regulations over the next few years. With limited data, the Best on the Market has been taken to have an efficiency factor of 0.7. Heat pump technology for water heaters should result in significantly reduced consumption; so this BOM may be considered on the conservative side.

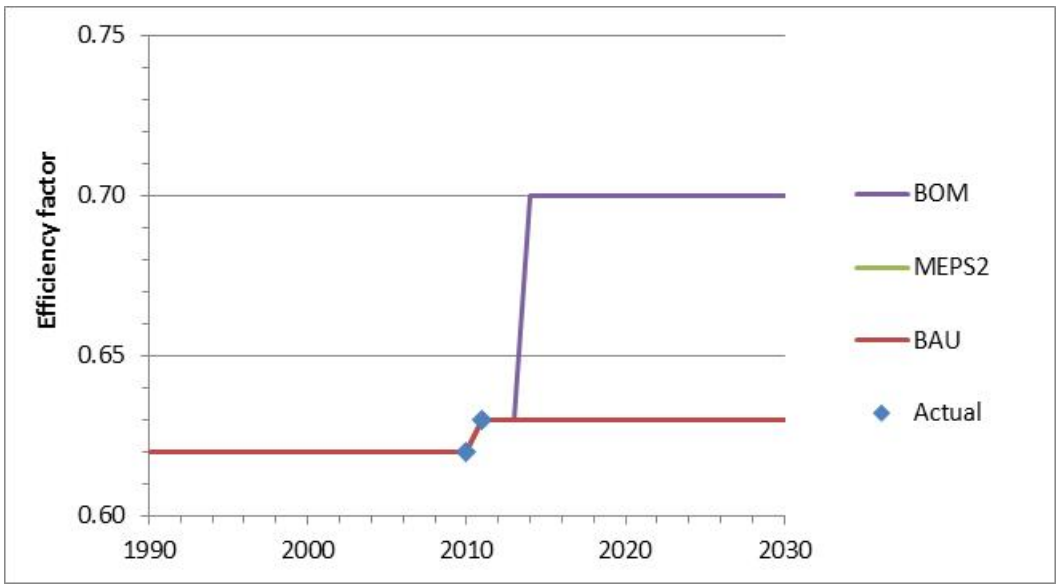


Figure 11: Average efficiency factor for electric storage water heaters under different scenarios

4.1.5 Converting test values to actual energy consumption

There are few data available on how water heaters are used in practice, and none found on how best to convert the test data to reflect actual use in practice. In this analysis we have generated a usage profile, such that overall consumption would match the national energy consumption in CNIS (2012) using the same set of household ownership. The average UEC figure assumed is 415kWh/year, and this figure is projected into the future. This UEC figure is a combination of efficiency, size, and use.

4.1.6 National energy consumption

Using the variables developed earlier, and the assumptions included, it is possible to project consumption under the BAU scenario and compare with the CNIS 2012 information. The fit is exceptionally good, probably because much of the input data was aligned to the CNIS data.

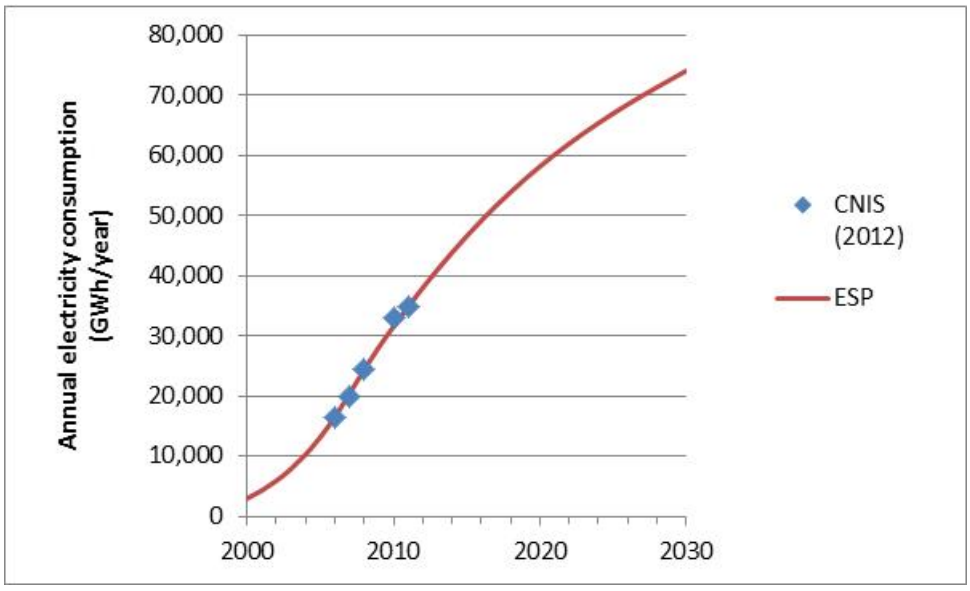


Figure 12: National electricity consumption for electric storage water heaters (BAU scenario)

The CNIS (2012) report suggested that in 2010 all ESWH used 33.1 TWh/year, an increase of 6.6% from 2009. Other data are reported in Table 15.

Table 15: National energy consumption (TWh/year) for electric storage water heaters

	2005	2006	2007	2008	2009	2010	2011	2012
CNIS		16.5	20	24.5		33	34.89	
ESP	13.22	16.58	20.49	24.45	28.18	31.62	34.91	38.05

Source: CNIS (2012) and MACEEP-ESP (2013) modelling

Using this model, it is possible to run the different scenarios described earlier; which are shown in Figure 13.

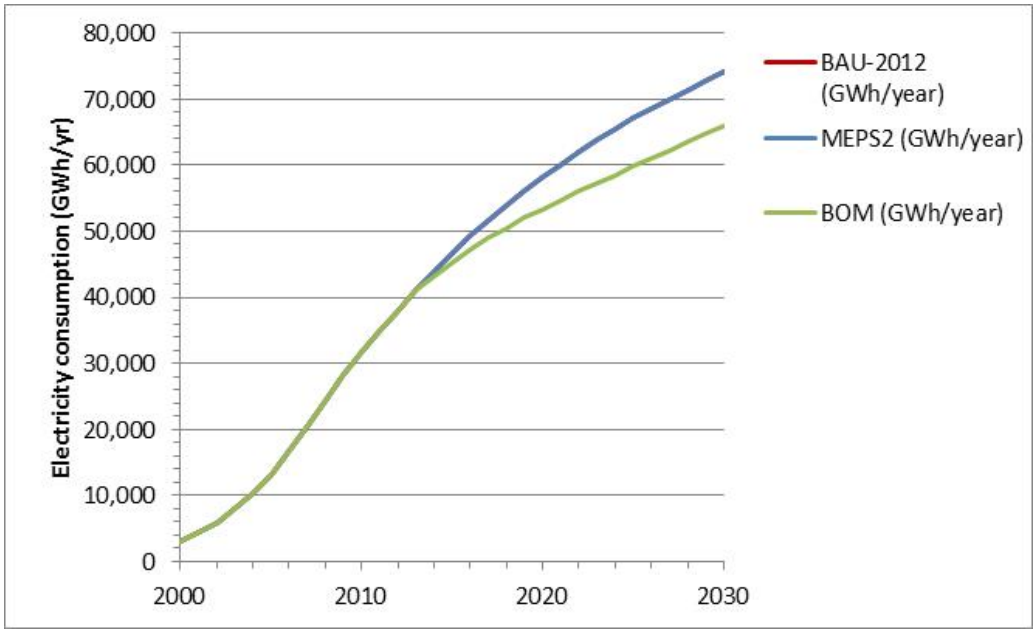


Figure 13: National electricity consumption for electric storage water heaters under different scenarios

Note: Since no MEPS2 scenario has been developed, the MEPS2 scenario is set to be the same as the BAU..

4.2 Gas instantaneous water heaters

4.2.1 Household ownership

There are data on household stock in the CNIS (2012) white paper. Using these stock values it is possible to estimate the household ownership (Table 16).

Table 16: Available stock/implied household ownership for gas instantaneous water heaters

Year	2007	2008	2009	2010	2011
Stock (million)	78	82	90	97.09	106
Text			(from 2009 to 2010 is a 9% increase		
Household numbers (m)	414.9	421.0	426.9	432.8	438.5
Implied household ownership (%)	18.8	19.5	21.1	22.4	24.2

Source: stock from CNIS (2012), household numbers from separate ESP analysis
[Chart read error about up to 5%]

Using these ownership data, a projection of future ownership has been made (Figure 14), with an assumption that there were virtually none of these appliances before 1990 and that household ownership will be around 40% in 2030.

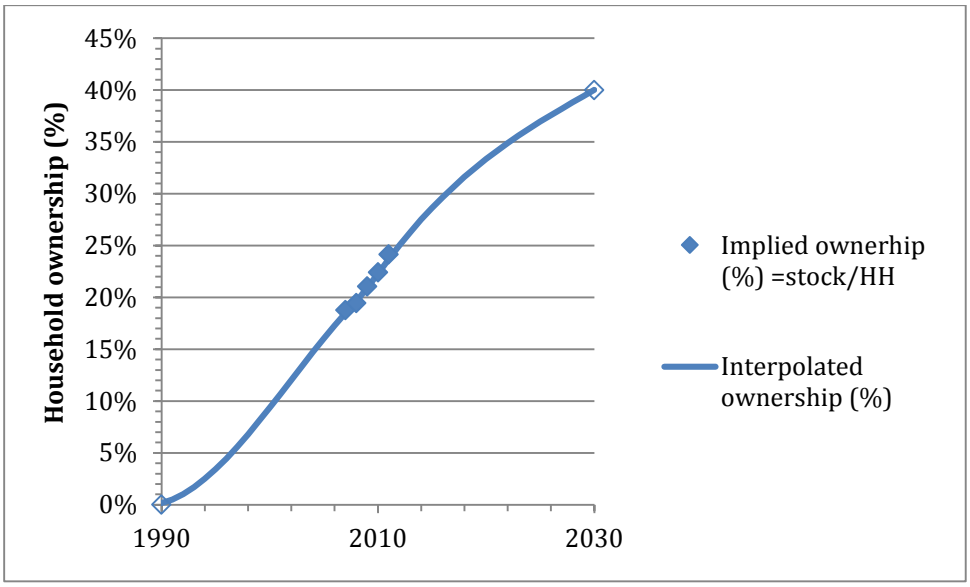


Figure 14: Household ownership of gas instantaneous water heaters

4.2.2 Sales volume

Like the ownership data, only have access to sales data published in CNIS (2012), which have been read from a chart and shown in the table below (Table 17).

Table 17: Annual sales of residential gas instantaneous water heaters in China

Year	2006	2007	2008	2009	2010	2011
Sales (million)		8	8.05	8.7	10	9.11
Text					From 2009 to 2010 is an increase of 19.4%	Decrease of

Source: CNIS (2012)

Using a lifespan figure of 15 years, an optimisation of available sales and sales estimated from ownership, the best fit for estimated sales is presented in Figure 15.

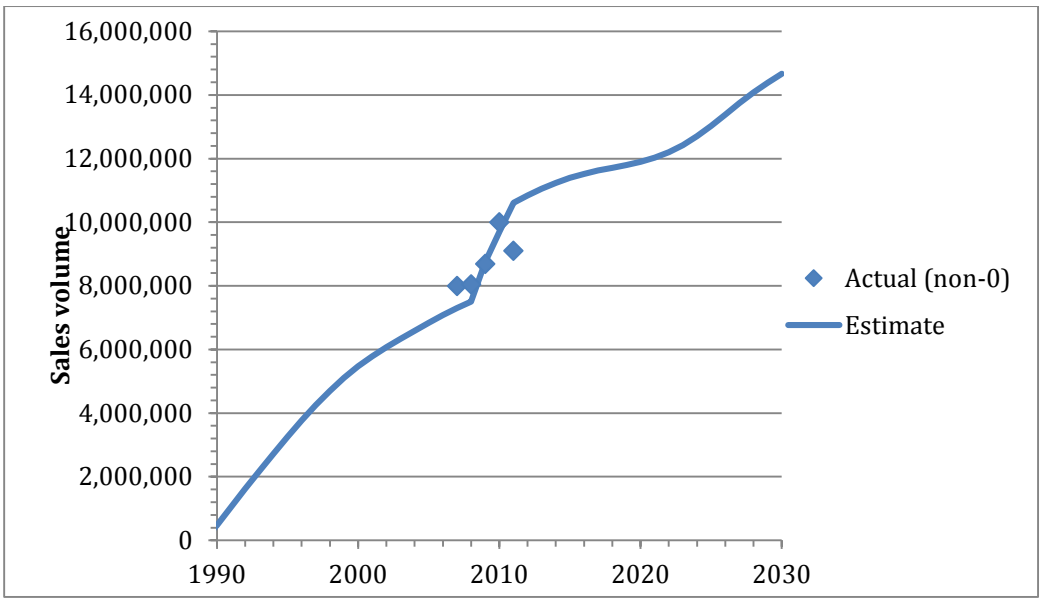


Figure 15: Volume of sales, estimated and actual. For gas instantaneous water heaters

4.2.3 Lifespan

Gas instantaneous water heaters tend to last a long time, especially when not in hard water areas, and 10-15 years is not untypical. From the optimisation of available sales and stock levels, the average over the available data is 15 years.

4.2.4 Use

There are few data on hot water use in China.

Initially, as an estimate it is thought that, on average, each person consumes 40 litres of hot water per day. This could be used to multiply by the average number of persons/household to get estimated average hot water use (litres) per household per year.

However, this may be on the high side, based on what on the electrical storage water heating analysis. This has a direct impact on the energy consumption, so if we have any other evidence it would be worth including.

Using the stock model developed here it is possible to try and infer the amount of hot water used in the CNIS (2012) study. From the analysis, the figure is around 10 litres/person/day of hot water (where hot means rising the temperature from the inlet temperature of 15^{o}C to 60^{o}C, a rise of 45^{o}C). A temperature rise of half this amount would imply twice as much hot water being generated. For this study it is the energy required to heat the water that is important, and a figure has been chosen such that it matches the outputs from the CNIS model.

This use appears to be on the low side, but is the figure consistent with the CNIS study, so this is used in the current analysis.

4.2.5 Scenarios

The most efficient water heater products on the market have an efficiency of **96%** (from CNIS white paper).

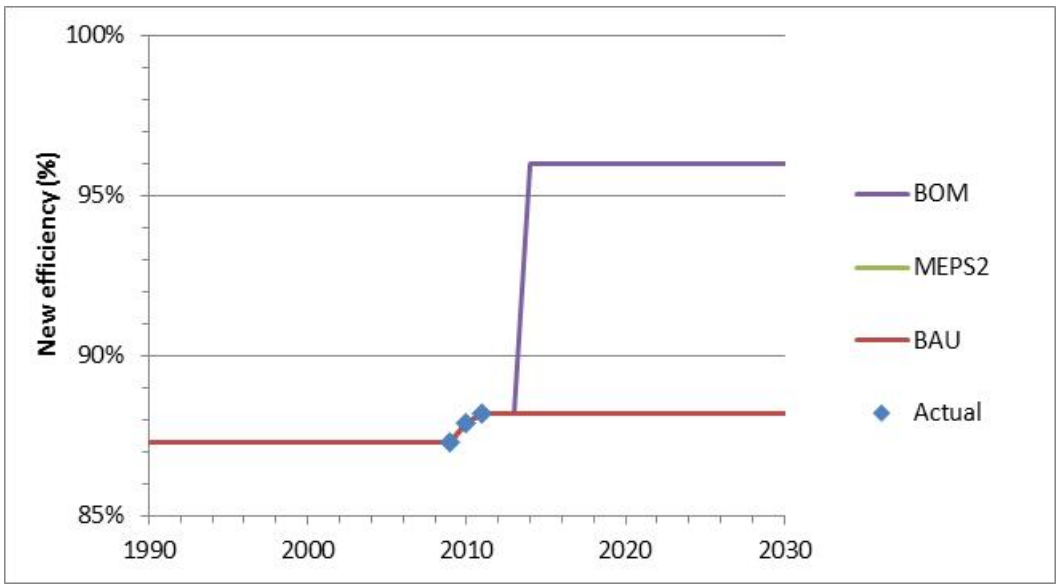


Figure 16: Average new efficiency (%) of gas water heaters under different scenarios
Note – the MEPS2 scenario is set to be the same as the BAU.

The BAU has been projecting at the current efficiency level of 88% constant. It could be argued that the efficiency could continue to rise with current policy measures (LBNL study made this assumption).

The current model has not had access to a MACEEP style, market or engineering analysis, so the projections are less certain, and there is no MACEEP-ESP scenario to include here. If such an analysis were to be undertaken it would be useful to see if the high efficiency water heaters require more costly technology (such as condensing).

4.2.6 Projected energy consumption, savings, benefits

Using the variables developed earlier, and the assumptions included, it is possible to project consumption under the different scenarios. With a lifespan of 15 years it takes some time for the full effect of the BOM scenario to be seen.

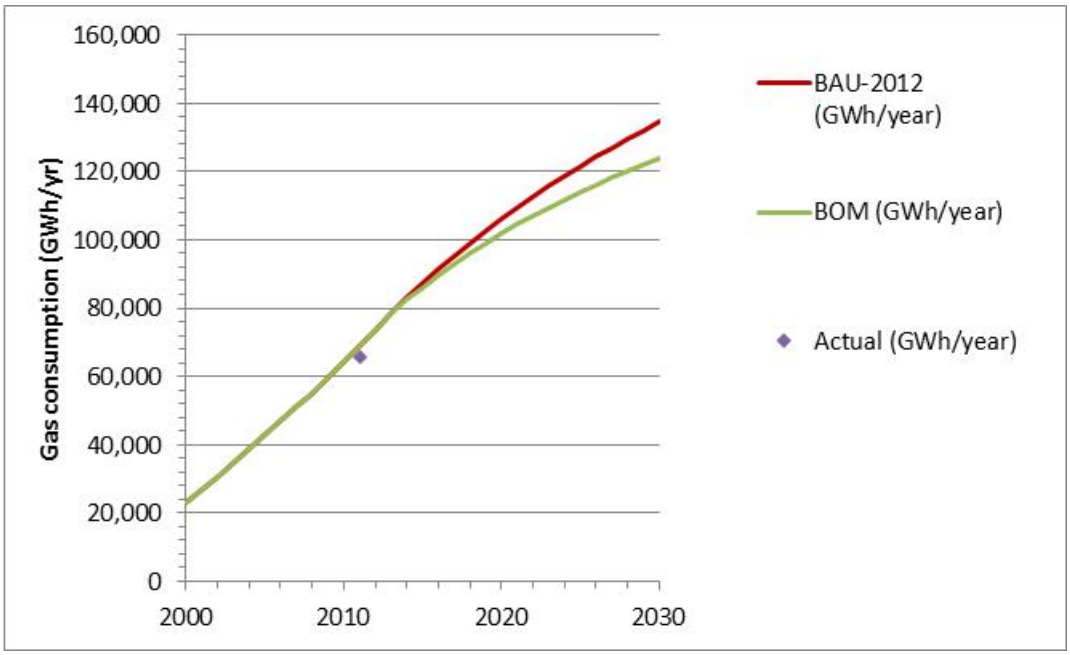


Figure 17: National consumption under different scenarios, GWh/year, for gas instantaneous water heaters

Note: Plotted on the chart is the 2011 estimate from CNIS (2012) white paper. The close match is not surprising, as the use input for the model has been revised so that the energy consumption should match closely to the CNIS value.

Once the energy savings have been estimated, it is possible to convert these to running cost savings to the consumer and also reductions in carbon emissions using standard conversion factors. Specifically:

- Consumer price of natural gas in Beijing is 2.28 CNY/m^3 (source: SZ, pers comm) [0.76 RMB/kWh]
- Emission factor: 2.688 kg CO_2/Kg of Natural Gas (source: SZ, pers comm) [0.18kgCO2/kWh]

Table 18: Summary of savings from the BOM scenario for gas instantaneous water heaters

	2020	2025	2030
Annual gas savings (TWh/yr)	4.3	7.6	10.4
Annual financial savings (RMB billion)	36	92	166
Annual carbon reductions ($MtCO_2$)	0.80	1.40	1.92
Cumulative gas savings (TWh)	17	49	95
Cumulative financial savings (RMB billion)	118	458	1,137
Cumulative carbon reductions ($MtCO_2$)	3.2	9.0	17.6

5 Comparison of two studies (MACEEP ESP and LBNL) (Task 1, Task 4)

The general approaches are similar; the main differences should be the differences in the scenarios run.

Table 19: Comparison of the two studies

Aspect	LBNL	MACEEP-ESP	Comparison, note
Modelling approach	Bottom-up model, using the BUENAS tool	Bottom-up model, using the DECADE model (Lane 2000)	Very similar approach, though there will be some difference in detail, and of course the numbers used
Model - Efficiency/performance disaggregation	Combined UEC, though efficiency assumptions also listed	Disaggregated to show efficiency, use, power rating (same effect of UEC)	In principle similar approach, though the disaggregation is more apparent in MACEEP ESP.
Model - Transparency of underlying evidence	Poor, no specific references to data.	All source data used are quoted	Not all LBNL data traceable.
Data access	May have access to more CNIS data	All known national statistics and publicly available data	LBNL may have access to more CNIS data (which they do not make public).
BAU scenario	No further product policy	No further product policy	In principle, very similar approaches though in practice the values chosen may be different.
Best on market/Reach scenarios	Reach scenario is for best in the world	Best on market scenario is for best in China currently.	The LBNL scenario is a more challenging target. Both are unrealisable in the near term

CIS and MACEEP (MEPS2) scenarios	CIS is a continued improvement, may be achievable with effort from CNIS	MACEEP (MEPS2) scenario is realistic and ambitious next round of product policy measures for CNIS in the near term.	CIS is on-going and multiple iterations, whereas MACEEP-MEPS2 is once-only iteration. CIS is generally more ambitious, though potentially less realistic.
Data - historic national sales volume	From CNIS and previous LBNL studies.	Using national statistics and CNIS white papers.	Should be the same data sets
Estimate of future sales	Taken from previous LBNL/CNIS analysis and BSRIA.	Based on projection ownership and using lifespan to estimate sales	The BSRIA one is unknown and potentially unrealistic. There is a difference in the future sales and these are examined further in the next tables.
Data - historic household ownership	From CNIS	Using national Government statistics	The CNIS data are most likely from the national statistics
Data - efficiency and performance of products sold	From CNIS registrations, contact with CNIS (not published).	From CNIS registrations data available, an assessment of 2012 market, and CNIS white paper publications	The CNIS may have more direct access to registration information (and sales) – as implied by the white paper.

The two studies covered different products and had different scenarios.

Table 20: Comparison of products and scenarios

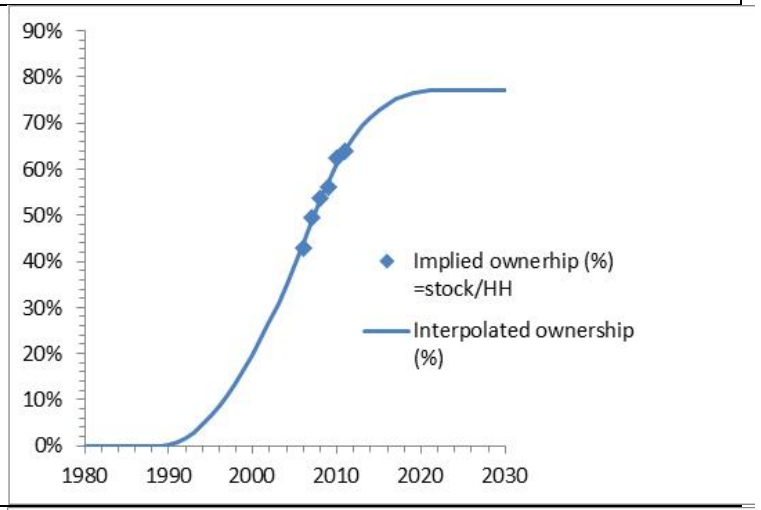
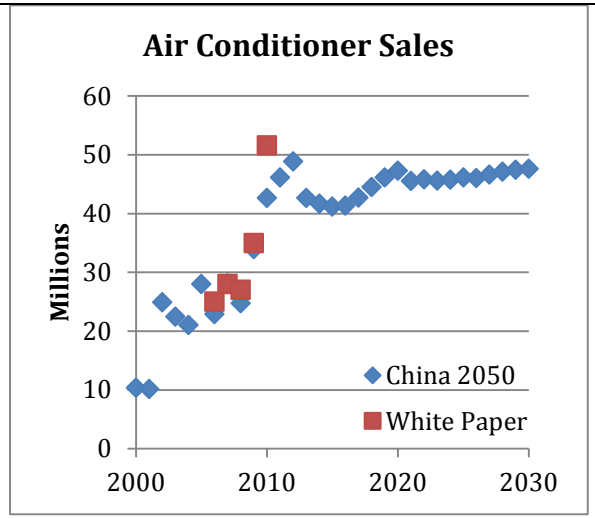
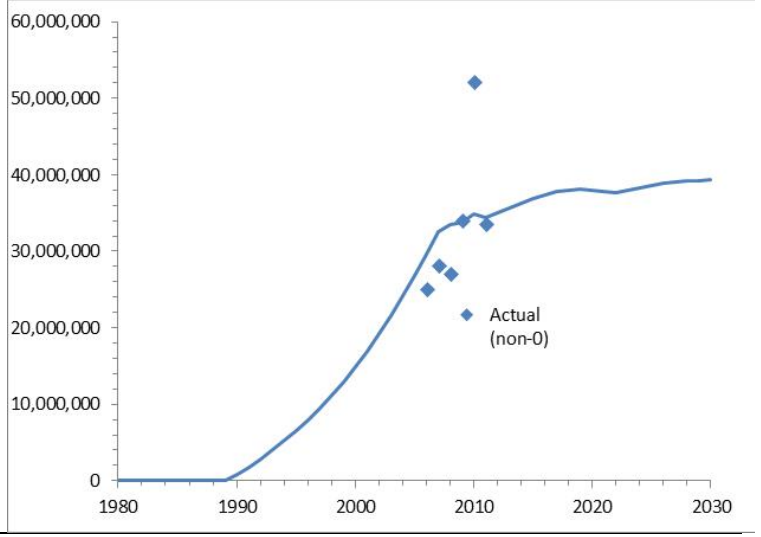
Study	ESP			LBNL		
Product	**BAU (ESP)**	**MACEEP-ESP (ESP)**	**BOM (ESP)**	**BAU (LBNL)**	**CIS (LBNL)**	**Reach (LBNL)**
1-AC-Fixed	X	X	X	X	X	X
2-AC-VSD	X		X			
3-Refrigerator	X	X	X	X	X	X
4-WM	X		X	X	X	X
5-TV	X	X	X			
6-Rice-cooker	X	X	X	X	X	X
7-Induction-cooker	X	X	X			
8-Copier	X	X	X			
9-Monitor	X	X	X			
10-ESWH	X		X	X	X	X
11-GWH	X		X	X	X	X

A detailed comparison of the data is shown in the following tables.

For air conditioners, the MACEEP-ESP study separated the products into fixed-speed and variable speed (VSD) air conditioners since the policy measures and underlying test methods are different.

The following tables compare the LBNL input variables with the MACEEP-ESP variables where they are available for easy comparison. Some commentary is included in the first column. Although the scope for the project was just for the four overlapping products, the new water heater products have also been included.

Table 21: Summary of Air conditioner (fixed-speed)

Comparison	LBNL	MACEEP-ESP
Household ownership	NA	
Estimated sales • Similar, though ESP is lower projection, which could be partly due to increase in VSD (separately modelled)		

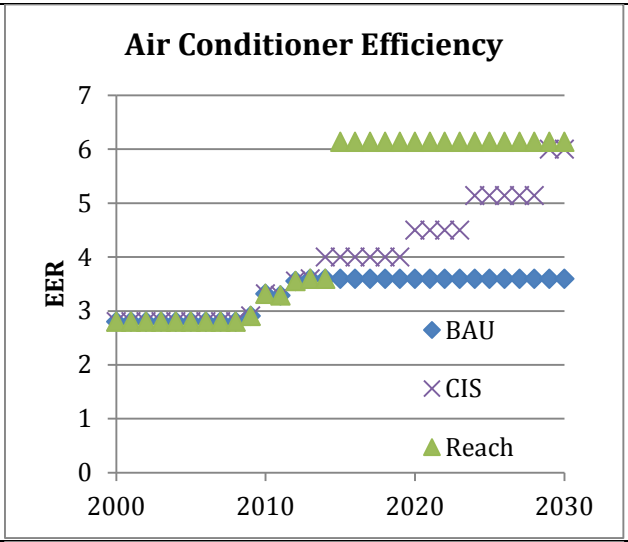
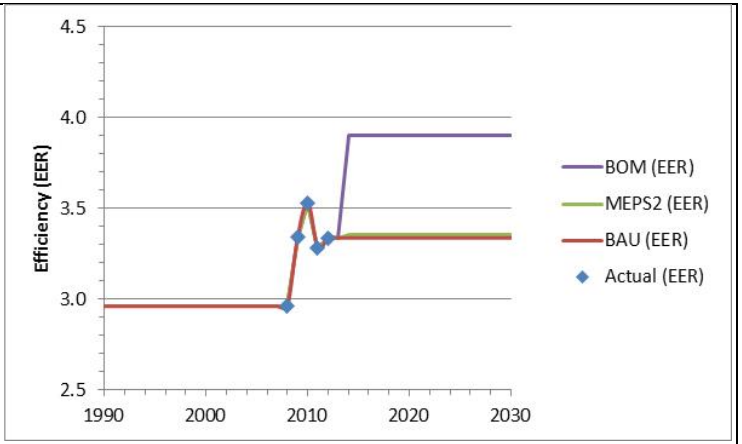
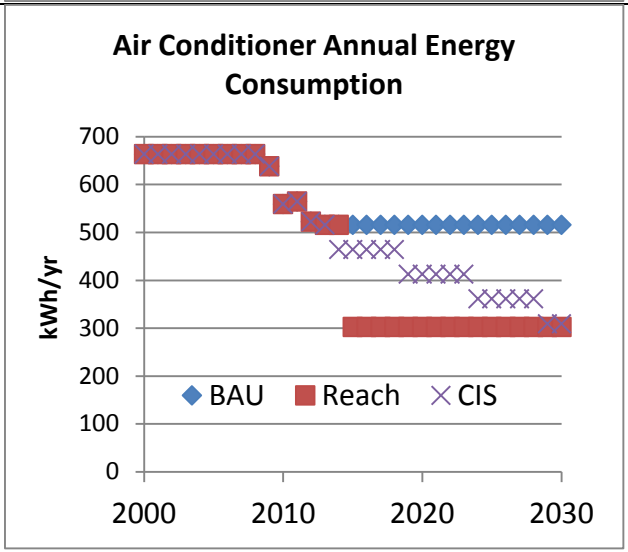
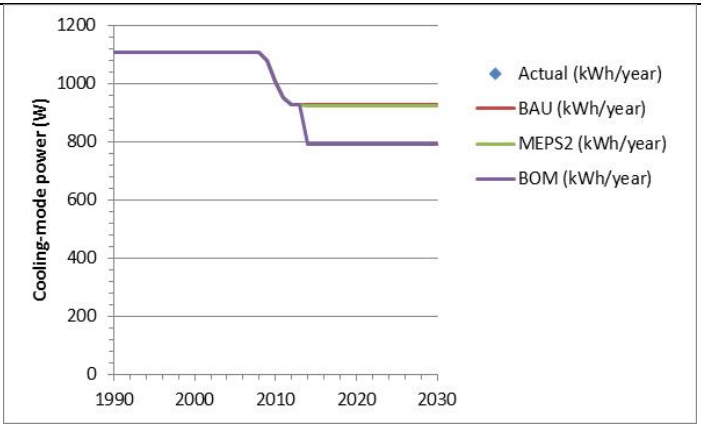
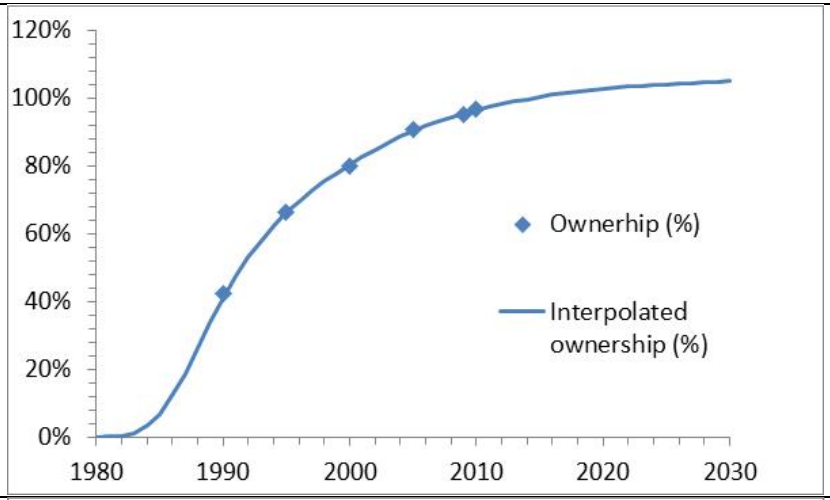
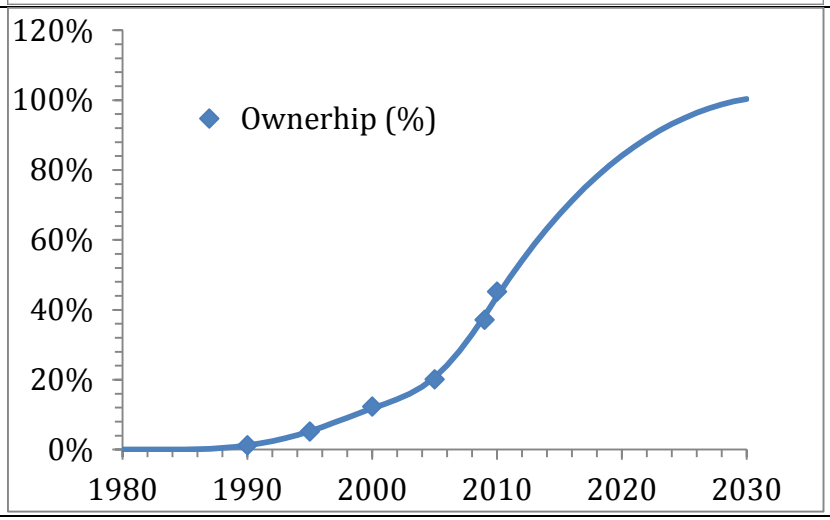
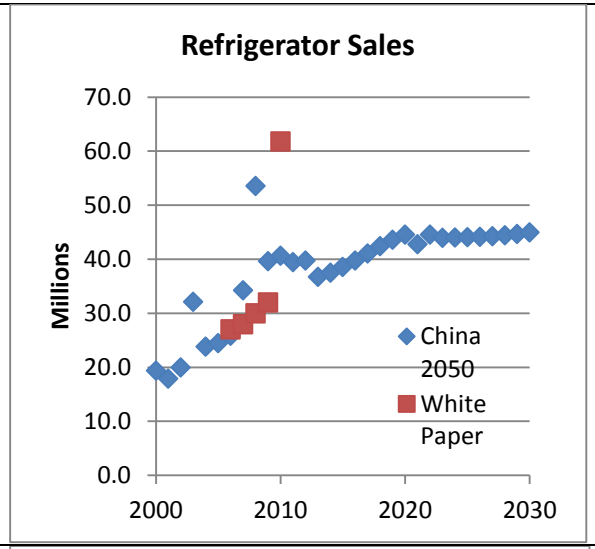
Efficiency – EER • BAU very similar • Very small impact from MEPS2 • Reach significantly larger (>50%) than BOM		
New UEC • ESP based on 2 hours/day; UEC is significantly higher.		
Other		• Average 2 hours/day assumed • In 2012, 1.3kW average input power

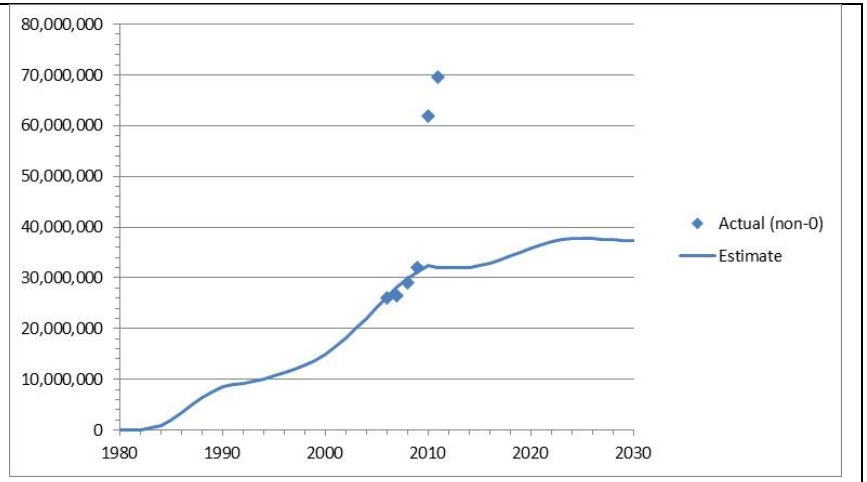
Table 22: Comparison of Refrigerator

Comparison	LBNL	MACEEP-ESP
Household ownership (urban)	NA	
Household ownership (rural)	NA	

Sales

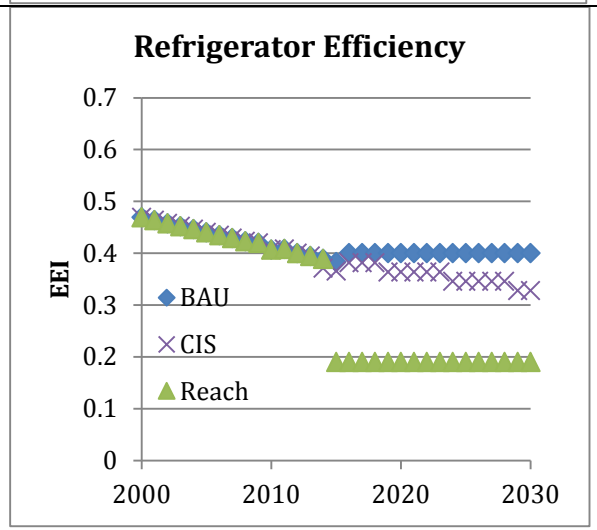
- Projection is slightly higher (ca <20%) for LBNL than ESP.
- ESP may have a longer lifespan





Efficiency – EEI

- Since LBNL should be based on CNIS data, it is likely that the implied EEI for ESP would be similar.

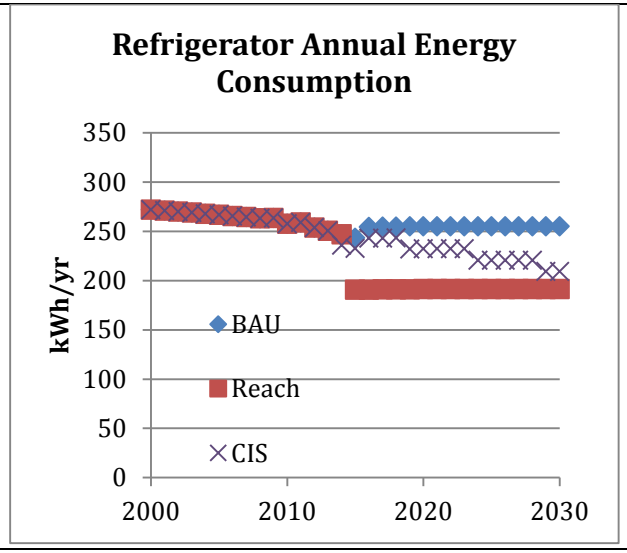


Summary:

- Average EEI data not available from CNIS report.
- Could be included from the later 2012 CLASP analysis, where this variable should be available for some later years.

New UEC

- Previous LBNL estimates were much higher, at values higher than 500kWh/year, so these are more realistic.
- However, ESP still noticeably lower, especially the latest 2012 value.



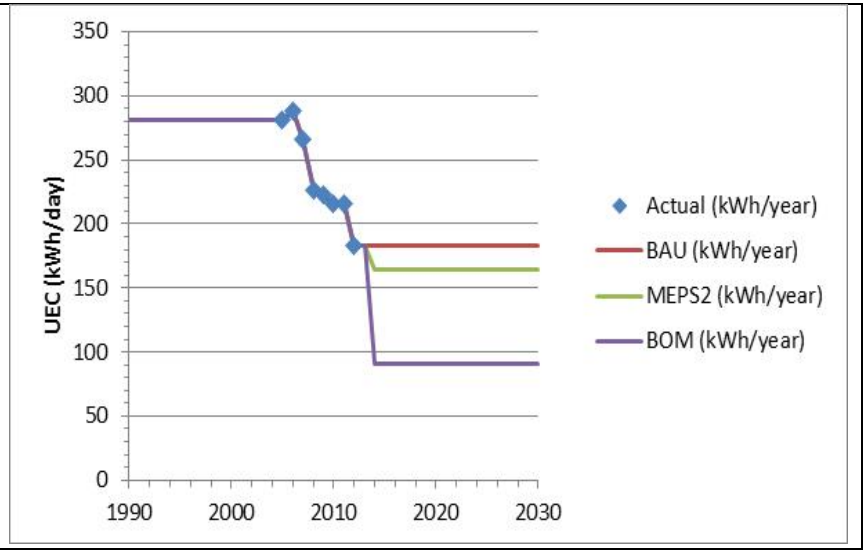
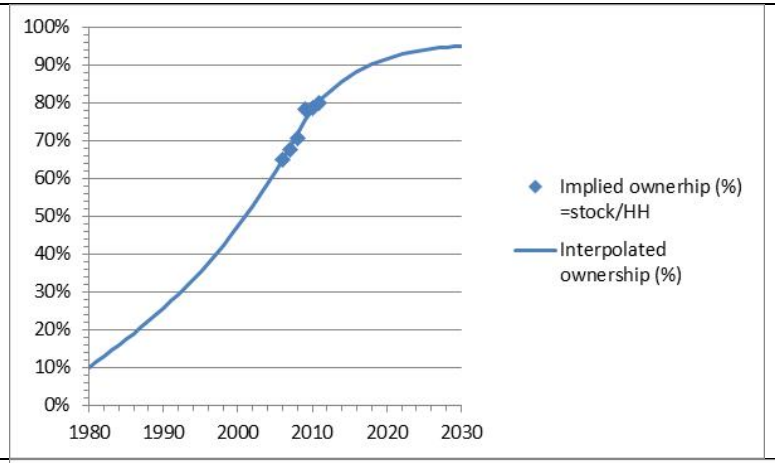
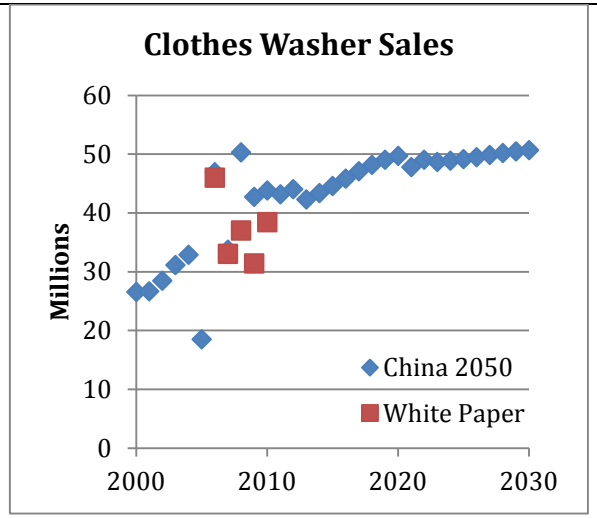
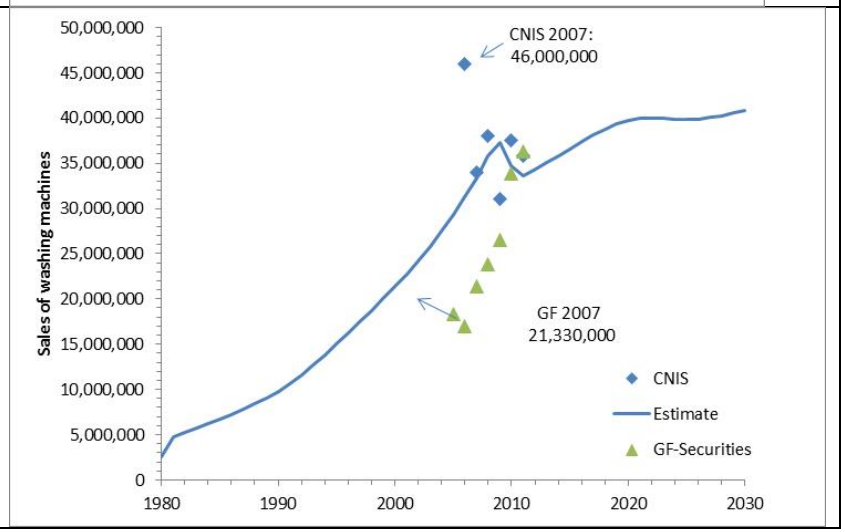
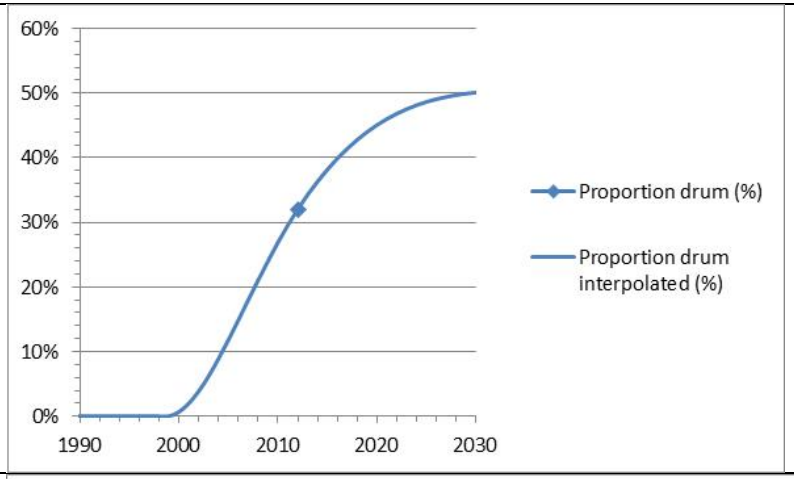
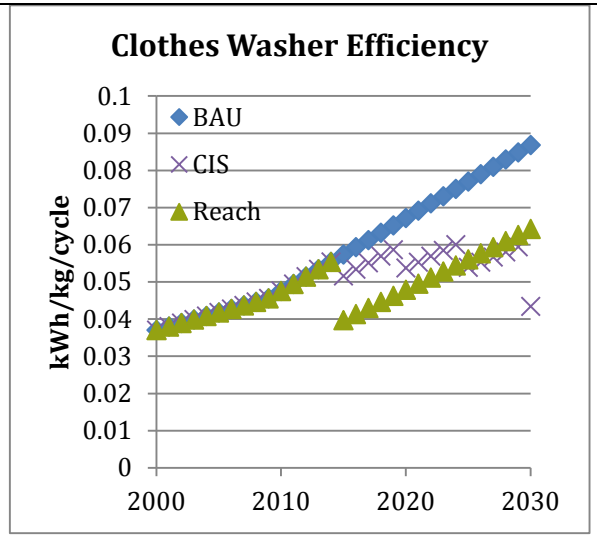
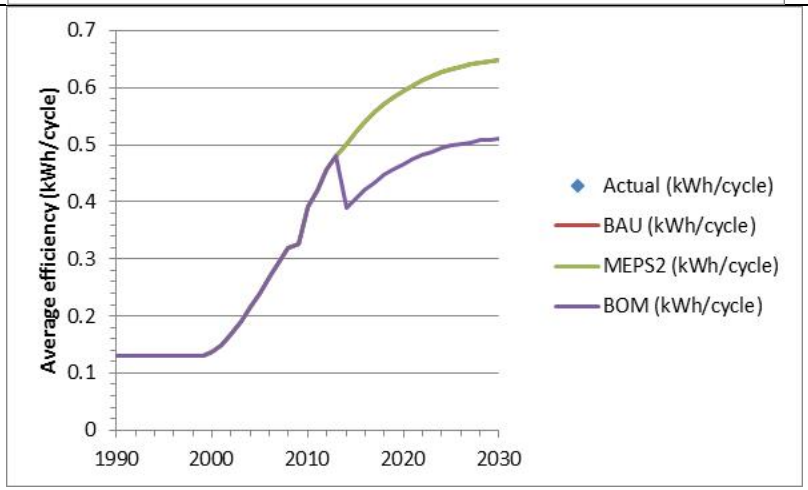


Table 23: Comparison of washing machines

Comparison	LBNL	MACEEP-ESP
Household ownership	NA	
Sales • Projection for ESP is slightly lower, likely longer lifespan		

Proportion drum • This is needed to estimate a sales-weighted combined top-front average efficiency.	na	
Efficiency – • Similar effect, • Note LBNL is per kg, so a different basis. • It should be possible to create this chart for ESP figure • No MEPS2 scenario for MACEEP study (= BAU).		

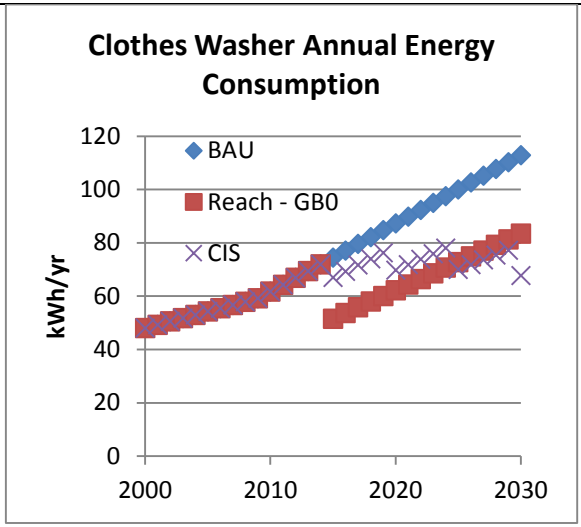
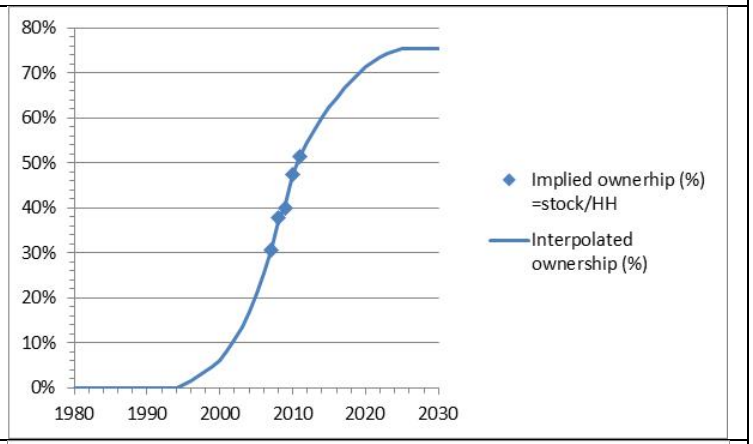
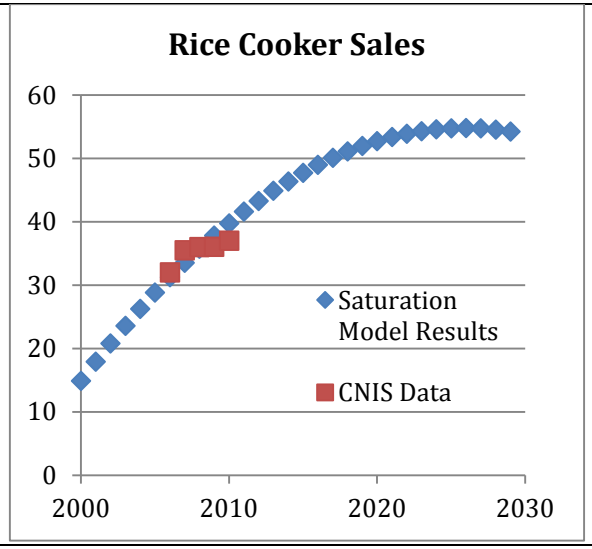
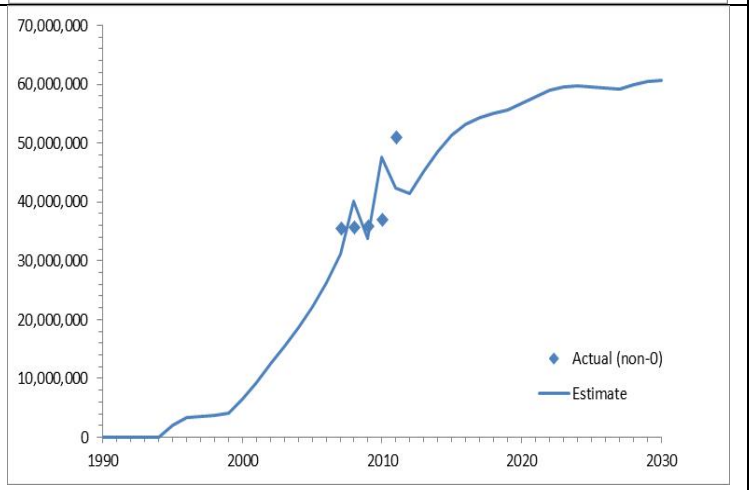
UEC (kWh/year) • This figure not directly created for ESP since use (temperature, load) over time may be different from the year of purchase. • However, could calculate for ESP using use (temp, load) in the year of the sale to multiply by efficiency and load, to get UEC.		NA

Table 24: Comparison of rice cookers

Comparison	LBNL	MACEEP-ESP
Household ownership	na	
Estimated sales • Similar. ESP slightly higher, later data point available. • LBNL CNIS data are the same national statistics in the ESP study (which has a year extra data).		

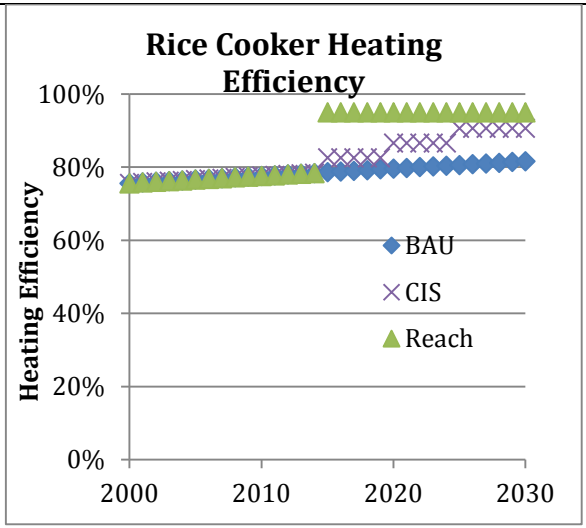
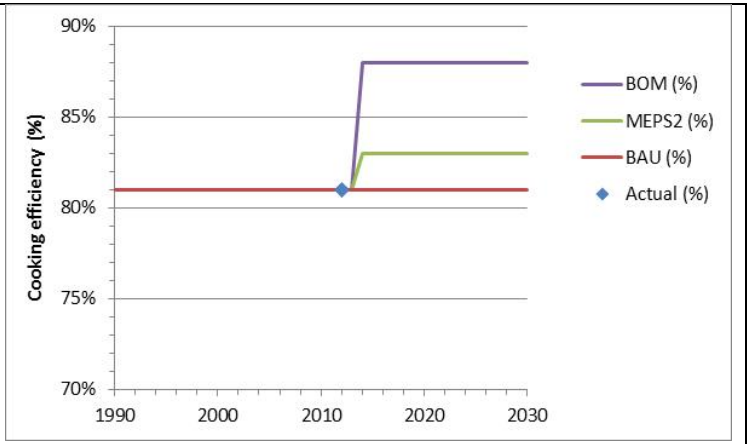
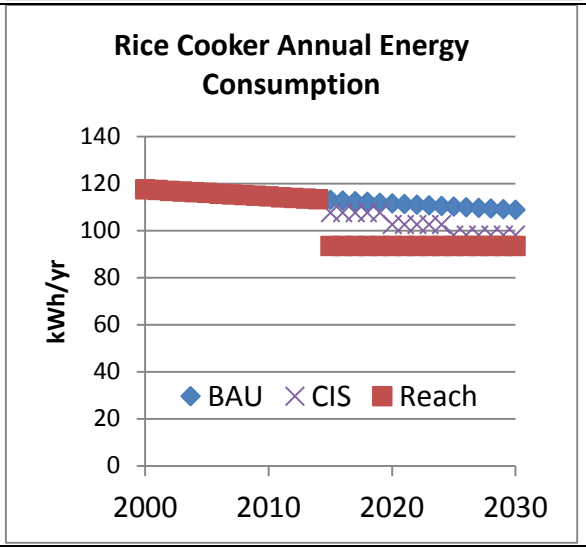
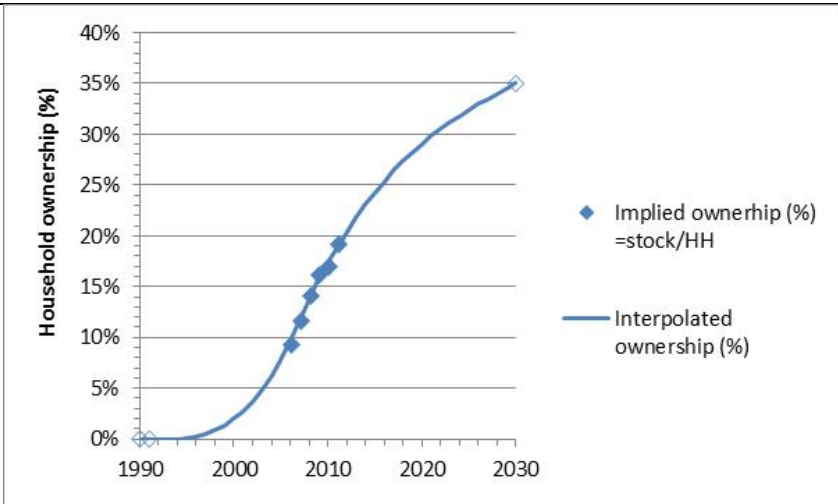
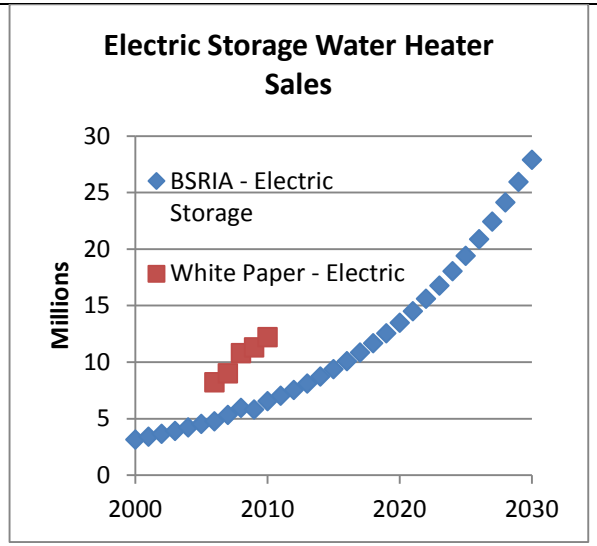
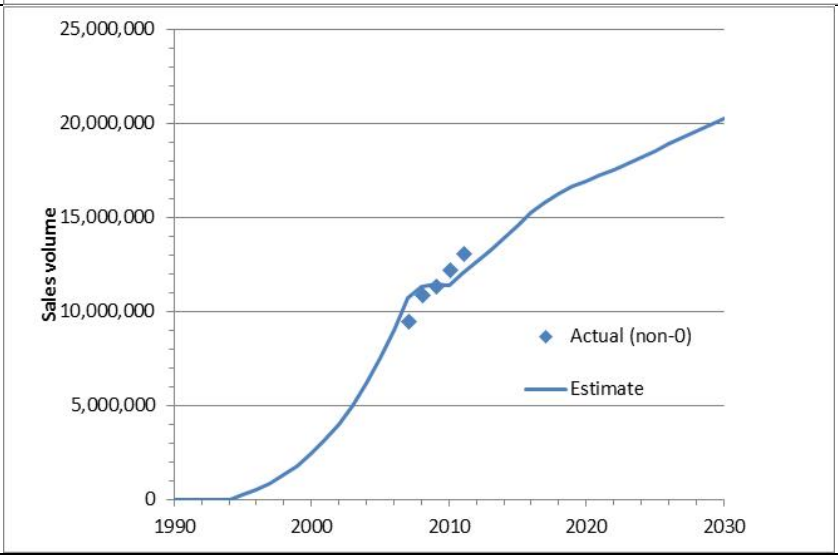
Efficiency - % • Reach of 95% is very challenging. • ESP 2012 BAU value is marginally higher than LBNL (81% compared to just under 80%)		
UEC • This figure not directly created for ESP since use (all modes) over time may be different from the year of purchase. • However, could calculate for ESP using use (modes) in the year of the sale to multiply by efficiency and load, to get UEC.		NA

Table 25: Comparison of electric storage water heaters

Comparison	LBNL	MACEEP-ESP
Household ownership		
Estimated sales • LBNL does not match CNIS WP data; though claim that some instantaneous data are included. • LBNL exponential projection is different to others. • BSRIA source not given.		

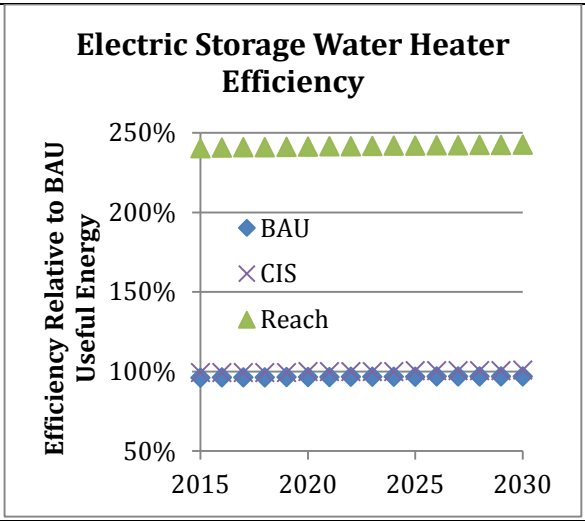
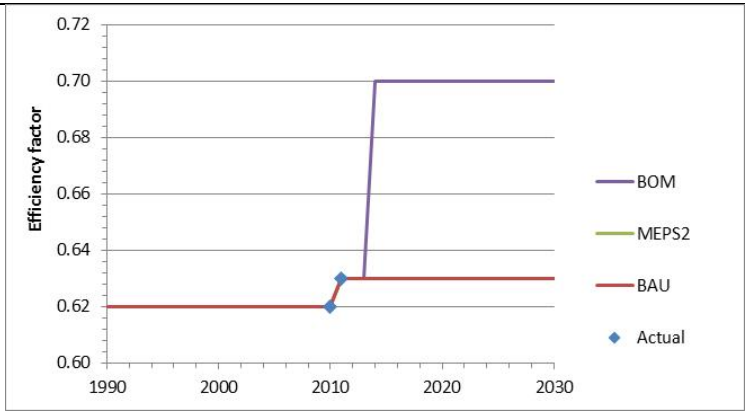
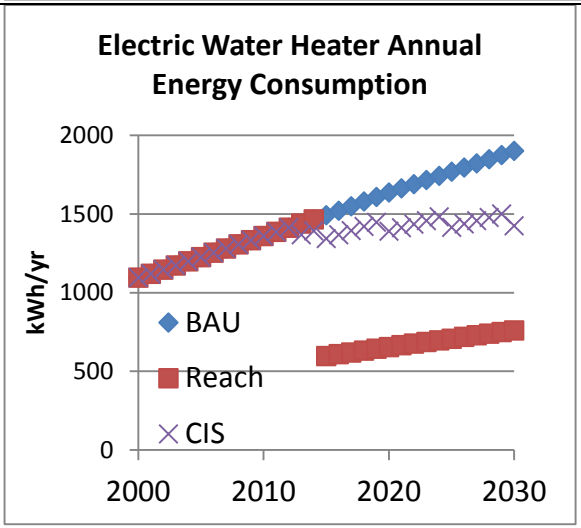
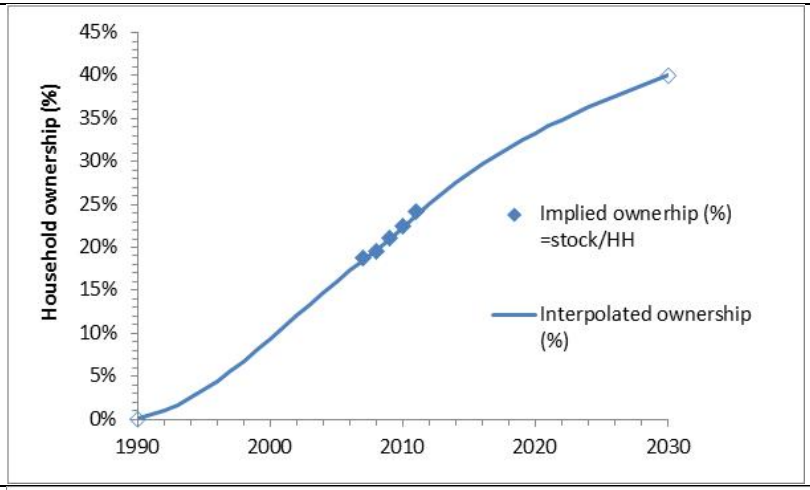
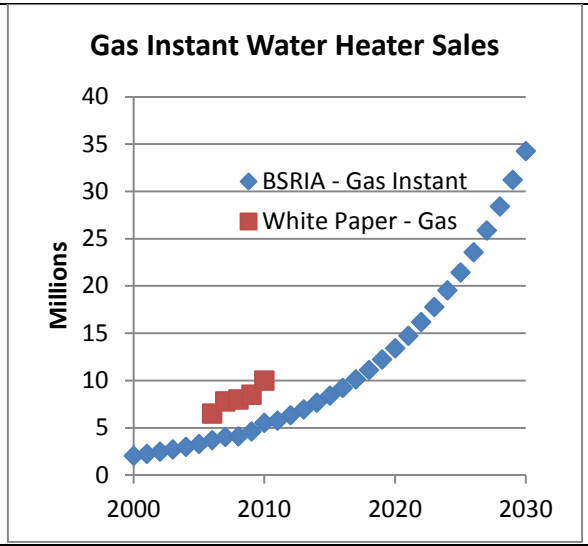
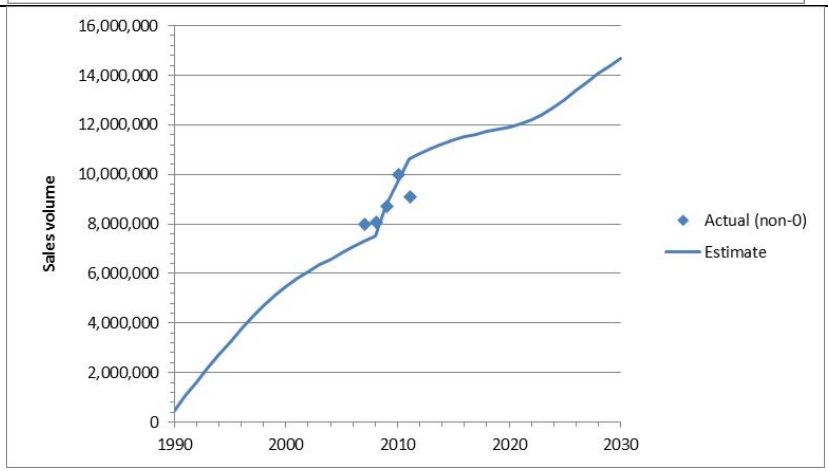
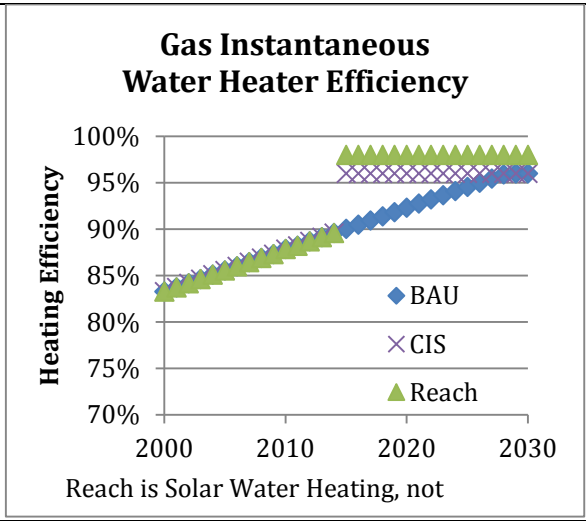
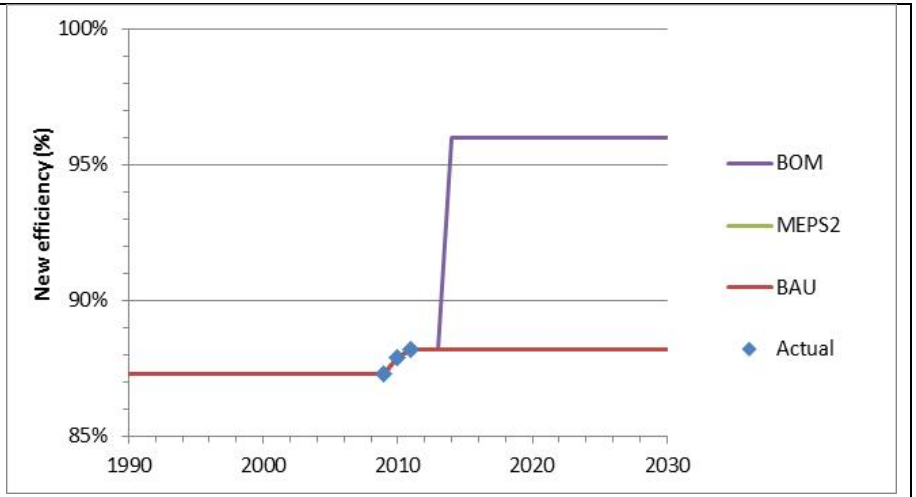
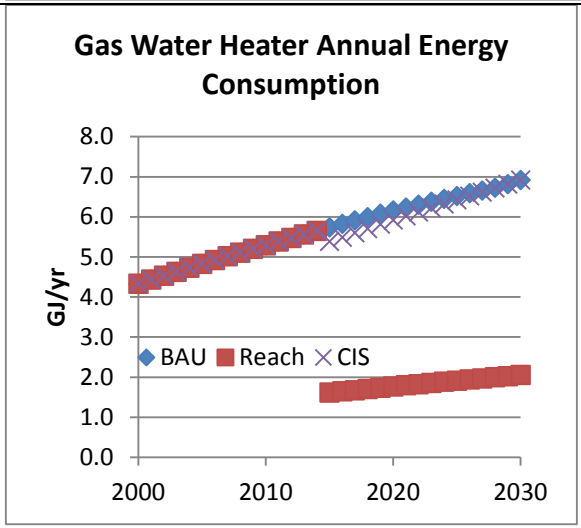
Efficiency (%) • The LBNL value is relative. • ESP is an efficiency factor, as used in the regulation.		
UEC. • **Significant difference here**. The ESP figure has been used so that it makes the national consumption match CNIS white paper. • The LBNL is much higher, and expected to continue to increase.		It is approximately 420kWh/year for all years in BAU

Table 26: Comparison of gas instantaneous water heaters

Comparison	LBNL	MACEEP-ESP
Household ownership (%)	na	
Sales • LBNL do not match CNIS WP data, or the national statistics. Likely that some of these products are not instantaneous ones. • LBNL exponential projection is different to others. • BSRIA source not given, so cannot trace issue.		

Efficiency (%) • Very similar, though baseline for LBNL is 90% versus 88.2% for MACEEP-ESP. • BOM = Reach = 96%	 Reach is Solar Water Heating, not	
UEC • Without additional evidence, made ESP BAU match as best as possible		Can calculate UEC. Need to translate ESP to GJ from kWh.
Use		ESP based on making match to CNIS (2012) total, so around 10 litres/person/day of hot water. This is much less than implied by LBNL study.

6 Re-running of ESP with LBNL projected scenarios (Task 2)

The previous sections compared the two sets of energy savings potential scenarios: LBNL and MACEEP-ESP. It should be clear that it is not possible to directly compare the MACEEP-ESP and LBNL scenarios since the underlying assumptions and the models themselves are slightly different. The only variables which should be different for a fair comparison of the different scenarios are the assumed changes in efficiency into the future under the different scenarios.

To overcome this, it is possible to use the efficiency values assumed in the LBNL models in the MACEEP-ESP models, such that all the other variables are the same in the different scenarios. This is the purpose of Task 2 of the study and summarised in this section.

This section will use the available information from the LBNL efficiency data for each of the scenarios and make them consistent with the MACEEP-ESP scenarios. This will need to ensure that the baseline match up, up to 2012 or so. As such, there are some minor changes to the input data. For these baselines, all the values should match the MACEEP-ESP models.

For each of the MACEEP-ESP products which have LBNL counterparts, the following subsections will:

- Describe the efficiency input variables used to drive the model
- Show the estimated national consumption
- Show the estimated energy savings for each scenario.

And these will all be on a consistent basis, such that the underlying variables are all the same, as well as any conversion factors.

6.1 Air conditioner (fixed-speed only)

The basis for air conditioner models are EER.

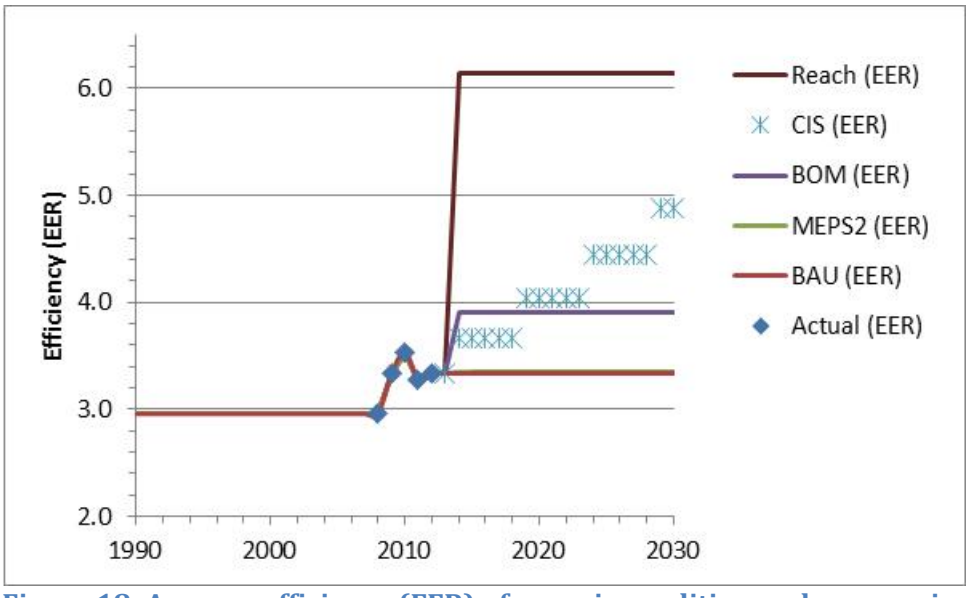


Figure 18: Average efficiency (EER) of new air conditioners by scenario

Using these input variables and the MACEEP-ESP model, the following consumption is estimated.

249.1 TWh 2011

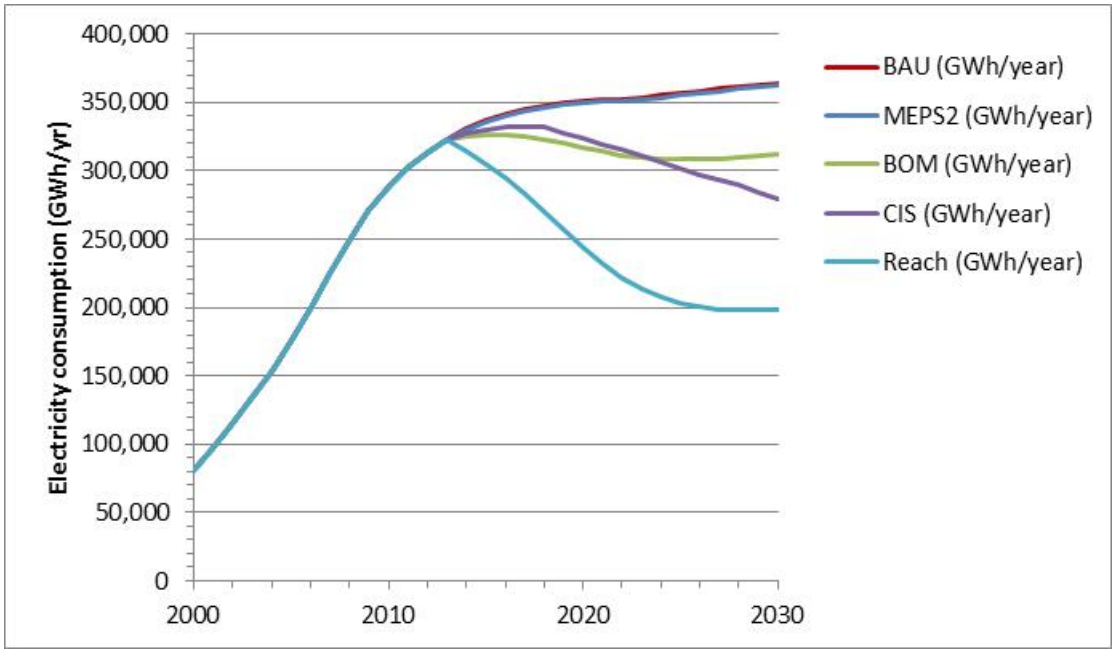


Figure 19: National energy consumption by air conditioners by scenario

It is the difference between the scenarios that is important, as these describe the energy savings, and their estimates are more reliable than the absolute consumption levels.

6.2 Refrigerator

For refrigerators the parameter driving the model is the average new UEC (kWh/year), though ideally the parameter should be average EEI. The LBNL data are higher than the MACEEP-ESP values, so the re-running has used the percentage improvement rates the LBNL CIS scenario and the absolute Reach value. The Reach value is for a product already on the Chinese market, so this Reach value matches in the BOM value in this analysis.

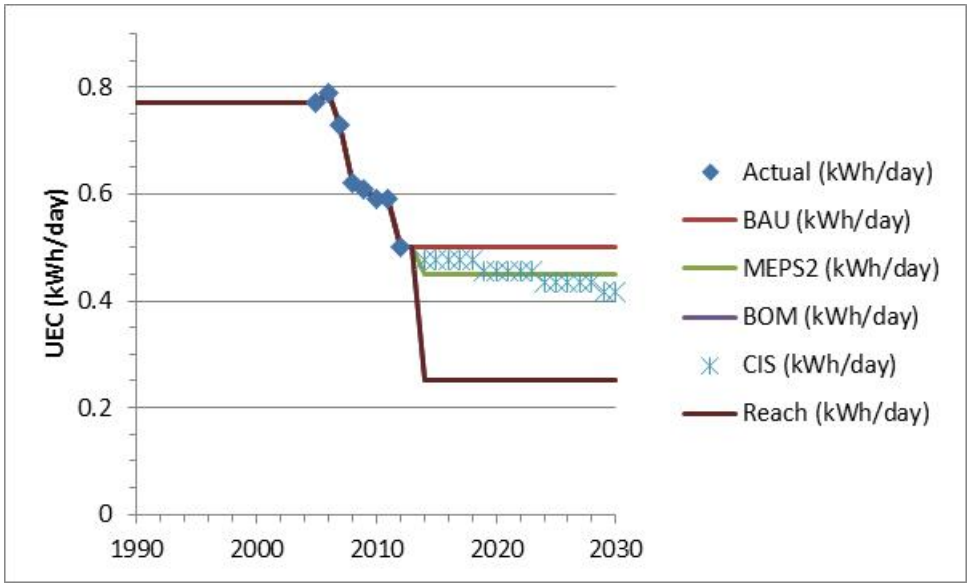


Figure 20: Average consumption (kWh/year) of new refrigerator by scenario

Using these input variables and the MACEEP-ESP model, the following consumption is estimated.

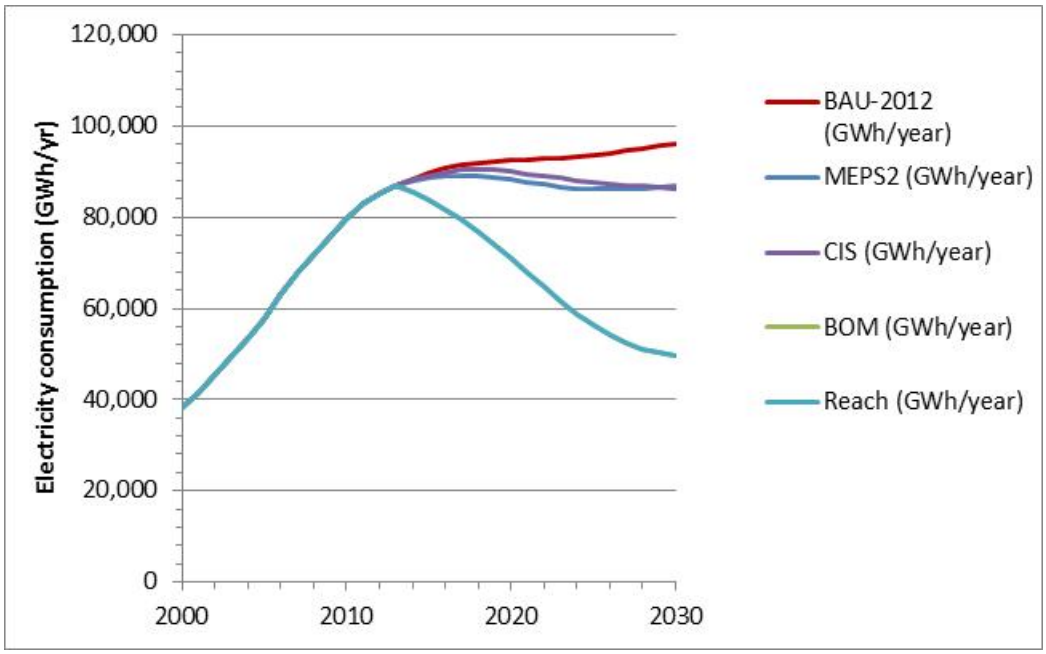


Figure 21: National consumption by refrigerators by scenario
Note – Reach = BOM

It is the difference between the scenarios that is important, as these describe the energy savings, and their estimates are more reliable than the absolute consumption levels

6.3 Washing machine

Washing machines include both top-loading and front-loading machines. The increasing uptake of front-loaders (drum, higher energy consumption since warm wash) and decreasing sales uptake of top-loaders (impellers, which use less energy since cold wash), means that the average new washing machine is using more energy on average.

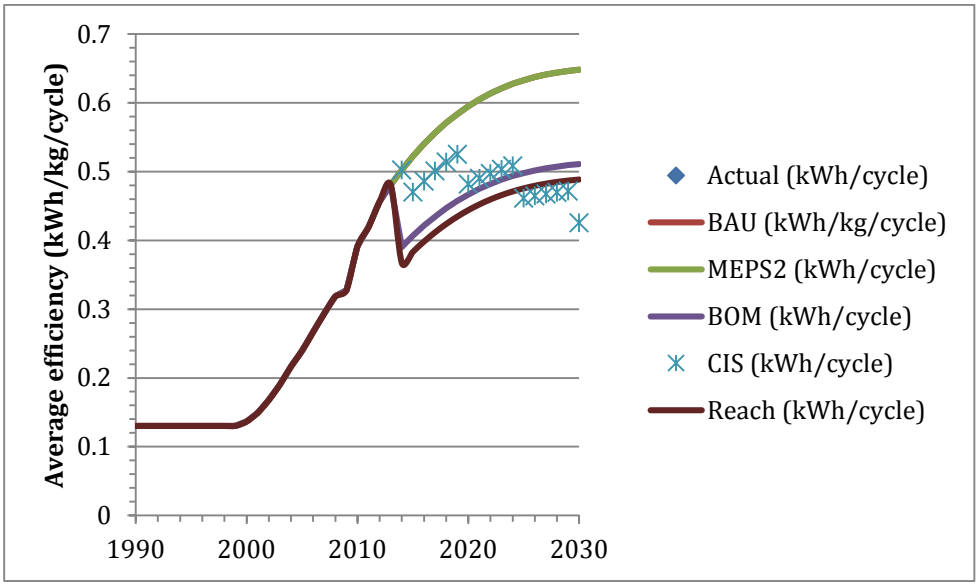


Figure 22: Average 'efficiency' (kWh/kg/cycle) of new washing machines by scenario

Note – this metric is not strictly an efficiency one. All other things being equal, an improvement in efficiency should lower the kWh/kg/cycle figure.
Using these input variables and the MACEEP-ESP model, the following consumption is estimated.

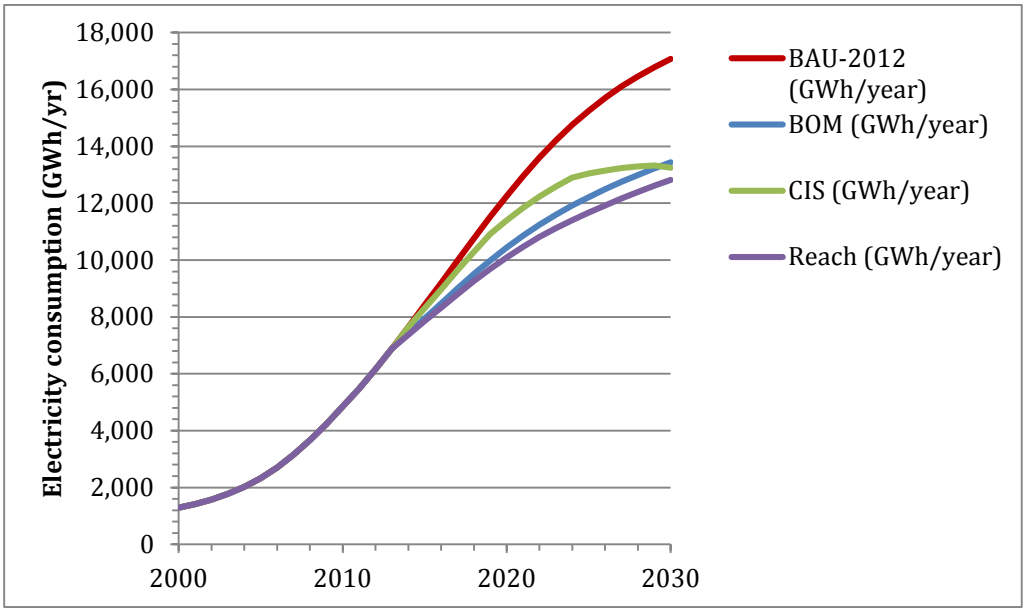


Figure 23: National energy consumption by washing machines by scenario (GWh/year)

It is the difference between the scenarios that is important, as these describe the energy savings, and their estimates are more reliable than the absolute consumption levels

6.4 Rice cooker

Using the cooking efficiency in the two studies, the following input series are used for the re-running analysis.

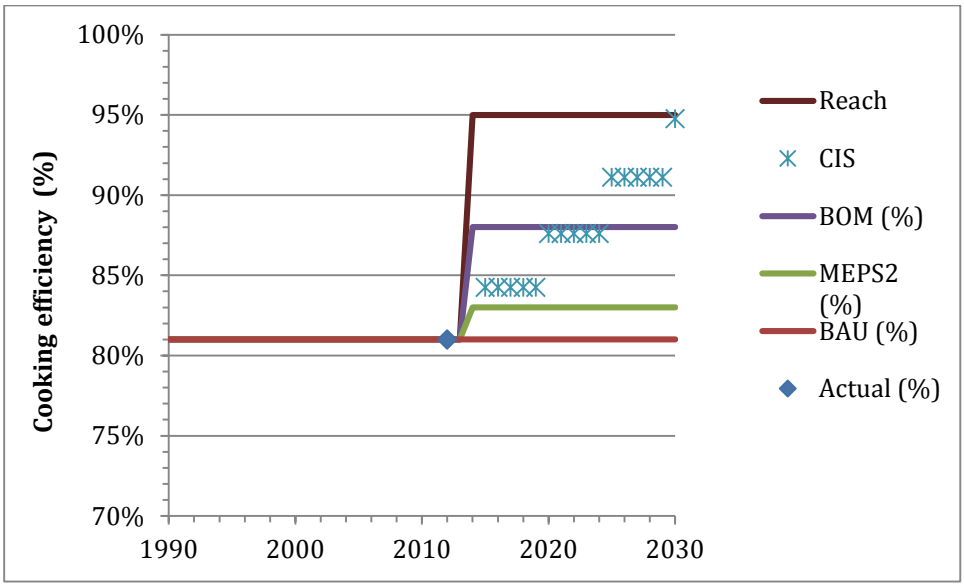


Figure 24: Average cooking efficiency (%) of new rice cookers by scenario

Using these input variables and the MACEEP-ESP model, the following consumption is estimated.

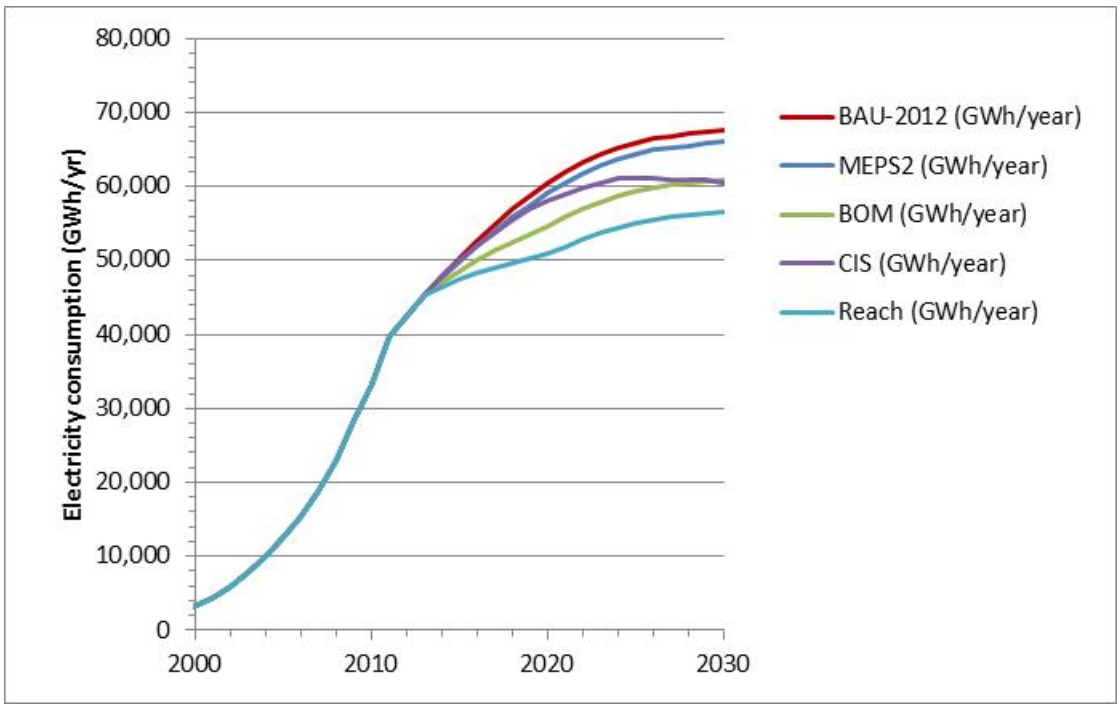


Figure 25: National energy consumption by rice cookers by scenario

It is the difference between the scenarios that is important, as these describe the energy savings, and their estimates are more reliable than the absolute consumption levels.

6.5 Electric storage water heater

Using the new electrical storage water heater model developed for this comparison project, a set of consistent input variables has been generated which relate to the efficiency factor. The Reach scenario is substantially more efficient than the current average efficiency due to the new heat pump technology.

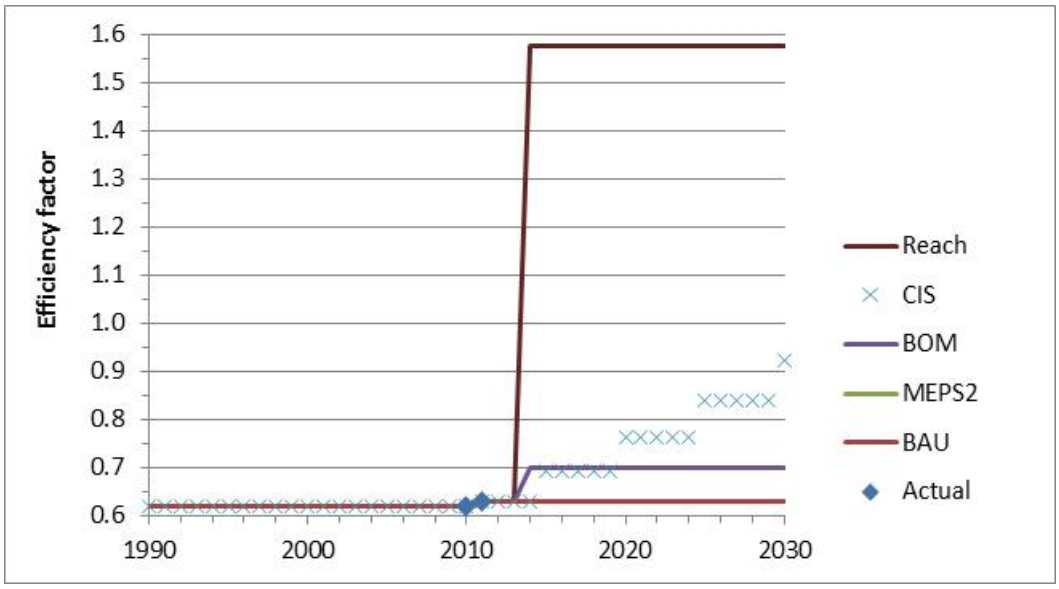


Figure 26: Average efficiency (efficiency factor) of new electric storage water heaters by scenario

Note: this is to reflect efficiency improvement to match the Reach scenario (relative 250%).

The MACEEP-ESP electric water heater model produces outputs which are similar to the CNIS White Paper (2012) results, which are about half the consumption reported in the LBNL study. From the available data, the difference between the two is believed to be due to inferred hot water usage.

Using these input variables and the MACEEP-ESP model, the following consumption is estimated.

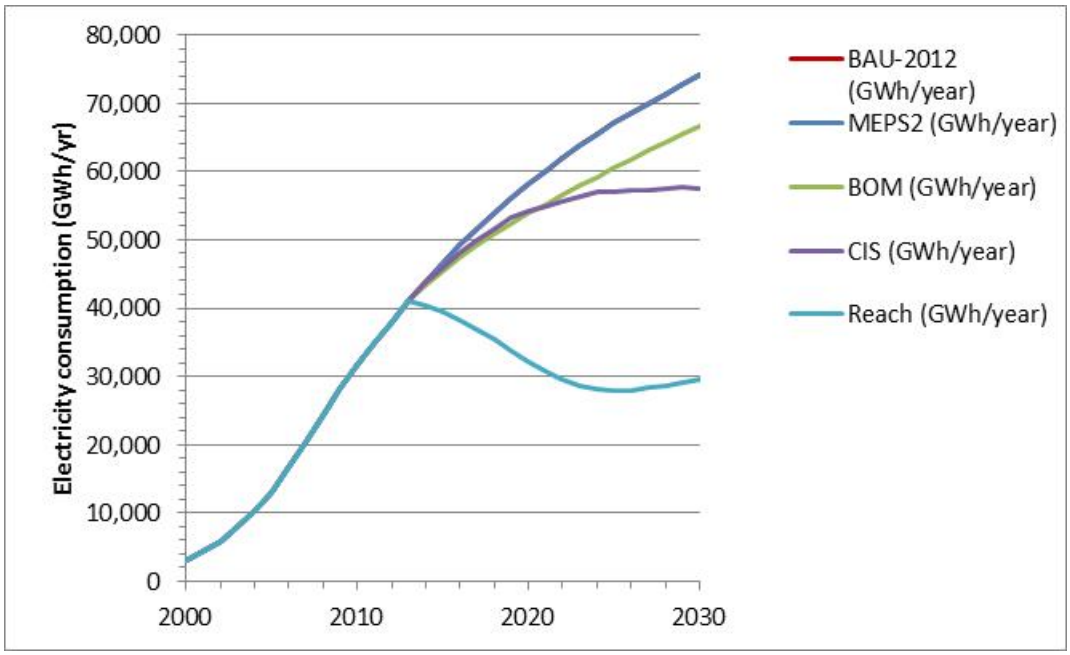


Figure 27: National electricity consumption of electric storage water heaters by scenario

It is the difference between the scenarios that is important, as these describe the energy savings, and their estimates are more reliable than the absolute consumption levels.

6.6 Gas instantaneous water heater

We have assumed that CIS is 6% higher than the MACEEP-ESP BAU, and that Reach is equivalent to the BOM at 96%.

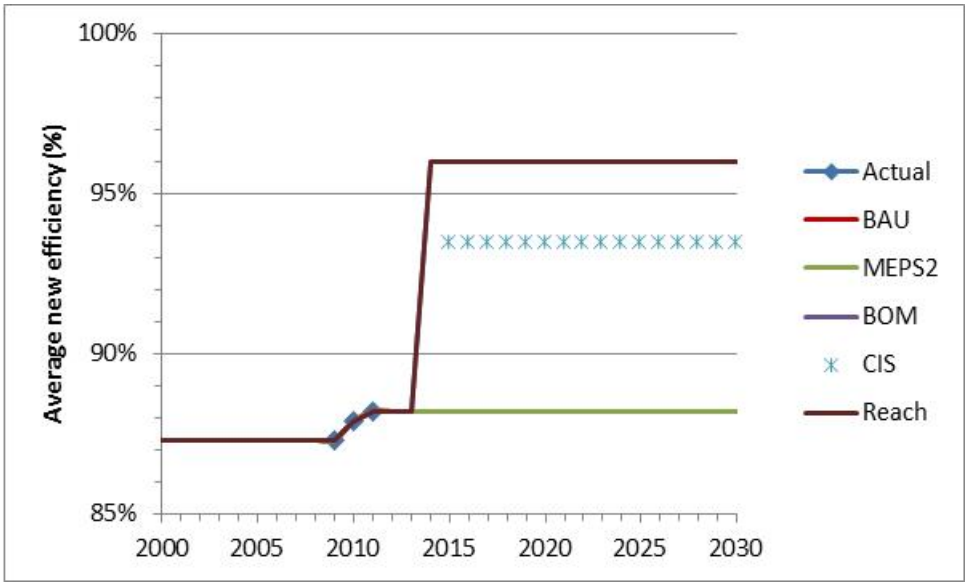


Figure 28: Average efficiency (%) of new gas instantaneous water heaters by scenario

Using these input variables and the MACEEP-ESP model, the following consumption is estimated.

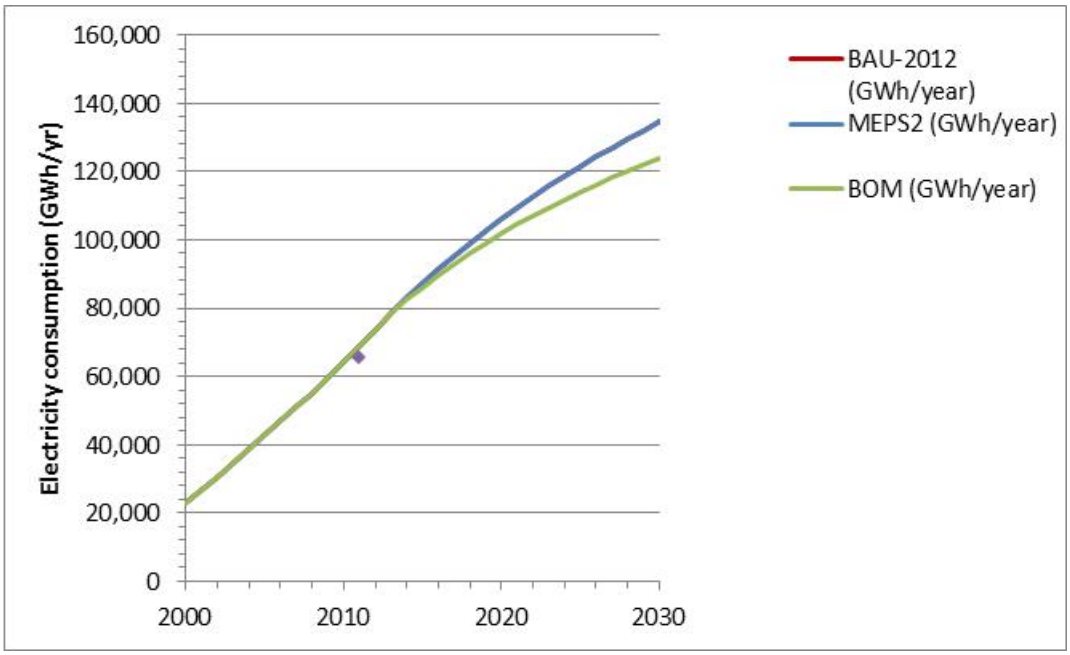


Figure 29: National consumption of gas instantaneous water heaters by scenario (GWh/year)

6.7 Comparison of LBNL CIS/Reach and new CIS/Reach scenario

This section describes the differences between the new MACEEP-ESP CIS/Reach scenarios and the ones developed by LBNL. The differences are explained by different assumption of sales, lifespan, and use. The efficiency should not be a major factor in the difference, as they are trying to show the same effect.

The main differences between the two sets of projections, which mostly explain the differences in the estimated national energy savings, are:

- ESWH is smaller than LBNL savings due to the much lower use in the MACEEP-ESP scenario. Also, LBNL assumed increasing use to 2030. Getting better information on typical usage of water heaters should be a priority.
- AC-fixed in MACEEP-ESP uses 2 hours/day as the average use, the implied figure in LBNL study is noticeably lower (around 30% or more, lower). Again, better data on use patterns could refine the estimate of such models.
- Refrigerators savings are lower using the MACEEP-ESP model as the reference BAU is much lower in 2012 than the LBNL study. It should be easy to confirm which better reflects consumer purchasing patterns.

7 Summary and product prioritization (Task 4)

Two separate CLASP-funded studies have examined the further potential for energy savings from improving the efficiency of products: the LBNL study and the MACEEP-ESP study. The MACEEP-ESP study was summarized in Section 2. The LBNL study was summarized in Section 3. Since water heaters were in the LBNL study, additional ESP models for water waters were presented in Section 4. The two studies were compared in detail in Section 5. Section 6 is a reconciliation of the estimates, using the ESP approach for all other variables, and comparing results from using ESP or LBNL efficiency inputs.

In this section, we present some interpretation of the combined results:

7.1 The LBNL study

Figure 30 presents the estimated energy savings from the Continuous Improvement (CIS) and Reach scenarios in the LBNL study.

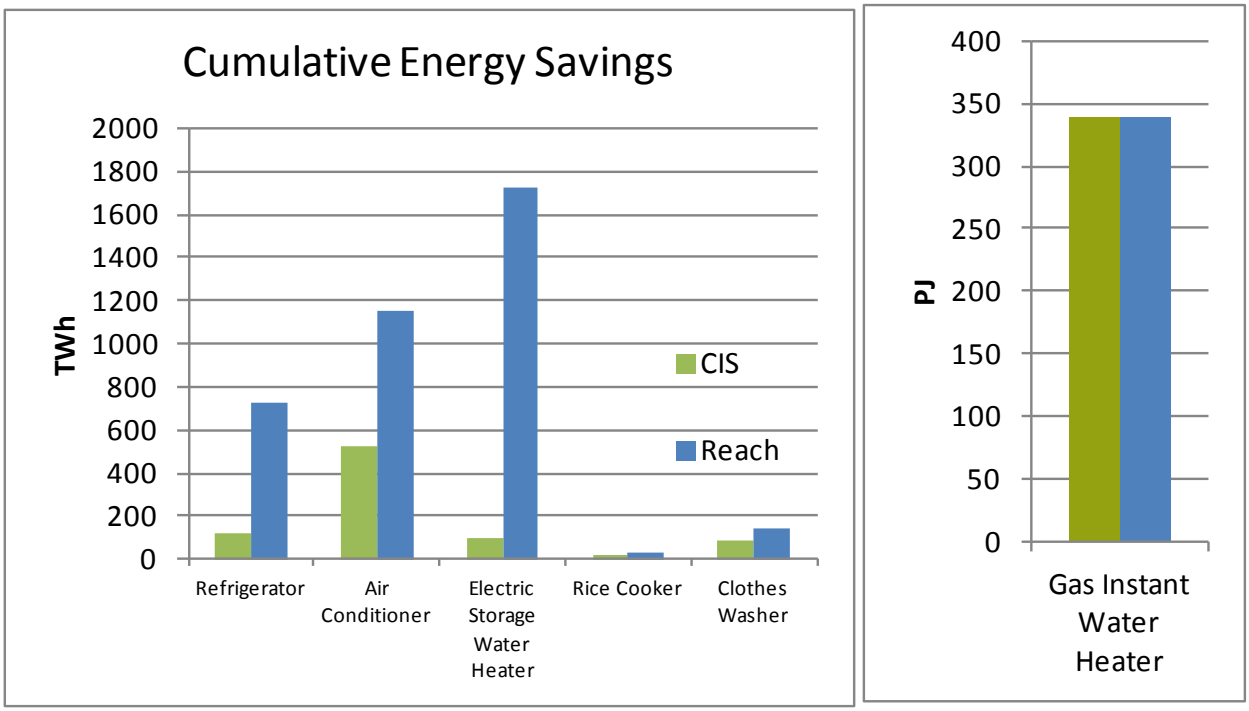


Figure 30: Cumulative energy savings to 2030, LBNL study

From the LBNL study, electric storage water heaters (ESWH) show the greatest potential in the long term; current policies do not realise these significant savings.

- Long-term potential is also identified for air conditioners and refrigerators;
- Near-term, greatest potential is identified for air conditioners.

7.2 MACEEP-ESP study

The MACEEP-ESP study identified the following savings (Figure 31) from scenarios for MEPS and best on market (BOM). (No MEPS scenarios were studied for AC-VSD or washing machines.

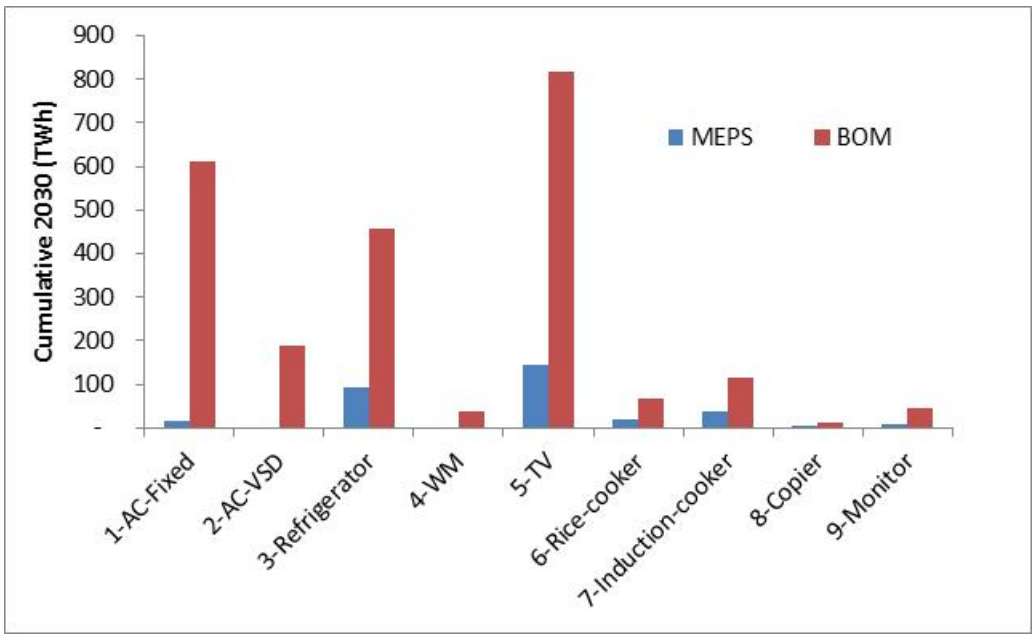


Figure 31: Cumulative energy savings to 2030, MACEEP-ESP study

Findings from the MACEEP-ESP study include:

- Near term policies could achieve largest savings for televisions and refrigerators, with smaller savings for induction cookers, rice cookers, and fixed speed air conditioners.
- Long term policies have greatest potential for televisions and fixed-speed air conditioners, with smaller savings for variable-speed air conditioners, refrigerators, induction cookers, and other products.
- Water heaters were not analysed.

Additional observations:

- Energy savings for televisions are harder to realise and disentangle from multi-national policy and drivers
- Best practice AC-VSD could achieve significant energy savings, though policies need to be careful to only promote, and not ban, lower efficiency ones (which will be better than AC-fixed)

7.3 Lessons from combining MACEEP-ESP and LBNL

The two studies were very similar in approach, with the main differences revolving around different products and different scenarios, summarised below.

Table 27: 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-GWH	X		X	X	X	X

Note the electric and gas water heaters were later ESP analyses, and not part of the original MACEEP study.

The main differences are summarised in Table 19 in Section 5 above.

7.4 Re-running on the same basis

The results for the overlapping products in the different studies are not directly comparable for several reasons:

- The underlying models have different assumptions;
- The baselines (BAU) are not exactly identical;
- The scenarios are showing different saving potential.

It is possible to remove the first two differences by running the same model for all the products. Furthermore, it is possible to run the all the scenarios on the same data set. This has been done using the ESP models and a consistent set of data for all scenarios, which is summarised in Section 6 above. Figure 32 presents the results.

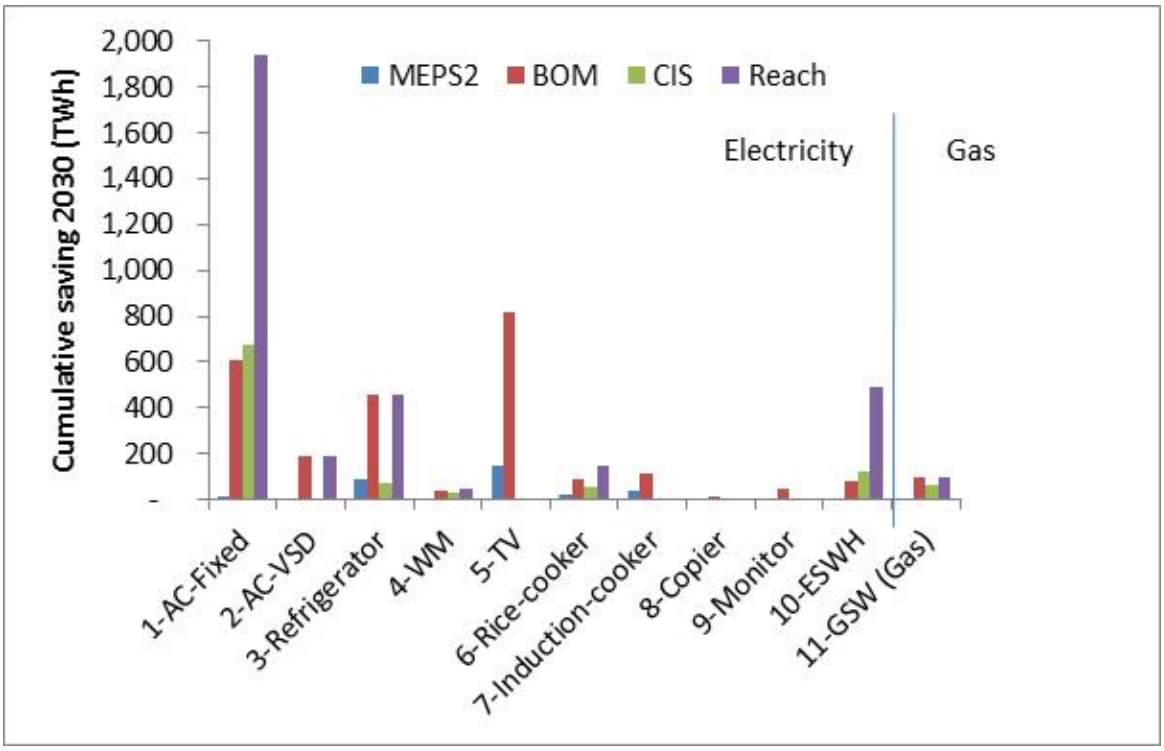


Figure 32: Cumulative energy savings to 2030, combined results from LBNL and MACEEP-ESP

Note – gas consumption by gas water heaters are also shown on the same scale, both are delivered or final energy consumption figure.

The three products with greatest potential energy savings that were identified in the LBNL and MACEEP-ESP studies are evident in Figure 32and in Table 31.

Table 28: Cumulative energy savings to 2030

	MEPS2	BOM	CIS	Reach	2011 Power Consumption
1-AC-Fixed	18	610	673	1,933	249.1
2-AC-VSD	-	189	-	189	38.0
3-Refrigerator	92	458	72	458	78.1
4-WM	-	37	27	44	13.0
5-TV	147	816	-	-	176 (Kevin Lane)
6-Rice-cooker	21	89	58	148	47.7
7-Induction-cooker	40	117	-	-	71.1
8-Copier	6	11	-	-	3.71
9-Monitor	9	45	-	-	5.2
10-ESWH	-	82	120	490	34.9
SUM	332	2,454	949	3,262	716.7

Note these are now done on the same basis. AC-fixed is much larger than LBNL would imply. For ESWH the LBNL model would show higher.

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 shown in the table below. This shows that the relative impact of gas savings is less than when comparing on a delivered energy (GWh) basis.

Table 29: Cumulative carbon reductions to 2030

	MEPS2	BOM	CIS	Reach
1-AC-Fixed	18	611	675	1,937
2-AC-VSD	-	190	-	190
3-Refrigerator	92	459	72	459
4-WM	-	37	27	44
5-TV	147	818	-	-
6-Rice-cooker	21	90	58	148
7-Induction-cooker	40	117	-	-
8-Copier	6	11	-	-
9-Monitor	9	45	-	-
10-ESWH	-	82	120	491
11-GSW (Gas)	-	18	11	18
SUM	**333**	**2,477**	**963**	**3,286**

7.5 Concluding discussion on prioritisation

The three largest potential savers theoretically (shown in the BOM and Reach scenarios) are:

- Air conditioners using variable speed technology
- Televisions
- Electric storage water heaters (ESWH) using heat pump technology

However, realising much of these savings is challenging in the near term, and realising the BOM or Reach target values for ESWH (especially) and the uptake of AC-VSD will take longer. Improvements in TV's efficiency are not being driven strongly by policy, there are other reasons why televisions are increasing in efficiency and they may continue to do so independent of policy effort. Nonetheless, MEPS serve a useful unique function to ensure that less efficient designs are no longer manufactured.

Simply 'ratcheting-up' the levels by a fixed amount every few years is not the most efficient way of delivering the technology (for these three products). For these technology switches other policy support measures should be considered. At a minimum, it is recommended that energy labels are made neutral, so that comparisons on the same basis for fixed and variable speed air conditioners or, as another example, for electric resistance and heat pump water heaters.

From the ESP analysis, copiers and monitors do not provide much short term savings – relatively speaking. Though if the changes to regulations are easy (from a policy-makers point of view) then they could still be considered.

Note the above prioritisation is based on the size of energy savings and carbon emission reductions, and the likeliness of them being realised. However, other aspects may also be taken into account by policy makers choosing to prioritise products and policy measures, which include:

- Impact on load (not just total energy consumption). In this instance air conditioners become more important for China.
- Ease of supply side to meet the challenge of improved performance levels.
- Secondary benefits, which support other policy targets.
- Cost to government or consumers for the raised performance levels. This can be up-front costs or life-cycle costs.
- Time and effort of regulators.

In addition, to suggestions for ratcheting-up product policy measures, there is also the need for improved evidence. This is especially the case for understanding the use of appliances, where the greatest emphasis should be placed on water heaters.

8 References

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Appendix A: Scope of task

Background:
In 2012, CLASP China Program and Top10 China jointly implemented a project named Market Analysis of China Energy Efficient Products (MACEEP). The project used market data to analyze the status of energy efficiency of major appliances in Chinese market, and the energy saving potential of different policy interventions. Based on MACEEP data, Kevin Lane conducted an energy savings potential analysis (refer as MACEEP ESP thereafter) for eight products: AC (fixed speed and VSD), panel TV, refrigerator, electric rice cooker, induction cooker, PC monitor, washer, and copier.

In 2012, the Lawrence Berkeley National Laboratory (LBNL), with support from CLASP, initiated a study(refer as LBNL study thereafter) of the energy savings and greenhouse gas reduction potential for six energy intensive appliances: air conditioners, clothes washers, electric storage water heaters, refrigerators, rice cookers, and gas instantaneous water heaters. This study used the BUENAS model developed by LBNL and CLASP as analysis tool.

Based on the findings of both studies, on May 2nd, 2013, CLASP organized a policy workshop at CNIS and presented both studies to the Chinese policy researchers. The findings were highly acknowledged by the audience. In general, the CNIS audience regarded both studies useful as each of them provided a different perspective on energy saving potential under different assumptions and scenarios. Nevertheless, some CNIS audiences raised questions and concerns on the connections between both studies and how to present both to the policy makers who may feel confused about which one is better to use. To avoid the confusion and maximize the impact of both studies, the China Program and Global Research team initiated this study in a hope of, through the support of Kevin Lane, we can summarize the findings of both studies, and provide an integrated overview and policy recommendations on product prioritization and energy saving potential to Chinese policy makers.

Scope of Work:
1. Compare MACEEP ESP and LBNL ESP projections. Explain the differences between the two approaches and examine in detail the available underlying data for the 4 overlapping products.
2. Re-run the ESP model with scenarios to match LBNL.
3. Develop ESP model and scenarios for other products(electric storage water heaters and gas instantaneous water heaters)
4. Write a report to explain both sets of scenarios, summarize product prioritization and energy savings potential based on both studies.