This Mapping Document is one of a number which present the recent and historical energy performance of gas and electric storage, instantaneous and heat pump water heaters for a number of individual countries. The performance of products at the national level will subsequently be compared against products from other countries in a Benchmarking Document.

These comparisons of product performance made in this Mapping Document are based on both a delivered energy and on primary energy basis. The generic methodology used for product comparisons is detailed in “Water Heaters - Overall Approach to the Analysis - IEA 4E” and the methodology used for delivered to primary energy conversions is detailed in “Water Heater Energy and Fuel Conversion Factors”. All documents related to water heaters developed under the 4E Mapping and Benchmarking activities can be found at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=18.
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed nor robust for use in setting specific performance requirements. Details of information sources and assumption, simplification and transformations are contained within the document.

**Key notes on Graph (see notes section 1)**

- The performance standard for gas instantaneous water heaters is a minimum requirement for thermal efficiency. A draw off demand of 2 kWh/day is assumed in order to present this as a maximum daily Total Unit Energy Consumption.
- There are technically no "volume" limitations on instantaneous water heaters. But to allow presentation of regulations in parallel with the storage water units, a nominal volume of up to 20 litres has been allocated to instantaneous water heater units.
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**Water Heater Daily Energy Consumption (as declared)**

Comparison of the energy performance of all types of water heaters in 2014 against national regulatory and voluntary performance requirements.  
(Basis: delivered energy as declared under local test conditions.)

Key notes on Graph (see notes section 1)

- The performance standard for gas instantaneous water heaters is a minimum requirement for thermal efficiency. A draw off demand of 2 kWh/day is assumed in order to present this as a maximum daily Total Unit Energy Consumption.
- Similarly, only the thermal efficiency of the gas instantaneous water heaters is listed. The same draw-off demand is therefore assumed in order to present an example Total Unit Energy Consumption for each model.
- Both the regulations and product performance for electric storage water heaters are presented, as they are regulated, as values for standby energy consumption only.
- The scales of the x-axes (volume) are different on the two sides of the graph.
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**Water Heater Daily Energy Consumption (equivalent service)**

Comparison of energy performance of all types of water heaters in 2014.  
*(Basis: Delivered energy use with identical local daily draw-off profiles.)*

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**Key notes on Graph (see notes section 1)**

- All models are assumed to draw off 37.4 litres of water per day at a temperature of 60°C with ambient conditions at 20°C.
- The scales of the x-axes (volume) are different on the two sides of the graph.
**Water Heater Daily Consumption**
(equivalent service – primary energy)

Comparison of energy performance of all types of water heaters in 2014.
*(Basis: Primary energy use with identical local daily draw-off profiles.)*

- All models are assumed to draw off 37.4 litres of water per day at a temperature of 60°C with ambient conditions at 20°C.
- Primary energy is estimated using total losses (as listed in the 2012 IEA World Energy Balance data) of: gas: 2.0%, electricity: 60.1%.
- The scales of the x-axes (volume) are different on the two sides of the graph.

*Key notes on Graph (see notes section 1)*
- China Electric Storage 2014
- China Gas Instantaneous 2014

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**Water Heater Daily Energy Consumption over time**

As data was only available for one year, no time series analysis is presented.
Major Policy Interventions (See notes Section 3)

Chinese energy efficiency regulation of water heaters, referred to as the Energy Efficiency Standard or EES, began in 2006 (effective July 2007) with the introduction of mandatory minimum performance and labelling requirements for instantaneous water heaters and combi-boilers. This was followed in 2008 with the introduction of mandatory efficiency requirements and comparative labelling for electric storage water heaters, with MEPS for these products raised in 2010. May 2015 saw proposals to revise the test method, performance requirement and labelling of gas instantaneous units with requirements becoming effective 1 June 2016.

In addition to the MEPS and labelling requirements, in 2012 the Chinese government implemented the largest subsidy program in Chinese history, investing over US$ 4.2 billion in promoting energy efficient appliances. Electrical storage water heaters were the only type of water heater not covered by this subsidy, while gas instantaneous, solar and heat pump water heaters all received significant levels of support. This resulted in the stalling in growth of sales of electrical water heaters, but this growth appears to have returned following the ending of the subsidy programme.
Cultural Issues (See Notes Section 4)

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

Due to higher income and generally living standards, water heaters are more commonplace in urban China. The urban ownership of water heaters has been increasing steadily for the past decades from 13.0 units/100 households in 1992, to 91.0 units/100 households in 2012 (Figure 1). Ownership of water heaters in rural areas is much lower at 20 units/100 households in 2011 (89 units/100 households in urban areas in the same year). However, as urbanization accelerates and personal income increases, the total ownership of water heaters in China, especially in rural areas, is very likely to increase in the near future.

There are four major types of water heaters for domestic use in China (more details of each are included in the Notes Section 4):

- Electrical storage water heaters;
- Gas instantaneous water heaters;
- Solar water heaters;
- Heat pump water heaters. Electrical storage water heaters and gas instantaneous water heaters are the most popular water heaters on the Chinese market and together account for approximately 2/3 of all water heaters installed in China. Gas water heaters have higher levels of ownership, but in recent years, lower annual sales than electrical water heaters.
Key notes on data, analysis and additional information

1 Regulatory Requirements

The majority of regulatory information on China water heaters is summarised from the CLASP “Market Analysis of China Energy Efficient Products (MACEEP)” report\(^1\), with additional support directly from CLASP\(^2\). Readers are recommended to review the MACEEP report directly for more comprehensive information, information sources and analysis of product performance.

1.1 Electric Water Heaters

The most recent energy efficiency standard (EES) for electrical storage water heater is GB 21519-2008. This EES was issued in 2008 and became mandatory on 1 November of the same year.

The EES metrics used to define energy efficiency tiers are 24 hour standby energy loss index (\(\varepsilon\)) and hot water output rate (\(\mu\)). Note there is no metric for the actual water heating efficiency as this is direct electrical resistance heating and in China is assumed to be 100% efficient in all cases.

1.1.1 Summary of Required Test

The test method for electrical storage water heaters is included in the 2008 EES. The two primary parameters are measured by the test:

24 hour standby energy loss

The water heater is fully filled and the water heated until it reaches a steady-state with an average temperature (\(\theta_m\)) of 65±3°C in an ambient environment of (20°C). Once the water heater reaches the steady-state, the measurement of standby energy loss can begin and lasts for a minimum of 48 hours.

A kilowatt meter is used to measure the total standby energy loss (\(E_I\)) during the test period with adjustments then made to account for variations in ambient temperature during the test, and to normalize the losses to a 24 hour period.

Hot water output rate

The hot water output rate test simulates the use of water heaters under real condition, where hot water is being used continuously while cold water is entering the storage tank. Water inlet flow rates must satisfy the requirements shown in Table 1.

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\(^2\) In particular the authors would like to thank Yu Yang of CLASP.
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### China

**Domestic Water Heaters**

#### Table 1: Energy efficiency Tier requirements for electrical storage water heaters (2008 EES)

<table>
<thead>
<tr>
<th>Rated Volume (liters)</th>
<th>Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_R&lt;10L</td>
<td>2L/min</td>
</tr>
<tr>
<td>10L≤C_R≤70L</td>
<td>5L/min</td>
</tr>
<tr>
<td>70L&lt;C_R≤200L</td>
<td>10L/min</td>
</tr>
<tr>
<td>200L&lt;C_R</td>
<td>C_R⋅5%/min</td>
</tr>
</tbody>
</table>

Initially, the water heater is filled by cold water to half its rated volume thus activating the thermostat to initiate water heating (if the thermostat does not turn on when the water heater is filled to half of its rated volume, cold water (at 15°C) is added to the point where the thermostat is activated and water heating begins). As soon as the initial temperature (A_1) reaches the required 65±3°C, and the thermostat turns off for the first time, the hot water output rate test starts immediately. The procedures are as follows:

Hot water is continuously drained from the water heater while cold water is filled at the specified flow rate. Inlet temperature (q_ci) and outlet temperature (q_pi) are recorded in 5s intervals 15s after the test starts. The maximum outlet temperature (q_MAX) is recorded. Hot water is continuously drained until the outlet temperature drops to (q_MAX - 20)°C. The total mass of the hot water drained during the test m_p is measured. The hot water output rate is then calculated (refer to section 1.2.2 for calculation method).

#### 1.1.2 Mandatory and Voluntary Performance Requirements

**24 hour standby energy loss index (ε)**

The 24 hour standby energy loss index measures how much energy is lost in 24 hours while maintaining the temperature of hot water once the water heater reaches steady state. The 24 hour standby energy loss index is defined by the following equation:

\[
\varepsilon = \frac{Q_{pr}}{Q}
\]

Where:

- \(\varepsilon\) = 24 hour standby energy loss index;
- \(Q_{pr}\) = 24 hour standby energy loss after the fully filled water heater reaches steady state, without water being drawn (kWh);
- \(Q\) = Baseline 24 hour standby energy loss, which is calculated from Table 2 (kWh).

#### Table 2: Baseline 24 hour standby energy loss of electrical storage water heaters

<table>
<thead>
<tr>
<th>Rated volume (C_R) in L</th>
<th>Baseline 24 hour standby energy loss (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0&lt;C_R≤30</td>
<td>Q=0.024 C+0.6</td>
</tr>
<tr>
<td>30&lt;C_R≤100</td>
<td>Q=0.015 C+0.8</td>
</tr>
<tr>
<td>100&lt;C_R≤200</td>
<td>Q=0.008 C+1.5</td>
</tr>
<tr>
<td>C_R&gt;200</td>
<td>Q=0.006 C+2.0</td>
</tr>
</tbody>
</table>

Where C_R is the rated volume and C is the measured volume.
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**Hot water output rate (μ)**

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

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

Where:
- \(\mu\) = Hot-water output rate; (%);
- \(\theta_p\) = Average output water temperature; (°C);
- \(\theta_c\) = Average input water temperature; (°C);
- \(\rho\) = Density of water at the temperature of \(\theta_p\); (kg/cm\(^3\));
- \(m_p\) = Hot water output mass; (kg);
- \(\theta_{A1}\) = Initial temperature when the power is first cut-off in the hot-water output rate test; (°C);
- \(C_R\) = rated volume of the water heater. (L).

**Energy Efficiency Tiers and Minimum Energy Performance Requirements**

Table 3 shows the five energy efficiency tiers (EET) set in the 2008 EES, with Tier 1 being the most efficient. A water heater must satisfy both parameters (ε and μ) in order to qualify for a specific tier. Water heaters with Tier 1 or Tier 2 efficiencies are deemed to be energy efficient products according to the EES.

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

<table>
<thead>
<tr>
<th>Energy Efficiency Tier</th>
<th>24 hour standby energy loss index (ε)</th>
<th>Hot-water output rate (μ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>≤0.6</td>
<td>≥70%</td>
</tr>
<tr>
<td>2</td>
<td>≤0.7</td>
<td>≥60%</td>
</tr>
<tr>
<td>3</td>
<td>≤0.8</td>
<td>≥55%</td>
</tr>
<tr>
<td>4 (MEPS -2010)</td>
<td>≤0.9</td>
<td>≥55%</td>
</tr>
<tr>
<td>5 / MEPS – 2008</td>
<td>≤1.0</td>
<td>≥50%</td>
</tr>
</tbody>
</table>
1.1.3 Mandatory and Voluntary Labelling Requirements

The application of the China Energy Label to electrical storage water heaters became mandatory on 1 March, 2009. Figure 2 illustrates the energy label.

Figure 2: China energy label for electrical storage water heaters (current)

The label has five coloured bars indicating the specific energy efficiency Tier of the water heater, each aligning with the original EETs defined in the EES (noting that only the top four Tiers are currently in use as Tier 5 products fall below the current Tier 4 MEPS level).

The specific registered Tier for an individual model is highlighted on the label. In addition to indicating the EETs, the label also includes basic identification information of the model number, manufacturer, the 24 hour standby energy loss index and hot water output rate.

1.2 Gas Instantaneous Water Heaters

The most recent energy efficiency standard (EES) for gas water heaters is GB 20665-2015 (enforceable in 2016). However, all the data available for analysis has performance declarations made against the preceding GB 20665-2006. Consequently, all analysis undertaken in the report relates to product performance declarations and comparisons based on the energy efficiency requirements of GB 20665-2006, NOT the 2015 revision. However, additional information is provided on the 2015 standard where relevant.

1.2.1 Summary of Required Test

The 2006 EES cites GB 6932-2001: Domestic Gas Instantaneous Water Heater as the test method to be used in evaluating the performance of both conventional and condensing instantaneous gas water heaters. The primary metric measured (and the only one regulated) is Thermal Efficiency.

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2006 EES: Thermal Efficiency

The testing conditions specified by GB20665-2006 and GB 6932-2001 are:

- Ambient temperature should be set to 20°C±5°C;
- Inlet cold water temperature should be set to 20°C±2°C;
- For tests using the rated heat input, the water temperature increase should be 40°C±1°C; and for tests using 50% of the rate heat input, the water temperature increase should be 30°C±1°C;

During the test the instantaneous water heater is initially operated for 15 minutes to allow the hot water output temperature to reach a steady state. The energy consumption test is then conducted by measuring the total amount of hot water output during a period over which the gas flow meter finishes one or more complete cycles.

2015 EES

The revised 2015 EES uses a different test methods for conventional water heaters and condensing water heaters. However, the revised test methods are very similar to the preceding method with only very slight modifications (refer to the CLASP report for further details).

1.2.2 Mandatory and Voluntary Performance Requirements

In 2006 EES, thermal efficiency (η) is used to define the energy efficiency tiers (EETs). The thermal efficiency is essentially the ratio of the energy absorbed by the water relative to the amount of energy released by burning the natural gas in the heating process.

Table 3 shows the classification of EETs and required thermal efficiencies for the types of product covered by the scope of the standard. The thermal efficiency is measured firstly using the rated heat capacity, and again using 50% of the rated heat capacity. In order for a product to qualify for one particular efficiency Tier, the product has to satisfy both requirements under that Tier (noting there is no efficiency requirement for 50% capacity tests for Tier 3 products). It is worth noting that while the EES is technology-neutral, it is almost impossible for a non-condensing boiler of any type to achieve Tier 1 performance.

The EES also specifies a minimum energy performance requirement that aligns with the lower threshold value of Tier 3.

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4 Rated heat input refers to the rated maximum heating capacity of the unit in kWh.
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Table 4: Energy efficiency Tier requirements for gas instantaneous water heaters (2006 EES)

<table>
<thead>
<tr>
<th>Heat input</th>
<th>Minimum thermal efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy Efficiency Tiers 1 2 3</td>
</tr>
<tr>
<td>Rated heat input</td>
<td>96 88 84</td>
</tr>
<tr>
<td>≤ 50% rated heat input</td>
<td>94 84 -</td>
</tr>
</tbody>
</table>

The boundary levels under the 2015 EES are more stringent for every Tier in terms of numerical values, but it should be noted the changes to the test methods make actual comparisons between the 2006 and 20145 values in not possible. Further, in the current 2006 EES the products are required to be tested under both rated heat input and 50% (or less) rated heat input, and the respective thermal efficiency obtained must satisfy the requirement for each test in order to qualify for a particular energy efficiency tier. However, in the revised 20145 EES, thermal efficiency must still be tested under the same two heat input conditions specified in the 2006 EES, but the results of the two tests may be used differently. Under the 2015 EES, irrespective of whether tested under rated heat input conditions or 50% of rated heat input, the higher value of the two thermal efficiencies obtained in the tests will be \( \eta_1 \) and the lower value will be \( \eta_2 \). Again the product must satisfy both the \( \eta_1 \) and \( \eta_2 \) requirements to qualify for a particular Tier.

Table 5: Energy efficiency tier requirements for gas instantaneous water heaters (revised 2015)

<table>
<thead>
<tr>
<th>Minimum thermal efficiency (%)</th>
<th>Energy Efficiency Tiers 1 2 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \eta_1 )</td>
<td>98 89 86</td>
</tr>
<tr>
<td>( \eta_2 )</td>
<td>94 85 82</td>
</tr>
</tbody>
</table>

1.2.3 Mandatory and Voluntary Labelling Requirements

The labeling of gas instantaneous water heaters became mandatory on 1 June 2008 as part of the China Energy Labelling program. The labels for gas water heater are categorical labels with three tiers aligning with the EETs defined in the EES (and differing from the electric label which has 5 Tiers). In addition to the colored bars indicating the specific energy efficiency Tier, the labels also include basic identification information of the model number, manufacturer, rated heat input and thermal efficiency for water heating.
2 Data Analysed and Specific Assumptions Made

The overall approach to the analysis undertaken in order to present the results shown in this mapping report is described in “Water Heaters - Overall Approach to the Analysis - IEA 4E”. This report also describes in detail a number of general assumptions that were necessary for the dataset analysed. Details of each of the datasets presented in this mapping report and the specific assumptions made in order to process the data are presented below.

2.1 China MACEEP

2.1.1 Source

The China data was sourced from CLASP and was gathered for analysis for their “Market Analysis of China Energy Efficient Products (MACEEP)” report. The data was sourced in the Chinese market in September 2014 (more details are provided in the MACEEP report).

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Instantaneous</td>
<td>338</td>
</tr>
<tr>
<td>Electric Storage</td>
<td>595</td>
</tr>
</tbody>
</table>

2.1.2 Limitations and specific assumptions made for this dataset

For gas instantaneous models, the only data available for the thermal (recovery) efficiency was the energy efficiency tier. Recovery efficiency for these models is assumed to be at the minimum limit of the tier in which they are listed. This means that the Total Unit Energy Consumption of models with a higher efficiency than the tier limit will be slightly overestimated.

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For **electric storage** waste heaters, data was provided for both volume and the 24hr energy standby loss index ($\varepsilon$) from which a value for standby heat loss rate and, in turn, standby energy consumption in 24 hours is calculated.
3 Notes on Policy

Refer to Notes Section 1

4 Notes on Cultural Issues

Again, all market and cultural information on China water heaters is summarised from the CLASP “Market Analysis of China Energy Efficient Products (MACEEP)” report7. Readers are recommended to review the report directly for more comprehensive information, sources and analysis of product performance.

4.1 Electrical Storage Units

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

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

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

4.2 Gas instantaneous water heaters

There are two types of gas water heater, combination (combi) and instantaneous water heating only units. Typically gas instantaneous water heaters are installed in the kitchen where easier installation of the exhaust duct makes them safer to use.

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

4.3 Solar Water Heaters

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

- The government’s “Appliance to rural areas” program began in 2009. The program provided for household appliance purchase in rural areas. As one of the 9 subsidized products, solar water heaters benefited greatly from a 13% subsidy and rapidly gained significant popularity in rural areas.
- Compared to electrical and gas water heaters, the operational costs for solar water heaters are minimal as they do not use, or use very little, other energy sources such as gas or electricity. In addition, the unavailability of natural gas supply in rural areas contributed to the increase in popularity of solar water heaters in these areas.


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• It was more difficult for urban families who live in apartment buildings to install individual solar water heaters on rooftops.

There are two primary types of solar collectors, evacuated tube and flat plate. Solar water heaters with evacuated tube collectors are the dominant models in the Chinese market with over 95% market share. The number of evacuated tube collectors is often used as a proxy for the hot water capacity with units on the Chinese market typically having 14 to 36 evacuated tube collectors (corresponding to 140L to 360L of hot water storage).

4.4 **Heat Pump Water Heaters**

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