Policy Opportunities for More Efficient Residential Water Heating

Final report

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Contents

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Glossary

BAU	Business as Usual
BEE	Bureau of Energy Efficiency (India)
BIS	Bureau of Indian Standards
CEN	European Committee for Standardization
CES	Clean Energy Standard
CNIS	China National Institute of Standardization
COP	Coefficient of Performance (the measure of heat pump efficiency)
CQC	China Quality Certification Centre
CTP	Coefficient of Thermal Performance
ECBC	Energy Conservation Building Code (India)
EEO	Energy Efficiency Obligation
EF	Energy Factor (USA)
EIWH	Electric Instantaneous Water Heater i.e. tankless
ESCO	Energy Service Company
ESWH	Electric Storage Water Heater
ETC	Evacuated Tube Collector
FI	Financial Institution
FPC	Flat Plate Collector
GCWH	Gas-combi water heater (provides hot water and space heating)
GDP	Gross Domestic Product - Exchange rate method
GDP-PPP	Gross Domestic Product - Purchase Power Parity method
GIWH	Gas Instantaneous Water Heater i.e. tankless
GSWH	Gas Storage Water Heater
HPWH	Heat Pump Water Heater
IREDA	Indian Renewable Energy Development Agency Limited
ITC	investment tax credit
JNSSM	Jawaharlal Nehru National Solar Mission plan (India)
LLCC	Least Life Cycle Cost
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
MC	Municipal Corporation
MEPS	Minimum Energy Performance Standard
MNRE	Ministry of New and Renewable Energy (India)
MoF	Ministry of Finance - India
MVE	Monitoring Verification and Enforcement
NCEF	National Clean Energy Fund (NCEF) - India
NREL	National Renewable Energy Laboratory (USA)
PACE	Property-Assessed Clean Energy
PPA	Power Purchase Agreement
R&D	Research & Development
REC	Renewable Energy Credit
RESCO	Renewable Energy Service Company
RPS	Renewable Portfolio Standard
SECI	Solar Energy Corporation of India
SHC	Solar Heating and Cooling
SME	Small and Medium-sized Enterprise
SNA	State Nodal Agencies (India)
SREC	Solar Renewable Energy Certificate
SV	Storage Volume (EU)

SWH	Solar Water Heater
TSD	Technical Support Document (USA)
UEC	Unit Energy Consumption (kWh/year)
USDOE	US Department of Energy
V40	mixed water at 40 °C (EU water heater capacity metric)
VAT	Value Added Tax

Executive Summary

Water heating accounts for a considerable proportion of domestic energy use in all economies. Yet, the most common technologies used to provide warmed water are far from optimized from an energy performance perspective. This study reports the findings of an investigation into the potential to save energy through the adoption of more efficient water heaters in three major economies, China, India, and the USA. The analysis indicates that the share of residential final energy consumption taken by water heating varies significantly across all these economies. In China water heating is estimated to have accounted for 7.1% of all residential commercial energy consumption in 2015, in India 5.4%, and in the US 18.5%. These variations indicate that there is considerable scope for demand for hot water to increase as per capita GDP and urbanization rises in China and India. That growth can also reflect the influence of technology choices, climate, and cultural factors in the demand for energy to heat hot water.

Energy policy has been relatively successful in promoting relatively high efficiency water heaters using the same fuel type (i.e. electricity or gas).However these policies have been much less successful, with the exception of in China, at stimulating adoption of the most energy efficient technologies across all fuel types. China and the US apply energy labeling and MEPS for different water heater technologies while India has energy labeling for electric storage water heaters. However, none of these economies have yet followed the EU's lead and introduced energy labeling that applies consistently across all water heater technologies, be they gas storage water heaters, gas instantaneous ("tankless") water heaters, electric storage water heaters, heat pump water heaters or solar water heaters. The implementation of labeling and other policy measures that reveal the true energy efficiency performance of all competing water heater technologies presents a major energy savings opportunity. The energy savings advantages of the most energy efficient technologies (currently solar water heaters and heat pump water heaters) need to be apparent to the market in order for consumers to be properly informed regarding their available choices. Current labeling practices where a conventional electric storage water heater with relatively low standby losses might be indicated as being highly efficient risk confusing consumers if they are not able to see how this compares with products using a different technology that offer much better energy performance.

The actual savings attributable to using the most efficient water heater technologies are partly dependent on locally specific factors such as: climate and water usage profiles. However, accepting more efficient technologies also depends on physical constraints affecting the way water heaters site, relative willingness to wait for water to be heated, accepting periods with lower delivered hot water temperatures, and aesthetic preferences. Water heater selection is also strongly affected by consumers' willingness or ability to invest in the initial higher cost technologies that save energy and costs over their functional life. Most siting limitations can be mitigated for new build housing through integrating efficient water heater technology at the outset. However, there can be more constraints when an efficient water heater technology is considered as an option for replacement of an existing technology.

In general the most energy efficient and cost effective solutions over the water heater life span are solar and heat pump water heaters. While these technologies can be used successfully in most circumstances they are not applicable in all locations. Their suitability varies as a function of several factors such as available space to mount collectors or heat pump water heater units, climate, water usage patterns, and required recovery times, etc.

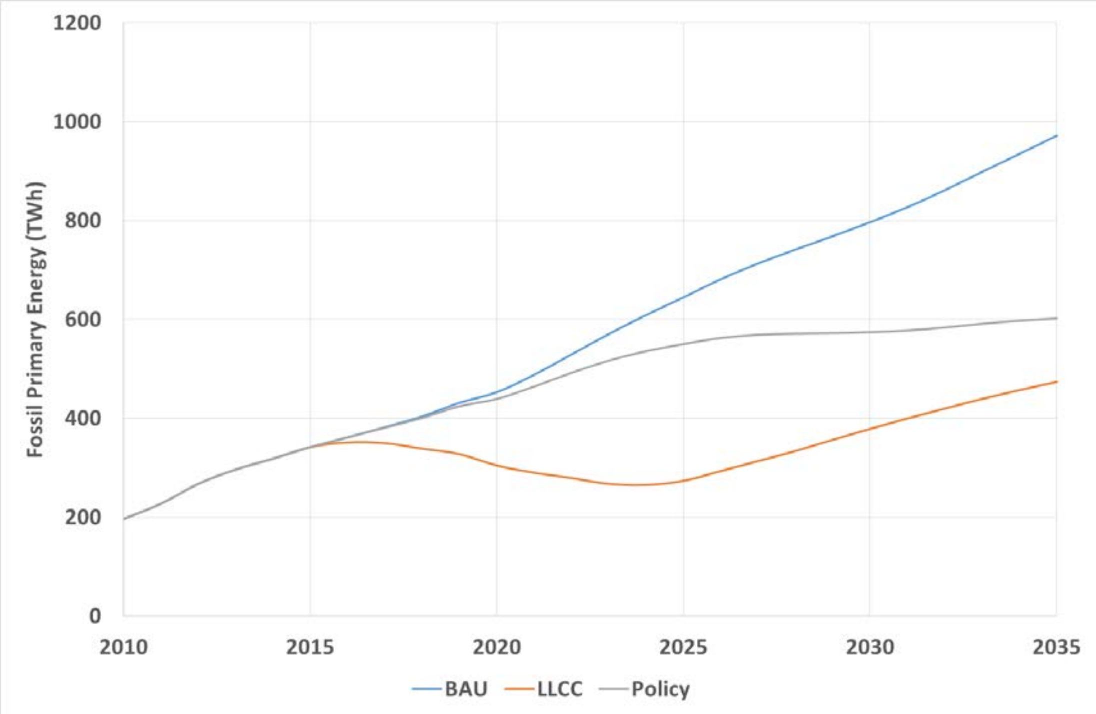
Water heater energy scenarios

This study assessed the likely energy consumption for water heating in the three economies from 2015 to 2035. Three scenarios were considered as follows:

- a Business as Usual (BAU) scenario wherein it is assumed that current policies are maintained
- a LLCC (LLCC) scenario, wherein viable water heater technologies which offer the lowest costs to consumers over their operating lifespan are adopted
- a Recommended Policies scenario, wherein the policy measures recommended in this report are implemented

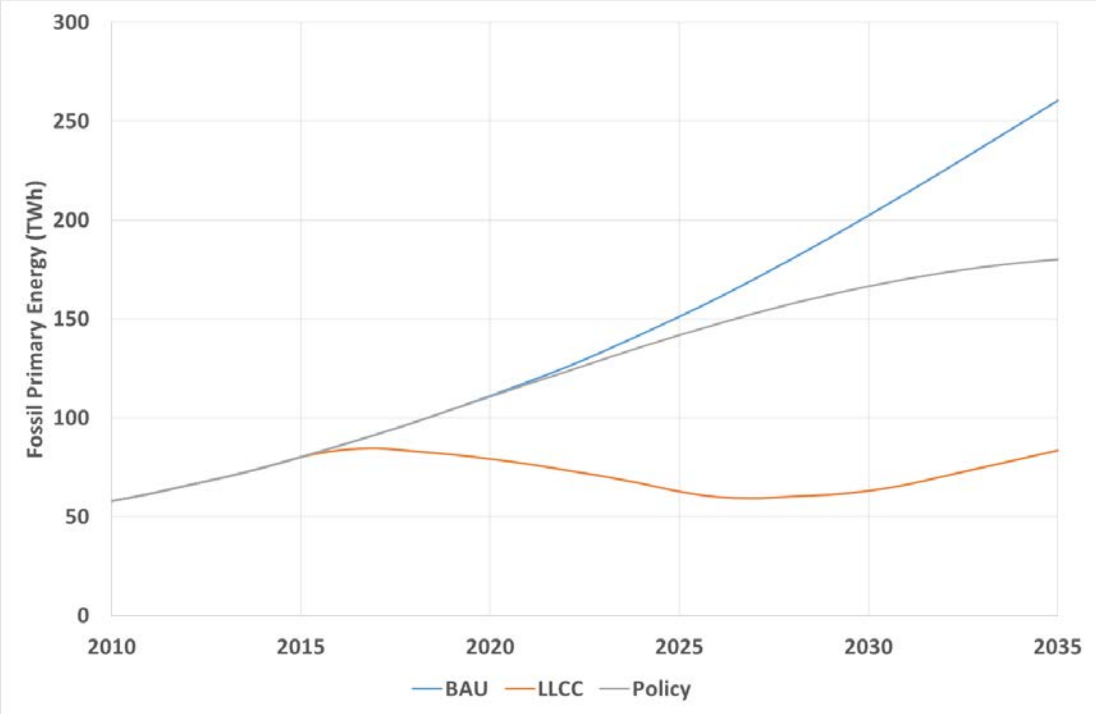
Figure ES1 shows that water heater energy demand is expected to rise by over a factor of 2.8 from 2015 to 2035. The BAU scenario includes the effects of the various energy efficiency policies China has already implemented to encourage high efficiency water heating. By contrast, if energy efficient water heaters were chosen whenever they can be physically deployed, demand would only rise by a factor of 1.4. This is despite the fact that of the three economies considered, China has comfortably the highest proportion of solar water heaters (comprising about 35% of the stock). The extra savings in the LLCC scenario are due to the adoption of an even higher proportion of solar water heaters. It replaces most remaining electric storage water heaters by heat pump water heaters. In the recommended policies scenario, case water heater energy consumption stabilizes at about 65% above the 2015 levels by 2026 and is roughly 38% below BAU levels in 2035.

Figure ES1. Estimated Water Heater Primary Energy Consumption in China for the BAU, Recommended Policy and LLCC Scenarios



The equivalent analysis is shown in Figure ES2 for India. In this case water heater commercial energy consumption is set to rise by a factor of 3.2 from 2015 to 2035 for the BAU Scenario, but only by 1.04 under the LLCC scenario. Adopting the LLCC water heater technologies would save 68% of all water heater energy use in 2035. In reality there are many reasons why the LLCC scenario will not come about but if the policies recommended in this study are vigorously implemented it is estimated that water heater energy use would be 31% less than under the BAU in 2035.

Figure ES2. Estimated Water Heater Primary Energy Consumption in India for the BAU, Recommended Policy and LLCC Scenarios

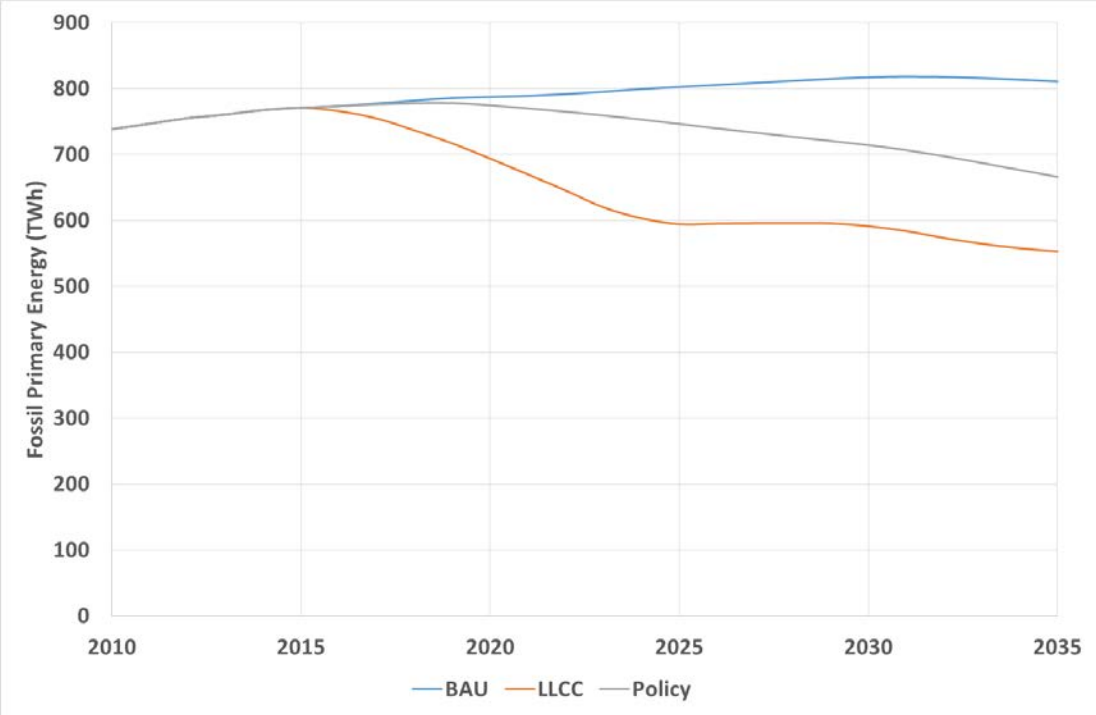


The findings for the US have some similarities but also some differences. Under the BAU scenario, water heater energy demand is expected to peak in 2031 at only slightly higher levels than in 2015. This is due to a relatively saturated demand for hot water and the impact of existing policy measures that tend to offset the ongoing increase in population. The savings under the LLCC scenario reach 32% in 2035. These are less than in the case of India and China but this is not because the US has already adopted more efficient water heater technology. Rather, it reflects that water heater ownership is already fully saturated in the US. Thus the relative importance of replacement sales as opposed to new build is much greater. This reality imposes greater constraints on the suitability of solar and heat pump water heaters. The other important factor is that US citizens will not generally accept solar water heaters without back-up heaters. The installed cost of solar water heaters is much higher than in the other economies, making this technology less competitive with incumbent technologies.

Yet promotion of sales of the higher efficiency technologies is a critical aspect of means of making them more competitive on an initial costs basis with the incumbent water heater technologies. Solar thermal water heaters are reported to have a long term learning rate of -15% which means that for each doubling of the installed stock the price of installed systems is expected to reduce by 15%. For heat pump water heaters a slightly faster rate of decline is expected. A key objective of promotional measures should be accelerating the rate of adoption in the early years so that these technologies develop a stronger market position through increased first cost competitiveness. All the scenarios considered above take the effect of technology learning curves into account. As a result, scenarios that see faster rates of adoption of the high efficiency technologies with respect to the incumbent technologies experience progressively greater cost effectiveness over time.

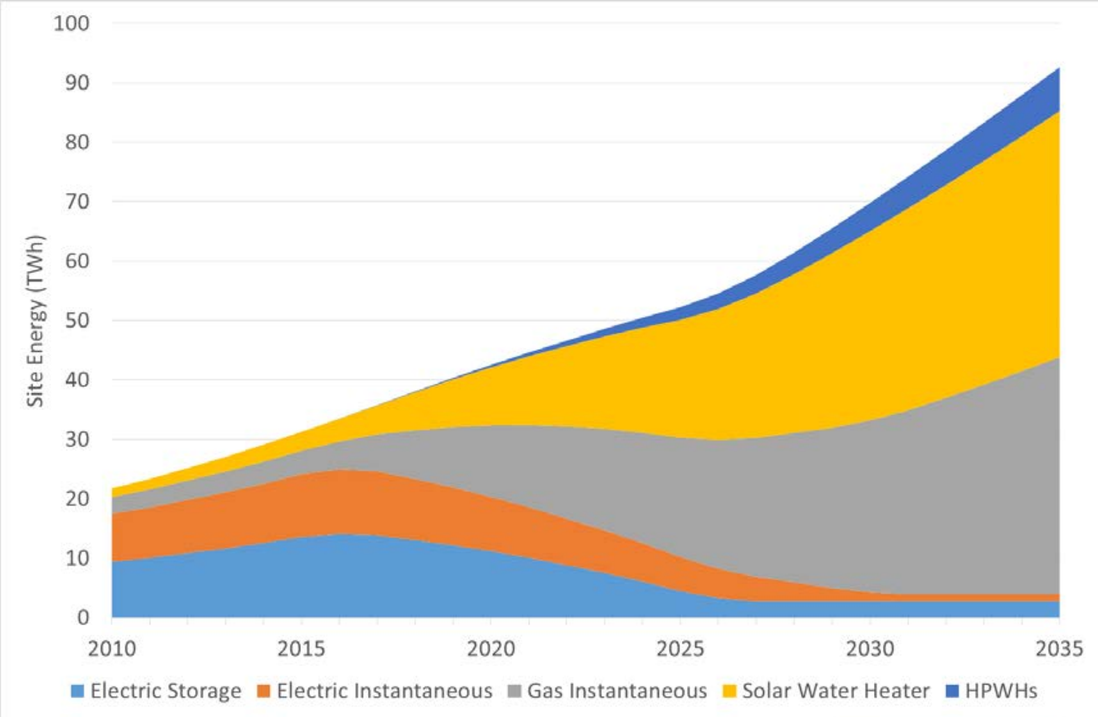
The recommended policies scenario in the US leads to primary energy savings of 18% compared to the BAU scenario by 2035. These savings would be expected to grow considerably beyond this time frame. They would also progressively become more into line with the relative levels of savings reported in China and India.

Figure ES3. Estimated Water Heater Primary Energy Consumption in the US for the BAU, Recommended Policy and LLCC Scenarios



In each of the higher efficiency scenarios considered there is a substantial shift in the installed base of water heaters towards the higher efficiency options. An example is shown in Figure ES4 for water heaters in India under the least life cycle cost scenario. In this case the stock of water heaters migrates from a base wherein electric storage and instantaneous water heaters predominate into one where solar water heaters, gas instantaneous, and heat pump water heaters account for the large majority of hot water supply.

Figure ES4. Estimated Water Heater Final Energy Consumption in India for the LLCC Scenario by Water Heater Technology



In the higher efficiency scenarios, the cost of adopting the higher efficiency technology does not exceed the value of the savings. The US recommended policies scenario's cost is higher than its benefits up to the 2035 cut-off period (but would be much lower were the scenario period to be extended). This is because the study only includes higher efficiency technologies that are cost effective over their operational life span as potential substitution technologies. The least life cycle cost scenarios produce the greatest cost savings to 2035. These scenarios lower the total hot water service delivered cost by 27% in China, 42% in India, and 12% in the US over the scenario period. This amounts to annual savings of 154 billion RMB in China, 296 billion Rupees in India, and US$6.3 billion in the US in 2035. Energy savings on such a scale would also produce substantial reductions in CO_2 emissions. Under the LLCC scenario some 186 Mt of CO_2 emissions would be saved across the three economies in 2035 (119 Mt in China, 34 Mt in India, and 33 Mt in the US) compared to the BAU case. Under the Recommended Policies scenario the savings would be 124 Mt of CO_2 emissions across the three economies in 2035 (88 Mt in China, 16 Mt in India, and 19 Mt in the USA). Cumulatively to 2035 the LLCC scenario saves 2364 Mt of CO_2 compared to the BAU scenario whereas the Recommended Policies scenario saves 944 Mt of CO_2.

Water heater energy policies

There is substantial potential in China, India, and the US to save energy and CO_2 emissions through the promotion of stronger policies to encourage the adoption of high efficiency water heating technology across all energy source types. There are already many policy measures in place to promote water heater efficiency. The study includes a detailed review of existing policy measures and a gap analysis to indicate policies that could be considered but have not yet been implemented. Table ES1 indicates the implementation status of generic policy instruments that could be applied to support high efficiency water heater choices in each economy. They can be structured to create an incentive or obligation to install more efficient or renewable energy based water heaters. Some of these measures may exist but are not necessarily established in a manner that supports high efficiency water heaters. For example, utility renewable energy portfolio standards may be structured so they only focus on renewable electricity supply rather than renewable thermal energy supply. They may favor heat pump water heaters but not solar thermal water heaters. Equally, building codes may be structured so they give no incentives to renewable energy sources or to the efficiency of installed equipment, such as water heaters. The strength of impact of such measures very much depends on their details.

Table ES1 Summary of generic policies that could be applied to high efficiency water heaters

Policy tool	China	India	USA
National renewable energy targets	Yes	India	No
National energy efficiency targets	Yes	Yes	No
Renewable Heat Incentives	No	No	No
Renewable Heat Obligations	No	No	No
Utility Renewable Energy Portfolio Standards or Obligations	Some	No	Some
Utility Energy Efficiency Portfolio Standards or Obligations	Some	No	Some
Renewable Energy Credits	No	Some	Some
Renewable Energy Certificate Schemes	No	No	Some
Energy Efficiency Certificate Schemes (White Certificates or Tags)	No	No	Some
Building Energy Codes	Yes	No	Some
Building Energy Performance Certificates or Disclosure	Some	Some	Some
Solar Energy Obligations	Some	No	One

Mandatory policy tools to address convenience of energy efficient water heaters

Mandating the installation of high efficiency water heaters is the main policy tool used to ensure that high efficiency water heaters are installed regardless of any short-term inconvenience issues. Mandated measures can take the form of: prohibiting inefficient water heaters from sale, prohibiting low efficiency water heaters from being installed, or requiring certain high efficiency technologies, such as solar water heaters, to be installed.

Both China and the US have extensive MEPS applying to specific water heater technologies but India does not yet have these. None of these economies has implemented MEPS that apply across water heater types and is based on ensuring that no water heaters are used that are less than a certain efficiency.

Only China, India, and Hawaii in the US have local solar ordinances or building codes in place that require solar water heating installation. The scope of application of these measures varies. They are more common in China than India and currently only affect a modest proportion of the total building stock. Such ordinances are likely to be more effective at transforming the market when there is significant new build and low levels of water heater adoption. Ordinances are less likely when it predominantly replaces market with existing incumbent technologies. Such measures are also more politically and socially acceptable in economies with traditions of central planning and/or where water heating is a newer service.

Energy labeling and visibility of high efficiency water heater performance

China has the most extensive water heater energy labeling program among the three economies as they have energy labels for electric, gas, solar and heat pump water heaters. The US has labeling for all types except solar water heaters. India currently only has energy labels for electric storage water heaters. They do not yet permit differentiation between a conventional product with very low standing losses and a heat pump water heater with much greater energy efficiency. The problem with the labeling in these economies is that they do not allow comparison across the different water heater energy types: gas, electric and solar. Nor do they always permit comparison between heat pump water heaters and other electric water heaters. Consumers cannot clearly see the difference in expected performance from adopting one technology and source-energy configuration compared to another.

Incentives to ensure upfront costs are affordable for consumers

All of the economies have some economic incentives in place for solar water heaters; however, these have only been in place at the national scale, at a significant level and for a sustained period of time in China. This is the main reason the penetration of solar water heating is so much higher in China than the other two markets. To stimulate the market for solar water heaters, markets need subsidies/rebates/financing to significantly reduce the incremental first cost of solar compared to competing water heater technologies and to remove risk for the end-user. To make a significant difference to the solar market share, these financial incentives and financing mechanisms need to be sustained for some considerable period of time. As the market develops, and consumer familiarity and acceptance of the technology increases, incentives can and should be structured to reduce. Incentives should reduce even more sharply as the increase in market volume accelerates the learning curve for the cost of deployment; ie by which extra sales volume helps foster economies of scale in manufacturing (turning solar water heaters from an SME to consolidated industrial production activity) and in the costs of installation (noting that installer costs are a significant part of the overhead for solar water heaters and are quite sensitive to scale).

In the US the current federal tax credits for solar water heaters which are valued at 30% of the system cost, are due to expire in 2016. In China the long-running national level subsidies for gas, heat-pump and solar water heaters all ended in 2013. However, these two cases differ. The US tax credits are relatively recent in origin and have not been in place long enough to make a serious difference to the size of the market. Whereas the Chinese incentives were sufficient and sustained for long enough to help stimulate a transformation in the Chinese market.

Awareness raising

Each of the Chinese, Indian, and US governments have implemented some awareness raising measures for solar water heating and in the case of China and the US heat pump water heaters, but these measures have been of a modest scale, see Chapter 3. In the case of the US many of the promotional efforts managed at the Federal level seem to be aimed at practitioners or relatively well engaged consumers rather than at the public at large.

Quality assurance

China and the US have adopted schemes to assure and promote the quality of solar water heaters and India has a scheme under development, see Chapter 3. The US also has quality assurance schemes for conventional gas and electric storage water heaters.

Recommendations

Adopting the LLCC technologies is expected to save between 23% and 68%[1] in primary energy compared to continuing with BAU and to appreciably reduce the life cycle cost of the water heating service. However, stronger and more coherent policies are needed to achieve these changes. In particular, measures are needed that:

[1] The Least Life Cycle Cost scenario leads to maximum water heater primary energy savings compared to the BAU scenario of 23% in the USA, 58% in China and 68% in India.

- Allow easy comparison of the overall energy performance of different water heater technologies across technology types to help clarify the value proposition of the different choices available;
- Help explain and promote the value proposition of high efficiency water heater technologies to consumers so they feel informed and empowered to select the most efficient and cost effective technology choices;
- Lower initial cost barriers to the adoption of high efficiency water heaters;
- Support the deployment of high efficiency water heater choices, most notably solar and heat pump water heaters, so that their incremental costs compared to traditional less efficient choices decline due to learning curve effects
- Ensure quality is maintained in the technology, installation, and servicing of high efficiency water heating technologies to build competence and confidence in the supply chain.

While the specifics of the measures that are needed in each of the economies investigated (China, India, and the US) differs there are many common elements. Specifically, energy efficiency regulators need to adopt test procedures that measure and compare water efficiency across technology types. They equally need to implement energy labeling and other product rating, ranking and consumer awareness raising measures that facilitate easy comparison of product energy performance across technology and energy types. Public awareness efforts are necessary to clarify the value proposition of high efficiency water heater technologies and explain how best to acquire and use them. Economies need financial measures to remove the higher first cost barrier, be it through incentives or modified pay-as-you-save business models. Most importantly, financial incentives must be of a sufficient scale to promote wide spread adoption. Technology adoption risk needs to be minimized by supporting quality assurance schemes and through underwriting risk in the event of failures. Over the medium term the additional cost of the high efficiency solutions needs to be minimized through stimulating large scale deployment and accelerating learning curve effects. Once the quality of service is sufficiently reliable, the scale of delivery at a suitable level and the economic benefits established it may be appropriate to lock in the higher efficiency choices through mandatory regulatory measures such as minimum energy performance standards, building codes, and ordinances.

Overall the development of a coherent program will require the conscious development and implementation of a high efficiency water heater strategy. While this may be steered at the national level, input and implementation will often be at the local level. Thus resources will be required to help develop and roll out the strategy both nationally and locally. The benefits from an effective program are high. They will need strongly resourced activities aiming at the long-term transformation of the water heater market towards the highest efficiency options. Broad-based stakeholder engagement combined with sustained public policy efforts will be essential for the successful implementation of this strategy.

01 Introduction

This report was prepared by Waide Strategic Efficiency Ltd (UK), MP Ensystems Advisory (India), Hot Water Research (USA), Top10 China (China) and ARMINES (France) for the CLASP project RFP#8-14 "Policy Opportunities for More Efficient Residential Water Heating". It aims to supply information on policy coverage and indicate where there are gaps in the current policy portfolios to promote energy efficient water heaters in China, India, and the US. It further analyzes energy savings potentials and their associated impacts and proposes a set of policy recommendations for each economy. The detailed scope of work for the project is specified below.

Scope of work

The policy study covers residential water heaters –including electric, gas and solar powered appliances, tank, tank-less, and heat pump types in the economies of: China, India, and the US. The study is divided into three tasks as indicated below with their associated sub tasks and the sections of the report where the information is presented.

Task I. Gap Analysis

A gap analysis shows where there is a dearth of existing policy coverage that could produce significant savings were the gap(s) to be addressed. The gap analysis should be conducted for each economy under the scope, by comparing the existing policy coverage in the economy (by water heater type), and overlaying the information on market share by water heater type, to see if there are significant policy gaps against preponderant water heater types.

Task II. Derivation of energy, $CO_{2,}$ and economic savings scenarios from systematic move towards a more efficient mix of water heater technologies

The objective of this analysis is to identify and quantify the policy opportunities in each economy from encouraging the adoption of the most efficient types of water heater and the migration away from the least efficient. This includes a derivation of the energy savings potential from adopting an alternative high efficiency water heater technology (e.g. solar or heat pump based instead of storage tanks heated by electric resistance) rather than choosing an incrementally higher efficiency product from within one of the conventional technology classes (e.g., better insulated electric resistance storage tanks). The development of this exercise should consider long range energy scenarios that mapped movement towards solar and heat pump water heating. It should also take into account economic considerations, interaction with space heating (e.g. via combi-units where these are prevalent), and any limiting factors (e.g., availability of the energy source, etc.).

Task III. Policy recommendations (by economy)

Based on findings of Tasks I and II, develop a set of policy recommendations targeted to each economy under scope, not only considering MEPS and labels but also policies that stimulate technology switching.

A note on how to read the report. In order to facilitate comparison and for completeness tables by economy are mostly presented in a common format that shows the relevant parameter (e.g. energy performance test procedure or regulation) for each type of water heater considered by the study. If cells are empty it indicates that there is no such test procedure, regulation or other requirement for that product type within the specified economy.

General context

In most economies sanitary water heating is one of the largest residential energy end uses and typically accounts for from 5% to 25% of delivered energy. This makes it one of the most important sources of energy use and CO_2 emissions and a major part of domestic energy expenditure.

Water heaters may be gas, electric, or solar powered. They can be instantaneous, typically positioned close to the point of demand, or they may use storage tanks connected to the points of demand by a distribution system. Electric water heaters may use heat pump technology (usually air-source) to increase the overall efficiency or they may be more conventional designs that simply use electric resistance heaters. In some economies, most notably Europe, water heating can also be provided by the same device used to provide space heat through a "combi-boiler" design that has one heating loop for sanitary hot water and another to supply water into a hydronic heating system.

MEPS and labeling schemes developed for water heaters around the world have traditionally been based on a specific set of standards and metrics differentiated by water heater type. For each subtype (with/without storage, energy source, controls, and so on), there are specific energy performance metrics that express the ratio of heating energy delivered to the energy consumed. In the US these are known as the "energy factor". These numerous differentiated classifications reveal the difference in performance of products within the same technology sub-class. At the same time, they can actually act as a barrier to energy efficiency improvement through inhibiting comparison across water heater technology classes. This is especially true for water heaters where there is far greater energy savings potential from adopting an alternative high efficiency water heater technology (e.g. solar or heat pump based instead of storage tanks heated by electric resistance) than there is from choosing an incrementally higher efficiency product from within one of the conventional technology classes (e.g., better insulated electric resistance storage tanks). Thus the propagation of efficiency definitions within technology "silos" has encouraged a conservative market.

The most interesting international equipment standards and labeling policy development in recent years has occurred in Europe. The Ecodesign Lot 2 process began in 2006. It built firmly on earlier work looking at efficiency within technology classes. The Ecodesign Lot 2 process also recognized the need to develop a means of putting all water heater technologies on a single scale. The intention was to allow end-users to compare different technologies and their energy performance on a single efficiency scale. For example, consumers can compare electric storage water heater and a condensing boiler with storage across several criteria to decide which one suits their needs best. After seven years of intensive work and policy development, the new regulation on water heaters was adopted in 2013. The approach gives a much larger potential in terms of energy efficiency improvement from MEPS and labeling because the differences in energy efficiency between the different technologies are much larger than within the same technology type.

Figures 1 and 2 show the range of difference found between water heater products available on the market. The study used the US Energy Factor[2] approach to define water heater efficiency. The higher the Energy Factor value the more energy efficient the product. Figure 1 shows the actual Energy Factor which is based on site (i.e. final) energy and hence does not take into account typical losses from the generation and distribution of electrical energy. Figure 2 shows the same data once primary to secondary energy conversion losses have been taken into account by assuming a primary energy conversion factor of 0.4 for electricity and 0.97 for gas. The results are shown in each case for:

ESWHs = electric storage water heaters
EIWHs = electric instantaneous (i.e. tankless) water heaters

[2] https://en.wikipedia.org/wiki/Energy_factor

GSWHs = gas storage water heaters
GIWHs = gas instantaneous (i.e. tankless) water heaters
HPWHs = heat pump water heaters

Figure 1. Typical Energy Factor ranges for different types of water heater

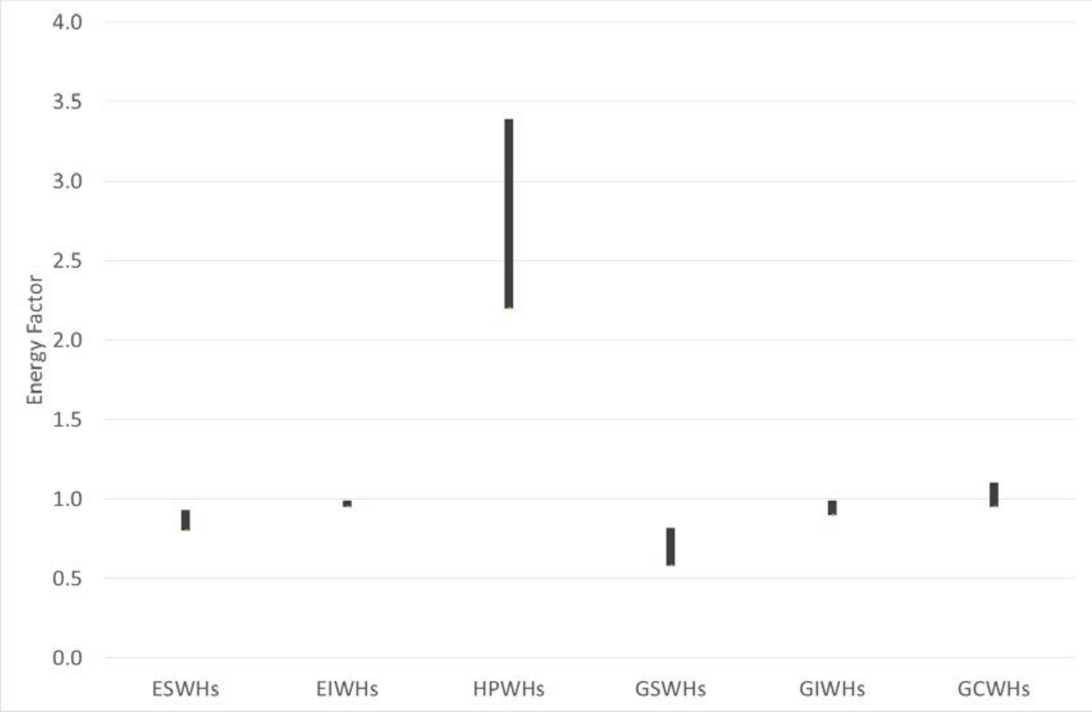
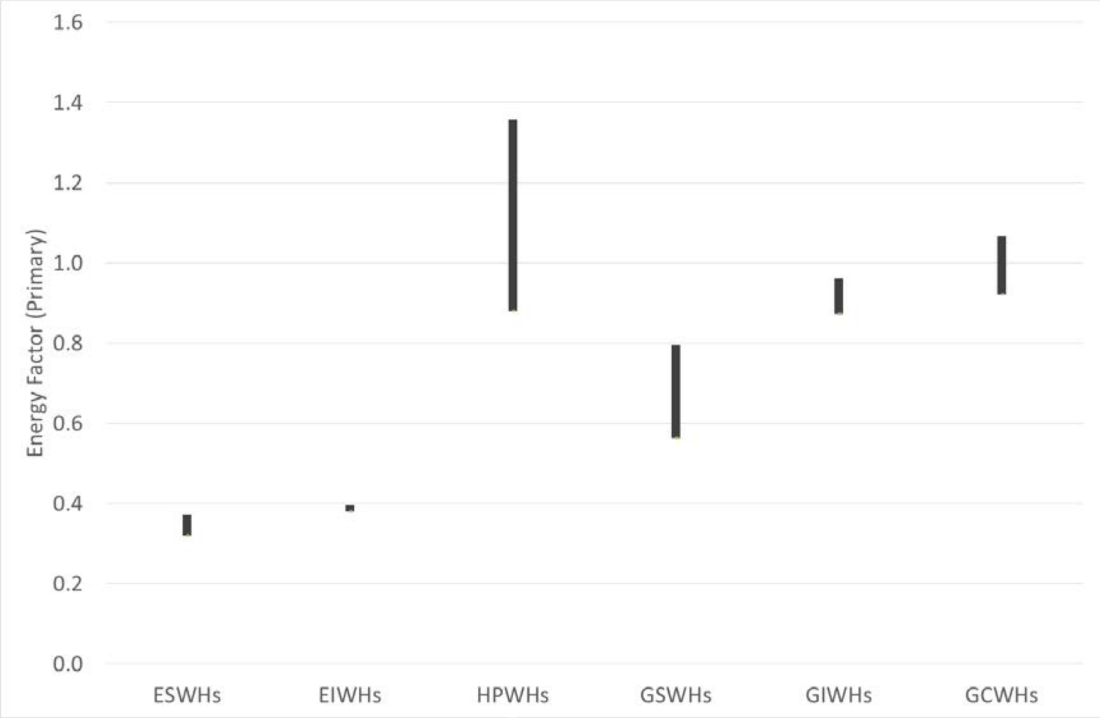


Figure 2. Typical Energy Factor ranges for different types of water heater after adjusting for primary to secondary energy losses



The high efficiency data in the graphs for some of the water heater technology types (HPWH, GSWH, GIWH) comes from the Energy Star product database as accessed in October 2015[3].
The graphs show there is much greater difference in efficiency between product types than within them. Furthermore using the Energy Factor based on site (final) energy as in Figure 1 gives the impression that there is little difference in efficiency between electric and gas water heaters and that conventional electric water heaters are slightly more efficient; however, this ignores typical thermally generated electricity conversion losses. If these are taken into account (using a fairly typical primary to secondary energy conversion factor as shown in Figure 2) the gas water heaters have a clear energy efficiency advantage except compared to heat pump water heaters[4].

Solar water heaters are not shown on these figures because the Energy Factor metric has no meaning for these products unless they are designed to be used with a back-up conventional energy source (i.e. electric or gas-fired back up systems). In this case the Solar Energy Factor[5] (SEF) can be considered as a roughly comparable metric. This is typically shown to be between 1.2 and 20 i.e. up to more than 20 times higher than the best electric water heaters (not using heat pump technology). All solar water heaters will have some losses and thus they are not 100% efficient at converting solar energy into heated hot water; however, as the primary energy source is renewable it is freely available and non-polluting and thus they are inherently require less commercial energy than other technologies. Solar water heaters that use no back-up system require no commercial energy and have an infinite SEF but those that use a commercial energy back-up system will have lower SEFs.

Importantly, these figures clearly illustrate the limitations of water heating energy policy which is focused purely on making efficiency improvements within each technology type. The scope to improve instantaneous water heater (gas or electric) efficiency is usually negligible thus these are rarely subject to policies such as comparative energy labeling. There is some potential to improve the efficiency of storage water heaters, mostly by limiting their standing losses, but the real improvements occur when substituting between water heating technologies and especially to either heat pump or solar water heaters.

Details of how the European Labeling scheme puts all these products onto a single scale are given in section 2; however, in summary it categorizes the efficiency of water heaters into one of ten efficiency classes (A+++, A++, A+, A, B, C, D, E, F, G). Standard gas or electric storage tank water heaters will tend to be in the G to D classes, while only solar water heaters are currently capable of attaining the A+++ class.

Labeling is only one means to promote competition between water heating technologies on the basis of their efficiency. The most significant set of national policies in terms of the overall water heating energy savings produced have been China's policy portfolio to promote the adoption of solar water heaters. As discussed in this report, China has the world's largest stock of installed water heaters and has one of the higher per capita ownership levels of solar water heaters. The policies that have helped create this situation are briefly summarized later in this report although

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3 https://www.energystar.gov/productfinder/product/certified-water-heaters/results?scrollTo=0&search_text=&sort_by=energy_factor&sort_direction=desc&fuel_filter=&type_filter=&brand_name_isopen=&input_rate_thousand_btu_per_hour_isopen=&markets_filter=United+States&page_number=0&lastpage=0)

4 The Primary Energy Factor (PEF) will vary by economy and depends on the blend of generating technologies used, but those economies that have a high proportion of fossil fuel generated electricity will have the largest differences between primary and secondary energy and hence the smallest PEFs..

5 The Solar Energy Factor is described at: http://www.solar-rating.org/facts/system_ratings.html

most of the focus is on establishing what policies are currently in place and where there are gaps in each of the target economies.

The overall efficiency of the hot water delivery system depends on more than just the energy efficiency of the water heater. The further the water heater is situated from the point of demand the greater losses are likely to be from drawing hot water into the piping system. For example, if a small amount of hot water is needed and the water heater is some distance from the point of demand e.g. a tap (faucet) then as the whole length of the pipe work needs to be filled with hot water before the user receives any it is likely that a good proportion of the thermal energy within the pipe will be wasted before the next occasion the user draws hot water (especially if being used outside the heating season). These larger energy balance concerns would tend to favour using a number of instantaneous water heaters in preference to systems using centrally distributed storage. Equally, there are options to reduce the energy consumption of the hot water system by reducing demand for hot water. These include: using energy efficient (low flow) shower heads and taps (faucets), and more energy efficient washing machines (clothes washers). There is also increasing (or renewed) interest in using electric water heaters for demand response and renewables integration purposes e.g. (Murphy & Schare 2015).

This report does not examine these factors but rather focuses on the issues and options that concern the efficiency of the water heaters themselves.

The report is structured such that it begins with a summary of equipment standards (MEPS) and labeling policies in place per economy (Chapter 2), then gives a summary of other policies that have been adopted to promote energy efficient water heaters (Chapter 3) before systematically detailing in Chapter 4 which policies are in place and in so doing indicating where there are gaps. Chapter 5 assesses the factors affecting water heater energy use in each economy and presents energy, economic and environmental impacts from a set of detailed water heater energy scenarios. Chapter 6 presents policy recommendations regarding how to promote energy efficient water heaters in each economy and Chapter 7 offers short conclusions. The appendices contain extra technical and market information.

2 Water heater standards and labelling initiatives in each economy

This sections provides details of the water heater standards and labeling programs in place in each of the three target economies. It begins with a similar description for the European Union because it is the only economy that currently implements standards and labeling in manner that allows all types of water heaters to be compared on a common basis.

The EU: A case study in common treatment of all water heater types

The EU has recently pioneered a system of standards and labeling for water heaters that is common to all types of water heaters. It enables energy efficiency performance comparison between them. Details are presented below by way of comparison with those policy measures applied in the three target economies.

Test procedures

Existing procedures for the different types of water heaters are to be revised by 2015 when Ecodesign and labeling regulations are enacted. In Europe, regulations do not refer precisely anymore to existing standards.

Regulations define metrics and testing conditions references that are communicated to the European Committee for Standardization (CEN) via mandate. When standards have been updated and do comply with the regulation, they become harmonized and may be referred to for the application of the regulations. This is notified in the Official Journal of the European Union.

Hence the main lines of the testing procedure (size, tap water profile by size, metrics definition) are defined in the regulation. An additional document (here a Communication from the Commission) specifies acceptable transitional methods, which are based on existing test standards plus notified modifications of the test procedures. These modifications should normally be integrated in the revised test standards.

Regulations

Two regulations were enforced in 2013 for water heaters: a MEPS (Ecodesign) regulation and a Labeling regulation:

- Commission Regulation (EU) No 814/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to eco-design requirements for water heaters and hot water storage tanks
- Commission Delegated Regulation (EU) No 812/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device - OJ L 239, 06.09.2013, p. 83–135.

MEPS

MEPS are defined in the Ecodesign regulation. Combination water heaters are included in the space heating regulation. Solid fuel water heaters and “water heaters specifically designed for using gaseous or liquid fuels predominantly produced from biomass” are excluded.

The same requirements do apply for all types of water heater with a rated output lower than or equal to 400 kW and a storage volume lower than or equal to 2000 L.

Requirement are defined in terms of 'water heating energy efficiency', which means the ratio between the useful energy provided by a water heater and the energy required for its generation, expressed in %.

For electric and fuel water heaters:

$\eta_{wh} = Q_{ref} / [(Q_{fuel} + CC \times Q_{elec}) \cdot (1 - SCF \times smart) + Q_{cor}]$
With:

- Q_{ref}: sum of the useful energy content of water draw-offs, expressed in kWh. Useful means the energy content of hot water, expressed in kWh, provided at a temperature equal to, or above, the useful water temperature, and at water flow rates equal to, or above, the useful water flow rate. Useful temperatures and flows to reach are specified in the water profiles supplied in the regulation
- Q_{fuel}: fuel consumption
- CC: primary energy factor of 2.5
- Q_{elec}: electricity consumption
- SCF: smart control factor, performance increase measured on two consecutive weeks, the first week without the smart control enabled and the second one with the smart control enabled
- smart: indicator of smart compliance (0 if SCF < 0.07, or 1)
- Q_{cor}: standby correction term (negative).

For solar water heaters:

$\eta_{wh} = 0.6 \times 366 \times Q_{ref} / Q_{tota}$; with $Q_{tota} = Q_{nonsol} / (1.1 \times \eta_{wh,nonsol} - 0.1) + Q_{aux} \times CC$

With:

- Q_{nonsol}: 'annual non-solar heat contribution' means the annual contribution of electricity (expressed in kWh in terms of primary energy) and/or fuel (expressed in kWh in terms of GCV (Gross Calorific Value)) to the useful heat output of a solar water heater, taking into account the annual amount of heat captured by the solar collector and the heat losses of the solar hot water storage tank
- $\eta_{wh,nonsol}$: 'heat generator water heating energy efficiency' means the water heating energy efficiency of a heat generator which is part of a solar water heater, expressed in %, established under average climate conditions and without using solar heat input
- Q_{aux}: 'auxiliary electricity consumption' means the annual electricity consumption of a solar water heater that is due to the pump power consumption and the standby power consumption, expressed in kWh in terms of final energy.

Solar water heaters shall be tested component by component but can also be tested as a water heater if this is not possible. Calculations should then be used to calculate Q_{nonsol}.

Water heater sizes are defined in terms of storage volume (SV) or 'mixed water at 40 °C' (V40), which means the quantity of water at 40 °C, which has the same heat content (enthalpy) as the hot water which is delivered above 40 °C at the output of the water heater, expressed in liters. The EU scheme distinguishes between water heaters based on their size using the categories shown in Table 2.1

Table 2.1 Water heater size categories in the EU

Declared load profile	3XS	XXS	XS	S	M	L	XL	XXL	3XL	4XL
from 2015 onwards	SV	SV	SV	SV	V40	V40	V40	V40	V40	V40
L (liters)	<= 7	<= 15	<= 15	<= 36	>= 65	>= 130	>= 210	>= 300	>= 520	>= 1040

Table 2.2 lists the mandatory MEPS for water heaters sold in the EU. The MEPS are expressed as Water heating energy efficiency, which is determined in the test procedure part above.

Table 2.2 Water heater MEPS in the EU

Declared load profile	3XS	XXS	XS	S	M	L	XL	XXL	3XL	4XL
MEPS 2015 (Sept 26th)	22%	23%	26%	26%	30%	30%	30%	32%	32%	32%
MEPS 2015 (Sept 26th) with smart control	19%	20%	23%	23%	27%	27%	27%	28%	28%	28%
MEPS 2017 (Sept 26th)	32%	32%	32%	32%	36%	37%	37%	37%	37%	38%
MEPS 2017 (Sept 26th) with smart control	29%	29%	29%	29%	33%	34%	35%	36%	36%	36%

In addition to system MEPS, maximum tank standby losses are defined as well as:

$S \leq 16.66 + 8.33 \cdot V^{0.4}$ (in Watts)

Mandatory labels

The EU label scope for water heaters is less extended than the Ecodesign scope, with the idea that larger products are rather business-to-business (B2B) products than business-to-consumer (B2C). The label is required for all types of water heaters with a rated output lower than or equal to 70 kW and a storage volume lower than or equal to 500 L. Solar devices (solar components not included in solar water heating packages) are not included. There are 5 different versions of the label, for conventional generators (gas or electric), solar water heaters, heat pump water heaters, packaged water heaters containing at least one conventional generator and one solar generator, and hot water storage tanks. For heat pump and solar water heaters, consumption has to be given for the average climate and two supplementary climates; a cold and a warm climate.

Energy efficiency classes from A+++ to G are defined by size of water heater. Energy efficiency classes from A+++ to G are given in Table 2.3.

Depending on the year (2015 or 2017) and water heater type, the permitted labeling classes to be included in the label vary:

- for all generator types except packages of solar and conventional water heaters, the present regulation specifies that in 2015 only classes A to G will be used and that in 2017, only classes A+ to F will be used
- for packages of solar and conventional water heaters, the full extent of the efficiency scale, from A+++ to G, may be used from 2015.

An example of the label is shown in Figure 3.

Figure 3. The EU Mandatory Energy Label for Water Heaters

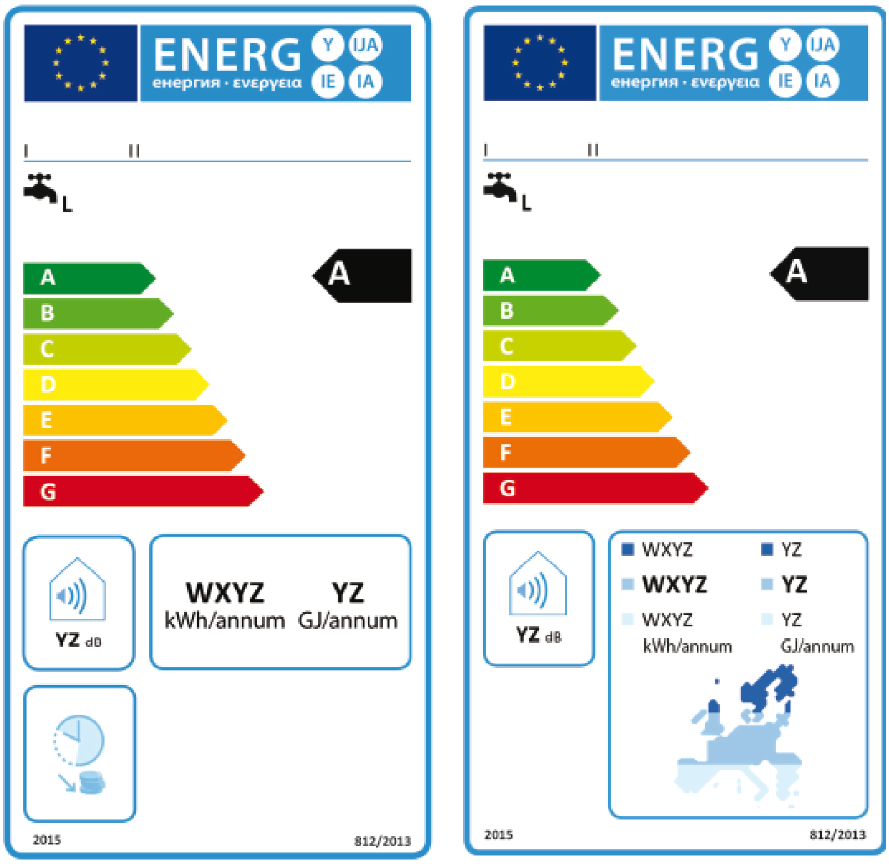


Table 2.3 Water heater energy efficiency classes in the EU

Declared load profile	3XS	XXS	XS	S	M	L	XL	XXL
A+++	ηwh > 0.62	ηwh > 0.62	ηwh > 0.69	ηwh > 0.9	ηwh > 1.63	ηwh > 1.88	ηwh > 2	ηwh > 2.13
A++	0.53 < ηwh ≤ 0.62	0.53 < ηwh ≤ 0.62	0.61 < ηwh ≤ 0.69	0.72 < ηwh ≤ 0.9	1.3 < ηwh ≤ 1.63	1.5 < ηwh ≤ 1.88	1.6 < ηwh ≤ 2	1.7 < ηwh ≤ 2.13
A+	0.44 < ηwh ≤ 0.53	0.44 < ηwh ≤ 0.53	0.53 < ηwh ≤ 0.61	0.55 < ηwh ≤ 0.72	1 < ηwh ≤ 1.3	1.15 < ηwh ≤ 1.5	1.23 < ηwh ≤ 1.6	1.31 < ηwh ≤ 1.7
A	0.35 < ηwh ≤ 0.44	0.35 < ηwh ≤ 0.44	0.38 < ηwh ≤ 0.53	0.38 < ηwh ≤ 0.55	0.65 < ηwh ≤ 1	0.75 < ηwh ≤ 1.15	0.8 < ηwh ≤ 1.23	0.85 < ηwh ≤ 1.31
B	0.32 < ηwh ≤ 0.35	0.32 < ηwh ≤ 0.35	0.35 < ηwh ≤ 0.38	0.35 < ηwh ≤ 0.38	0.39 < ηwh ≤ 0.65	0.5 < ηwh ≤ 0.75	0.55 < ηwh ≤ 0.8	0.6 < ηwh ≤ 0.85
C	0.29 < ηwh ≤ 0.32	0.29 < ηwh ≤ 0.32	0.32 < ηwh ≤ 0.35	0.32 < ηwh ≤ 0.35	0.36 < ηwh ≤ 0.39	0.37 < ηwh ≤ 0.5	0.38 < ηwh ≤ 0.55	0.4 < ηwh ≤ 0.6
D	0.26 < ηwh ≤ 0.29	0.26 < ηwh ≤ 0.29	0.29 < ηwh ≤ 0.32	0.29 < ηwh ≤ 0.32	0.33 < ηwh ≤ 0.36	0.34 < ηwh ≤ 0.37	0.35 < ηwh ≤ 0.38	0.36 < ηwh ≤ 0.4
E	0.22 < ηwh ≤ 0.26	0.23 < ηwh ≤ 0.26	0.26 < ηwh ≤ 0.29	0.26 < ηwh ≤ 0.29	0.3 < ηwh ≤ 0.33	0.3 < ηwh ≤ 0.34	0.3 < ηwh ≤ 0.35	0.32 < ηwh ≤ 0.36
F	0.19 < ηwh ≤ 0.22	0.2 < ηwh ≤ 0.23	0.23 < ηwh ≤ 0.26	0.23 < ηwh ≤ 0.26	0.27 < ηwh ≤ 0.3	0.27 < ηwh ≤ 0.3	0.27 < ηwh ≤ 0.3	0.28 < ηwh ≤ 0.32
G	ηwh < 0.19	ηwh < 0.2	ηwh < 0.23	ηwh < 0.23	ηwh < 0.27	ηwh < 0.27	ηwh < 0.27	ηwh < 0.28

Note, the load profiles used are defined to be the largest profile for which the water heater is able to provide enough hot water. In the USA, by comparison, there is a separate test, known as the First Hour Rating, which is used to assign which draw pattern is used to test the water heater.

Voluntary labels

None in place at either EU or country level.

China

Test procedures

In China the test procedures for rating the efficiency of water heaters are included in the MEPS and labeling documents. Table 2.4 maps which water heaters types are to be tested to which test standards in China.

Table 2.4 Water heater energy performance test procedures in China

Water heater type	Exist. std (Y/N)	Standard reference	Rated Volume	Rated Input	Temperature
Gas					
Gas storage	Y	GB 18111-2000		<50kW required but recommended to <100kW	82°C
Gas instantaneous	Y	GB 20665-2006 and 2015 specify MEPS and some test procedure aspects. The 2015 version will be enforced from June 1st 2016. It references more test standards than the 2006 version, including: GB 6932 (the main test method for instantaneous water heaters), GB 25034, CJ/T 336: 2010 and CJ/T 395: 2012		<=70kW	80°C
Combi-boilers	Y	GB 20665-2006 and 2015 specify MEPS and some test procedure aspects. The 2015 version will be enforced from June 1st 2016. It references more test standards than the 2006 version, including: GB25034 (the test method for standard combi-boilers), and CJ/T 395: 2012 (for condensing hot water and heating combi boilers).		<=70kW	80°C
Electric					
Electric storage	Y	GB 21519-2008			65±2°C

Water heater type	Exist. std (Y/N)	Standard reference	Rated Volume	Rated Input	Temperature
Electric instantaneous	N				
Electric heat pump	Y	GB 29541-2013			55±0.5℃
Oil					
Storage	N				
Solar					
Solar water heater system	Y	GB 26969-2011	≤600L		
Solar collector	N				
Solar tank	N	GB/T 18708-2002			≥50℃
Tank					
Unvented	N				

Regulations

MEPS

China has mandatory MEPS and labeling requirements for gas-fired instantaneous water heaters and hot water combi-boilers, electric storage water heaters, heat pump water heaters, and solar water heating systems. The MEPS are shown in Table 2.5.

Table 2.5 Water heater MEPS in China

Type	Status	Standard	MEPS
Gas			
Gas storage	None		
Gas instantaneous	current	GB 20665-2015[1]	thermal efficiency(η) ≥ 86% at rated load thermal efficiency(η) ≥ 82% at partial load
Combi-boilers	current	GB 20665-2015	water heating thermal efficiency η ≥ 84% at rated load, η ≥ 82% at partial load space heating thermal efficiency η ≥ 84% at rated load, η ≥ 82% at partial load
Gas + solar	None		
Gas + electric heat pump	None		

Type	Status	Standard	MEPS
Electric			
Electric storage	current	GB 21519-2008	Rated Capacity (L) 24 hour standing loss (kWh) $0<C_R\leq30$ Q=0.024C+0.6 $30< C_R \leq100$ Q=0.015C+0.8 $100< C_R \leq200$ Q=0.008C+1.5 $C_R>200$ Q=0.006C+2.0 C_R is rated capacity. C is measured capacity
Electric instantaneous	None		
Electric heat pump	current	GB 29541-2013[2]	COP standard temperature, add-on HP 3.70 standard temperature, integral HP 3.40 low-temperature, 3.00
Oil			
Storage			
Solar			
Solar water heater system	Current	GB 26969-2011	Coefficient of Thermal Performance CTP≥0.10
Solar collector	None		
Solar tank	None		
Tank			
Unvented	None		

[1] to be implemented from 1st June 2016

[2] applies to for HP<10kW

Mandatory labels

Labels are mandatory for all water heater types which have MEPS. The lowest grade on the energy label corresponds to the MEPS level.

Gas instantaneous water heaters and combi-boilers are divided into three grades of energy efficiency, of which Grade 1 represents the highest energy efficiency. The minimum allowable values of heat efficiency for each grade are listed in Table 2.6.

Table 2.6 Water heater energy efficiency grades for instantaneous gas water heaters and combi-boilers in China

Type		Heat Load	Minimum Heat Efficiency Value (%) Energy Efficiency Grade		
			1	2	3
Water heaters		Rated Heat Load	98	89	86
		≤50% Rated Heat Load	94	85	82
Combi-boilers	Heating	Rated Heat Load	96	89	86
		≤50% Rated Heat Load	92	85	82
	Hot water	Rated Heat Load	99	89	86
		≤50% Rated Heat Load	95	85	82

An example of the mandatory label for a combi-boiler is shown in Figure 4.

Figure 4. The Chinese Energy Label for Combi-boiler Water Heaters

Electric storage water heaters are divided into five grades of energy efficiency, of which Grade 1 represents the highest energy efficiency. The required standing loss per 24 h and hot water output rate for each grade of electric water heater are shown in Table 2.7.

Table 2.7 Electric storage water heater energy efficiency grades in China

Energy Efficiency Grade	Standing Loss per 24 Coefficient(ε)	Hot Water Output Rate (μ)
1	≤0.6	≥70%
2	≤0.7	≥60%
3	≤0.8	≥55%
4	≤0.9	≥55%
5	≤1.0	≥50%

Solar water heating systems

Solar water heating systems are divided into three grades of energy efficiency, of which Grade 1 represents the highest energy efficiency. The required coefficient of thermal performance for each grade of solar water heating system is shown in Table 2.8.

Table 2.8 Domestic solar hot water system energy efficiency rating in China

Domestic solar hot water system type	Coefficient of Thermal Performance（CTP）Energy Efficiency Grade		
	1	2	3
Compact	CTP≥0.50	0.32≤CTP＜0.50	0.10≤CTP＜0.32
Separate direct (split single loop)	CTP≥0.48	0.30≤CTP＜0.48	0.10≤CTP＜0.30
Separate indirect (split dual circuit)	CTP≥0.45	0.28≤CTP＜0.45	0.10≤CTP＜0.28
Integral	CTP≥0.60	0.40≤CTP＜0.60	0.10≤CTP＜0.40

Voluntary labels

China applies a certified quality label to water heaters as operated by the China Quality Certification Centre (CQC), Figure 5. To be eligible for this certification label products must meet the efficiency limits for grade 1 products under the mandatory energy label.

Figure 5. The Chinese Voluntary Energy Label

India

Test procedures

The Bureau of Indian Standards (BIS) has four test procedures for water heaters, IS 2082-1993, Stationary Storage Type Electric Water Heaters (includes standing loss requirement, Table 1, amendment 4); standard IS 8978: 1992 for instantaneous electric water heaters;
IS 5115-1969, Specification for Domestic Storage Type Water Heaters for use with LPG; (provide a ready supply of hot water at a maximum water temperature of 85°C, having nominal capacities between 6 and 100 liters, thermal efficiency shall be not less than 70 percent); and IS 15558-2005, Mini Domestic Water Heater for use with LPG (nominal useful less than 25 kW, thermal efficiency specified in section 16). These BIS standards are voluntary.

Regulations

MEPS

As of May 2014, India does not have any MEPS for water heaters.

Mandatory labels

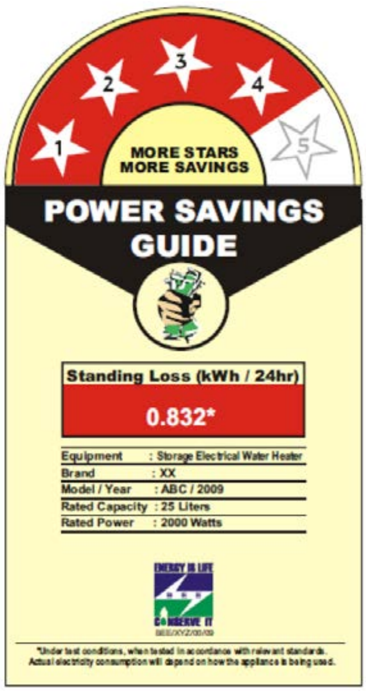
The Bureau of Energy Efficiency (BEE) issues mandatory labels for storage electric water heaters. The label uses a star rating plan based on the standing losses (kwh/24hour/45 °C difference) calculated according to IS 2082:1993. Water heaters are categorized in 10 different rated capacities ranging from 6 to 200 L. The rating ranges from 1 star (less efficient) to 5 star (more efficient) (Table 2.9).

Table 2.9 Water heater energy label efficiency classes in India

Rated Capacity (liters)	1 Star	2 Star	3 Star	4 Star	5 Star
	Standing Losses (kwh/24 hour/45C)				
6	≤ 0.792 & >0.634	≤ 0.634 & >0.554	≤ 0.554 & >0.475	≤ 0.475 & >0.396	≤ 0.396
10	≤ 0.990 & >0.792	≤ 0.792 & >0.693	≤ 0.693 & >0.594	≤ 0.594 & >0.495	≤ 0.495
15	≤ 1.138 & >0.910	≤ 0.910 & >0.797	≤ 0.797 & >0.683	≤ 0.683 & >0.569	≤ 0.569
25	≤ 1.386 & >1.109	≤ 1.109 & >0.970	≤ 0.970 & >0.832	≤ 0.832 & >0.693	≤ 0.693
35	≤ 1.584 & >1.267	≤ 1.267 & >1.109	≤ 1.109 & >0.950	≤ 0.950 & >0.792	≤ 0.792
50	≤ 1.832 & >1.466	≤ 1.466 & >1.282	≤ 1.282 & >1.099	≤ 1.099 & >0.916	≤ 0.916
70	≤ 2.079 & >1.663	≤ 1.663 & >1.455	≤ 1.455 & >1.247	≤ 1.247 & >1.040	≤ 1.040
100	≤ 2.376 & >1.901	≤ 1.901 & >1.663	≤ 1.663 & >1.426	≤ 1.426 & >1.188	≤ 1.188
140	≤ 2.673 & >2.138	≤ 2.138 & >1.871	≤ 1.871 & >1.604	≤ 1.604 & >1.337	≤ 1.337
200	≤ 2.970 & >2.376	≤ 2.376 & >2.079	≤ 2.079 & >1.782	≤ 1.782 & >1.485	≤ 1.485

An example of the BEE star rating label for the storage electric water heaters is shown in Figure 6.

Figure 6. The Indian Energy Label for Electric Storage Water Heaters



Voluntary labels

BEE labeling scheme has been in place for several years and was voluntary until July 2015 when it became mandatory (see above). There are now no voluntary energy labeling schemes for water heaters in India.

USA

This section shows the mapping of existing standards and labeling initiatives and their characteristics for residential water heaters in the USA.

Test procedures

Table 2.10 maps which water heaters are to be tested to the standards in the USA.

Table 2.10 Water heater energy performance test procedures in the USA

Water heater type	Exist. std (Y/N)	Standard reference	Rated Volume	Rated Input	Temperature
Gas					
Gas storage	Y	10CFR430—Appendix E to Subpart B	76 L to 380 L	< 21.94 kW	< 82 °C
Gas instantaneous	Y	10CFR430—Appendix E to Subpart B	< 7.6 L	14.7 kW to 58.3 kW	< 82 °C
Combi-boilers	N				
Gas + solar	Y	10CFR430—Appendix E to Subpart B	76 L to 380 L	< 21.94 kW	< 82 °C
Gas + electric heat pump	Y	10CFR430—Appendix E to Subpart B	76 L to 380 L	< 21.94 kW	< 82 °C
Electric					
Electric storage	Y	10CFR430—Appendix E to Subpart B	76 L to 450 L	≤ 12 kW	< 82 °C
Electric instantaneous	Y	10CFR430—Appendix E to Subpart B	Reserved	Reserved	Reserved
Electric heat pump	Y	10CFR430—Appendix E to Subpart B	≤ 450 L	≤ 6 kW	< 82 °C
Oil					
Storage	Y	10CFR430—Appendix E to Subpart B	≤ 190 L	≤ 30.56 kW	< 82 °C
Solar					
Solar water heater system	Y	SRCC 300-2013-09			
Solar collector	Y	SRCC 100-2013-11			
Solar tank	Y	10CFR430—Appendix E to Subpart B	76 L to 450 L	≤ 12 kW	< 82 °C
Tank					
Unvented	N				

Regulations

The following regulations apply for water heaters in the USA.

MEPS

Table 2.11 lists the mandatory minimum energy performance standards for water heaters sold in the USA. The MEPS are expressed as Energy Factor which is determined using the US test procedure.

Table 2.11 Water heater MEPS in the USA

Type	Status	Standard	MEPS
Gas			
Gas storage	Current	10CFR430.32 (d)	Energy Factor ≥ 0.67 – (0.0019 × Rated Volume in gallons)
	16 April, 2015		Energy Factor ≥ 0.675 – (0.0015 × Rated Volume, gallons) if ≤ 208.2 L Energy Factor ≥ 0.8012 – (0.00078 × Rated Volume, gallons) if > 208.2 L
Gas instantaneous	Current	10CFR430.32 (d)	Energy Factor ≥ 0.62 – (0.0019 × Rated Volume in gallons)
	16 April, 2015		Energy Factor ≥ 0.82 – (0.0019 × Rated Volume in gallons)
Combi-boilers	None		
Gas + solar	see Gas Storage		
Gas + electric heat pump	see Gas Storage		
Electric			
Electric storage	Current	10CFR430.32 (d)	Energy Factor ≥ 0.97 – (0.00132 × Rated Volume in gallons)
	16 April, 2015		Energy Factor ≥ 0.96 – (0.0003 × Rated Volume, gallons) if ≤ 208.2 L Energy Factor ≥ 2.057 – (0.00113 × Rated Volume, gallons) if >208.2 L
Electric instantaneous	Current 16 April, 2015	10CFR430.32 (d)	Energy Factor ≥ 0.93 – (0.00132 × Rated Volume in gallons)
Electric heat pump	see Electric Storage		
Oil			
Storage	Current	10CFR430.32((d)	Energy Factor ≥ 0.59 – (0.0019 × Rated Volume in gallons)
	16 April, 2015		Energy Factor ≥ 0.68 – (0.0019 × Rated Volume in gallons)
Solar			
Solar water heater system	None		
Solar collector	None		
Solar tank	See Electric Storage		
Tank			
Unvented	None		

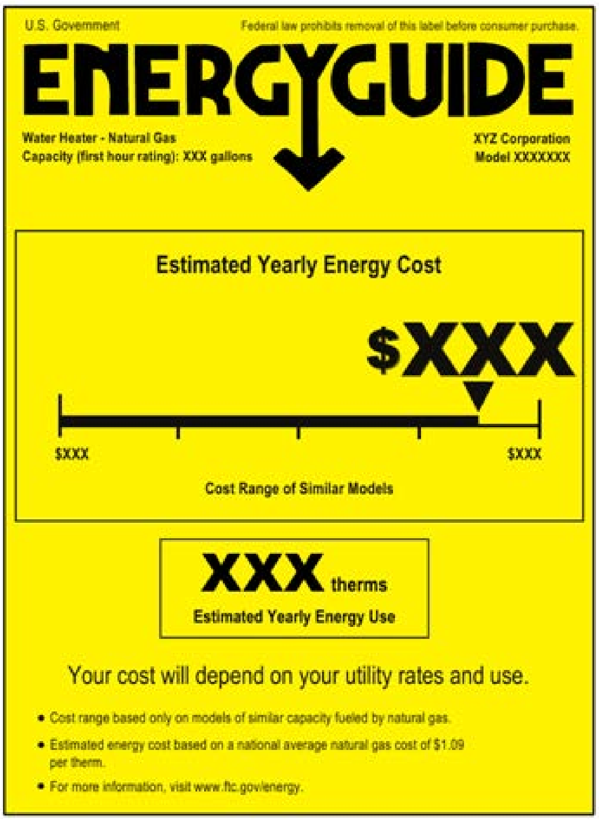
Note the above values are in accordance with the old test procedure. The MEPS under the new test procedure have not yet been determined. A conversion factor to translate the EF determined under the previous test procedure to the UEF determined under the new test procedure is being developed. Once that is finalized, the new MEPS will be calculated.

Mandatory labels

All water heater types with a MEPS listed in Table 2.11 are required to have an attached label at the time of sale to the final consumer. The label contains a graphic display of the relative projected annual energy consumption of the water heater relative to water heaters with similar capacity based on the test procedure. The label also displays an estimated annual energy cost based on national average energy prices. The requirements for size, color, contents, etc. of the label are fully described in 16CFR 5—Rule Concerning Disclosures Regarding Energy Consumption and Water Use of Certain Home Appliances and Other Products Required Under the Energy Policy And Conservation Act ("Appliance Labeling Rule") .

A sample EnergyGuide label for a gas storage water heater is shown in Figure 7 below.

Figure 7. The US Energy Label for Gas-Storage Water Heaters



Voluntary labels

Energy Star is a voluntary endorsement label in the USA. Water heaters meeting the efficiency criteria listed in Table 2.12 are eligible to apply for an Energy Star rating. In addition to the efficiency rating, the water heaters must meet additional warranty criteria.

Table 2.12 Voluntary water heater energy efficiency label requirements in the USA

Type	Standard	Efficiency Requirement
Gas		
Gas storage	ENERGY STAR Residential Water Heaters Specification Version 3.0	EF ≥ 0.67, V ≤ 208 L EF ≥ 0.77, V > 208 L
Gas instantaneous	ENERGY STAR Residential Water Heaters Specification Version 3.0	EF ≥ 0.90
Combi-boilers	None	
Gas + solar	ENERGY STAR Residential Water Heaters Specification Version 3.0	SEF ≥ 1.2
Gas + electric heat pump	None	
Electric		
Electric storage	ENERGY STAR Residential Water Heaters Specification Version 3.0	EF ≥ 2.00, V ≤ 208 L EF ≥ 2.20, V > 208 L
Electric instantaneous	None	
Electric heat pump	see Electric Storage	
Oil		
Storage	None	
Solar		
Solar water heater system	ENERGY STAR Residential Water Heaters Specification Version 3.0	SEF≥ 1.8
Solar collector	None	
Solar tank	None	

An example of the Energy Star label is shown in Figure 8 below.

Figure 8. The US Energy Star Label

3 Other types of water heater energy efficiency policies

In addition to regulatory standards and labels for water heaters implemented at the national level there are a number of other policies to encourage higher energy efficiency or energy savings in water heaters that have been implemented at either the national, regional, or local level as detailed by country below.

China

Macro-policy targets

Currently China has a macro-level policy target for 9.5% of all final energy consumption to be derived from renewable energy sources by 2015 and 11.5% of primary energy production (IRENA policies database accessed April 2015). As of 2013 roughly 9.3% of final energy consumption was from renewable energy (REN21 2014, p 121). As part of this objective it has set a national target of 280 GWth (400 million m^2) from solar water heating by 2015.

Table 3.1 Macro renewable energy policy targets in China

Country:	China
Year:	2012 (August 8th)
Policy status:	In Force
Jurisdiction:	National
Date Effective:	2012 (August 8th)
Policy Type:	Policy Support>Strategic planning, Regulatory Instruments
Policy Target:	Multiple RE Sources, Hydropower, Wind>Offshore, Solar, Solar Thermal, Bioenergy, Geothermal, Ocean
Policy Sector:	Electricity, Framework Policy, Heating and Cooling, Multi-sectoral Policy
Size of Plant Targeted:	Small and Large
Agency:	National Energy Administration
Description:	According to The Twelfth Five-Year Plan for Renewable Energy, the total consumption of renewable energy will reach 478 Mtce by the end of 2015, which accounts for 9.5% of the total energy consumption. Also development indicators for different types of renewable energy are outlined: • the installed capacity of hydropower will reach 290 GW, including 260 GW conventional hydropower and 30 GW pumped storage power station; • grid-connected wind power will reach 100 GW, including 5 GW offshore wind power; • solar power 21 GW, • solar thermal 400 million square meters; • biomass 50 Mtce per year; • geothermal energy 15 Mtce; • ocean energy 50,000 KW.

Renewable energy law

Solar thermal energy is reported to have received a significant boost in China with the adoption of the Chinese Renewable Energy Law, which went into effect on 1st January 2006.

Link to the Chinese Renewable Energy Law (in Chinese)
www.mep.gov.cn/law/law/200802/t20080202_117982.htm

Urban planning

Hong Kong: Hong Kong sets the strategy to become China's "greenest region" by taking action on several initiatives:

- Limiting the contribution of coal to less than 10% of the electricity generation mix by 2020,
- Phasing out existing coal plants between 2020 and 2030,
- Investing in construction/operation of district cooling infrastructure using seawater,
- Meeting the power demand of 100,000 households using biogas from landfills and sewage water treatment by 2020,
- Installing SWH on all government buildings and swimming pools,
- Installing wind turbines to meet 1–2% of total electricity demand by 2020,
- Raising awareness by demonstrating solar PV arrays on government buildings,
- Developing a website to provide information on renewable energy technologies suitable for local use, and
- Providing news/ events, educational resources, and information on renewable energy equipment suppliers.(REN 21 2012, p134)

Subsidy programs

Rural subsidies for solar water heaters

The first national incentive program for installing solar water heaters in China's rural areas was introduced in 2009. The program, known as the Home Appliance Information System, reduced the cost of solar water heaters in rural areas by 13% (which effectively removed all VAT) and covered approximately 75% of the market.

From April 2009, solar thermal system suppliers could bid to become part of the national subsidy program. This incentive scheme was part of a huge rural development program, which also subsidized other technologies for villages. Bidders to the tender round were required to be legally registered companies, which are able to supply solar water heaters in acceptable quantities. The rules for the tender also only allowed company groups to bid once. “The mother company, a subsidiary or a 50% holding of a bidding company is not allowed to join the tender,” one of the rules published by the central government states.

The second tender round of the national rural incentive program in 2010 saw more companies with higher-priced products qualifying for it. The 2010 price limit was RMB 5,000, a substantial increase from the RMB 4,000 last year (10 RMB is about 1 EUR). Government authorities approved 168 companies for the incentive program in 2010, among them 79 new companies. Eighty-nine of those companies had already succeeded in the first tender round in spring 2009.

The number of products offered to customers increased from 806 in 2009 to 1,366 in 2010. There was a clear shift towards offering more expensive systems from 2009 to 2010, such that in 2009, 40% of the approved solar water heaters were for sale at prices below RMB 2,500 while in 2010 their share fell below 20%.

The national incentive program for residential solar water heaters is understood to have substantially increased the proliferation of solar technology in China’s rural areas.

NDRC efficient water heaters subsidy scheme 2012-13

In 2012 the Chinese government took further steps to consolidate the water heater market and improve the quality of solar water heaters. The National Development and Reform Commission (NDRC) and China’s Ministry of Finance launched a new initiative to support the distribution of high-efficiency solar water heaters (SWH), heat pump water heaters and gas fired storage water heaters. Since 1 June 2012, SWH with sizes between 80 and 600 liters were subsidized at different rates, which varied between Renminbi (RMB) 100 and 550 (see the Table 3.2). The subsidy scheme differentiated between compact solar water heaters, in which the water-filled tubes are linked directly to the tank in one unit, and split solar water heaters (balcony solar water heaters). The latter are mostly indirect, pressurized systems, in which tank and collector are set up apart from each other.

Table 3.2 Chinese Solar water heater subsidies 2012-2013

Product type and hot water tank volume		Grant [RMB/set] based on the China Energy Label	
		Energy label Grade 1	Energy label Grade 2
Compact solar water heater	80 ≤ 140 liters	150	100
	140 ≤ 250 liters	260	210
	250 ≤ 600 liters	350	300
Split solar water heaters	80 ≤ 140 liters	300	200
	140 ≤ 250 liters	430	330
	250 ≤ 600 liters	550	450

The following tables (3.4 and 3.5) illustrate the level of subsidies for gas water heaters and heat-pump water heaters.

Table 3.3 Chinese gas water heater subsidies 2012-2013

Product type		Allowances (RMB / unit)
Gas water heater	14 kW ≤ Rated thermal load ≤ 20 kW	200
	Rated thermal load > 20 kW	300
Gas space heating water heaters[1]		400

[1] i.e. combi-boilers

Table 3.4 Chinese heat-pump water heater subsidies 2012-2013

Product Type	Energy Efficiency	Specifications (W)	Allowances (RMB / unit)
Static heating air source heat pump water heaters (machine)	3.4≤COP < 4.0	Rated heating capacity ≤4500	300
		Rated heating capacity >4500	350
	COP≥4.0	Rated heating capacity ≤4500	500

From 2012 China implemented a national subsidy program for gas water heaters (including gas-combi water heaters), solar water heaters and heat pump water heaters. Other types of electrical water heaters were not included in this subsidy program. This subsidy program ended in May 2013.

No impact or implementation evaluation assessment is available for this policy; however, Table 3.5 puts the magnitude of the subsidy into context.

Table 3.5 Calculations by the Chinese Solar Thermal Industry Federation (CSTIF) for a research report on the development of China's solar thermal industry from 2008-2010

Technology providing 100 liters of hot water per day	Electric water heater	Gas water heater	Solar water heater
Investment costs (RMB)	1200	1000	1800
Annual running costs (RMB)	500	350	5
Life time (years)	8	8	10
Annual average total costs (RMB)	650	475	185
Investment ratio with solar water heater as 1	3.5	2.6	1

Source: REW (2012)

In the case of solar water heaters, the Chinese government's requirements for the subsidized products and suppliers of the solar water heater were as follows:

- Subsidized products must fulfil the new national standard GB / T 19141-2011 (Specification of domestic solar water beating systems), which specifies how to calculate the thermal coefficient of performance. Regarding domestic solar water heaters, the standard includes three efficiency levels: 1, 2 and 3. Eligible systems for the subsidy scheme must reach either level 1 or 2.
- The products must be produced and set up in mainland China.
- The supplier must have a comprehensive sales network and a product sales capacity of more than 50,000 units annually.
- The supplier must have been inspected by the National Quality Supervision and must have had no negative inspection reports over the last three years.

Solar obligations and building codes

In 2007, some provincial and city governments in China began to implement solar installation requirements. Since then, an increasing number of authorities at different administrative levels have made the installation of solar thermal systems mandatory in new-builds in the residential and public sector, for example, in universities, schools, hospitals and nursing homes. The policy measures which have led to the development of provincial and municipal solar water heater installation requirements were the 11th Five-Year Plan New Energy and Renewable Energy Development (2006-2010) and the Renewable Energy Law of China of 2006. Under most of these requirements solar water heaters in residential buildings need to be sized to provide 40 liters of hot water per day per person. A solar heating system in a public building, on the other hand, must cover at least 60% of the hot water demand. Thus far there have not yet been any solar building requirements specified at the national level.

Table 3.6 presents a summary of these requirements. Other locations may have requirements not captured here. The sources for this information are:

Xie, H., Zhang, C., Hao, B., Liu, S., & Zou, K. (2012). Review of solar obligations in China. Renewable and Sustainable Energy Reviews, 16, 113-122.

Yuan, X., Wang, X., & Zuo, J. (2013). Renewable energy in buildings in China - A review. Renewable and Sustainable Energy Reviews, 24, 1-8.

Sun's Vision. (2012). Compilation of solar thermal policies and regulations (太阳能热利用政策法规 - 汇编) (Chinese). Dezhou: Sun's Vision.

Table 3.6 Solar water heater obligations in China

Location	Date of implementation	Type of buildings eligible
Shandong Province	October 2009	Residential buildings below 13 floors and buildings with centralized hot water supply in cities above county-level shall use SWH systems in design and construction.
Jinan	January 2014	New residential buildings below 100 meters or 33 floors
Yantai	February 2010	New residential buildings below 13 floors
Dezhou	2008	New residential buildings below 13 floors
	2010	Hospitals, schools, offices and other public buildings
Qingdao, Weihai, Linyi, Weifang, Dongying Binzhou, Zibo	Between 2009 and May 2012	New residential buildings below 13 floors and for hospitals, schools, offices and other public buildings.
Jiangsu Province	December 2009	New public buildings with the demand of hot water, such as hotels, commercial-residential buildings and new residential buildings below 12 floors
Nanjing, Jiangsu	January 2011	New residential buildings; new public buildings with the demand of hot water (including the renovation and extension) below 12 floors
Suzhou, Jiangsu	May 2008	New residential buildings; new public buildings with the demand of hot water (including the renovation and extension), such as hotels, hospitals below 13 floors
Wuhan, Hubei	April 2008	New residential buildings; hospitals, dormitories, hotels, swimming pools, and government buildings which have conditions for solar thermal below 13 floors
Yunnan Province	May 2008	New residential buildings below 11 floors; new public buildings with the demand of hot water below 24 meters
Kunming, Yunnan	April 2010	New residential buildings below 12 floors and for hospitals, schools, offices and other public buildings that have the a need and the conditions for solar collection (including renovation and extension)
Taiyuan, Shanxi	January 2010	New residential buildings below 12 floors and new hospitals, schools, offices and other public buildings
Hefei, Anhui	March 2009	New residential buildings below 13 floors and for new hospitals, schools, offices and other public buildings.
Tongling, Anhui	January 2010	New residential buildings below 12 floors and for public buildings with the demand for hot water.
Qinghai Province	November 2009	New residential buildings which have conditions for solar water heating systems; other buildings, such as hospitals, schools, restaurants, indoor swimming pools, public baths
Fuzhou, Fujian	January 2010	New private and commercial residential buildings below 12 floors
Ningxia Province	January 2010	New residential buildings, dormitories and apartments (including the renovation) below 12 floors; new public buildings with the demand of hot water (including the renovation and extension), such as government office buildings, hospitals, schools, kindergartens, hotels, public baths
Yinchuan, Ningxia	January 2010	New residential buildings below 12 floors
Hainan Province	March 2010	New residential buildings (including the renovation and extension) below 13 floors; public buildings, such as dormitories, hospitals, hotels, restaurants, public baths
Shanghai Municipality	January 2011	New public buildings with the demand of hot water; new residential buildings below 7 floors

Sources: see above

Table 3.7 presents a partial list of earlier regulations.

Table 3.7 Solar water heater obligations in China continued

Province	Date when building code came into effect	Type of buildings eligible
Anhui	1st March 2009	Civic buildings with fewer than 12 floors, public buildings like hotels, schools, swimming pools and hospitals
Hainan	1st January 2007	Civic buildings and hotels with fewer than 12 floors
Jiangsu	1st January 2008	Civic buildings with fewer than 12 floors, restaurants, hotels
Fujian	1st November 2006	New Civic buildings with fewer than 12 floors
Yunnan	1st May 2008	Civic buildings with fewer than 11 floors, public buildings less than 24 m high
Hebei	1st November 2008	New civic buildings with fewer than 12 floors

Implementation of the mandatory installation requirements is carried out by the respective Construction Bureaus. So-called Construction Document Evaluation Centers review the construction documents. If the solar water heater systems are in line with the specified requirements and technical standards, the center will issue a certificate to the developer. Only this certificate will allow the builder to apply for a building permit. The construction site, including the solar water heater installation, will be inspected regularly by the local construction bureau. The inspection following completion of the structure will include an energy efficiency check of insulation, shading and solar water heaters systems. If all regulations are fulfilled, the developer receives a certificate which enables him to apply for a sales permit.

Shandong province

Since 2008, solar water heating has been mandatory for new buildings with less than 13 floors in Shandong Province, Table 3.8. Since 2014, the city council of Jinan promulgated another mandatory installation policy targeting new buildings with less than 33 stories. These high-rise buildings need the integration of new solar water heater technologies, such as split solar water heaters (solar water heaters designed for use on the balconies of multi-story apartment blocks).

Another current support measure of the Shandong provincial government is the promotion of the national green building standard which requires energy efficiency of public buildings to 65% during the 13th Five-Year Plan. Shandong province requires the installation of solar water heaters in buildings that want to reach the one-star class, which is the lowest of the three green building standards. According to a news article on china.org.cn from 14 May 2013, Shandong “announced instructions for the creation of new green buildings with a total area of more than 50 million m² by the end of 2015.” More than 50% of the new buildings must use renewable energies by then.

Subsidies to support solar thermal were introduced in Shandong province in 2007, Table 3.9.

Table 3.8 Shandong Province One Million Rooftops Sunshine Plan

Country:	China
Year:	2008
Policy status:	In Force
Jurisdiction:	State/Regional
Date Effective:	2008
Policy Type:	Regulatory Instruments, Economic Instruments>Direct investment
Policy Target:	Solar Thermal, Solar>Solar photovoltaic, Geothermal
Policy Sector:	Multi-sectoral Policy
Agency:	Shandong Province Government, Department of Construction
URL:	http://(in Chinese)
Description:	In January 2008, Shandong Province announced implementation of its One Million Rooftops Sunshine Plan, designed to stimulate the integration of various renewable energy sources into building construction. The Plan targets the use of solar power and geothermal power into buildings. Following this, compulsory regulations went into effect in the cities of Yantai and Jinan, for the integration of solar energy in the construction and design of certain buildings.

Source: http://www.iea.org/policiesandmeasures/pams/china

Table 3.9 Shandong Province Energy Fund

Country:	China
Year:	2007
Policy status:	In Force
Jurisdiction:	State/Regional
Date Effective:	2007
Policy Type:	Research, Development and Deployment (RD&D)>Research program >Technology deployment and diffusion, Economic Instruments>Direct investment
Policy Target:	Solar Thermal
Policy Sector:	Heating and Cooling
Agency:	Shandong Province Government
URL:	http://(in Chinese)
Description:	In 2007, the government of Shandong Province established a CNY 2.133 billion fund to support energy conservation and emissions reductions. Drawing on this fund, the provincial government planned to allocate funds to subsidize the construction and adoption of solar hot water supply systems by hotels, schools and other establishments. In 2007, a total of 15 million m^2 of buildings in Shandong had a solar hot water heating system. In January 2008 it was estimated that 99% of city center residents used solar power for water heating.

Source: http://www.iea.org/policiesandmeasures/pams/china

Beijing

On 1 March 2012, Beijing followed many other large Chinese cities in introducing its own solar thermal mandatory law. The new regulations are stipulated in document No. 3/2012, "Beijing Urban Construction Applications Management Approach". Article 9 describes the scope of the new regulations: Newly built residential houses of up to 12 floors - as well as hotels, schools, hospitals, and swimming pools - are obliged to install a solar thermal hot water system if no waste heat is used to cover domestic hot water demand.

Under these requirements builders do not receive a building permit from the municipality unless they have demonstrated how they will integrate solar hot water into the building. After the building has been completed, municipal inspectors visit the site. In Beijing, the Municipal Bureau of Quality and Technical Supervision is said to be responsible for the review and approval of applications and installations.

Document 3/2012 also includes a separate section about multi-family houses. At least two thirds of the flat owners in a multi-family house have to agree to the installation of a centralized or decentralized solar hot water installation. Only then will the housing company be allowed to install a solar thermal system for the entire building, with the costs having to be split among the flat owners themselves.

To limit the risk for the housing company when investing in solar energy, it has been suggested to employ the so-called smart card billing. In this case, the tenants pay the measured hot water demand of their single flat and the running costs for maintenance and repair work upfront, either per month or year.

The city has also announced financial incentives for the multi-family housing sector. To apply for these investment subsidies, projects need to include more than 50 m² of collector area and fulfil the municipality's requirements.

According to web portal www.21tyn.com, Beijing's solar obligation is one of the measures designed to fulfil the city's 12th Five Year Plan, which was released in December 2011. The Beijing Municipal Commission of Development and Reform aims at reaching a total installed collector area of 10.5 million m², of which 5 million m2 have already been installed in the rural areas around the city.

Online articles about the solar obligation (all in Chinese):
http://www.21tyn.com/news/echo.php?id=25620.htm
http://news.dichan.sina.com.cn/2012/02/27/447929.html

Survey of implementers

In 2011 a survey on the implementation of solar obligations was posed questions to 300 architects and engineers in the cities along the coast, such as Beijing, Haining, Jinan, Xingtai, Sanmenxia, Shenzhen, Nanjing, Wuhan, and Qinhuangdao, across which solar water heating systems are mandatory in new buildings. All of these cities require new residential buildings of up to 12 floors to use solar collectors for the hot water of the inhabitants. In some of them – such as Haining, Xingtai, Nanjing, and Wuhan – newly built hotels must also use solar technology to supply their hot water demand. However, the obligations do not stipulate any specific requirements, such as a minimum solar fraction, or a minimum collector area per apartment or head.

Only half of the survey participants knew about the solar obligations in their city or region. When asked why solar water heating system designs often do not fulfil the requirements of the obligation, the interview partners stated the following reasons (the number in brackets shows the share of interview partners agreeing with the respective statement:

- Design institutes are not specialized in solar or do not trust the technology (57%)
- The complete solutions of solar water heating systems supplied by the industry are not suitable for mandatory applications (48%)
- No inspection or checking of installed solar thermal systems (32%)

- No encouraging policy in this segment or loopholes in the obligations (42%).

The survey established that the majority of designers did not know about or use a software tool to plan and design solar thermal systems for multi-family buildings. Only 2% of the interview partners actually used such a tool, all the others had either never heard about it (88%), or heard about simulation tools, but had never used them (10%). Consequently, the IMSIA (Chinese International Metal Solar Industry Alliance) planned to develop free-of-charge software to plan and design larger solar thermal systems in urban areas.

Solar water heater quality requirements

Solar water heater quality provisions have already been mentioned under the text describing the Chinese water heater subsidies and the solar obligations and building codes.

Example from Shandong

The Shandong Solar Energy Industry Association and the Shandong Construction Development Research Institute have been cooperating to establish new solar water heater quality standards. The laboratories create new standards and monitoring schemes for solar thermal products. In that respect, they act as a bridge between the government and the industry. This is especially important in Shandong, because in the province, standards have been tighter than at national level. All standards in China are still voluntarily, but recommended.

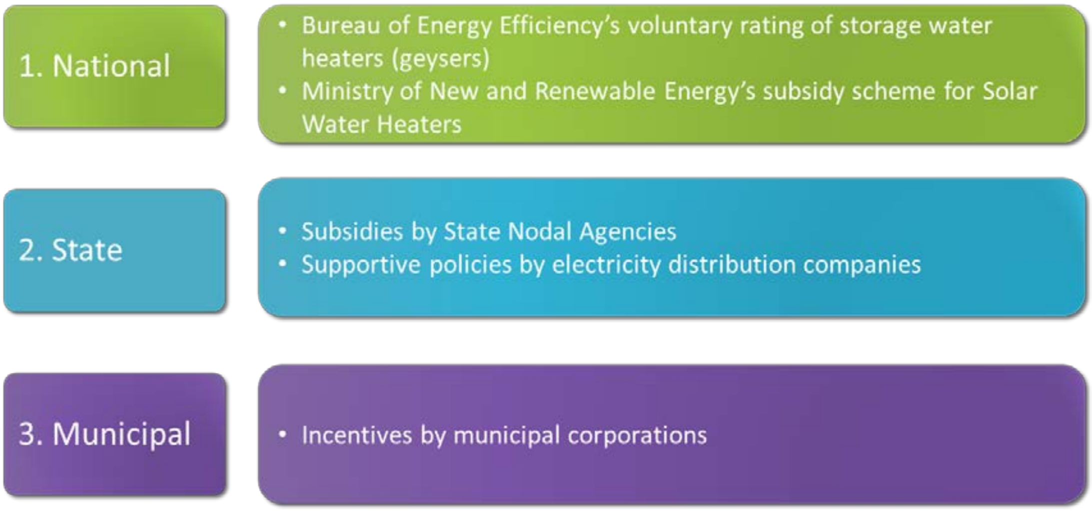
Allegedly there are still many small companies which do not comply with standards and, thus, produce low-quality products such that unfair competition from companies that do not adhere to the standards can bring discredit upon the whole solar industry, due to low quality and unsafe products.

The Solar Application Product Inspection Laboratory based in Jinan is a subdivision of the National Supervision and Inspection Center and employs a staff of 12. The laboratory tests solar thermal systems from various Chinese companies for compliance with national and provincial standards. It is also responsible for supervising the quality of solar products and for devising standards related to solar applications.

India

India currently has no quantified national target for RE as a whole (REN21, p121) but in the case of solar water heating it has a target of 5.6 GWth (8 million m^2) of new capacity to be added between 2012 and 2017.

To support water heating efficiency in India, various policies have been implemented at different levels. These are shown in the graphic below.



Early focus on SWHs

For a successful implementation of the above policies, former Ministry of Non-Conventional Energy Sources (MNES) (now the Ministry of New and Renewable Energy (MNRE)), along with the Ministry of Urban Development (MoUD), in the year 2005, has amended the building by-laws in municipalities for mandating Solar Water Heaters (SWH) for various categories of new buildings.
Further, MoUD in consultation with MNES circulated the model regulations / building by-laws for installation of solar assisted water heating systems in the buildings to all States and Union Territories.

As per the amended building by-laws, certain new buildings have to mandatorily have SWH. Some of these buildings include hospitals, hotels, lodges, guest houses, hostels, training centers, armed-forces barracks, para-military forces and police, individual residential buildings having area greater than 150 m^2 of plinth area, buildings of railway stations and airports, inspection bungalows, catering units. A one-time financial assistance of Rs. 5-10 lakh would be provided by the MNES to municipal and local bodies that adopt this clause in their building by-laws. The financial support is being provided for organizing trainings, study tours, awareness creation, preparation of brochures/ manuals, creating infrastructure etc. for implementing the mandatory provision. The 12 (of 28) states and 2 (of 7) union territories where the local bodies issued orders for incorporating these bye –laws were: Andhra Pradesh, Haryana, Himachal Pradesh, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Delhi, Uttar Pradesh, Uttarakhand, Chhattisgarh, and Union Territories of Dadra and Nagar Haveli and Chandigarh.

Provisions related to Water Heaters under National Building Code (NBC) of India, 2005

The National Building Code (NBC) was first published in 1970 and later was revised in 1983. The major amendments were made in the year 1987 (2) and 1997 (1).

The NBC 2005 was then formulated by the Bureau of Indian Standards (BIS) which is currently under amendment and a revised version is expected to be released in 2015.

The revised NBC 2015 would contain a standardized requirement for design and construction of several types of buildings in India and is applicable for adoption by infrastructure departments, municipal administrators, public bodies and private agencies. It also contains administrative regulations, development control rules, general building requirements, fire safety requirements, specifics on use of materials, structural design, construction plumbing services, etc.

In case of provisions related to Water Heaters, NBC focuses on design, installation, safety, testing and inspection considerations (e.g. wire size, wire color, etc.).

Provisions supportive of SWH under Integrated Energy Policy 2006 (IEP 2006)

Solar energy has large potential in India. In 2006, under the Indian Energy Plan (IEP), it states that the potential of solar thermal energy generation is economical and can be used to meet hot water demand for both industry and households.

Around more than 100 Municipal Corporations/ Municipal Committees /Development Authorities across several states in India have amended their building by-laws or have several orders issued for offering incentives on solar water heating systems. Some of the important points mentioned under building by-laws are as follows:

- Ensure that all new buildings and factories have SWH
- Existing households/ commercial establishments/ factories are encouraged to install SWH through electricity utilities initiatives
- Incentives may be given in the form of rebates for income tax, property tax, transfer fees, or electricity charges

Further, R&D on SWH is covered under the extensive R&D on solar thermal technologies that is being pursued in India as per Jawaharlal Nehru National Solar Mission (JNNSM) provisions. The BIS standards and appropriate test facilities have also been established. There are about 60 BIS approved manufacturers for producing SWH systems using FPC and over 150 manufacturers have been empanelled for ETC based systems.

The IEP 2006 also mentions about mandating time bound targets of energy efficiency for water heaters among other technologies. Whereas, the schedule 10 of the Bureau of Energy Efficiency Standards and Labeling Program specifies time-bound efficiency requirements for storage type electric water heaters.

Genesis of specific focus on Solar Water Heating Systems in India, post 2010

The Jawaharlal Nehru National Solar Mission (JNNSM) launched in January 2010 has one of the eight core missions as the National Action Plan on Climate Change (NAPCC, June 2008). The mission would be carried out in three phases: Phase 1 (2010-2013), Phase 2 (2013-17) and Phase 3 (2017-22). The initial target of this mission would be to deploy 20,000 MW of solar power by the year 2020 which has recently been revised to 100,000 MW by the year 2020.

The mission also focuses on the Solar Heating Systems by setting ambitious target for ensuring that domestic and industrial applications below 80°C are solarized. The policy also intends to meet this objective by:

- Making solar heaters mandatory, through building byelaws and incorporation in the National Building Code
- Ensuring introduction of effective mechanisms for certification and rating of manufacturers of solar thermal applications
- Facilitating measurement and promotion of individual devices through local agencies and power utilities
- Supporting technology upgrades and manufacturing capacities through soft loans, to further reduce costs and achieve higher efficiency levels.

Capital subsidy scheme for installation of solar thermal systems

Overview

The scheme launched under the Off-grid and Decentralized Solar Thermal Application Scheme in Phase 2 of the JNNSM has SWH as one of the seven applications covered.

The objectives of the scheme were:

- Promote off-grid applications of solar thermal systems,
- Create awareness and demonstrate effective and innovative use,
- Encourage innovation,
- Provide support to channel partners and potential beneficiaries,
- Create paradigm shift needed for commoditization,
- Support consultancy services, seminars, symposia, capacity building, awareness campaigns, human resource development, and
- Encourage replacement of kerosene, diesel and wood wherever possible.

The various implementation partners identified for the scheme were:

- State Nodal Agencies,
- Solar Energy Corporation of India (SECI),
- System integrators/ Channel Partners,
- Financial Institutions/ Intermediaries: NABARD, NHB, SEC/IREDA other financial institutions,
- Large PSUs/Government departments

The scheme was being implemented by 31 banks through the State Nodal Agencies or Municipal Corporations, including Energy Service Company (ESCO).

Under the JNNSM Phase 2, of the actual target of installing 7 million m2 of collector area by 2013, 7.01 million m2 of collector area or 4893 MW has already been achieved. The scheme was discontinued from October 2014 for SWH. Currently there are no figures available in the public domain to indicate the impact of this program.

Financial Assistance

As per the scheme, the projects eligible for financial assistance would have a minimum size of 1000 m^2 and a maximum size of 15000, 20000 or 25000 m^2 based on the ratings of the system integrators (including manufacturers) and Renewable Energy Service Companies (RESCOs). The benchmark costs for the purpose of providing loans by Banks/FIs/IREDA would be 3.3 times of MNRE subsidy for general category states and 1.65 times for special category states.

The financial assistance under the scheme, for different categories of beneficiaries would be:

- Benchmark Cost: ETC based systems - Rs. 10000/m^2, FPC based systems - Rs. 11,000/m^2
- General category states (all beneficiaries): 30% capital subsidy or loan at 5% interest
- Special category states (domestic & non-commercial categories not availing accelerated depreciation): 60% capital subsidy or loan at 5% interest
- Special category states (commercial users availing accelerated depreciation): 30% capital subsidy or loan at 5% interest
- All loans computed at 80% of benchmark cost
- Actual subsidy:
  - ETC - Rs. 4500 per 100 lpd system in general category states and Rs. 9,000 in special category states or 30%/ 60% of benchmark cost whichever is less
  - FPC - Rs. 6600 per 100 lpd system in General category states and Rs. 13200 in special category states or 30%/ 60% of benchmark cost whichever is less

Institutional Arrangements for Implementation

For implementation of SWH under the scheme may be installed by:

- Domestic Systems, through
  - State Nodal Agencies
  - Accredited Channel Partners of MNRE

- Institutional Systems, through
  - State Nodal Agency
  - DGS & D rates,[6]
  - Accredited Channel Partners.

Provisions for various stakeholders

The plan articulates various stakeholder provisions:

Users & Motivators

- Loans at 2 to 5% interest rate for different categories,
- Users: Interest free loans to domestic users of certain States
- Motivators: Rs. 200 per 100 lpd system,
- Capital subsidy: Rs. 1750 for institutions, Rs. 1400 for commercial,
- Service charges @ Rs.100/m2,
- Direct release to Government Departments/ Public Sector Undertakings if installed for own use,
- Similar subsidy for builders and developers/ housing boards/ development authorities of institutional/ commercial establishments/ resident welfare associations (RWAs),
- Housing complexes: Rs. 1900/m2 of collector area.

Banks and Financial Institutions

- Interest subsidy and administrative charges to banks/FIs through Indian Renewable Energy Development Agency Limited (IREDA) @ 1% of loan disbursed,
- PSU banks allowed to operate intermediary scheme at 0% interest and obtain advance interest subsidy.

Manufacturers

- Can become intermediary of PSU banks/IREDA,
- Support up to Rs. 5 lakhs/year for publicity on cost sharing basis,
- Loans at 5% to approved manufacturers for technology improvements & expansion of production facilities,
- Support for study tours/ exposure visits abroad by industry delegation.

Other provisions:

- Support up to Rs. 10 lakhs for publicity campaign to banks/FIs/ intermediaries/ SNAs/ MCs/ Utilities,
- Higher monitoring charges to State Nodal Agencies (SNAs) for domestic systems (Rs. 100 per system),
- Support up to Rs. 10 lakhs to Municipal Corporations (MCs) for making amendment in building by-laws and announcing rebates in property tax,
- Support to distribution utilities for announcing rebate in electricity tariff,
- Administration charges to SNAs for assisting MCs/ utilities for announcing such rebates,
- Support up to Rs. 2 lakhs per activity for seminars/ training/ workshops/ publicity etc. to banks/MCs/SNAs,
- Support for surveys and evaluation studies.

[6] DGS&D refers to "Director General of Supplies and Disposals" (http://www.dgsnd.gov.in) They publish rate structures for common use items that are followed by all suppliers when supplying through government contracts unless a specific bidding process is launched

Provisions supportive of SWH and efficient water heaters under Energy Conservation Building Code (ECBC), 2007

The Energy Conservation Building Code (ECBC) was formally launched by the Ministry of Power, Government of India in May 2007 for its voluntary adoption in the country. The Energy Conservation Act 2001 authorized BEE to prescribe guidelines for ECBC, which sets minimum energy efficiency standard for design and construction. The main purpose of this guideline is to promote energy efficiency in the building sector in India. The ECBC is also expected to impact and promote market development of various energy efficient products including SWHs. It is enforced by the state governments and urban local bodies through notification within their states as per their regional requirements. The guidelines are applicable for new commercial buildings with connected load greater than 100 kW. The building envelope, heating, ventilation and air-conditioning (HVAC), service water heating and pumping, interior and exterior lighting, electrical power systems and motors are the focusing areas of ECBC.

The ECBC states that the service water heating equipment shall meet or exceed the performance and minimum efficiency requirements presented in the available Indian Standards. Provisions related to Solar Water Heaters includes:

- design norms for solar water heating systems for service water heating, among other systems
- residential facilities, hotels and hospitals with a centralized system shall have solar water heating for at least 20% of the design capacity (except systems that use heat recovery for 20% of the capacity)
- ECBC also specifies that where gas is available, not more than 20% of the heat shall be met from electrical heating
- SWH shall meet the performance/ minimum efficiency level mentioned in IS 13129 Part 1&2 *(these standards are under development and currently do not provide such performance/ minimum efficiency levels)*

Provisions related to Equipment Efficiency:

The ECBC states that gas instantaneous water heaters (i.e. mini domestic water heaters for use with LPG) shall meet the performance/ minimum efficiency level mentioned in IS 15558 (thermal efficiency not less than 84% when nominal heat input greater than 10 kW and not less than 82% when less than10 kW) with above 80% thermal efficiency. It also states that electric water heaters shall meet the performance/ minimum efficiency level mentioned in IS 2082 (standing loss in kWh/day for hot water temperature difference of 45deg is 0.792 for 6L rated capacity, 1.832 for 50L, 2.376 for 100L, 2.970 for 200L).

The ECBC further states that supplemental water heating systems shall (i) maximize heat recovery, (ii) use gas fired heaters where gas is available and (iii) use electric heaters as the last resort.

Table 3.10 shows the status of activities under Energy Conservation Building Code (ECBC), 2007:

Table 3.10 Status of activities under the Energy Conservation Building Code (ECBC), 2007

S.No.	Status of Activities	Name of States/UTs
1	Notification Issued – 7 States/UTs	Rajasthan, Odisha, Uttrakhand, Punjab, Karnataka, Andhra Pradesh and UT of Puducherry
2	Amended ECBC to suit their local and regional climatic condition – 9 States	Uttar Pradesh, Kerala, Chhattisgarh, Gujarat, Bihar, Tamil Nadu, Haryana, Maharashtra and West Bengal
3	In process of amendment – 7 States	Himachal Pradesh, Assam, Tripura, Mizoram, Jharkhand, Goa and Madhya Pradesh

Provisions supportive of SWH under Green Rating for Integrated Habitat (GRIHA)

The Green Rating for Integrated Habitat (GRIHA) is adopted as the National Rating System for Green Buildings by the Government of India in 2007 (100 point scale). This rating system is developed for all types of buildings in different climatic zones of the country. The criterion 19 of GRIHA applies to the Renewable Energy Based Hot Water System and states that:

- "Annual energy saved by proposed renewable energy system is 20% to 100% of annual energy required for water heating to meet the hot water requirement of the occupants in the building,"
- Non applicability condition: If hot water requirement is less than 500 liters per day,
- Worth 3 points.

Under certain optional clauses, points may also be allotted based on the annual energy saved by proposed renewable energy system as a certain percentage of the annual energy required for water heating to meet the hot water requirements of the occupants in the building:

- 20 to 50%: 1 point
- 50% to 70%: 2 points
- > 70%: 3 points

Currently, there are 575 registered projects across the country under GRIHA and another 150 are expected to be added in this year.

The current adoption pattern across India shows:

- Higher adoption of GRIHA in Northern India,
- Ministry of Environment and Forests (MoEF), Government of India – issued a memorandum to facilitate fast track environmental clearance for GRIHA pre certified projects,
- Small Industries Development Bank of India (SIDBI) – financial assistance to GRIHA building by offering concessional rate of interest (presently 50 basis points),
- Ministry of Urban Development – notification for local authorities to incentivize and provide 1% to 5% extra ground coverage and FAR for projects of more than 3000 sqm plot size on basis of GRIHA evaluation,
- Government of Sikkim – adopted GRIHA for all Government and semi-Government structures – need to conform to 3 star GRIHA rating,
- Jaipur Development Authority, Noida, Greater Noida and Department of Housing and Urban Development - Government of Punjab – notified that buildings constructed on plot area > 5,000 m2 will be eligible for additional 5% floor area ratio (FAR) free of charge if they get 4 or 5 star rating from GRIHA,
- Pimpri Chinchwad Municipal Corporation (PCMC) – incentivized developers with discounts on premium amount of building permission charges (from 10% discount for 1 star rating to 50% discount for 5 star rating); Discount of 10% in property tax for home owners.

State Based and Municipal Corporation Based Incentives on Solar Water Heaters

- About 100 Municipal Corporations / Municipal Committees / Development Authorities across several states in India have amended their building by-laws or have issued orders for offering incentives on Solar Water Heaters,
- Policy push is through subsidies/ rebates/ by mandating SWH,
- Key notifications/ orders issued in the States are given in Table 3.11,

Table 3.11 State and Municipal incentives for solar water heaters in India

State	State Subsidy	Rebate	Mandatory for
Andhra Pradesh	X	X	All high rise buildings
Assam	Rs.40 per month per 100 LPD	X	X
Chandigarh	FPC - Rs.2750 per m^2, ETC - Rs.2500 per m^2, limited to 10 m^2	X	Future buildings built on plot of >= 250 sq. yards
Chhattisgarh	Rs.25 per liter	X	☐
Delhi	Rs.6000 for residential, Rs.6000 per 100L limited to Rs. 60000 for non-residential	X	All Government buildings
Gujarat (Rajkot)	X	Annual property tax rebate: Residential - Rs.500, Commercial - Rs.1000 for five years	Rajkot city
Haryana	FPC - Rs.2000 per m^2 (max 4 m^2), ETC - Rs.1000 per m^2 (max Rs 3000/ 200 lpd)	Electricity Rebate Rs.100 per 100 liters per month	Future buildings built on plot of >= 500 sq. yards
Jammu & Kashmir	Government institutions - 60%, Commercial users - 30%	Residential – Rs.25 per month	X
Jharkhand	FPC - Rs105 per liter, ETC - Rs.80 per liter	X	X
Karnataka	X	Rs.0.50/kWh, maximum Rs.50 per installation per month	Buildings: 200 m^2 floor area / 400 m^2 site area and 500 lpd for apartments having 5 units
Kerala	Rs.3000/m^2 for residential	X	Mandatory in hotels and lodges with >= 10 rooms and in hospitals with >= 20 beds
Madhya Pradesh	Rs.750 per m^2, limited to 1000 m^2	X	X
Maharashtra	X	Property tax rebate of 5-10% in at least 6 municipalities	☐
Rajasthan	X	Rs.0.25/kWh, limited to Rs.300 per month	500 sq feet area buildings
Tamil Nadu	X	X	All districts and Municipal Corporations
Uttar Pradesh	X	X	X
Uttarakhand	X	Rs.100 per 100 liters per month	Government, residential and commercial buildings
West Bengal	institutions - Rs.1100 per m^2 collector area, Commercial - Rs.825 per m^2 of collector area	X	Rs.0.40 per kWh up to 200 kWh per month for initial 2 years

Other developments related to SWHs

The Solar thermal division of the MNRE has submitted three proposals to the National Clean Energy Fund (NCEF) to develop SWH systems which include:

- Installation of SWH systems for institutional and industrial sector in different states of the country with a cumulative area of 400,000 m^2, for 24 months → total cost Rs. 360 crores, Rs 108.00 crore approved

Table 3.12 Renewable energy tariff regulations in India

Country	India
Year	2009 (revised Nov 2010)
Policy status	In Force
Jurisdiction	National
Date Effective	2009 (revised Nov 2010)
Policy Type	Economic Instruments>Fiscal/financial incentives>Feed-in tariffs/premiums
Policy Target	Wind, Bioenergy>Biomass for power, Bioenergy>Co-firing with fossil fuels, Multiple RE Sources>Power, Solar>Solar photovoltaic, Solar Thermal
Policy Sector	Electricity
Size of Plant Targeted	Small and Large
Agency	Central Electricity Regulatory Commission (CERC)
URL	http://www.cercind.gov.in/Regulations/CERC_RE-Tariff-Regualtions_17_sept_09.pdf
Description	The CERC issued regulations in September 2009 providing guidelines on how feed-in tariff rates for renewable energy projects are to be calculated, for projects that the Commission would set tariffs for. The regulations cover all renewable energy technologies, and are to be reviewed every three years, though the first review will take place in March 2010, while benchmark capital costs for solar PV and solar thermal projects are to be reviewed every year. The tariff will be determined by taking into account the following fixed-cost components: a) return on equity; b) interest on loan capital; c) depreciation; d) interest on working capital; e) operation and maintenance expenses. The regulations specify the financial principles or assumptions of each component, some of which are technology specific (e.g. capital costs, interest on working capital). They also allow for project-specific tariffs to be determined for certain types of projects (e.g. municipal solid waste, hybrid solar thermal, certain solar PV and solar thermal), with relevant guidelines. The discount rate used in determining the tariff will be the average weighted cost of capital. The tariffs are defined as the levelised cost of energy, and are derived from the specific useful life of each technology. The feed-in tariff period for most renewable energy technologies is 13 years, extended to 35 years in the case of small hydro (below 5MW) and 25 years for solar PV and solar thermal. The regulations specify the capital and operation and maintenance costs per MWh for several technologies: wind, small hydro, solar PV, solar thermal, non-fossil fuel based cogeneration, and biomass-based power projects. Capital costs are adjusted yearly through an indexation mechanism. For wind power, the tariff will also vary based on resource intensity. Four bands of wind power density in watts/m2 give distinct capacity factors to be used in determining the feed-in tariff, as follows: - 200-250 W/m²: 20%. Levelised Total Tariff FY2011-12 of INR 5.33/kWh - 250-300 W/m²: 23%. Levelised Total Tariff FY2011-12 of INR 4.63/kWh - 300-400 W/m²: 27%. Levelised Total Tariff FY2011-12 of INR 3.95/kWh - >400 W/m²: 30%. Levelised Total Tariff FY2011-12 of INR 3.55/kWh In 2009, levelised Total Tariff FY2010-11for Solar power generation have been established as follows: -INR 17.91/kWh for solar PV projects whose PPA was signed on or before 31st of March 2011 -INR 15.31/kWh for Solar Thermal projects whose PPA signed on or before 31st of March 2011 In November 2010, the CERC adjusted levelised Total Tariffs allocated to solar power projects as follows: - INR 15.39/kWh for solar PV projects whose PPA was signed after 31st of March 2011 FY 2011-12. - INR 15.04/kWh for solar thermal projects whose PPA was signed after 31st of March 2011 FY 2011-12.

Source: http://www.iea.org/policiesandmeasures/pams/india

- Capital subsidy cum refinance scheme to be implemented by National Housing Bank (NHB) through Housing Finance Corporations (HFC)/Bank for Installation of SWH systems
- Installation of SWH systems in Domestic/Buildings sector, with cumulative collector area of 500,000 m^2 over 24 months → total cost Rs. 475 cr, Rs. 142.50 crore envisaged from MoF (approval pending)

Table 3.13 Rajasthan's Solar Policy

Country	India
Year	2011
Policy status	In Force
Jurisdiction	National
Date Effective	2011
Policy Type	Economic Instruments>Market-based instruments>Green certificates, Economic Instruments>Fiscal/financial incentives>Tax relief, Policy Support>Strategic planning, Policy Support>Institutional creation
Policy Target	Solar Thermal, Solar>Solar photovoltaic
Policy Sector	Electricity
Size of Plant Targeted	Small and Large
Agency	National Load Dispatch Centre (NLDC)
URL	http://www.rrecl.com/Solar Policy.pdf
Description	The state of Rajasthan is endowed with the highest radiation levels in India and implemented the Solar Policy to harness great untapped resources and meet its Renewable Portfolio Standard requirements. The state targets the installation of 1 to 1.2 GW of solar capacity by 2022, seeks to enhance energy security, create jobs in the solar manufacturing and become a main exporter of renewable power to third party and neighboring states. To reach such targets, the solar policy includes a combination of support tools: First, power producers are exempted from electricity duty on the energy they consume and can apply for incentives under the Industry Scheme. Producers of solar thermal energy are granted access to the water quantity required for generation by local authorities and solar power will be guaranteed grid access under both the Indian Solar Mission and the Rajasthan Solar policy. The solar policy seeks to widespread the installation of solar water heating systems on all industrial buildings where hot water is required, large residential buildings, government and private hospitals, hotels and swimming pools. Solar steam systems in residential institutions and hospitals will also be supported. Second, the solar policy creates the RE infrastructure Development Fund to finance transmission network extension, road construction and ease the integration of RE generation. Such Fund will be financed by the collection of a development charge of INR. 10 Lacs per MW installed transferred to the Rajasthan Renewable Energy Corporation. The policy also provides for the regulation framework to develop solar parks larger than 1, 000 MW capacity. Such Parks will include Solar Power Plants, Manufacturing Zones, R & D and Training Centres. Third, the Solar Policy creates the Solar Research Center of excellence. The solar policy will fulfil Rajasthan's engagements in the National Solar Mission -install 66 MW of solar capacity- and install additional capacity following a competitive bidding process. Central government will tender 50 MW of solar PV and 50 MW of solar thermal and best bidders will be guaranteed a fixed price by Discoms of Rajasthan. Moreover, the policy will promote the installation of solar PV and solar thermal plans for direct sale to Discoms of Rajasthan with a maximum capacity of 200 MW by 2013 and an additional 400 MW by 2017. Eligible projects will also be selected through auctions. The state will promote off grid and decentralized solar applications and hybrid systems in replacement of diesel based generators. The solar policy also facilitates the installation of solar power producers targeting solar power trade with third party or other states. In fact, Rajasthan aims to become a major issuer of solar Renewable Energy Certificates within the Indian Renewable Portfolio Obligation.

Source: http://www.iea.org/policiesandmeasures/pams/india

In addition, the city of Chandigarh, which is the state capital of the Punjab and Haryana, has required the mandatory use of solar water heating in industries, hotels, hospitals, prisons, canteens, housing complexes, and government and residential buildings since 2013. Table 3.12 summarizes the status of renewable electricity tariff regulations in India. While Table 3.13 and 3.14 detail Rajasthan's solar policy and the Indian National Action Plan on Climate Change respectively.

Table 3.14 India's National Action Plan on Climate Change

Country	India
Year	2008
Policy status	In Force
Jurisdiction	National
Date Effective	2008
Policy Type	Regulatory Instruments>Codes and standards
Policy Target	Solar Thermal
Policy Sector	Framework Policy
Size of Plant Targeted	Ministry of Power, Prime Minister's Council on Climate Change
Agency	http://www.pmindia.nic.in/Pg01-52.pdf
URL	http://www.pmindia.nic.in/climate_change.php
Description	http://india.gov.in/innerwin20.php?id=15651 On 30 June, India released its first National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs directed at climate change mitigation and adaptation. The plan outlines eight "national missions" running up to 2017, and ministries are directed to submit detailed implementation plans to the Prime Ministers Council on Climate Change by December 2008. The missions are wide ranging, targeting energy efficiency and renewable energy, as well as improved research capacity on climate change issues. Other missions target water efficiency, agriculture, forestation, and ecosystem conservation. The plan places a strong emphasis on solar energy in the National Solar Mission. Under the National Solar Mission, the plan includes specific goals for increasing use of solar thermal technologies in urban areas, industry and commercial establishments. It sets a goal of increasing production of photovoltaics to 1000 MW per year, and to deploy at least 1000 MW of solar thermal power generation. It also sets the objective of establishing a solar research center, increased international collaboration on technology development, strengthening of domestic manufacturing capacity, and increased government funding and international support. The plans long-term aim is to make solar competitive with fossil-based energy. The various missions each have a lead ministry, responsible for developing objectives, implementing strategies, timelines, and monitoring and evaluation criteria to be submitted to the Prime Ministers Council for Climate Change. The Council will be responsible for undertaking periodic reviews and reporting on the mission's progress. Relevant indicators, allowing assessment of both avoided emissions and adaptation benefits, are also to be developed. National Mission for Enhanced Energy Efficiency (NMEEE)

Source: http://www.iea.org/policiesandmeasures/pams/india

National Solar Mission

Officially launched in November 2009, Jawaharlal Nehru National Solar Mission (JNNSM) is one of the eight National Missions laid out in **India's National Action Plan on Climate Change (NAPCC)**. It aims to incentivize the installation of 22,000 MW of on- and off-grid solar power using both Photovoltaic (PV) Concentrated Solar Power (CSP) technologies by 2022, as well as a large number of other solar applications such as solar lighting, heating, and water pumps. As the power trading arm of the National Thermal Power Corporation (NTPC), NTPC Vidyut Vyapar Nigam Ltd (NVVN) has been designated as the nodal agency to ensure the execution of Phase 1 of the mission. The Solar Mission is to be implemented in three stages, with specific targets defined for the respective segments (see Table 3.15).

Table 3.15 Program targets of India's Jawaharlal Nehru National Solar Mission

Application segment	Target for Phase 1 (2010-13)	Target for Phase 2 (2013-17)	Target for Phase 3 (2017-22)
Solar collectors	7 million m^2	15 million m^2	20 million m^2
Off grid solar applications	200 MW	1,000 MW	2,000 MW
Utility grid power, including roof top	1,000 - 2,000 MW	4,000 - 10,000 MW	20,000 MW

USA

National macro-policy targets

The US has no quantified national target for renewable energy as a whole (REN21 2012 p122) nor for solar water heating specifically (REN21 2012 p121). Interestingly, leading publications like the DOE's Renewable Energy Databook, make no mention of renewable thermal energy (i.e. heat). The Department of Energy has a webpage that describes solar water heating (http://energy.gov/energysaver/articles/solar-water-heaters).

In addition the proposed Clean Power Plan, see http://www2.epa.gov/cleanpowerplan) requires states to reduce carbon pollution from power plants, which could include increased efficiency and renewable energy.

Urban planning and regional targets

The city of Boulder, Colorado has adopted a target for renewable energy sources to comprise 30% of all consumers' energy consumption by 2020.

Some states have also adopted solar energy policies and initiatives, most notably California as summarized in Table 3.16.

Table 3.16 The California Solar Initiative

Country	USA
Year	2007
Policy status	In Force
Jurisdiction	State/Regional
Date Effective	2007
Policy Type	Economic Instruments>Fiscal/financial incentives>Grants and subsidies
Policy Target	Solar Thermal, Solar>Solar photovoltaic
Policy Sector	Multi-sectoral Policy
Size of Plant Targeted	Small
Agency	California Public Utilities Commission.
URL	http://www.gosolarcalifornia.org/csi/index.html
Funding	Budget of USD 2,167 million (2007-2016)
	• The California Solar Initiative is part of the Go Solar California campaign and builds on 10 years of state solar rebates offered to customers in California's investor-owned utility territories: Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E). The California Solar Initiative is overseen by the California Public Utilities Commission (CPUC). This program builds on the 1998 Emerging Renewables Program (ERP) and the 2001 Self-Generation Incentive Program (SGIP). In August 2004, Governor Schwarzenegger affirmed his support for solar energy, and announced the Million Solar Roofs program, and in 2006, the CPUC developed the framework of the California Solar Initiative Program through 2016. This initiative creates a ten-year program to put solar on a million roofs in the state of California. Program components include: the Low-Income Single Family Program, the Multifamily Affordable Solar Housing (MASH) Program, the Research, Development, Deployment, and Demonstration (RD&D) Program, and the Solar Hot Water Heating Pilot Program.

Source: http://www.iea.org/policiesandmeasures/pams/US

Subsidy programs

The Database of State Incentives for Renewables & Efficiency (DSIRE) provides the best overview of support measures in the states (www.dsireusa.org). Established in 1995, the database is an ongoing North Carolina Solar Center and the Interstate Renewable Energy Council (IREC) project, funded by the US Department of Energy. However, this is a vast database that has few filters on it so it would take many days to compile a comprehensive list of any measures that may apply to solar or heat pump water heaters in the 50 US states.

Federal tax incentives and rebates

Under the American Taxpayer Relief Act of 2012 as amended in 2014 residential home owners across the US can claim a federal tax credit worth up to 10% of the purchase and install price for high efficiency residential water heaters (with a cap of $300). The credit is claimed within the annual tax return. Eligible technologies include solar water heaters, heat pump water heaters, and gas condensing boilers used for water heating. The precise wording is:

"Each American water heater model listed is a natural gas, propane, or oil water heater that has an energy factor of at least 0.82 or has a thermal efficiency of at least 90%. Accordingly, each is Qualified Energy Property and, when placed into service on or after January 1, 2014 and on or before December 31, 2014, each qualifies for the tax credit allowed under Section 25C of the

Internal Revenue Code of 30% (up to $300, subject to limitations set forth in Section 25C) of the purchase and installation (labor only) cost."

Solar Investment Tax Credit

The Energy Policy Act of 2005 (P.L. 109-58) created a 30 percent investment tax credit (ITC) for commercial and residential solar energy systems that applied from January 1, 2006 through December 31, 2007. These credits were extended for one additional year in December 2006 by the Tax Relief and Health Care Act of 2006 (P.L. 109-432).

The Emergency Economic Stabilization Act of 2008 (P.L. 110-343) included an eight-year extension of the commercial and residential solar ITC, eliminated the monetary cap for residential solar electric installations, and permitted utilities and companies paying the alternative minimum tax (AMT) to qualify for the credit. In 2009, under the American Recovery and Reinvestment Act (P.L. 111-5), the $2000 credit cap on solar hot water installations was eliminated. The Solar Energy Industries Association state,

"The solar ITC is the cornerstone of continued growth of solar energy in the United States. The ITC reduces the tax liability for individuals or businesses that purchase qualifying solar energy technologies. As a stable, multi-year incentive, the ITC encourages private sector investment in solar manufacturing and solar project construction. The ITC has been tremendously successful in increasing deployment and lowering costs of solar energy. Since the eight-year ITC was put into place, solar prices have consistently fallen year after year while installation rates and efficiencies have continued to climb. The success of the ITC shows that a stable, long-term incentive can reduce prices and create jobs in solar energy."

Instable incentives likely negatively affects investment and sales.

State tax incentives

States can offer a variety of tax incentives to residents and businesses helping reduce upfront cost burdens for new installations. Incentives can include personal, corporate, sales, and property tax incentives. Tax incentives were enacted in at least five states: Florida, Georgia, Iowa, Maryland (House Bill 510 and House Bill 786) and Missouri. In Missouri, for example, legislation reauthorized an income tax deduction for energy efficiency audits and the implementation of recommended products through 2020. While these tax incentives may be structured to apply to high efficiency or solar water heaters there is no readily compiled list available that enables the actual situation across the US to be known.

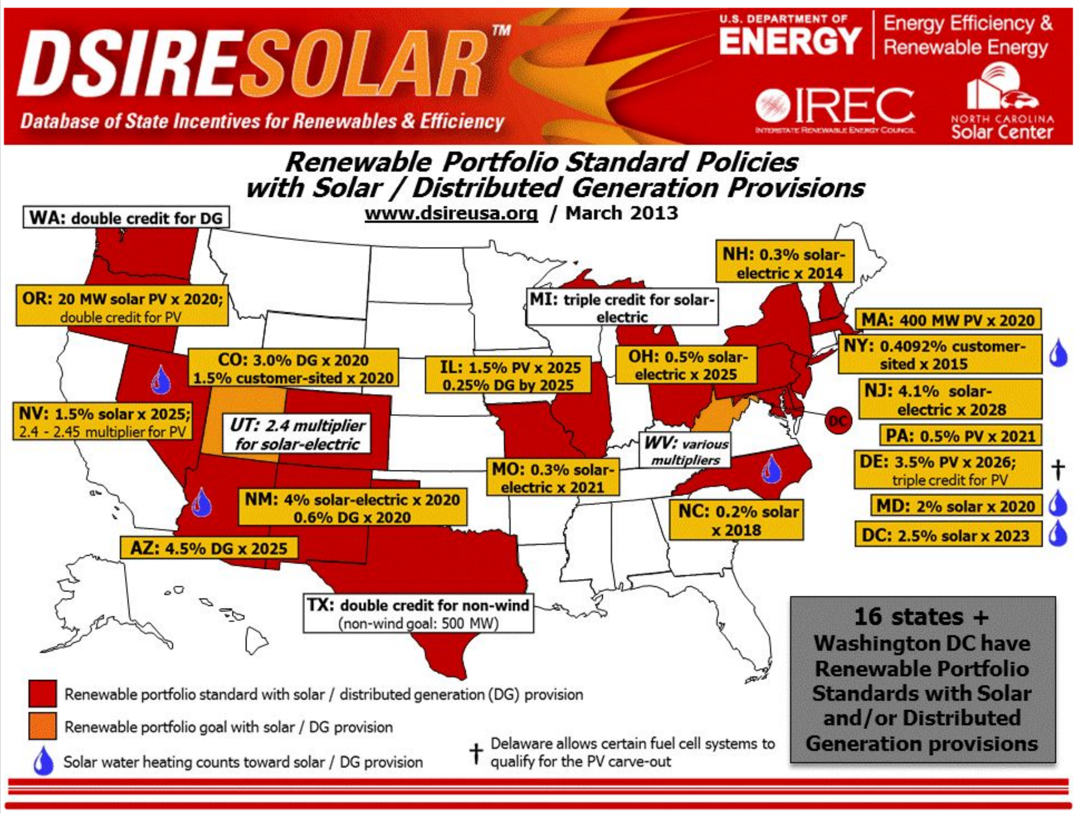
Renewable energy portfolio standards

In a few states, such as Arizona, Ohio, or North Carolina, solar thermal systems are also accepted in fulfilling the Renewables Portfolio Standards (RPS). RPS require all utilities in a state to supply a certain amount of electricity from renewable energy sources, for example 12.5% in 2020 in North Carolina. However, while RPS are quite common it is less common for them to include thermal applications such as solar thermal water heating.

Generally RPSs are most successful in stimulating renewable energy projects when combined with the federal production tax credit. States often design them to drive a particular technology by providing "carve out" provisions that mandate a certain percentage of electricity generated comes from a particular technology (e.g. solar or biomass). States may choose to apply the RPS requirement to all its utilities or only the investor owned utilities. Equally states also define what technologies are eligible to count towards the RPS requirements.

A snapshot of the situation in 2013 is shown in Figure 9 below. Most of the measures indicated appear to be purely electric orientated and hence presumably do not include solar thermal.

Figure 9. Renewable Energy Portfolio Standards in the US



Source: http://www.dsireusa.org/

Currently some twenty-nine states, Washington, DC, and two territories have requirements for utilities renewable portfolio standards and another eight states and two territories have established voluntary targets for utilities. Renewable energy producers may earn renewable energy credits (RECs) for electrical generation from renewable energy sources. REC ownership can be important in meeting RPS goals, whether the requirements are for distributed generation users, or utilities and cooperatives. In the 2014 legislative session at least 14 states and Washington, DC enacted legislation concerning RPS or REC policies, including California, Connecticut, Illinois, Maryland, Massachusetts, New Hampshire, New Mexico (House Bill 232 and companion Senate Bill 49), Ohio, Oregon (House Bill 4126 and Senate Bill 1520), Rhode Island (House Bill 8200 and companion Senate Bill 2692), Utah, Virginia (House Bill 822 and companion Senate Bill 498), Vermont, Washington (House Bill 2708 and House Bill 2733), Wisconsin (Assembly Bill 594 and Assembly Bill 596), and Washington, DC.

Most of these measures are thought to only apply to renewable electricity generation but some do include solar thermal. For example, a Massachusetts bill authorized renewable thermal technologies to qualify for alternative energy credits under the state Alternative Portfolio Standard. Legislation includes renewable thermal technologies such as solar heating and cooling, biofuels, wood pellets, wood chips, renewable natural gas, and geothermal and air source heat pumps.

Energy efficiency resource standards and targets

Some twenty-four US states are currently implementing long-term, binding energy savings targets. States have taken a variety of approaches to setting targets, including passing legislation to enact formal energy efficiency resource standards, setting long-term energy savings targets through utility commissions tailored to each utility, or incorporating energy efficiency as an eligible resource in renewable portfolio standards (RPS). The measures included can include measures designed to improve the efficiency of both electric and gas applications and hence may be applied to support both heat-pump and solar water heaters. In 2015 fifteen of the twenty four states with such measures in place included measures applicable to natural gas savings as well as electricity savings.

Some recent developments include:

- In Hawaii a recent bill requested the Public Utilities Commission and the Department of Business, Economic Development and Tourism to develop a forecasting program to better align energy efficiency and renewable energy efforts with technological innovations. Another bill re-established the Energy Systems Development Special Fund for developing an integrated approach to management of renewable energy and energy efficiency technology projects.
- Recent legislation in Vermont established that excess amounts raised from the energy efficiency charge will be used for thermal energy efficiency programs.

Building codes

Currently, forty-three states, Washington, DC, and four territories have state building energy codes for residential buildings. In the 2014 legislative session, at least 10 states and Washington, D.C., enacted legislation to modify building energy codes, including Alaska, Connecticut, Florida, Hawaii, Idaho, Illinois, Mississippi, North Carolina, New Hampshire, South Carolina, and Washington, DC. It is not known if any of these codes give recognition to the contribution that could be made by solar water heaters or heat pump water heaters.

Financing of energy efficiency

Financing can help eliminate upfront cost barriers to energy efficiency by allowing consumers to complete energy efficient upgrades and then pay installation and technology costs over a longer time frame. Energy performance contracting, on-bill financing or on-bill repayment, Property Assessed Clean Energy (PACE) financing, “green” state energy banks, bonds, loans and tax incentives are some of the vehicles states are using to achieve this.

At least five states enacted legislation concerning energy savings performance contracts, also known as guaranteed energy savings contracts: Colorado, Kentucky (House Bill 235 and Senate Bill 70), Mississippi, New Mexico, and North Carolina.

A bill in Colorado permitted the aggregation of energy efficiency or renewable energy projects in small or rural communities or schools to better attract private sector financing through energy service companies.

Legislation in Mississippi authorized state agencies and public universities to enter into energy savings performance contracts for up to 20 years.

California and Minnesota enacted legislation concerning on-bill financing or on-bill repayment programs. While California legislation expanded on-bill financing programs to include water efficiency, a Minnesota bill authorized on-bill repayment for all electric and gas utility customers for energy conservation improvements and certain renewable energy sources.

At least six states enacted legislation concerning Property Assessed Clean Energy (PACE) financing in the 2014 session. Bills were enacted in California (Assembly Bill 1883 and Assembly Bill 2597), Connecticut, Delaware, Maryland (House Bill 202 and companion Senate Bill 186), New Hampshire, and Oregon. Bills in California, New Hampshire, and Oregon concerned the mortgage underwriting in residential PACE programs. Several states are attempting to renew or modify residential PACE following Federal Housing and Finance Administration opposition to the primary underwriting of PACE loans.

At least six states enacted legislation for bonds or loans to increase energy efficiency financing. Florida, Kentucky, Minnesota, and Oregon enacted bond-related legislation for energy efficiency, while Maryland (House Bill 553, House Bill 1165 and Senate Bill 875), Minnesota and Vermont enacted loan-related legislation for energy efficiency.

Legislation in Maryland establishes an energy efficient home construction loan program and fund. A Vermont bill granted the state treasurer flexibility in structuring a credit facility through the Vermont Economic Development Authority to provide funds for sustainable energy projects through the Vermont Clean Energy Loan Fund.

State energy banks are public-private partnerships that combine public funding with private capital and expertise to promote renewable and efficient energy technology. In the 2014 legislative session, Maryland enacted legislation requiring the state Clean Energy Center, in collaboration with the Energy Administration, to conduct a study of green banks and clean bank financing initiatives. The legislation required the Clean Energy Center to consult with specific entities and requires a report be submitted to the legislature before December 2015.

US policies summary

Despite the plethora of policy measures in place that support higher efficiency water heaters the residential solar water heater market in the US remains under-developed and the heat pump water market is in its infancy. Even gas is underdeveloped in relation to its potential. In the case of solar thermal energy, such as water heaters, the Solar Energy Industries Association has called for the following measures:

- Extend the 30% federal ITC (expires 2016),
- Include SHC technologies as generating technologies to be eligible for Solar Renewable Energy Credits (SRECs) or Renewable Energy Credits (RECs) in state and federal Renewable Portfolio Standards (RPS) or Clean Energy Standards (CES),
- Establish a thermal RPS on a state and/or federal level,
- Adopt strong building energy codes that encourage builders to include SHC on new buildings,
- Implement section 523 of the 2007 Energy Act, requiring 30% of the hot water demand for all new or renovated federal buildings to come from solar energy,
- Establish strong manufacturing incentives (48c extension or additional funding),
- Increase workforce training for SHC,
- Continue to allow SWH to qualify for the ENERGY STAR label. As of May 2012, there were already 493 ENERGY STAR-certified solar water heating models.

4 Policy gap analysis

Understanding the most appropriate policy mixes requires an appreciation of the local barriers to the adoption of cost-effective low carbon technology solutions in the market in question. Cultural, social, historical, and economic differences between China, India, and the US mean that different sets of measures are required to stimulate a shift from low efficiency resistance electric water heating to lower life cycle cost, lower carbon emitting alternatives. Nonetheless some generic barriers and objectives can be determined across all these markets. The text below indicates the policy tools which are available to address barriers and objectives across all markets. It also indicates the extent of deployment of these policies in the three target economies of China, India and the USA.

By way of context Table 4.1 indicates the 2013 or 2012 market shares by type of water heater in the three target economies (see Appendix A3 for details).

Table 4.1 Water heater market shares in the three economies

	China 2012	India 2012	USA 2013
Solar	35.7%	13.8%	0.6%
Heat pump	1.2%	0.0%	1.5%
Gas Instantaneous	20.7%	9.8%	14.2%
Gas Storage	0.4%	0.0%	38.1%
Gas Combi	2.5%	0.0%	0.0%
Electric Instantaneous	2.9%	21.7%	0.0%
Electric Storage	36.6%	54.8%	45.4%
Oil	0.0%	0.0%	0.2%

Visibility

Barrier:
The relative energy performance of water heaters needs to be made apparent to consumers if they are to be able to make an informed choice about the best technology for their needs.

Objectives:
For consumers to be able to readily compare the energy efficiency of water heating provided by different product models within and across technology and fuel types.

Related issues:
Does the comparison take account of losses due to the production and distribution of energy? Is it possible to compare water heater types based on their expected life cycle economic performance? Is it possible to compare water heater types based on their expected environmental impacts?

Policy tools to address across-technology/fuel comparative performance visibility

- Energy labels that measure and rank how much non-renewable energy is needed to provide the water heating service e.g. as per the EU energy label

Policy tool	China	India	USA
Voluntary energy labels to allow comparison across water heater technology	No	No	No
Mandatory energy labels to allow comparison across water heater technology	No	No	No

- Public-sector managed product efficiency rating databases that rank water heaters in terms of their primary (commercial) energy demand

Policy tool	China	India	USA
Product efficiency rating databases that rank all water heaters in terms of their primary energy demand	No	No	Partial[1]

[1]DOE Appliance Standards Compliance Certification Database lists by energy factor all residential water heaters except solar. http://www.regulations.doe.gov/certification-data/CCMS-79222842113.html

Policy tools to address within-technology types/fuel comparative energy performance visibility

Policy tool	China	India	USA
Voluntary energy labels to allow comparison among gas storage water heaters	No	No	Yes[1]
Mandatory energy labels to allow comparison among gas storage water heaters	No	No	Yes
Voluntary energy labels to allow comparison among electric storage water heaters	Yes	Yes but not including HPWHs	Yes for HPWHs only[1]
Mandatory energy labels to allow comparison among electric storage water heaters	Yes but HPWHs have a separate label and scale	Yes but not including HPWHs	Yes including HPWHs
Voluntary energy labels to allow comparison among gas instantaneous water heaters	Yes	No	Yes[1]
Mandatory energy labels to allow comparison among gas instantaneous water heaters	Yes	No	Yes
Voluntary energy labels to allow comparison among electric instantaneous water heaters	No	No	No
Mandatory energy labels to allow comparison among electric instantaneous water heaters	No	No	Yes[2]
Voluntary energy labels to allow comparison among solar water heaters	Yes	No	Yes[1]
Mandatory energy labels to allow comparison among solar water heaters	Yes	No	No

[1] The Energy Star label is applicable for solar water heaters with electric or gas back-up, for storage HPWHs and for gas water heaters (storage or tank-less types) but it only provides a binary energy performance comparison i.e. a product either meets the minimum specification and is eligible for the Energy Star label or it doesn't.
[2] DOE Appliance Standards Compliance Certification Database lists by energy factor all residential water heaters except solar. http://www.regulations.doe.gov/certification-data/CCMS-79222842113.html

- Public-sector managed product efficiency rating databases that rank water heater energy performance for specific water heater types

Policy tool	China	India	USA
Efficiency rating database to allow comparison among gas storage water heaters	No	No	Yes[1,2]
Efficiency rating database to allow comparison among electric storage water heaters	Yes	Yes but not including HPWHs	Yes for HPWHs only[1,2]
Efficiency rating database to allow comparison among gas instantaneous water heaters	Yes	No	Yes[1,2]
Efficiency rating database to allow comparison among electric instantaneous water heaters	No	No	Yes[2]
Efficiency rating database to allow comparison among solar water heaters	Yes	No	Yes[1]

[1] The Energy Star label database is applicable for solar water heaters with electric or gas back-up, for storage HPWHs and for gas water heaters (storage or tank-less types) but it only provides a binary energy performance comparison i.e. a product either meets the minimum specification and is eligible for the Energy Star label or it doesn't.

[2] DOE Appliance Standards Compliance Certification Database lists by energy factor all residential water heaters except solar. http://www.regulations.doe.gov/certification-data/CCMS-79222842113.html

Summary and conclusions

None of the economies considered have implemented energy labeling that allows performance comparisons to be made across water heater technology types. As a result, the solar and heat pump water heater advantages are not made clear to end users. Nor are the primary energy advantages of gas compared to electric water heaters apparent.

Both China and the US have energy labels for most types of water heater technologies. China is missing energy labels for gas storage water heaters (presumably because these have negligible market presence) but does have them for solar water heaters. China's electric storage water heater label is distinct from its heat pump electric storage water heater label and hence it is not possible for consumers to compare the performance of electric storage water heaters across a single scale.

India has the least developed labeling program, which currently only applies to electric storage water heaters. Other types of water heater have smaller market shares but with the development of the solar market and of the gas network it is likely these water heaters will become much more prominent. Similarly there is currently no part of the labeling scale for electric storage water heaters that reflects the performance heat pump water heaters can attain.

The US has technology-specific mandatory energy labels for all types of water heater except solar water heaters. Different labels and energy performance scales are used for water heaters using different fuel types and depending on whether they are instantaneous or storage type – however, all electric storage water heaters, whether using simple resistance heating or heat pumps are ranked on the same label scale. The voluntary Energy Star label is applied to all types of water heater except electric instantaneous or storage (if using resistance heating) but it does not permit the relative performance of products to be compared, just whether they are eligible for the label or not.

Ensuring up-front costs are affordable for consumers

Barrier:
Consumers are deterred from investing in higher energy efficiency water heaters due to their high initial cost.

Objective:
Measures to be put in place which lower this barrier by reducing the incremental initial cost of energy efficient water heaters compared to conventional water heaters.

Issues:
This barrier may not just be a question of whether consumers have enough means to pay for a product but also how they perceive the initial cost compared to competing technologies and how they perceive the operating costs compared with competing technologies. The perception of investment risk is also important e.g. concerns that the investment may not pay back at all (because the technology doesn't perform as well as it is claimed to do), or that it doesn't pay back soon enough because, for example, the homeowner moves prior to securing a return on their investment.

Some water heaters, notably solar and heat pump types, are usually significantly more expensive than the other water heater types they compete with. Consumers can be:

a) unaware of the magnitude of life cycle economic benefits that they offer,
b) unable to pay the additional upfront costs, or
c) unwilling to pay the incremental costs because the benefit risk ratio is not deemed to be high enough.

With these scenarios, it can be appropriate to create subsidies and/or financing mechanisms to encourage their adoption. Such incentives will not usually apply to standard resistance electric or gas storage water heaters with somewhat lower losses than typical products or to non-solar instantaneous water heaters as there are only relatively modest differences in performance between different models of these water heaters.

Policy tools to address the affordability of energy efficient water heaters

- National-scale subsidies (rebates) for energy efficient water-heater types

Policy tool	China	India	USA
National level subsidies for gas storage water heaters	Yes[1]	No	No
National level subsidies for electric storage water heaters	No	No	No
National level subsidies for HPWHs	Yes[1]	No	No
National level subsidies for gas instantaneous water heaters	Yes[1]	No	No
National level subsidies for electric instantaneous water heaters	No	No	No

[1]These subsidies ended in 2013

[2]however, these are mentioned in the Jawaharlal Nehru National Solar Mission (JNNSM) launched in 2010

- National-scale tax credits for energy efficient water-heater types

Policy tool	China	India	USA
National tax credits for gas storage water heaters	No	No	No
National tax credits for electric storage water heaters	No	No	No
National tax credits for HPWHs	No	No	No
National tax credits for gas instantaneous water heaters	No	No	No
National tax credits for electric instantaneous water heaters	No	No	No
National tax credits for solar water heaters	No	No[1]	Yes

[1]Tax credits are mentioned as an objective in the Jawaharlal Nehru National Solar Mission (JNNSM) launched in 2010 but implementation seems to be focused at the state and municipal level.

- Local-scale subsidies (rebates) for energy efficient water-heater types

Policy tool	China	India	USA
Local level subsidies for gas storage water heaters	No	No	No
Local level subsidies for electric storage water heaters	No	No	No
Local level subsidies for HPWHs	No	No	Yes in some regions
Local level subsidies for gas instantaneous water heaters	No	No	No
Local level subsidies for electric instantaneous water heaters	No	No	No
Local level subsidies for solar water heaters	Yes in some regions	Yes in some regions	Yes in some regions

- Local-scale tax credits for energy efficient water-heater types

Policy tool	China	India	USA
Local level tax credits for gas storage water heaters	No	No	No
Local level tax credits for electric storage water heaters	No	No	No
Local level tax credits for HPWHs	No	No	Tbc
Local level tax credits for gas instantaneous water heaters	No	No	No
Local level tax credits for electric instantaneous water heaters	No	No	No
Local level tax credits for solar water heaters	No	Yes in two states	Yes in some regions

- Financing instruments for energy efficient water-heater types

To address the issue of the small up-front cost, solar integrators, and public policymakers have developed a number of financing options for solar water heaters.

In the US these include:

- Property-Assessed Clean Energy (PACE) – wherein the up-front cost is paid by a local government fund and repaid by the homeowner through property taxes
- Solar Renewable Energy Certificate (SREC) – in those states in which solar water heaters qualify as a generating technology for SRECs, the value of the SREC sold can help to offset the cost of the system
- Power-Purchase Agreements (PPA) – wherein the customer purchases only the thermal energy generated from the system.

Information is still to be collected on such schemes in India and China; however, the establishment of such schemes are mentioned in India's Jawaharlal Nehru National Solar Mission (JNNSM) launched in 2010.

Summary and conclusions

All of the economies have some economic incentives in place for solar water heaters; however, these have only been in place at the national scale, at a significant level and for a sustained period of time in China. This is the main reason given for why the penetration of solar water heating (at ~65% of all domestic water heaters) is so much higher in China than the other two markets. It is clear that to stimulate the market for solar water heaters subsidies/rebates/financing instruments are needed to significantly reduce the incremental first cost of solar compared to competing water heater technologies and to remove risk for the end-user. To make a significant difference to the market share taken by solar these financial incentives and financing mechanisms need to be sustained for some considerable period of time. However, as the market develops incentives can and should be structured to reduce as consumer familiarity and acceptance of technology increases. Incentives should reduce at an accelerated rate as the market volume accelerates the learning curve for the cost of deployment. Extra sales volumes help foster economies of scale in manufacturing (turning solar water heaters from an SME to consolidated industrial production activity) as well as the costs of installation (noting that installer costs are a significant part of the overhead for solar water heaters and are quite sensitive to scale).

In the US the current federal tax credits for solar water heaters which are valued at 30% of the system cost are due to expire in 2016. In China the long-running national level subsidies for gas, heat-pump, and solar water heaters all ended in 2013. A difference in these two cases; however, is that the US tax credits are relatively recent in origin and have not been in place long enough to make a serious difference to the size of the market. The Chinese incentives were sufficient and sustained long enough to help stimulate a transformation in the Chinese market.

Awareness

Barrier:
Consumers are likely to be unaware of the value proposition of investing in higher efficiency water heaters.

Objective:
Inform consumers of the value proposition of higher efficiency water heaters.

Issues:
To inform consumers of the benefit-cost ratios, the magnitude of savings, the pay back periods of the characteristics of higher efficiency water heaters.

Awareness raising of these issues often doesn't receive significant policy attention. It is an important factor in whether consumers are likely to feel motivated to make an investment in a higher efficiency water heating technology or not. It is often assumed to be the normal commercial role of the water heater vendors to make the case for the value proposition. When industries are nascent or stagnated at a small scale they often lack the means to reach a large audience and make the case effectively. Furthermore, public trust of the value proposition message is not likely to be as high as when the message is delivered by a respected independent third party. In principle, government can do a lot to raise awareness of the value proposition of a technology class and can help to promote the sector.

Policy tools to address consumer awareness of energy efficient water heaters

- Awareness raising campaigns

Details of any substantial efforts regarding awareness raising in the target economies have been difficult to obtain. Promoting energy efficient water heaters is mentioned in India's Jawaharlal Nehru National Solar Mission and some activity has certainly occurred at the state and local level. Few details are available regarding Chinese awareness programs although it seems highly likely that awareness campaigns have been launched there. In the USA, the Consortium for Energy Efficiency has funded a Coalition for Energy Star Water Heaters for this purpose.[7]

[7] http://www.eswaterheaters.com

Summary and conclusions
Each of the Chinese, Indian, and US governments have implemented some awareness raising measures for solar water heating and in the case of China and the US heat pump water heaters, but these measures have been of a modest scale. In the case of the US many of the promotional efforts managed at the Federal level seem to be aimed at practitioners or relatively well engaged consumers rather than at the public at large.

Quality

Barrier:
Poor quality products risk poisoning the market for high efficiency water heaters by eroding consumer confidence.

Objective:
Establish a quality scheme that either indicates that minimum quality levels have been obtained or makes quality apparent to consumers on a scale.

Issues:
Is it possible and simple to distinguish product quality prior to purchase? Are products with unacceptable product quality available on the market? Is the right balance struck between supporting product quality and consumer expectations with respect to price, longevity and service?

Policy tools to address the quality of energy efficient water heaters

- National-scale quality assurance schemes

Policy tool	China	India	USA
National-scale quality assurance for gas storage water heaters	No	No	Yes[2]
National-scale quality assurance for electric storage water heaters	No	No	Yes[2]
National-scale quality assurance for HPWHs	No	No	Yes[2]
National-scale quality assurance for gas instantaneous water heaters	No	No	No
National-scale quality assurance for electric instantaneous water heaters	No	No	No
National-scale quality assurance for solar water heaters	Yes – government led	Some development[1]	Yes – industry led

[1]Establishment of a SWH quality scheme is mentioned as an objective in the Jawaharlal Nehru National Solar Mission (JNNSM) of 2010. The Bureau of Indian Standards has developed some standards but the implementation status is unclear. Also the MNRE has issued standards for evacuated tube collectors (ETCs) and associated solar water heaters http://mnre.gov.in/schemes/decentralized-systems/solar-systems/solar-water-heatres-air-heating-systems/

[2] The Energy Star program includes minimum warranty and other quality requirements for eligible products; however, engagement is voluntary.

Summary and conclusions
All of the economies have some quality schemes in place for solar water heaters. In the US this is privately run by the industry association. In India it is administered by the Bureau of Indian Standards and in China by government entities. Questions remain about the appropriateness and adequacy of these quality schemes. In the US there was reported to be delays in getting certification (now seemingly resolved) that created an obstacle to receiving rebates and tax credits tied to this certification and hence which may have been an anchor on the market. The high emphasis on quality certification in recent times. However, was a rational reaction to a legacy of

an earlier period when solar was subsidized without being quality-assured which led to a poor public image due to poor quality installations. Reports on the appropriateness and usefulness of the Chinese and Indian schemes seem to be somewhat mixed. The Chinese scheme seems to be better established and the Indian scheme newer and less proven.

Convenience

Barrier:
There are many potential barriers that may hinder the convenience of high efficiency water heaters.

Objective:
Implement actions to improve the convenience of acquiring and using high efficiency water heaters or mandate their use in cases where the inconvenience of switching to the higher efficiency option is surmountable and not unreasonable.

Issues:
Determine what barriers need to be addressed so that higher efficiency products can be procured and installed. Is it sufficiently simple for end-users to procure and have them installed? Is the higher efficiency option a practical choice in distress replacement sales i.e. when an existing water heater fails? Can it be installed in the available space without major work? Will it function in the way intended in the site available? Are suitable back-up energy sources available for solar water heating? Is the orientation appropriate for solar water heating? Are there adequately qualified professionals to help specify the water heater and install it?

Mandatory policy tools to address convenience of energy efficient water heaters

Mandating the installation of high efficiency water heaters is the main policy tool used to ensure that high efficiency water heaters are installed regardless of any short-term inconvenience issues. Mandated measures can take the form of: prohibiting inefficient water heaters from sale, prohibiting low efficiency water heaters from being installed, or requiring certain high efficiency technologies, such as solar water heaters, to be installed.

- National-scale MEPS across water heater technology types

Policy tool	China	India	USA
National-scale MEPS across water heater types	No	No	No

- National-scale MEPS for specific water heater technology types

Table 4.2 Water heater MEPS by economy

Type	China	India	USA
Gas storage	N	N	Y
Gas instantaneous	Y	N	Y
Combi-boilers	Y	N	N
Electric storage	Y	N	Y
Electric instantaneous	N	N	N
Electric heat pump	Y	N	Y
Oil Storage	N	N	Y
Solar water heater system	Y	N	N
Solar collector	N	N	N
Solar tank	N	N	Y
Tank (Unvented)	N	N	N
Total types with MEPS (of 11)	5	0	6

- National-scale building codes or solar ordinances mandating high efficiency water heater technologies

Policy tool	China	India	USA
National-scale building code/ordinances mandates	No	No[1]	No[2]

[1]An objective of making SWHs mandatory within the national building code (which itself is currently voluntary) is mentioned as an action item in the Jawaharlal Nehru National Solar Mission (JNNSM) launched in 2010; however, in practice it only seems to be being applied at the local level currently.

[2]The exception is section 523 of the 2007 Energy Act, which requires 30% of the hot water demand for all new or renovated federal buildings to come from solar energy; however, this is not aimed at domestic water heaters and does not appear to be implemented.

- Local-scale building codes or solar ordinances mandating high efficiency water heater technologies

Policy tool	China	India	USA
Local scale mandates	In some regions[1]	In some jurisdictions[2]	No

[1]Some Chinese provinces and municipalities have implemented mandatory solar ordinances and/or provisions in building codes that require SWH to be installed before the building can be sold.

[2]An objective of making SWHs mandatory within the national building code (which itself is currently voluntary) is mentioned as an action item in the Jawaharlal Nehru National Solar Mission (JNNSM) launched in 2010; however, in practice it only seems to be being applied at the local level currently.

Summary and conclusions
Both China and the US have extensive MEPS applying to specific water heater technologies but India does not yet have these. None of these economies have implemented MEPS that apply across water heater types and is based on ensuring that no water heaters are used that are less than a certain efficiency.

Only China and India have local solar ordinances or building codes in place that require solar water heating to be installed and the scope of application of these measures varies. They are more common in China than India and currently only affecting a modest proportion of the total building stock. Such ordinances are likely to be more effective at transforming the market when there is significant new build and low levels of water heater adoption and less so when it a predominantly replacement market with existing incumbent technologies. Such measures are also more politically and socially acceptable in economies with traditions of central planning and/or where water heating is a newer service.

Public expectation and acceptance

Barrier:
The public is most used to the means they have always used for heating water and may be sceptical about adopting higher efficiency solutions if these seem less certain, carry perceived risks, or are deemed to have negative associations.

Objective:
Implement actions to improve public acceptance of the higher efficiency water heater technologies.

Issues:
Addressing public expectations for water heating technology may be a bigger barrier to address in affluent economies with a long history of commercial-energy based water heating than in those where this is a relatively new service without strong preferences and expectations having been established.

- Promotional campaigns for high efficiency water heater technology types

Promotional campaigns for high efficiency water heaters (especially solar) have been run in all the target economies but they have not been sustained except for in China. Some local campaigns have been run in India but the impact of these is not reported.

Summary and conclusions
Addressing the public perception of solar water heating to encourage people to view it as a desirable good is an essential part of increasing adoption levels in any market. Among the three markets the US is the one where the most work is needed as there is presently very modest demand for solar domestic hot water heating. Improving the image of the technology and positioning it as a desirable and self-evident choice is therefore a priority.

Industrial and supply chain capacity

Barrier:
Supply chains for the production, distribution, and installation of high efficiency water heaters lack development. In addition testing facilities may be limited in some instances.

Objective:
Implement actions to strengthen all aspects of the supply chain so that good quality high-efficiency water heaters are routinely available.

Issues:
Is the supply chain sufficiently developed to provide and install reliable and quality products to the market at large? Is the supply chain sufficiently developed for the costs of installing such systems to be acceptable due to economies of scale?

- Policy measures to strengthen industrial supply chains for high efficiency water heater technologies

Policy tool	China	India	USA
Industrial and supply-chain support measures	Apparent evidence of an industrial strategy	Limited	Limited

Summary and conclusions
China appears to be the only economy that has implemented significant policies to support the development of the industry and supply chain for water heaters (specifically for solar water heaters). For example, the significant subsidies offered for solar water heaters have been tied to requirements regarding meeting minimum domestic production volumes, elevated minimum energy performance levels and having a fully integrated distribution network and minimum sales-force capacity. In addition, quality of the supplier must be assessed annually under the National Quality Supervision scheme and have no negative inspection reports over the last three years. These measures seem to have helped stimulate higher quality and better performance but also to have ensured that the supply chain is properly operational, while encouraging more professionalism and scale in the sector. Reports on the industry structure indicate that solar water heater producers have been integrating in recent years and much more concentration has occurred in the sector. By contrast the US DOE prepared industry road-maps and helped foster some federal tax relief for suppliers of solar water heaters. Otherwise the Federal and State administrations have not used economic instruments in such a holistic manner to strengthen the solar water heating sector.

Legal and administrative constraints

Barrier:
Legal barriers may limit the deployment of high efficiency water heaters. These can take many forms such as how to agree to use a roof space in a multiple-tenant residences, local community aesthetic specifications, inappropriate constraints affecting the supply for backup energy and wiring; constraints on how ESCOs and energy performance contracting my operate and finance energy efficient solutions, etc. Equally administrative requirements may be burdensome and add cost to the sector and product.

Objective:
Ensure legal and administrative constraints are not unnecessarily burdensome.

Issues:
Determining the nature and importance of these factors normally requires close cooperative work with those involved in the supply and installation of energy efficient water heaters. Such barriers can be due to legal or administrative requirements specified at the national level but more commonly they will be local requirements.

- Policy measures to ameliorate legal and administrative barriers to the deployment of high efficiency water heater technologies

Policy tool	China	India	USA
Actions to target legal and administrative barriers	Some measures	Some measures1	Limited

[1]The need to address this issue is mentioned in the 2010 Jawaharlal Nehru National Solar Mission

Summary and conclusions

These measures can be very important for some markets but are usually needed to address local issues.

Generic policy frameworks

Is there a high degree of inertia in the existing market environment that needs to be overcome for the deployment of high efficiency technologies?

There are a variety of relevant generic policy frameworks that can be used to encourage deployment of energy efficient water heating technology and especially solar water heaters. These include:

- Renewable energy targets
- Energy efficiency targets
- Renewable heat incentives
- Renewable heat obligations
- Renewable energy portfolio standards or obligations for utilities
- Energy efficiency portfolio standards or obligations for utilities
- Renewable energy credits
- Renewable energy certificate schemes
- Energy efficiency certificate schemes (white certificates or tags)
- Building energy codes
- Building energy performance certificates or disclosure
- Solar energy obligations

In each case these can be structured to create either an incentive or an obligation to install more efficient or renewable energy based water heaters. The status of adoption of these policy measures in the target economy is indicated in Table 4.3.

Table 4.3 Summary of generic policies that could be applied to high efficiency water heaters

Policy tool	China	India	USA
National renewable energy targets	Yes	India	No
National energy efficiency targets	Yes	Yes	No
Renewable Heat Incentives	No	No	No
Renewable Heat Obligations	No	No	No
Utility Renewable Energy Portfolio Standards or Obligations	Some	No	Some
Utility Energy Efficiency Portfolio Standards or Obligations	Some	No	Some
Renewable Energy Credits	No	Some	Some
Renewable Energy Certificate Schemes	No	No	Some
Energy Efficiency Certificate Schemes (White Certificates or Tags)	No	No	Some
Building Energy Codes	Yes	No	Some
Building Energy Performance Certificates or Disclosure	Some	Some	Some
Solar Energy Obligations	Some	No	One

Some of these measures may exist but are not necessarily established in a manner that supports high efficiency water heaters. For example, utility renewable energy portfolio standards may be structured such that they only focus on renewable electricity supply rather than renewable thermal energy supply, thus they may favor heat pump water heaters but not solar thermal water heaters. Equally building codes may be structured so they give no incentives to renewable energy sources or to the efficiency of installed equipment, such as water heaters. Thus, the strength of impact of such measures very much depends on the details embedded within them.

Summary and conclusions

The generic policies mentioned above can be extremely powerful tools to support the development of energy efficient water heating technology. However, they are generally motivated by a much broader array of concerns and in consequence water heaters can be overlooked unless efforts are made to ensure they are included. Renewable Heat Incentives or Obligations are an exception to this in that they will always include solar thermal energy and probably also heat pumps. These are a relatively recent innovation internationally and do not yet seem to have been adopted in any of the target economies.

05 Potential for Energy Savings

Each of the three economies considered has a significant potential for additional fossil fuel energy savings from the adoption of more efficient water heater technology than is the current norm. To assess this potential detailed bottom-up water heater stock models have been developed for each economy and used to analyze specific scenarios. These bottom-up vintage stock models are well-suited to analyze the energy, economic, and environmental implications of changes in the water heater stock. They also integrate key drivers of demand to reflect the sensitivity of future market growth and consumer choices to: macro-economic and demographic trends, the initial cost of water heater technologies, and fuel costs. They are also adapted to consider the potential impact of economic incentives on high efficiency water heater adoption rates.

For each economy the following scenarios are considered:

- The Business as Usual (BAU) scenario which projects expected energy consumption by residential water heaters under the existing policy conditions and market trends
- The Least Life Cycle Cost (LLCC) scenario which projects residential water heater energy consumption were technologies to be systematically chosen that minimized the life cycle costs of the water heaters to the household
- The Recommended Policy (Policy) scenario which considers what would be expected to happen were the recommended policy packages set out in Chapter 6 to be adopted.

Market conditions and key assumptions

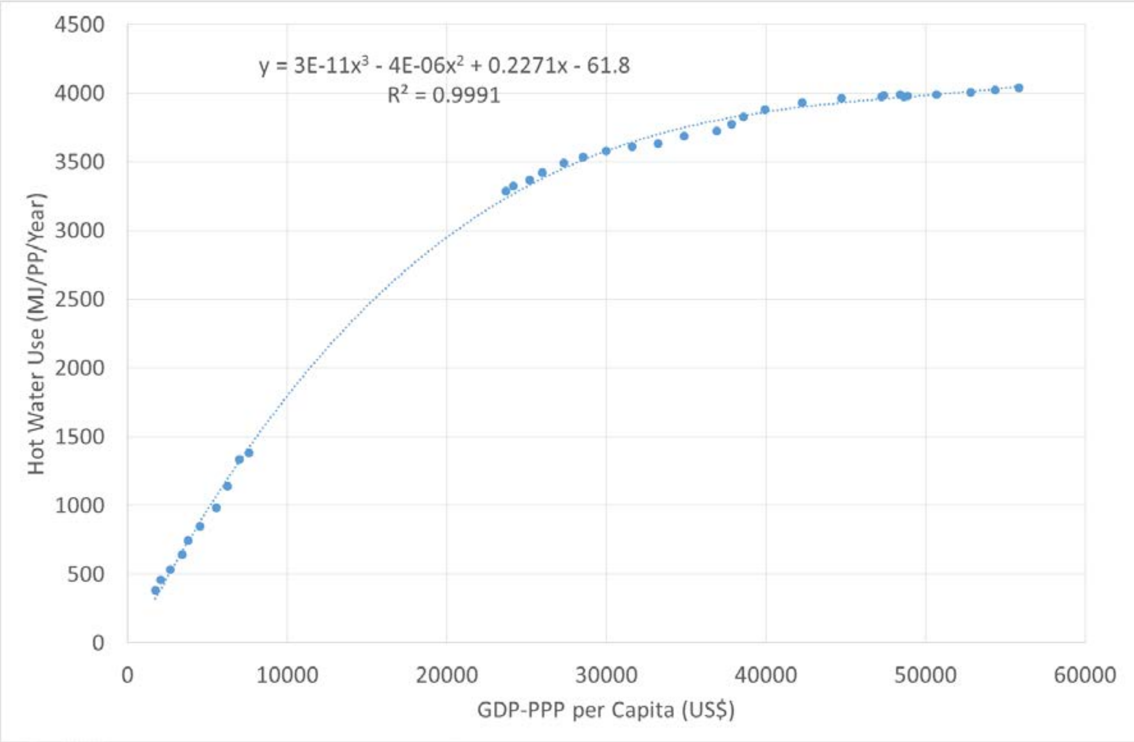
The energy used by water heaters is a function of the demand for hot water, the efficiency of the water heaters used to supply the energy and the efficiency of energy supply (the primary to final energy factor). If solar energy supplies the heat source then the energy cost is essentially free and has no significant environmental impact and hence can be discounted. Therefore, when it comes to assessing water heater energy impacts it is fossil energy sources that need to be fully accounted for as well as the lifecycle economics of the water heaters.

Demand for hot water

Underlying the demand for water heater energy use is the demand for hot water. The available data on hot water energy consumption was supplied by commercially produced water heaters in China and the US. The data was synthesized and analyzed to produce the scatter plot of annual hot water energy demand per capita as a function of GDP-PPP per capita as shown in Figure 10. The data shown in this figure is derived from a time series of estimated annual average hot water energy demand per capita in both economies. Developed within this study, which was subsequently mapped to the corresponding time series of annual average per capita GDP determined on a Purchase Power Parity (PPP) basis. A relationship of annual hot water energy demand per capita to GDP-PPP per capita was then derived via a polynomial regression and is shown on the figure, along with its R^2 value. As far as these two economies are concerned this regression shows a very good fit with the available data and hence is thought likely to provide as good an indicator as it was possible to derive of how hot water energy demand would be expected to evolve as a function of per capita GDP and population. As would be expected intuitively the relationship is highly non-linear and tends towards saturation at high per capita GDP levels. This illustrates that growth in demand for hot water is much more sensitive to changes in per capita GDP at lower per capita GDP levels than higher per capita GDP levels. Which suggests that there is a far greater potential for growth in domestic hot water demand in China than in the US.

It should be noted that this figure is based on data limited to commercial hot water devices and hence does not include demand for traditional biomass based water heating (it does include solar water heating however). Traditional biomass water heating is negligible in the USA, important but declining rapidly in China (and is only significant in rural areas), but is still the dominant form of domestic water heating in India. Application of this relationship to India and mapping it to the available data on hot water use from commercially manufactured water heaters suggests that it may correctly predict the trends (i.e. relative rate of change) in domestic hot water demand from commercial water heaters in India but that it overestimates the energy used in such water heaters by approximately two-thirds. This finding is consistent with the relative importance of biomass water heating in India compared to China and the US. Nonetheless, the relationship can still be applied to project the relative change in domestic hot water demand supplied by commercially manufactured water heaters as a function of GDP and population trends. Accordingly, this regression is used in each of the three economies to project the evolution in hot water demand from manufactured water heaters as a function of GDP and population from each start point determined from the available data in each economy. Hot water heating via traditional biomass is excluded from these projections. This projection in underlying water heater energy demand is constant in all the scenarios considered for each economy and hence only the technology used to supply the hot water varies from one scenario to another.

Figure 10. Estimated hot water energy use per capita as a function of per capita GDP (PPP) in China and the USA



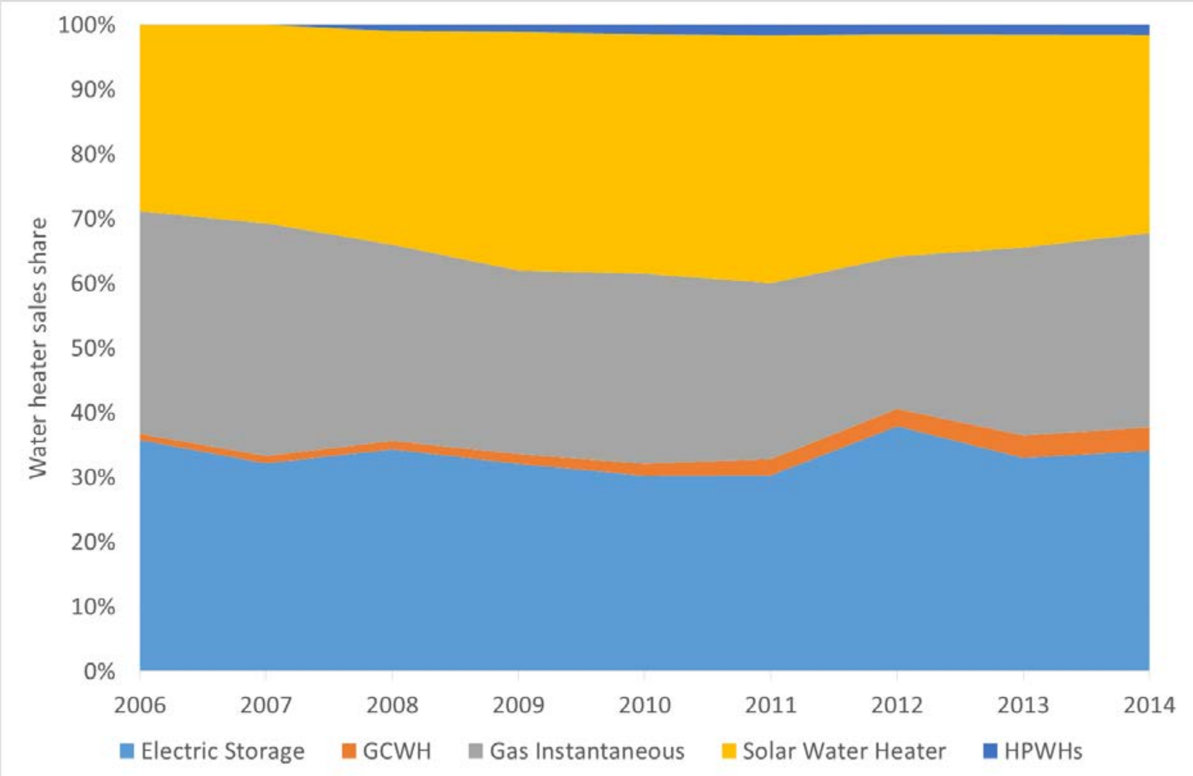
Characteristics of water heater technologies, markets and usage in each economy

China

The Chinese water heater market is dominated by solar water heaters and electric storage water heaters but it also includes gas instantaneous water heaters, electric instantaneous water heaters and to a much lesser degree gas-fired combination water heaters (that also provide space heating) and heat pump water heaters. The average capacity of electric storage water heaters is about 63 liters, which means that they are large enough to provide about three showers in succession. The most common solar water heater are evacuated tube types and have a storage capacity of 100 to 116 liters. They are usually sold with 2 square meters of collector per water heater. The gas-fired instantaneous water heaters are operated predominantly using natural gas but can also use LPG in off-network locations. Large gas storage water heaters are uncommon on the Chinese market but gas-combination boilers are gaining market share and indicate that a proportion of Chinese households in colder climates served by natural gas networks are beginning to adopt European style combined space and water heating technology. This is likely to become more prevalent as affluence rises and a greater proportion of households are connected to the gas network. Heat pump water heaters have also gained a foothold in the Chinese market and reached 1.5% of sales in 2013, in part with the help of subsidies. The average storage capacity of these is 108 liters.

The estimated sales shares of water heater by type in China over the last few years are shown in Figure 11.

Figure 11. Estimated Water Heater Sales Shares in China



Climatic and regional factors

China is a vast country with large variations in climate by region which affects water heater energy demand, not least through variation in annual average water inlet temperatures, and the energy performance of renewable energy powered water heaters such as solar and heat pump water heaters. The gas network is mostly limited to the larger cities but is being extended to a greater proportion of the urban population.

Energy prices

Residential energy prices are subsidized in China and are not reflective of the costs of producing energy nor of the impact that energy production, especially coal used for the large majority of power production, has on the economy. This is even more the case if environmental costs were to be factored in. Given this the study assumes that the current average residential electricity price, of ~0.5 RMB/kWh will double by 2035. This assumption is quite conservative as China's electricity council indicated mean 2015 prices were expected to be 27% higher than the 2010 prices and signaled that they believe long run prices will increase by an average of 5% per annum[8], which would imply a tripling of the price by 2035.

Residential gas prices are also heavily subsidized and are even harder to predict. In 2013 residential gas prices in major cities were found to vary from 1.37 to 3.45 RMB/cubic meter which on average is less than half the average industrial user gas prices charged in cities[9]. As with electricity prices the residential gas prices are not fully reflective of costs and as such are likely to act as a damper on the future development of the gas network unless allowed to increase. Nonetheless the supply of natural gas grew at an average rate of 12% per year for the decade to 2012 and now all major cities have access to domestic gas. Given the lifecycle cost advantage of gas-fired water heaters using typical natural gas prices compared to electric storage water heaters one might have expected to see a move away from electricity and towards gas based water heaters. This has not occurred and rather the respective market shares of electric and gas water heaters have remained relatively constant over the past decade.

Given the lack of long range price forecasts but the pressure of the need for market reform if the gas supply network is to be sustained and expanded this study assumes that China's residential sector gas prices keep track with electricity prices and will double by 2035. This projection actually enhances the competitiveness of gas-fired water heaters compared to electricity over the scenario period as the difference in energy costs widens over time due to the existing advantage enjoyed by gas. Note, natural gas price reforms for all end-use sectors have already been implemented and more are expected. Currently, just as is the case for electricity consumption a triple tier tariff structure has been adopted wherein those households that consume higher amounts of gas pay significantly higher tariffs than those using less[10]. This structure should act to limit the rate of growth in household demand but also redistributes wealth to poorer households. It makes the use of energy consuming technology more affordable for a greater proportion of the population. If maintained, this triple tier tariff structure should provide some impetus for heat pump water heaters and solar as a potentially more affordable means of increasing hot water demand than increasing electricity or gas use. It may also encourage ownership of both a gas and an electric water heater as a tactic to keep both types of energy consumption within the lower tariff boundary and yet allow some expansion of service.

Product prices, usage and life cycle costs

In China a typical electric storage water heaters costs between 1500 and 1600 RMB and has an unit energy consumption of about 870 kWh/year, whereas a gas instantaneous water heater will cost ~2200 RMB and a typical solar water heater ~3000 RMB. On average gas instantaneous water heaters will pay off compared to electric storage water heaters in between 2 to 3 years while solar water heaters take about 3 to 4 years to attain payback. On average HPWHs cost ~5000RMB and would take about 10 to 11 years to reach payback with present energy prices. As electricity prices are expected to almost double by 2035 while the cost of solar and heat pump water heaters is expected to decline the average payback period for these technologies is expected to decline to about 1 and 2 years respectively by the end of the scenario period.

The average estimated life cycle costs (annualized over the life time of the product) by different water heater technology are shown in Table 5.1.

[8] http://www.chinadaily.com.cn/business/2012-03/13/content_14826146.htm
[9] CEFC China Energy Focus – Natural Gas 2013, China Energy Fund Committee
[10] Energy Prices, Subsidies and Resource Tax Reform in China, Zhong Xiang Zhang, Asia & the Pacific Policy Studies, vol. 1, no. 3, pp. 439–454 doi: 10.1002/app5.46, September 2014.

Even under a BAU scenario the solar water heaters offer the lowest annualized life cycle cost in 2035, but with stronger deployment they would become the least cost option even faster.

Table 5.1 Average annual life cycle cost (RMB/year) for different water heater technologies

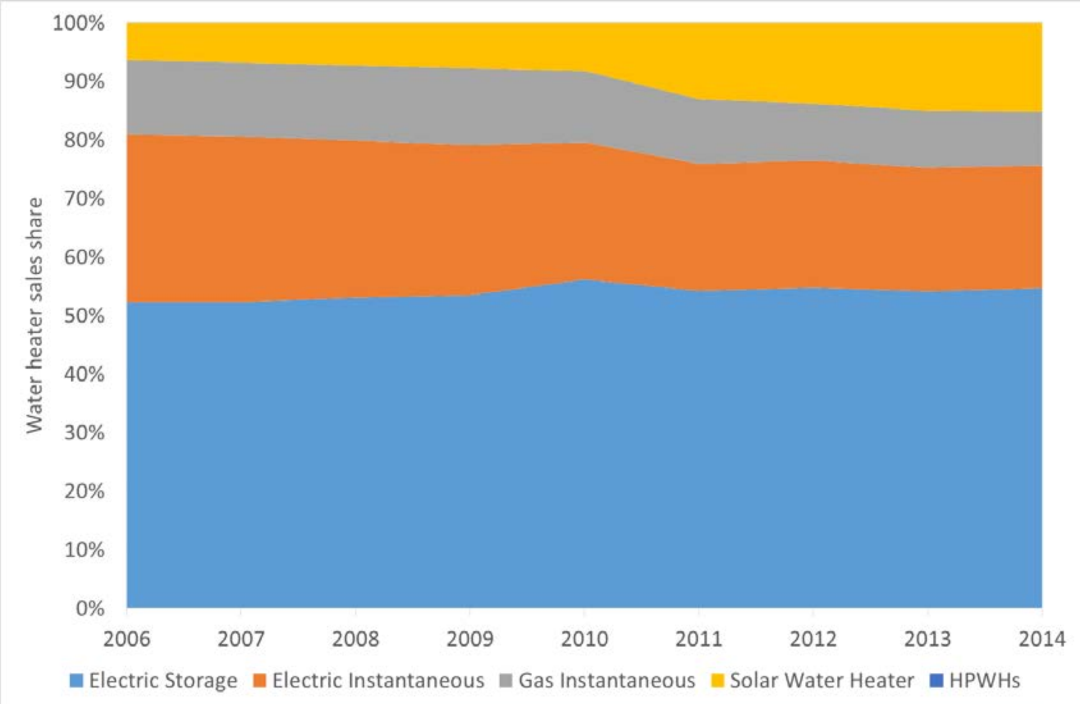
Product	Annualized life cycle cost	Annualized life cycle cost
	RMB/year in 2015	RMB/year in 2035
Solar Water Heater	363	288
HPWHs	453	428
Gas Instantaneous	290	430
Electric Storage	631	1066
GCWH	1053	1374

India

Incumbent water heater technologies and market trends

The Indian water heater market is dominated by electric storage water heaters. It also includes gas instantaneous water heaters, electric instantaneous water heaters, and solar water heaters. Heat pump water heaters are available in India but only in relatively large capacities (e.g. 100-200 liters size) and sales volumes are thought to be very low. The estimated sales shares of water heater by type in India over the last few years are shown in Figure 12.

Figure 12. Estimated Water Heater Sales Shares in India



Traditionally most domestic water heating in India has been via biomass and did not entail the use of dedicated water heaters. This is not so viable in urban environments and increasing affluence and urbanization has seen the development of a commercial water heater market over many decades. In rural communities with access to electricity the most common type of water heating is via small portable immersion electric water heating devices. They are somewhat similar to an element for a kettle. In general ownership levels of water heaters are much greater in urban households than rural households and thus increasing urbanization is the major driver for growth in water heater sales. Against a background of a growing population the share of the total population living in urban centers continues to grow and increased from 27.8% in 2001 to 31.2% in 2011. In addition, there are an increasing number of nuclear families living in high-rise buildings with multiple bathrooms in urban areas and thus the multiplication of hot water outlet spaces is also driving up demand.

The way hot water is used in India is somewhat different to the US and China. The applications of hot water are for bathing and washing (dishes and clothes). In the case of bathing it is still common for people to have so called “bucket showers” where a bucket is filled with warm water and emptied over the person who is bathing. The bucket filling location does not have to be in the same place as the bathing location although it often will be. This means there does not have to be a water heater in the bathroom and another in kitchen.

While storage water heaters are by far the most common type and account for 54% of all water heater sales, they tend to be much smaller than US models and even than most Chinese models. The average storage capacity is ~21 liters and the average heating element capacity is about 2.5kW. This is sufficient for a person to have a 5 minute long warm shower every 15 to 20 minutes. Larger storage water heater types do exist but their sales volumes make up a much smaller proportion of total sales. It should be noted that on average India has appreciably warmer year round inlet water temperatures than most parts of the US or China and hence less energy. Hence less storage and heating capacity is needed to produce warm water at about 40oC for bathing.

Instantaneous electric water heaters account for about 21% of the water heater market. They are capable of providing instantaneous hot water at the point of demand for bucket showers and washing up but generally have an insufficient throughput to support a direct shower. Their advantage compared to storage water heaters is that they are typically cheaper (about 3300 Rs. per unit compared to 6400 Rs. for storage water heaters) and they have no standing losses, and hence are slightly more efficient. However, their disadvantage is that they will not function during power interruptions. These factors may explain why very small, near to point of demand, electric storage water heaters are so popular in India.

Gas instantaneous water heaters (GIWHs) account for 10% of the market in India but unlike for the other types of water heater there is little evidence of significant market growth in the last few years for which sales data are available. A typical product costs about 2900 Rs. Only about 2.4 million (1%) of households have access to natural gas in India. When it is available, gas water heating would appear to be the obvious choice. It is significantly cheaper than electric water heating and has less reliability of supply issues. In fact, most GIWHs in India use LPG as the energy source. Once conversion efficiencies are taken into account the average cost of water heated via LPG works out to be very similar to the average cost of water heated by electricity, albeit perhaps a about 5% less. Just like electricity, LPG prices are quite variable as a function of location so the least cost solution for the consumer, between gas and electric water heating, will depend on their specific location. In un-electrified rural settings, the only practical choices for water heating, aside from biomass, are solar and LPG. There is no apparent market for gas storage water heaters in India which suggests that there is no need for storage capacity if the energy supply is reliable. LPG is used in a large proportion of Indian homes for cooking purposes. The same cylinders can be connected to the water heater as desired. There is no incremental cost in establishing a distribution network.

The market share taken by solar water heaters has been increasing in recent years, in part due to the support received through the JNSM program, and attained 15% of the market in 2013. In the case of solar water heaters the average tank capacity tends to be larger, around 100 to 150 liters, but given the factors mentioned above there is only limited need for back-up heating systems and thus SWHs in India do not generally seem to be sold with back-up heating capacity. A typical configuration will cost about 21500 Rs. including the cost of the collectors to install.

Water heater usage and the type of water heater used is closely linked to access to electricity and/or natural gas or LPG. The natural gas network in India currently only extends to some of the major metropolis but is expected to increase over the period to 2035.

With the advent of energy labeling for electric storage water heaters and promotional policies for solar water heaters in India there is a rising consciousness of the energy efficiency of water heaters, especially in urban areas. The channels used to sell water heaters are also evolving and products have been available on line for the last two years. These tend to be predominantly in the 3 to 5 star labeling class in the case of electric storage water heaters.

Climatic and regional factors

India is a large country with many climates but most of the country is quite hot. The average inlet temperature of water is higher than in the US or China, so the energy required to heat water to a desired temperature of about 40oC is less than in the other economies. The solar fraction tends to be higher in the eastern states where there is somewhat less dust and humidity but is quite high across the country. Electrification has not yet reached about 450 million people and in these cases solar and LPG water heaters are the only viable choices using commercial water heaters (as opposed to traditional biomass-based water heating). Natural gas networks are only slowly being rolled out and only reach municipal areas in some parts of the country. India has limited natural gas supplies and would need to import LNG were it to substantially expand its natural gas use. The high average air and water temperatures also means that heat pump water heaters will tend to have a higher COP all other factors being equal in India than in China or the USA, although this obviously depends on the region considered in each economy.

Energy prices

Residential energy tariffs in India are heavily subsidized and are not reflective of the cost of production and supply. As a result it is almost certain that they will be increased at above inflation rates over the time frame of the scenario in order to be able to continue to meet the growing demand for energy services. The analysis in this study assumes that average residential electricity tariffs will increase from 4.3 Rs./kWh in 2012 to 7.6 Rs./kWh in 2035. Average gas prices (LPG and natural gas) are conservatively assumed to increase in line with general inflation but to be on average 4.97 Rs./kWh in 2015 (as an average value of LPG and natural gas); however, actual gas prices vary appreciably by region.

Product usage and life cycle costs

The average estimated life cycle costs (annualized over the life time of the product) by different water heater technology are shown in Table 5.2. Solar thermal water heaters have slightly lower life cycle costs than gas instantaneous water heaters using natural gas. The latter can only be deployed in areas with access to the natural gas network. Heat pump water heaters have slightly lower annualized life cycle costs than electric water heaters, whether storage or instantaneous types, despite being almost a factor of 10 more expensive to procure. Solar water heaters are also relatively expensive to procure and install but pay back quite rapidly e.g. in about 2.4 years compared to electric water heaters compared with about 10.6 years for heat pump water heaters. Heat pump water heaters are a suitable technology for cases where solar water heaters cannot always be used (e.g. in urban apartments without access to roof spaces). Both solar and heat pump water heaters are expected to become significantly more competitive as the number installed increases due to the technology learning effect. As a result the life cycle cost of both these technologies would be expected to fall compared with the others, especially if strongly supported by public policy measures.

Table 5.2 Average annual life cycle cost (Rps/year) for different water heater technologies

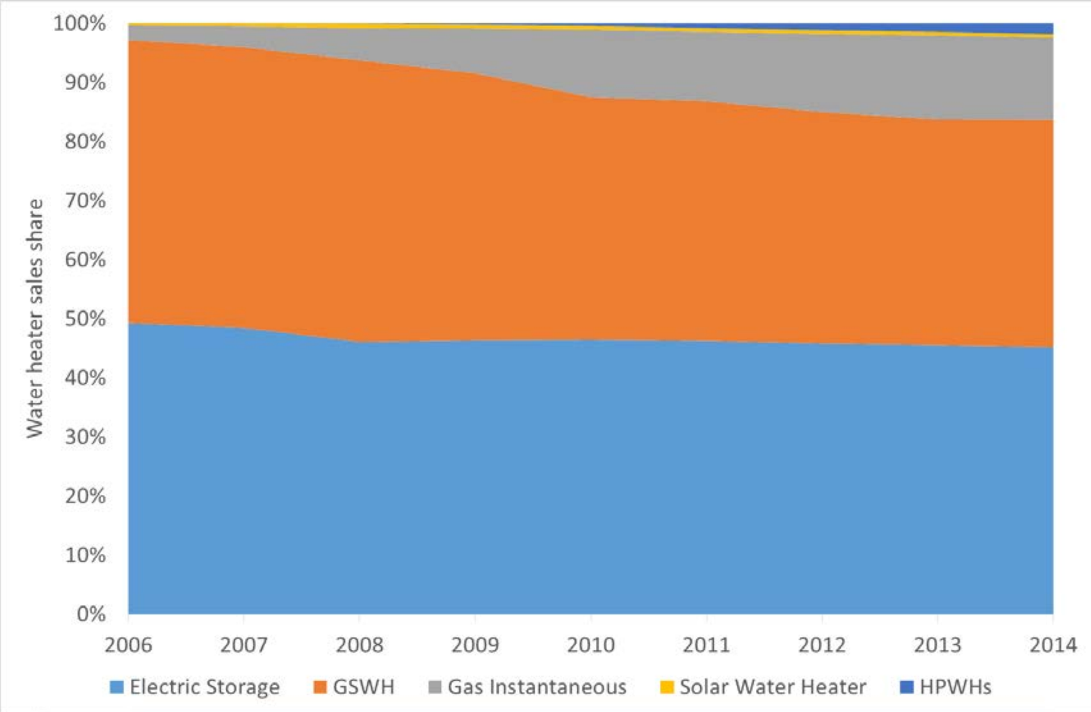
Product	Annualized life cycle cost
	Rps/year in 2015
SWH	1536
GIWH nat. gas	1914
HPWH	5736
GIWH LPG	5820
EIWH	6580
ESWH	6847

USA

Incumbent water heater technologies and market trends

The US water heater market has been saturated (i.e. all houses have had a water heater) for many years and hence is dominated by replacement sales occurring when existing water heaters fail and a much less important contribution from new build than is the case in China or India. Per capita consumption of hot water is much higher in the US than in the other economies, reflecting a substantially higher average level of affluence and the long standing availability of hot water in households. The dominant technologies are gas storage water heaters and electric storage water heaters. Gas instantaneous water heaters are also increasing their market share as are, but starting from a much lower base, heat pump water heaters. The estimated sales shares of water heater by type in the US over the last few years are shown in Figure 13.

Figure 13. Estimated Water Heater Sales Shares in the USA



Solar water heaters take a negligible proportion of sales in the US and the solar water heater market is much less developed than in China or India. Indeed, while solar PV has taken off across much of the US this has not been matched by a comparable increase in the deployment of renewable heat technologies and solar water heating is most likely to be used for heating private swimming pools than it is for heating domestic sanitary hot water. There are several factors underpinning this including:

- Solar water heating acquired a poor reputation in the 1970s and 80s due to public promotional schemes that did not take sufficient efforts to lock in quality and which led to poor user experiences with the technology at that time. That part of the industry which survived the subsequent slump in demand has since made extensive efforts to promote quality of product and of installation. Reputation damage takes a considerable effort and time to overcome,
- Comparatively cheap commercial energy including cheap gas and electricity prices in many part of the country which have taken pressure off life cycle costing considerations,
- Relatively high consumer affluence which means that consumers can afford to be less concerned about efforts to minimize energy bills than in less affluent economies,
- Lack of visibility of the relative energy efficiency of water heater technologies across technology and energy types which tends to favor the inexpensive to acquire but expensive to operate technologies,
- Small scale and relatively uncompetitive industries supplying solar thermal water heaters,
- Consumer expectation that hot water should be available at a designated temperature on demand all year round and hence there is no market for solar water heater systems that do not have back-up heating systems (this both increases the cost of the solar option and reduces its lifecycle cost benefit compared to the situation in China and India).

By contrast, the heat pump water heater market has begun to establish a clear position with the help of support through public-private R&D [11]and utility energy efficiency programs. This in part reflects that utility support programs are more likely to be focused on electricity savings than other fuels.

Climatic and regional factors

The climate in the US varies considerably by region and this influences the relative viability of renewable or semi-renewable water heater technologies such as solar water heaters and heat pump water heaters. While the whole country has access to electricity there are some gaps in the gas network and both gas and electricity prices vary significantly by state and region. The solar fractions for solar water heater assumed in the energy scenarios considered in the analysis presented in the results section vary from 0.5 to 0.75 with a national average of 0.62.

Energy prices

Residential energy tariffs in the US vary by state and even municipality by a factor of ~4 for electricity and somewhat less for gas. The national average price of residential electricity was assumed to be US$0.134/kWh in 2015 and for gas was assumed to be US$0.042/kWh in the energy scenario analysis. Future price fluctuations were modelled in agreement with the projections made by the US Energy Information Administration's Annual Energy Outlook 2014.

Product prices, usage and life cycle costs

The product price, usage and life cycle cost assumptions used to develop the scenarios presented in the results section take the product prices (including purchase price, cost of installation and maintenance), average UEC and product life spans from the USDOE's Technical Support Document (TSD) for all water heater types except solar thermal, which were not considered in that analysis. The energy prices, life cycle costs and solar fraction assumptions were simulated at the regional level broken down into the following regions: New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific Contiguous, and Pacific Non-contiguous. Regional energy prices were taken from the EIA website and average regional solar fractions from NREL publications. NREL sources were also used to determine what proportion of existing water heaters could be physically substituted by solar water heaters (assumed to be roughly 50%). It was further assumed that roughly 80% of electric storage water heaters could be substituted by heat pump water heaters.

The resulting variation in mean annual life cycle costs per technology and region are shown in Table 5.3 below. The table shows the life cycle cost of each technology per region, calculated over the product life span at a 3% real discount rate and then divided by the product life span to produce an average annual value.

[11] https://www.ornl.gov/news/ornl-general-electric-collaborate-super-efficient-electric-water-heater

Table 5.3 Average annual life cycle cost (US$/year) per region for different water heater technologies

Region	Water heater type					
	GSWH	GIWH	HPWH	SWH elec	ESWH	SWH gas
East South Central	296	294	256	311	343	424
West South Central	220	239	260	299	350	392
South Atlantic	250	260	264	325	358	415
West North Central	234	249	267	388	365	441
Mountain	318	310	270	359	371	462
East North Central	404	372	283	405	396	534
Pacific Contiguous	298	295	299	339	426	425
Middle Atlantic	202	225	319	381	466	402
New England	248	259	378	479	580	439
Pacific Non-contiguous	781	646	975	484	725	634
USA	268	273	289	355	400	425

The lower LCC technology varies by region between gas storage water heaters (6 regions) and heat pump water heaters (4 regions). For 8 regions, SWH with electric backup is less costly than electric storage water heating. The solar water heaters with gas back-up and electric storage water heaters are currently the least competitive from an average annual life cycle cost basis over the US as a whole.

Results

The findings from the modelling analysis of the three energy scenarios are presented below for each of the economies being considered.

China

The BAU and Least Life Cycle Cost Scenarios

The historic and projected energy consumption of water heaters in China under the BAU and LLCC scenarios is shown in Figure 14. Under the BAU Scenario water heater fossil energy use rises from 156TWh of final energy in 2015 to reach 480 TWh in 2035 at an annual average rate of growth of 5.8%. By contrast over the 20 years of the scenario period adopting the LLCC scenario would save 1970 TWh in final energy consumption compared to the BAU Scenario. This is equivalent to savings of 4132 kWh per water heater owning household over the period at an average of 207 KWh/year per water-heater. At the end of the scenario period the LLCC scenario is saving water heater final fossil fuel energy consumption of 159 TWh a year, or some 336 kWh per household per year.

In fossil primary energy terms the impacts are even greater due to the additional losses in the production of and distribution of electricity, see Figure 15. The LLCC Scenario produces cumulative primary energy savings of 6154 TWh over the scenario period that rise to 498 TWh/year in 2035, savings equivalent to 51% of the BAU water heater fossil primary energy consumption.

Figure 14. Estimated Water Heater Final Energy Consumption in China for the BAU and Least Life Cycle Cost Scenarios

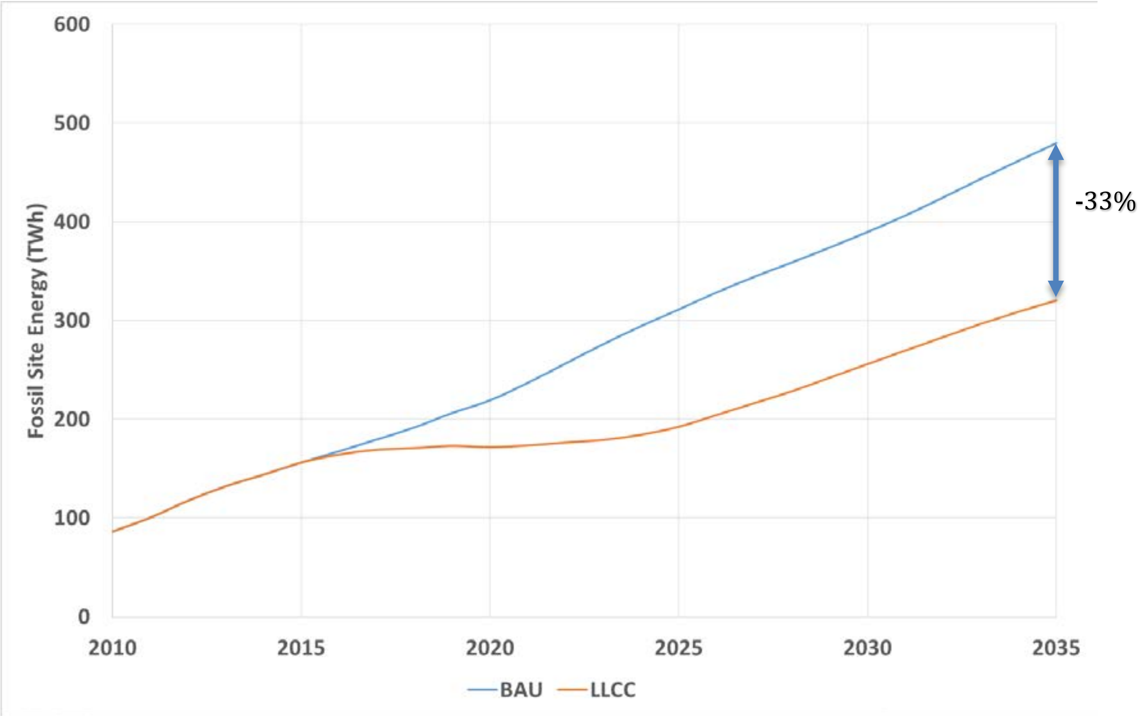
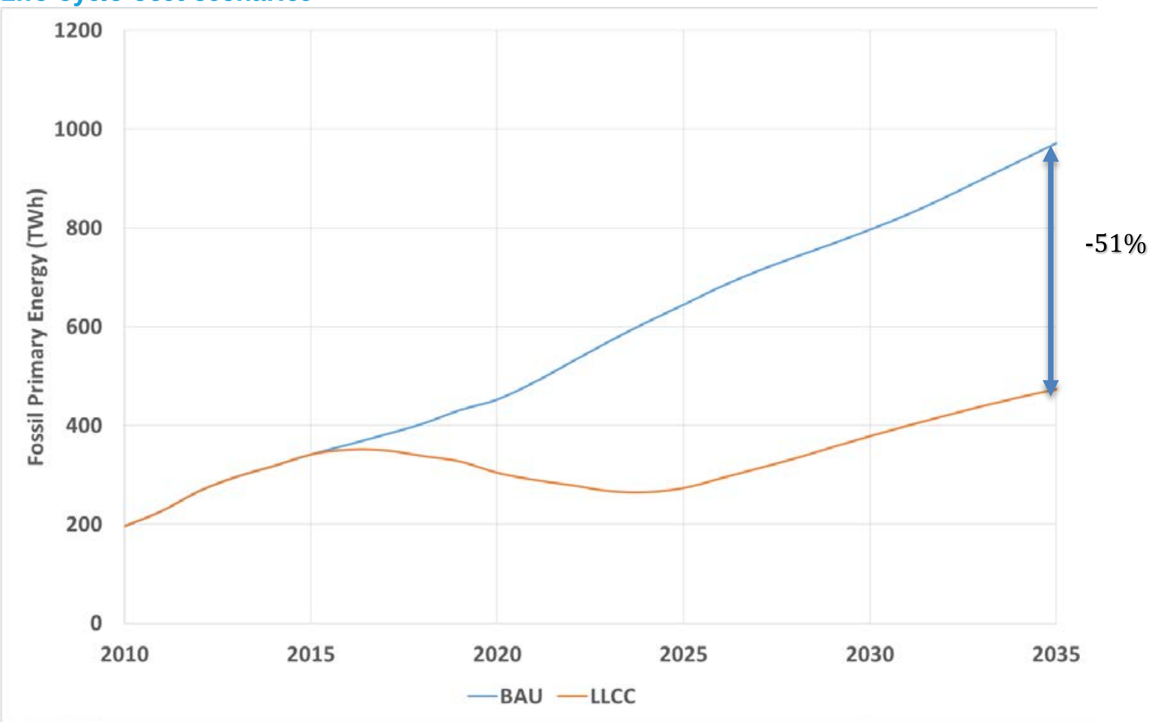
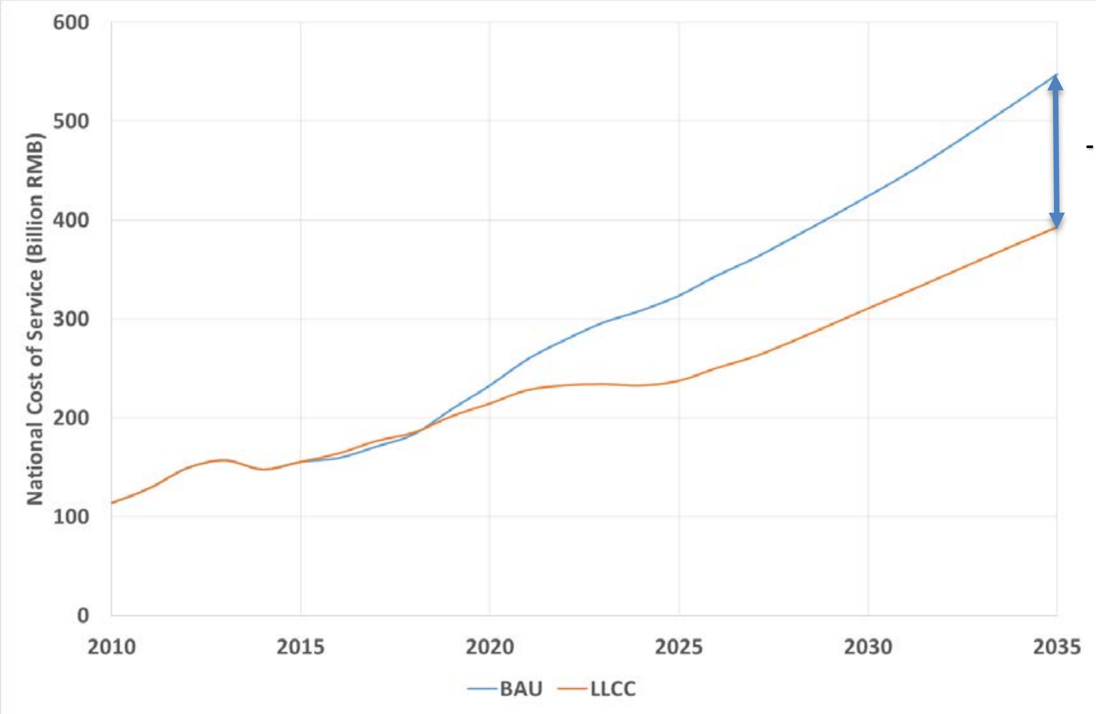


Figure 15. Estimated Water Heater Primary Energy Consumption in China for the BAU and Least Life Cycle Cost Scenarios



The impact of water heaters on the Chinese economy is indicated in Figure 16.

Figure 16. Estimated Water Heater Costs in China for the BAU and Least Life Cycle Cost Scenarios



Over the 20 years of the scenario period adopting the LLCC scenario would save 1516 billion RMB in consumer costs compared to the BAU Scenario. This is equivalent to savings of 3190 RMB per water heater owning household over the period at an average of 160 RMB/year per household with a water heater. At the end of the scenario period the LLCC scenario is saving water heater using consumers 154 billion RMB a year, or some 326 RMB per household.

The Recommended Policy Scenario

Figures 17 to 19 show the same information for the Recommended Policy scenario (see section 6) with the other two scenarios included for comparison. The cumulative final savings to 2035 under the Recommended Policy scenario are 864 TWh for site energy, 2700 TWh of primary fossil energy, and 653 billion RMB in consumer costs. These are respectively 44%, 44%, and 43% of the equivalent savings under the LLCC scenario. The principal reason for the reduction is the need for time to develop and roll out the program at an increasing scale for an economy of the huge scale of China. The energy savings per household using efficient water heaters in the program are exactly the same as under the LLCC Scenario so the lower level of savings simply reflects the real world challenges inherent in aiming to bring about transformation across a vast number of actors. Nonetheless, the savings are still very substantial and would be expected to continue to grow and become much closer to the LLCC scenario were the scenario time period to be extended beyond 2035.

Figure 17. Estimated Water Heater Final Energy Consumption in China for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios

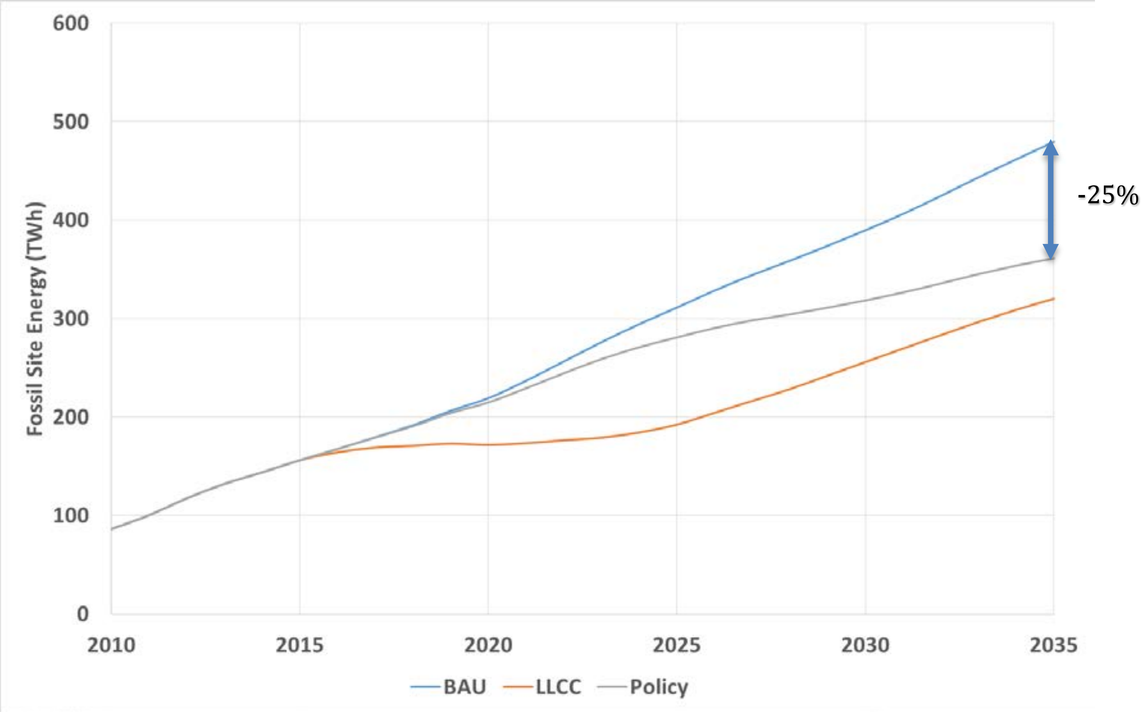


Figure 18. Estimated Water Heater Primary Energy Consumption in China for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios

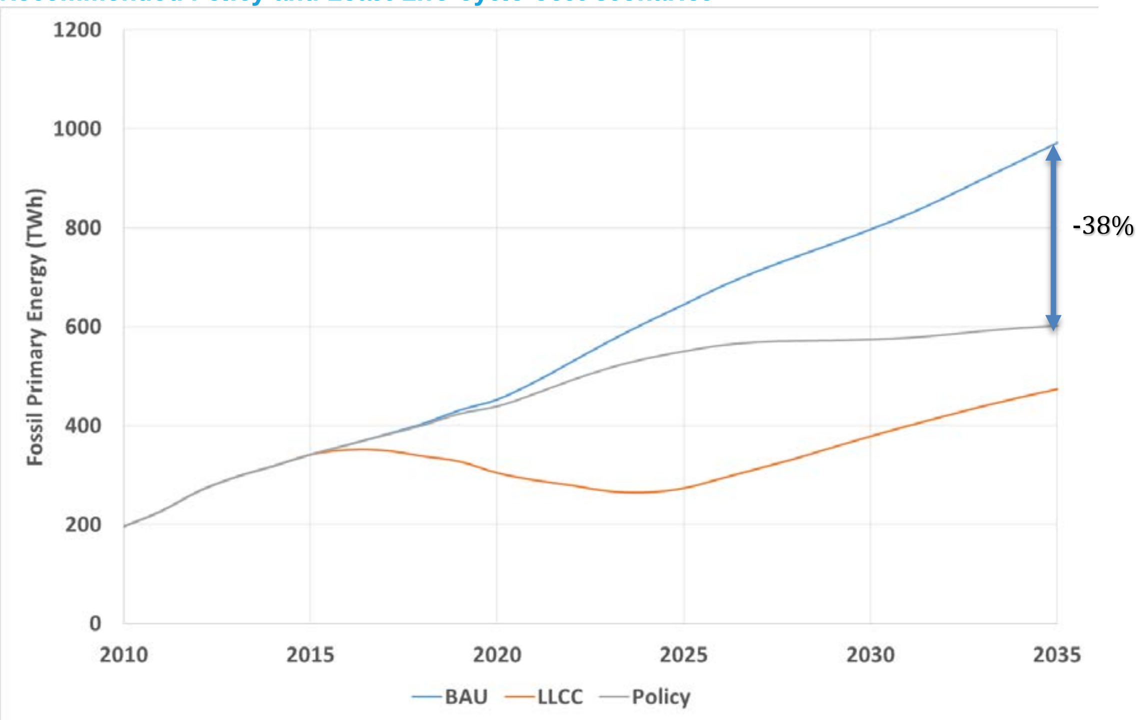
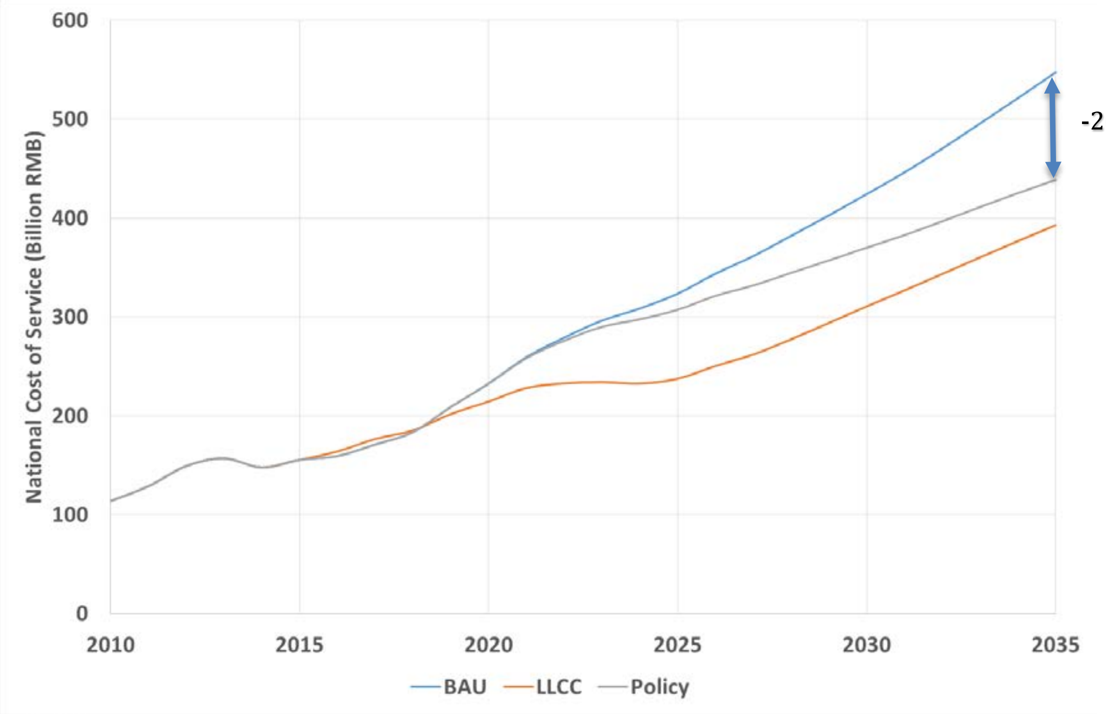


Figure 19. Estimated Water Heater Costs in China for the BAU, Recommended Policy, and Least Life Cycle Cost Scenarios



Figures 20 to 22 show how the site energy delivered by water heater technology varies as a function of the policy scenario, where GCWH = gas combination water heater, HPWH = heat pump water heater.

Figure 20. Estimated Water Heater Final Energy Consumption in China for the BAU Scenario by Water Heater Technology

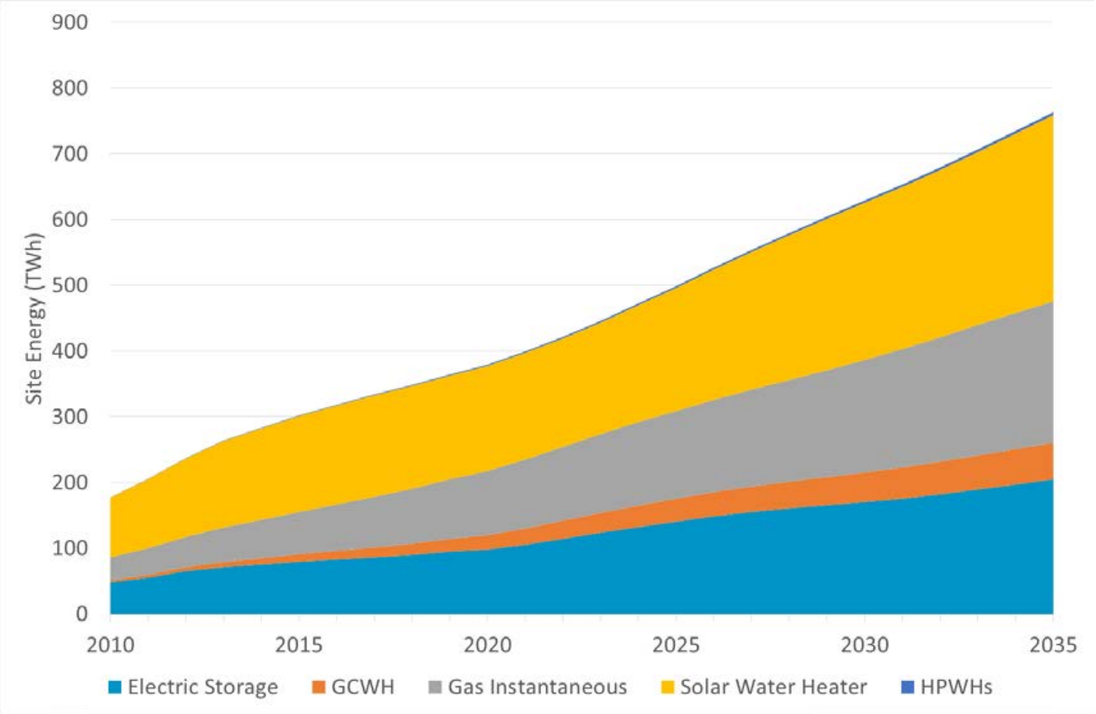


Figure 21. Estimated Water Heater Final Energy Consumption in China for the Recommended Policy Scenario by Water Heater Technology

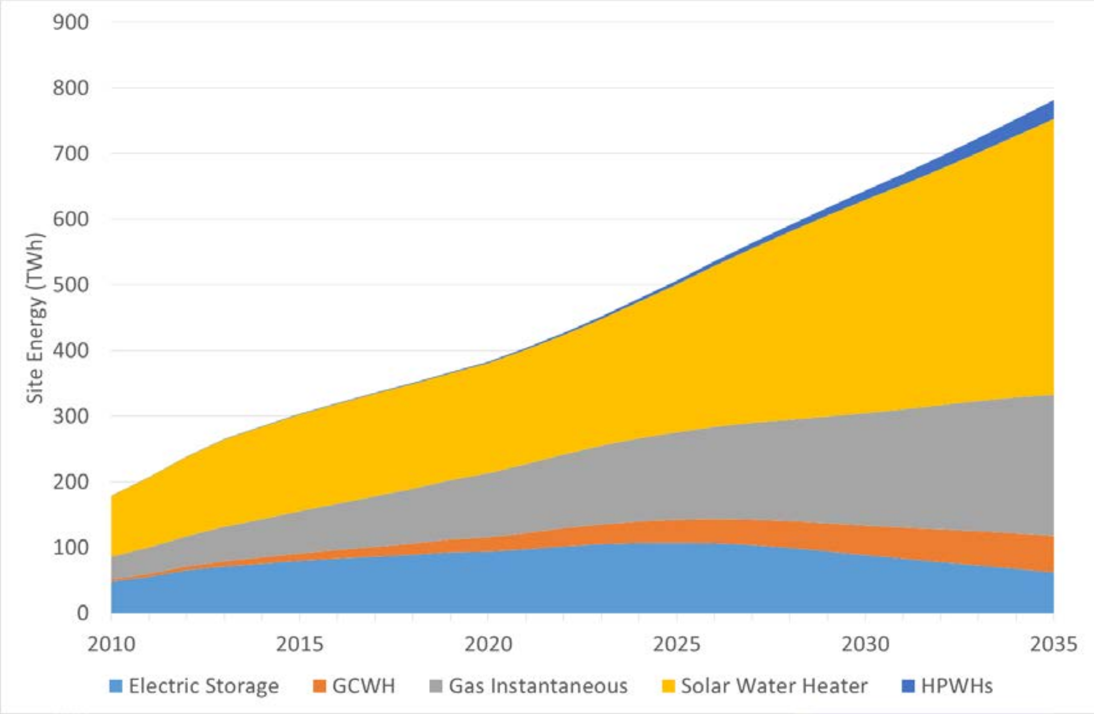
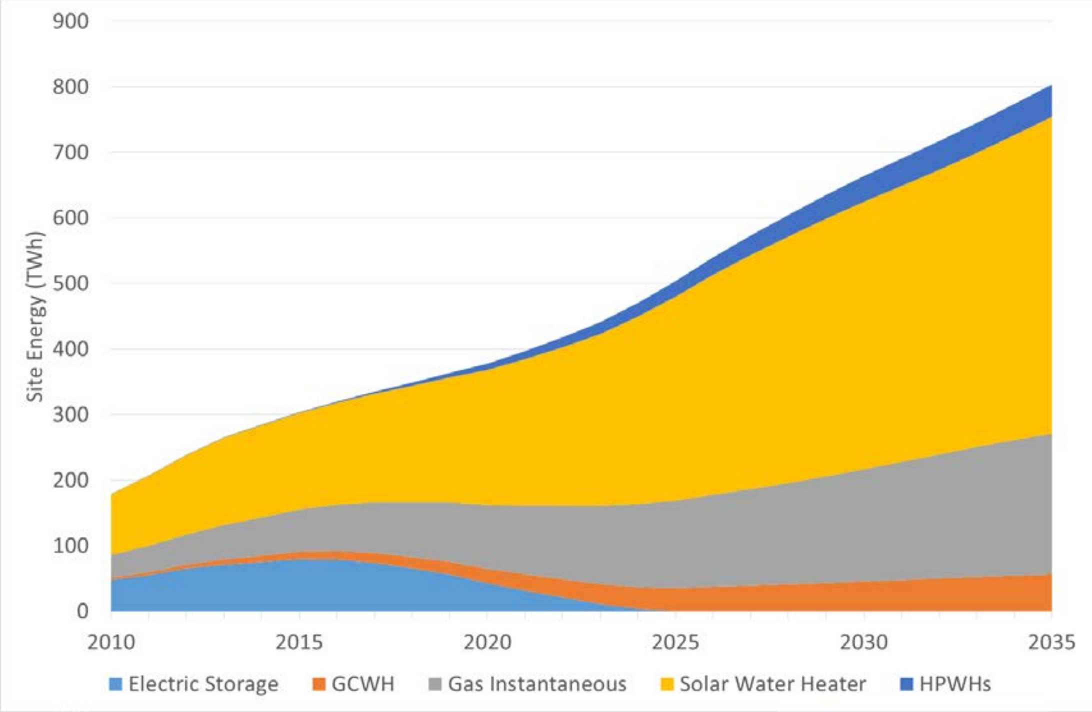


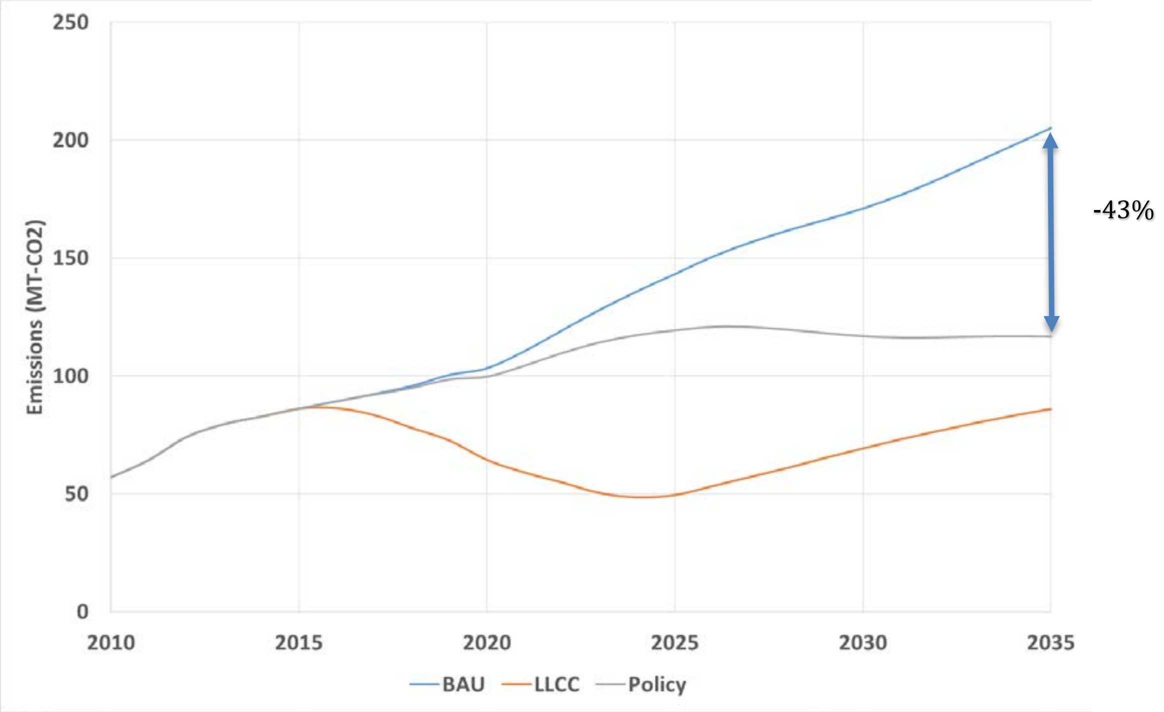
Figure 22. Estimated Water Heater Final Energy Consumption in China for the Least Life Cycle Cost Scenario by Water Heater Technology



Environmental impacts

The impact of water heaters on energy-related CO_2 emissions is shown in Figure 23. Under the BAU Scenario emissions rise from 80 to 205 Mt-CO_2 per year from 2015 to 2035. Under the LLCC Scenario they actually decline to 50 Mt-CO_2 in 2024 before rising back up to 80 Mt-CO_2 by 2035. The Recommended Policies scenario sees emissions rise gently to peak at 120 Mt- CO_2 in 2026 before declining slightly thereafter to 117 Mt-CO_2 by 2035. Cumulative emissions (2015-2035) in the policy scenario are 2304 Mt-CO_2, a reduction of 660 Mt-CO_2 (22%) from BAU emissions of 2964 Mt-CO_2.

Figure 23. Estimated Water Heater related CO_2 Emissions in China for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios



India

The BAU and Least Life Cycle Cost Scenarios

The historic and projected energy consumption of water heaters in India under the BAU and LLCC scenarios is shown in Figure 24. Under the BAU Scenario water heater energy use rises from 30.5TWh of final energy in 2015 to reach 87.6 TWh in 2035 at an annual average rate of growth of 5.9%. The share of households having a water heater rises from 11.2% to 24.8% over the same period. By contrast over the 20 years of the scenario period adopting the LLCC scenario would save 388 TWh in final energy consumption compared to the BAU Scenario. This is equivalent to savings of 5861 kWh per water heater owning household over the period at an average of 293 kWh/year per water-heater. At the end of the scenario period the LLCC scenario is saving water heater final fossil fuel energy consumption of 36.4 TWh a year, or some 407 kWh per household per year.

In fossil primary energy terms the impacts are even greater due to the additional losses in the production of and distribution of electricity, see Figure 25. The LLCC Scenario produces cumulative primary energy savings of 1810 TWh over the scenario period that rise to 177 TWh/year in 2035, savings equivalent to 68% of the BAU water heater fossil primary energy consumption.

Figure 24. Estimated Water Heater Final Energy Consumption in India for the BAU and Least Life Cycle Cost Scenarios

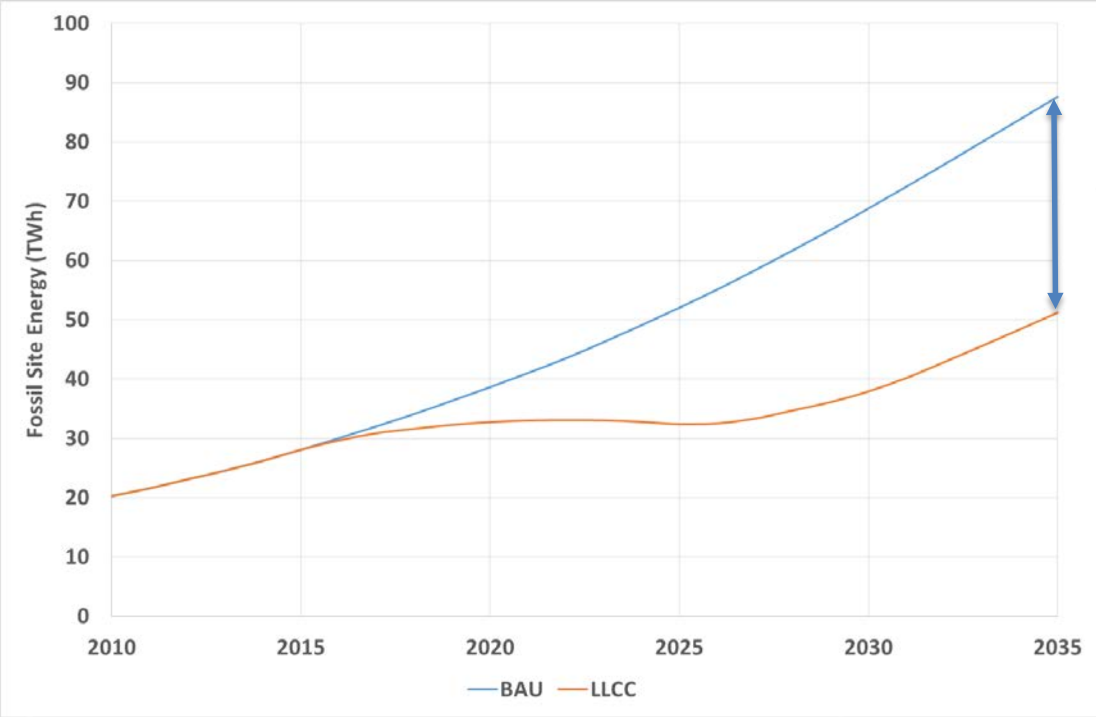
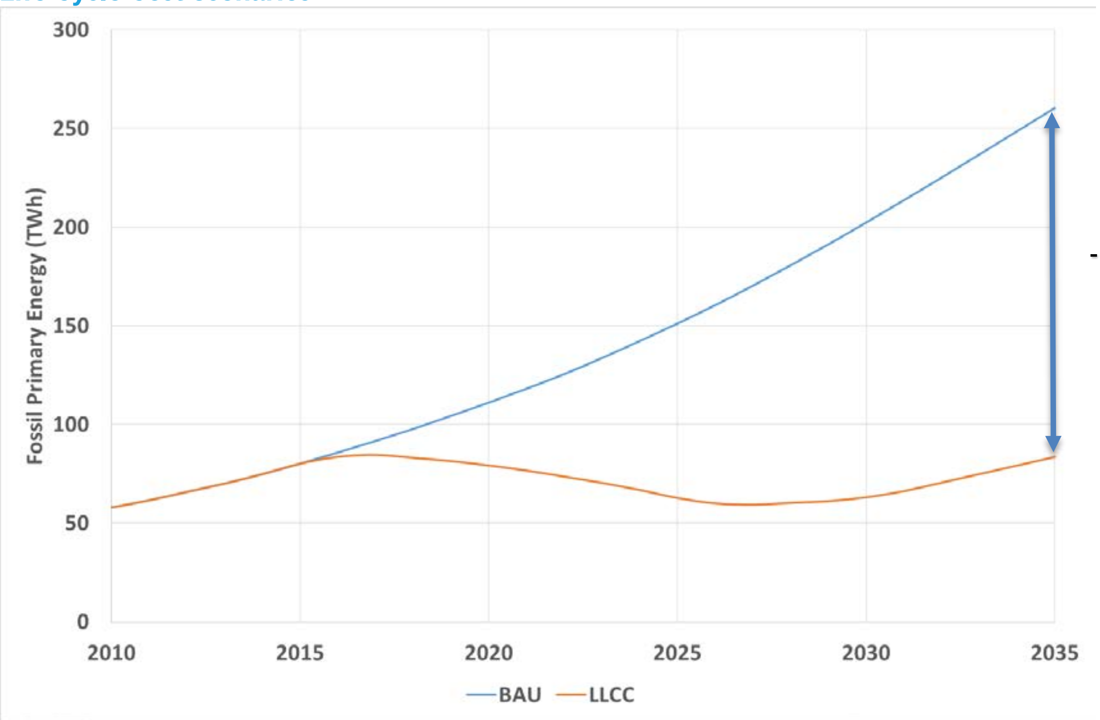
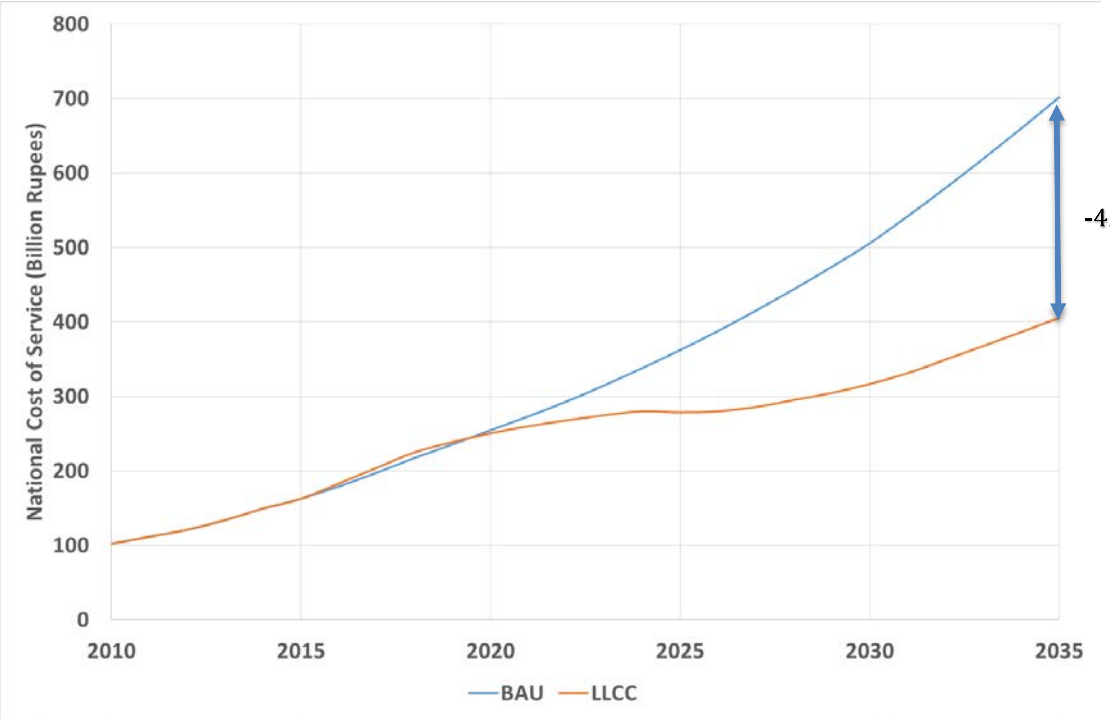


Figure 25. Estimated Water Heater Primary Energy Consumption in India for the BAU and Least Life Cycle Cost Scenarios



The impact of water heaters on the Indian economy is indicated in Figure 26. Over the 20 years of the scenario period adopting the LLCC scenario would save 2211 billion Rupees in consumer costs compared to the BAU Scenario. This is equivalent to savings of 30448 Rs per water heater owning household over the period at an average of 1522 Rs/year per household with a water heater. At the end of the scenario period the LLCC scenario is saving water heater using consumers 296 billion Rupees a year, or some 3311 Rupees per household.

Figure 26. Estimated Water Heater Costs in India for the BAU and Least Life Cycle Cost Scenarios



The Recommended Policy Scenario

Figures 27 to 29 show the same information for Recommended Policy scenario (see section 6) with the other two scenarios included for comparison. The cumulative final savings to 2035 under the Recommended Policy scenario are 143 TWh for site energy, 447 TWh of primary fossil energy, and 555 billion Rupees in consumer costs. These are respectively 37%, 25%, and 25% of the equivalent savings under the LLCC scenario. The principal reason for the reduction is the need for time to develop and roll out the program at an increasing scale for an economy of the huge scale of India. The savings per household participating in the program are exactly the same as under the LLCC Scenario so the lower level of savings simply reflects the real world challenges inherent in aiming to bring about transformation across a vast number of actors. The savings are expected to continue to grow and become much closer to the LLCC scenario were the scenario time period to be extended beyond 2035.

Figure 27. Estimated Water Heater Final Energy Consumption in India for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios

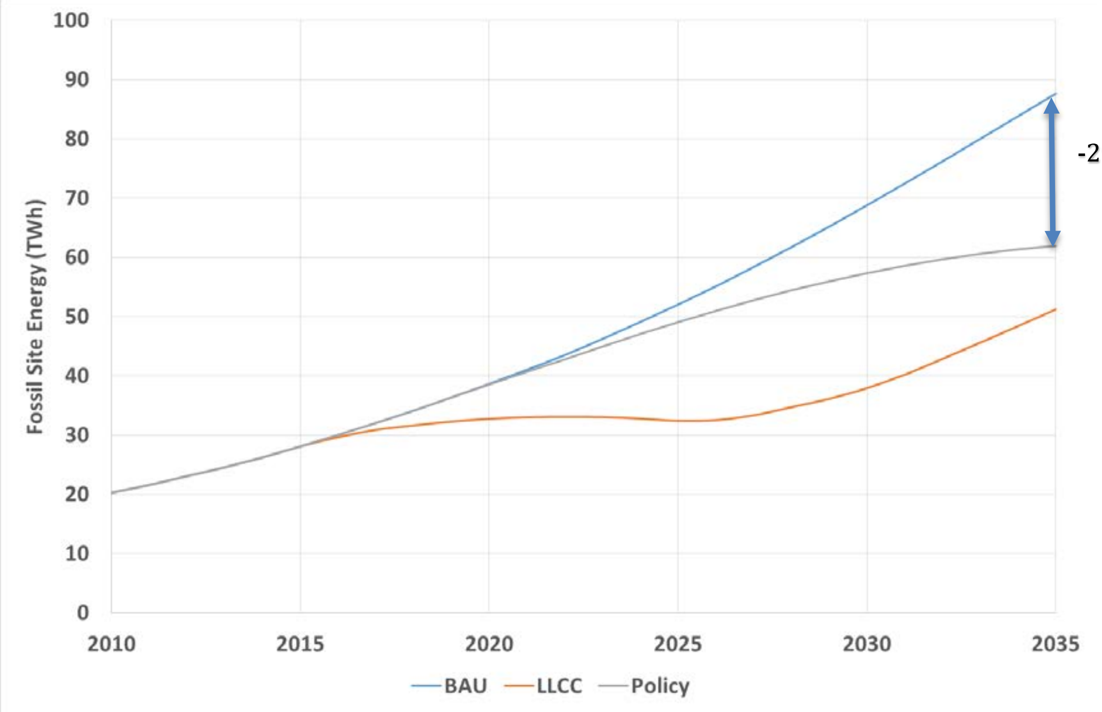


Figure 28. Estimated Water Heater Primary Energy Consumption in India for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios

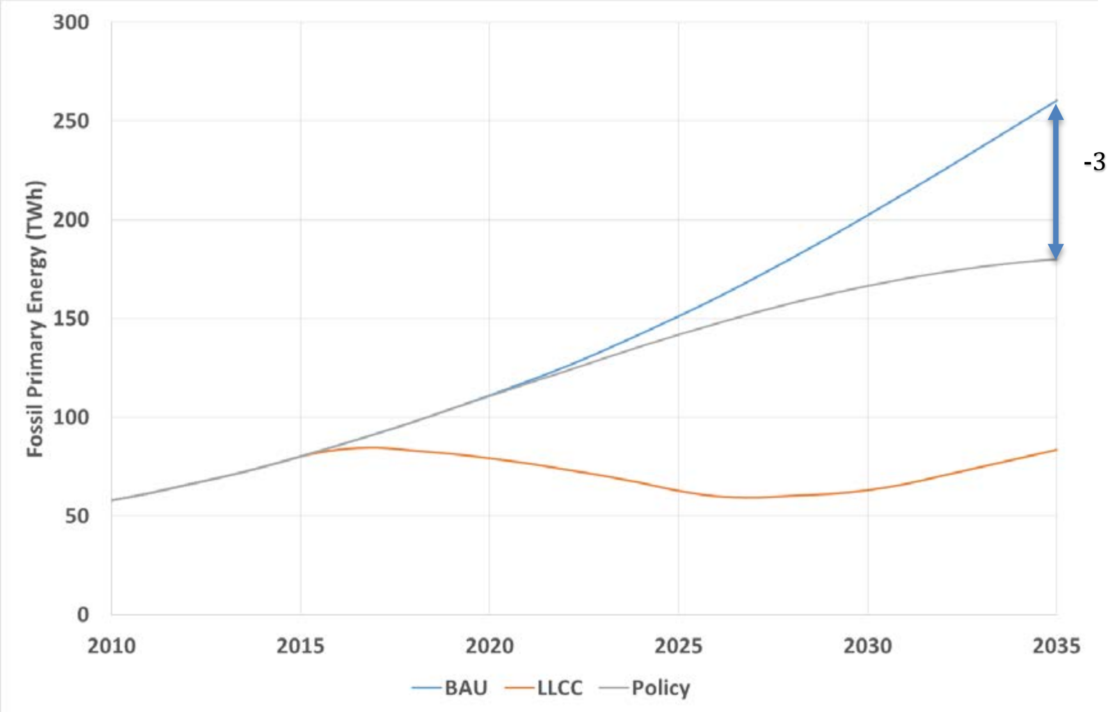
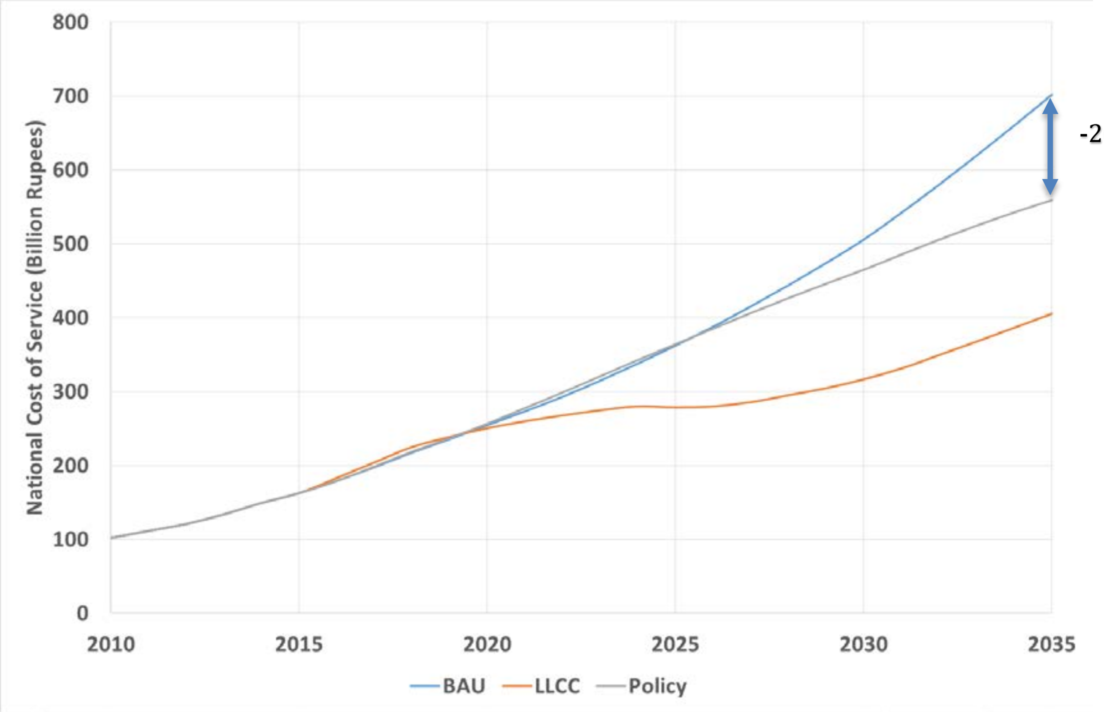


Figure 29. Estimated Water Heater Costs in India for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios



Figures 30 to 32 show the how the site energy delivered by water heater technology varies as a function of the policy scenario, where HPWH = heat pump water heater.

Figure 30. Estimated Water Heater Final Energy Consumption in India for the BAU Scenario by Water Heater Technology

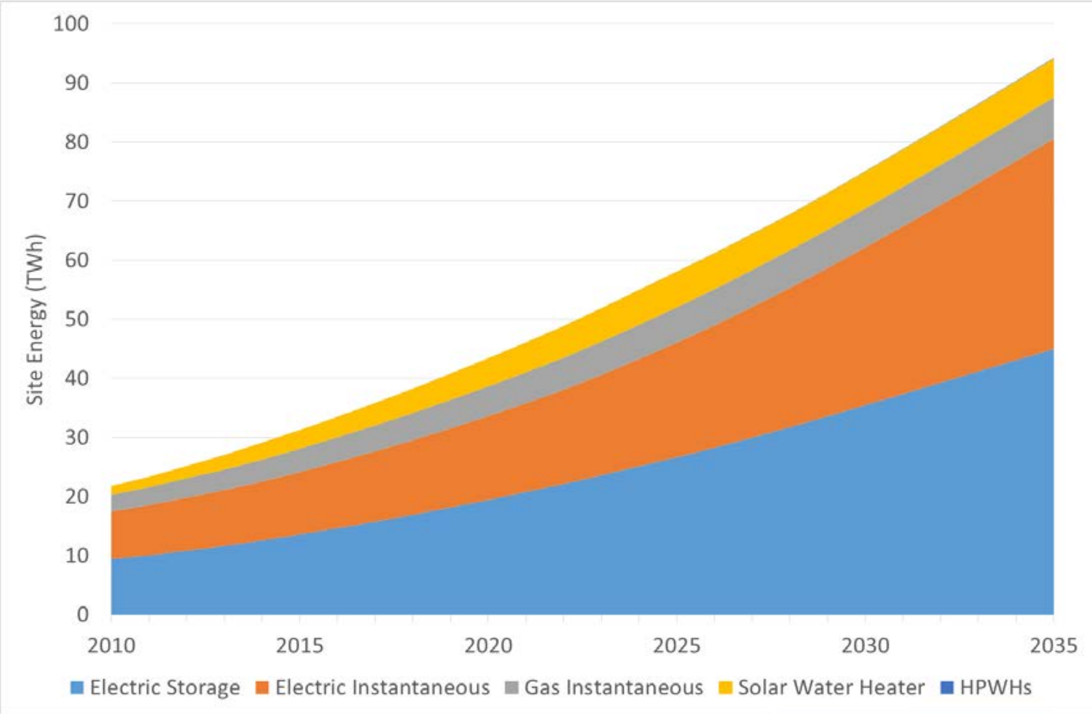


Figure 31. Estimated Water Heater Final Energy Consumption in India for the Recommended Policy Scenario by Water Heater Technology

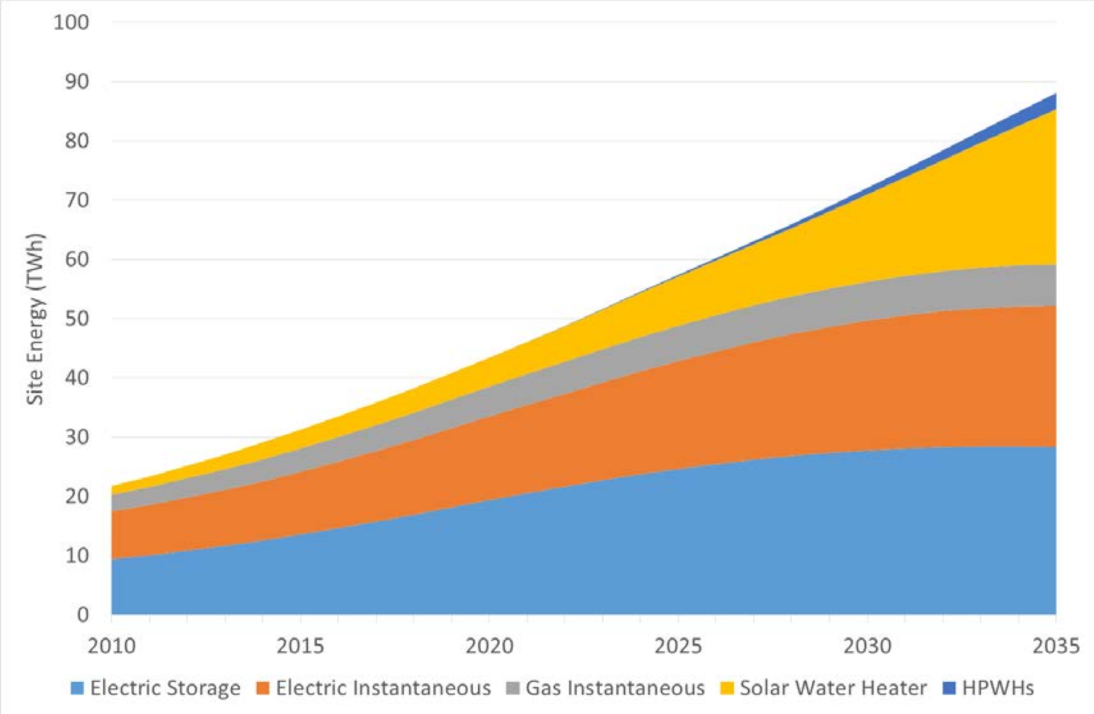
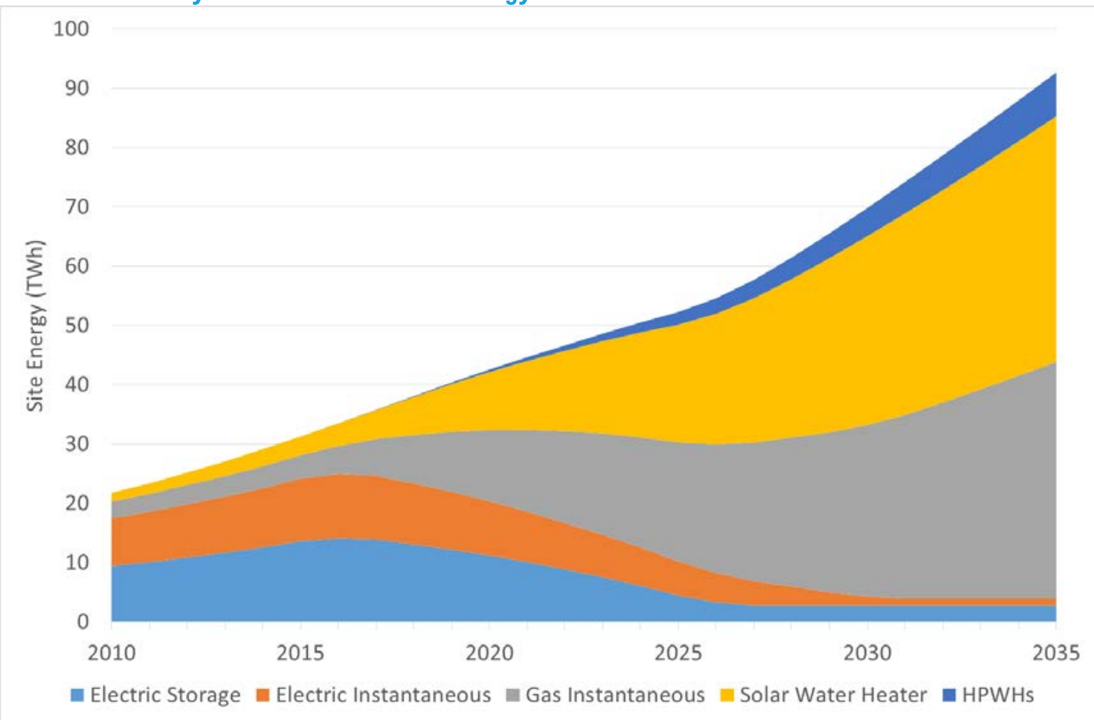


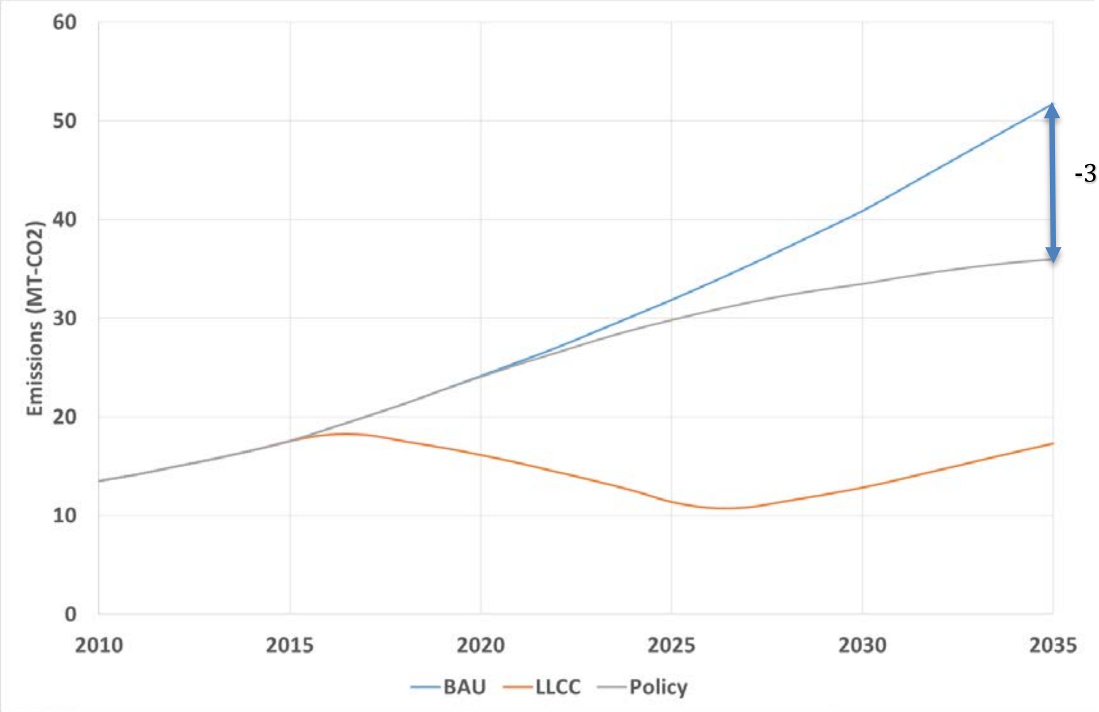
Figure 32. Estimated Water Heater Final Energy Consumption in India for the Least Life Cycle Cost Scenario by Water Heater Technology



Environmental impacts

The impact of water heaters on energy-related CO_2 emissions is shown in Figure 33. Under the BAU Scenario emissions rise from 18 to 52 Mt-CO_2 per year from 2015 to 2035. Under the LLCC Scenario they actually decline to 10.5 Mt-CO_2 in 2026 before rising back up to 17 Mt-CO_2 by 2035. The Recommended Policies scenario sees emissions rise gently towards a peak at 36.5 Mt-CO_2 in 2035. Cumulative emissions (2015-2035) in the policy scenario are 599 Mt-CO_2, a reduction of 91 Mt- CO_2 (13%) from BAU emissions of 691 Mt-CO_2.

Figure 33. Estimated Water Heater related CO_2 Emissions in India for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios



USA

The BAU and Least Life Cycle Cost Scenarios

The historic and projected energy consumption of water heaters in the US under the BAU and LLCC scenarios is shown in Figure 34. Under the BAU Scenario water heater energy use rises from 488TWh of final energy in 2015 to reach 506 TWh in 2035 at an annual average rate of growth of 0.2%. All US households have a water heater over the period. By contrast over the 20 years of the scenario period adopting the LLCC scenario would save 2781 TWh in final energy consumption compared to the BAU Scenario. This is equivalent to savings of 12372 kWh per water heater owning household over the period at an average of 1018 KWh/year per water-heater. At the end of the scenario period the LLCC scenario is saving water heater final fossil fuel energy consumption of 265 TWh a year, or some 1893 kWh per household per year.

In fossil primary energy terms the impacts are even greater due to the additional losses in the production of and distribution of electricity, see Figure 35. The LLCC Scenario produces cumulative primary energy savings of 3410 TWh over the scenario period that rise to 258 TWh/year in 2035, savings equivalent to 32% of the BAU water heater fossil primary energy consumption.

Figure 34. Estimated Water Heater Final Energy Consumption in the US for the BAU and Least Life Cycle Cost Scenarios

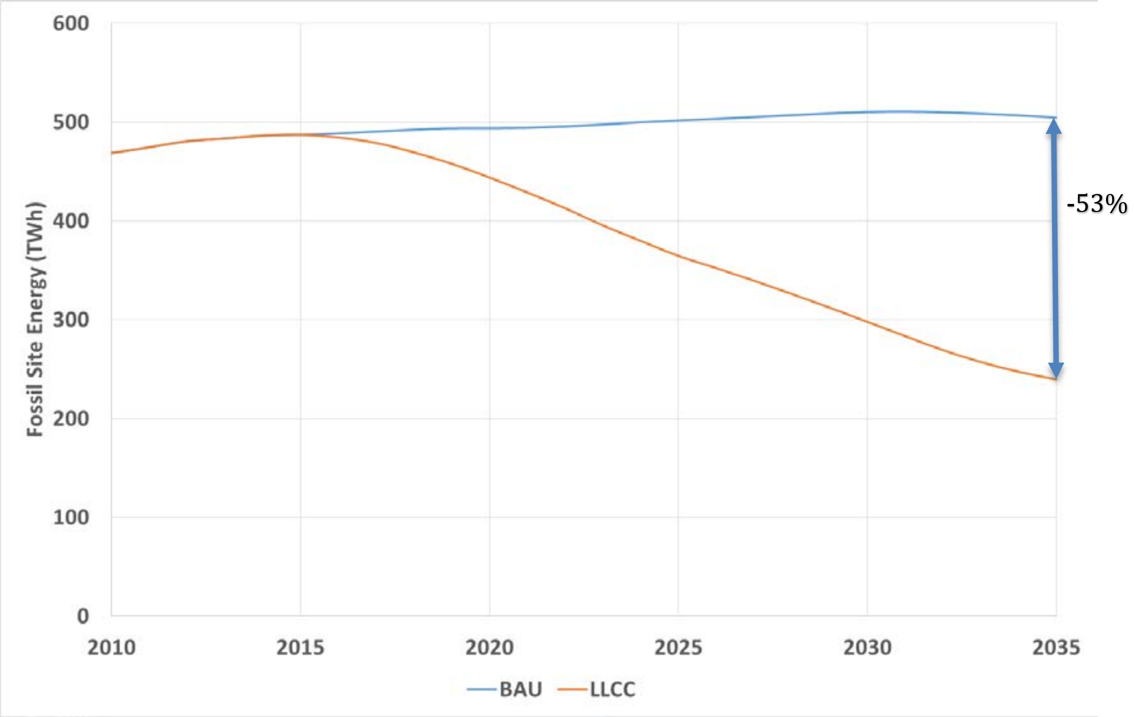
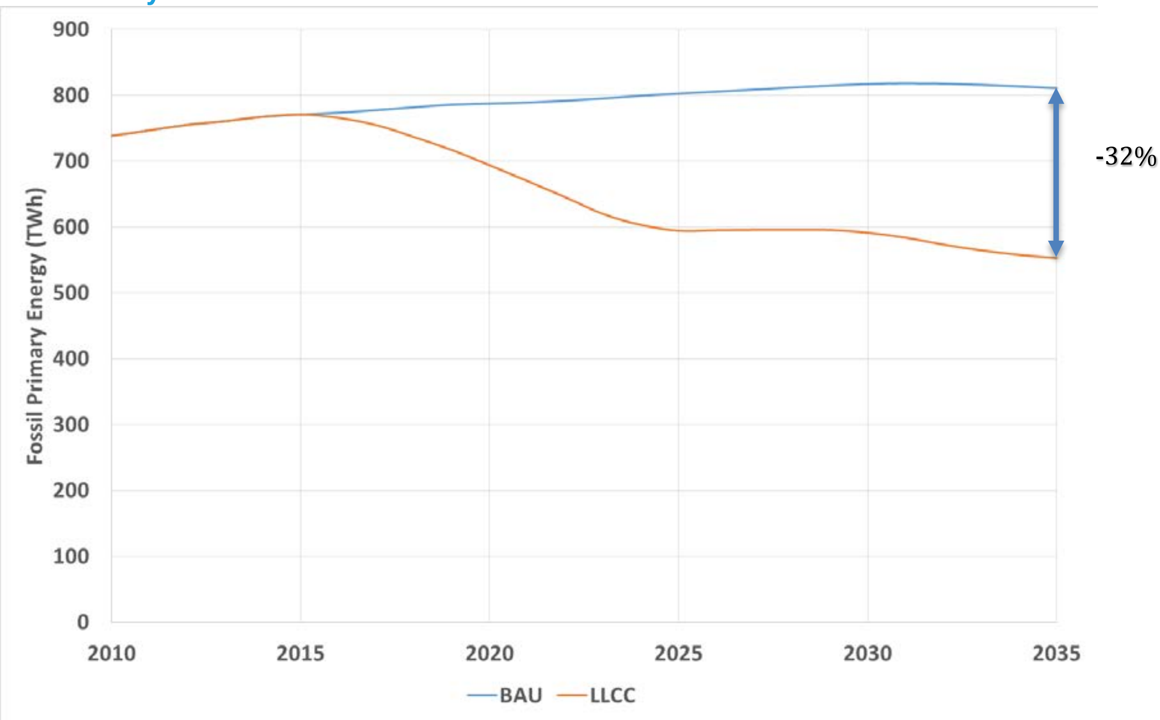
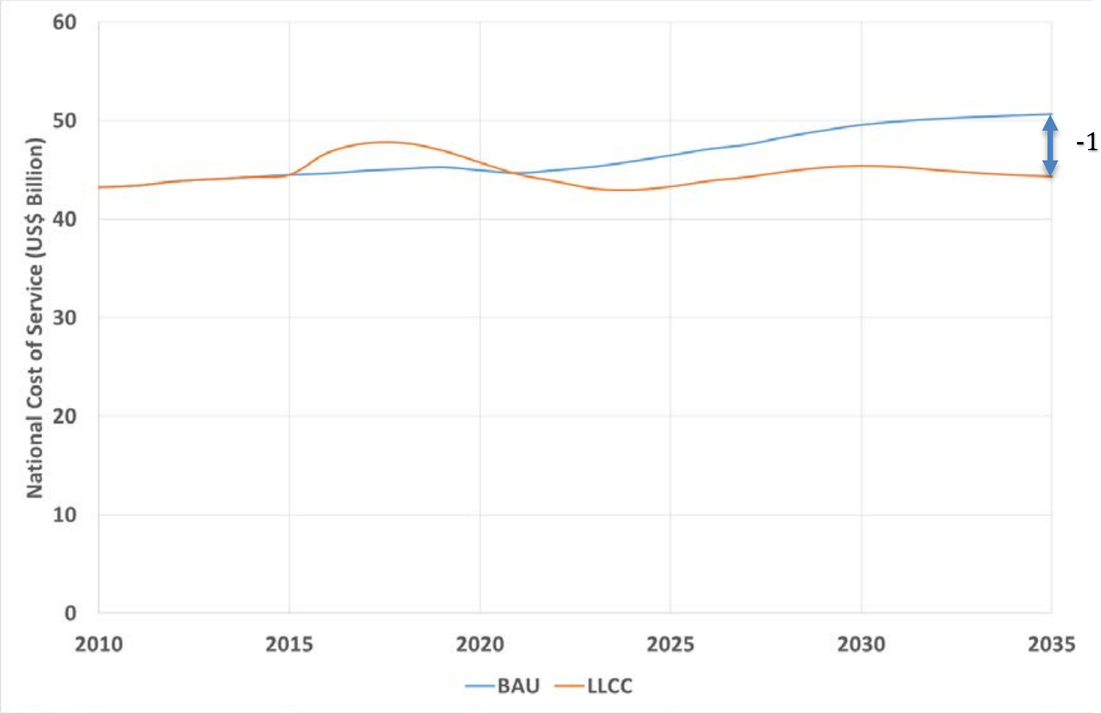


Figure 35. Estimated Water Heater Primary Energy Consumption in the US for the BAU and Least Life Cycle Cost Scenarios



The impact of water heaters on the US economy is indicated in Figure 36. Over the 20 years of the scenario period adopting the LLCC scenario would save US$45 billion in consumer costs compared to the BAU Scenario. This is equivalent to savings of US$333 per household over the period at an average of US$17/year per household. At the end of the scenario period the LLCC scenario is saving water heater using consumers US$6.3 billion a year, or some US$46 per household.

Figure 36. Estimated Water Heater Costs in the US for the BAU and Least Life Cycle Cost Scenarios



The Recommended Policy Scenario

Figures 37 to 39 show the same information for Recommended Policy scenario (see section 6) with the other two scenarios included for comparison. The cumulative final savings to 2035 under the Recommended Policy scenario are 793 TWh for site energy, 1275 TWh of primary fossil energy, and US$63.5 billion of consumer costs. These are respectively 43%, 56%, and 36% of the equivalent savings under the LLCC scenario. The savings per participating household are exactly the same as under the LLCC Scenario. The lower level of savings simply reflects the real world challenges inherent in aiming to bring about transformation across a vast number of actors. The savings are expected to continue to grow and become much closer to the LLCC scenario if the scenario time period extended beyond 2035. In particular, the cost-effectiveness of the scenario would become evident in the period immediately beyond 2035. By that time, energy savings incurred by the investments would outweigh the additional incremental investment costs leading to clear net cost savings.

Figure 37. Estimated Water Heater Final Energy Consumption in the US for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios

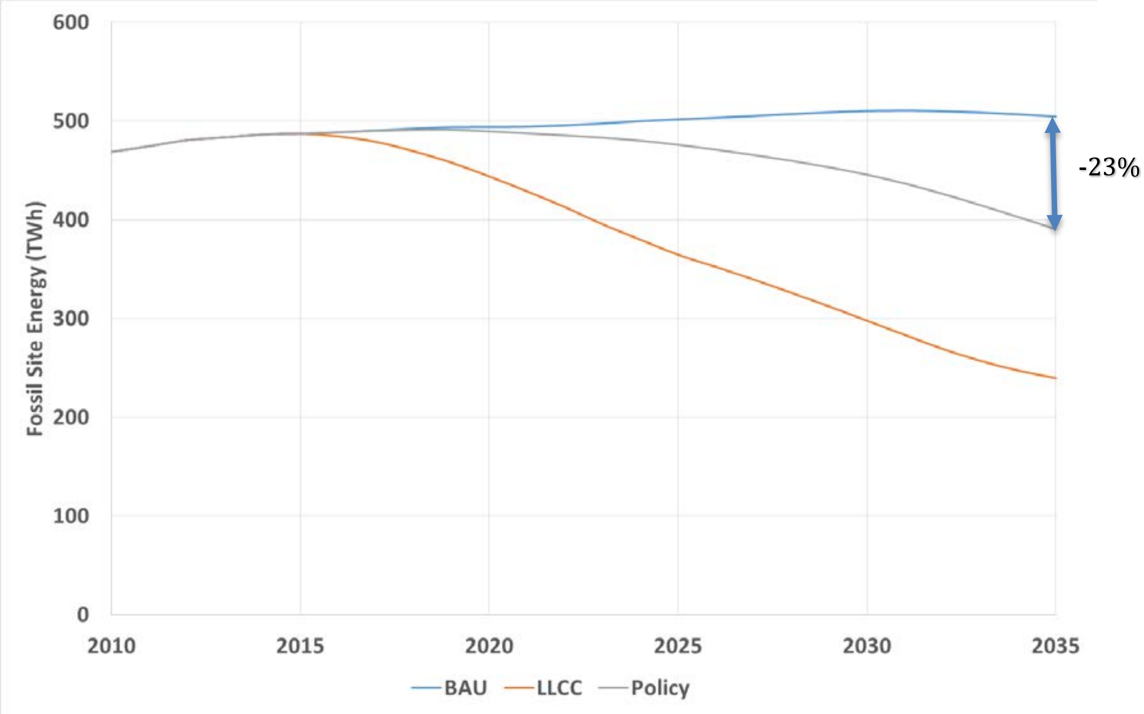


Figure 38. Estimated Water Heater Primary Energy Consumption in the US for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios

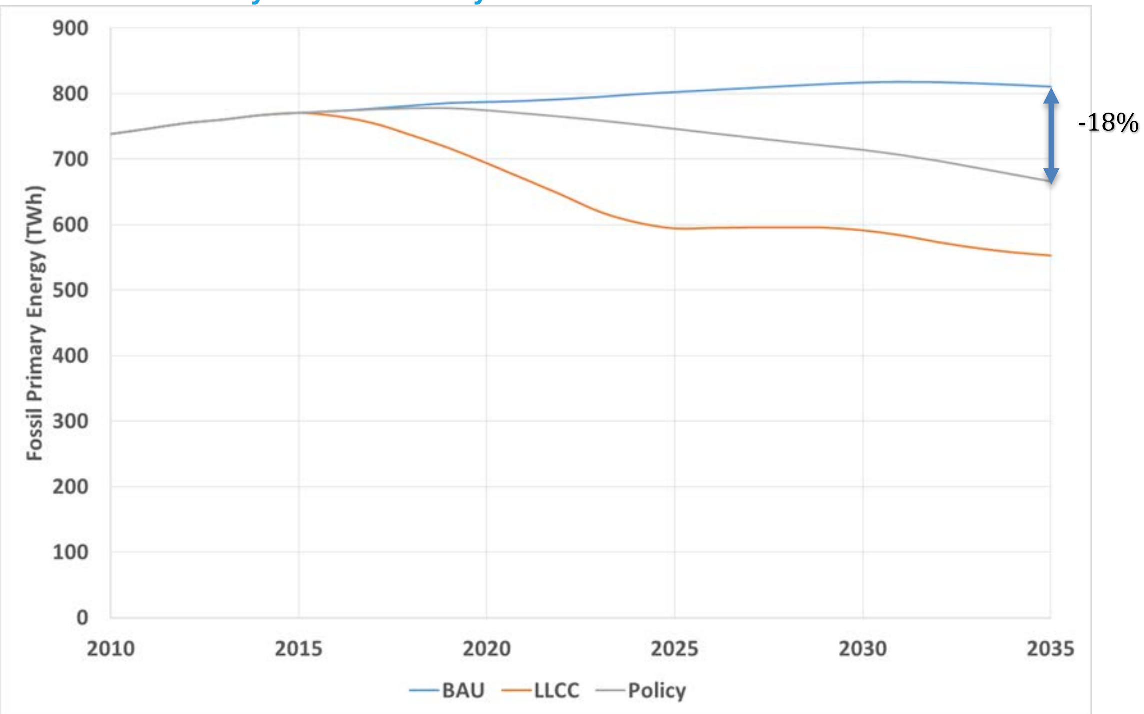
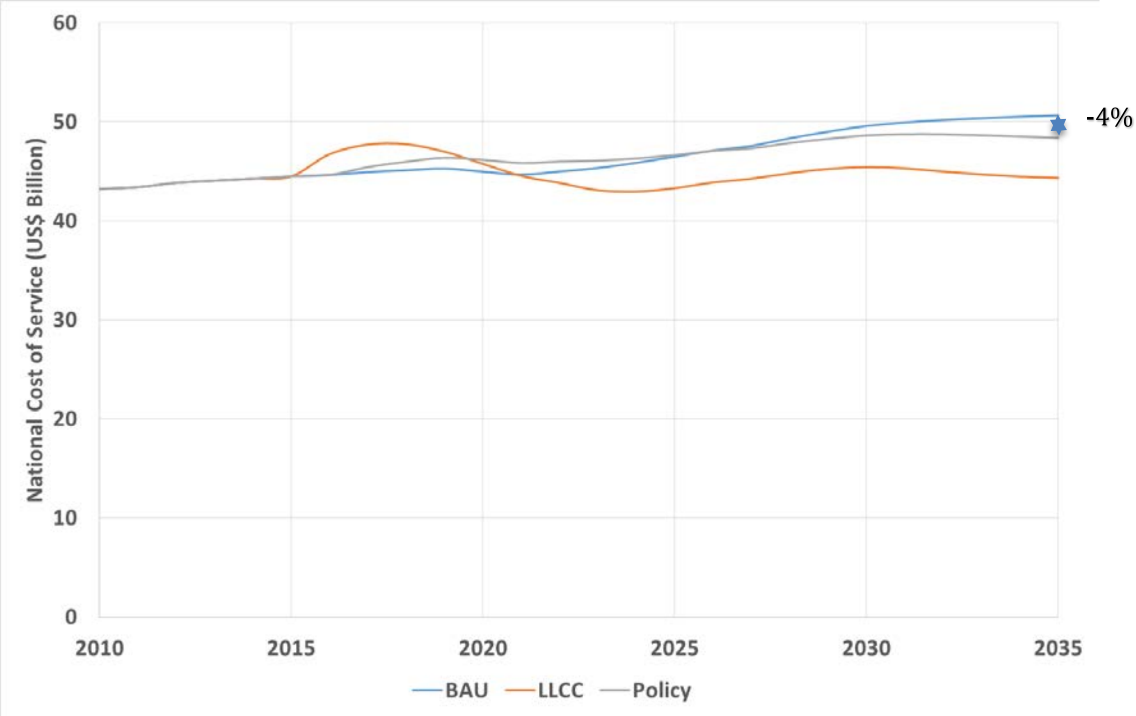


Figure 39. Estimated Water Heater Costs in the US for the BAU, Recommended Policy and Least Life Cycle Cost Scenarios



Figures 40 to 42 show the how the site energy delivered by water heater technology varies as a function of the policy scenario, where HPWH = heat pump water heater.

Figure 40. Estimated Water Heater Final Energy Consumption in the US for the BAU Scenario by Water Heater Technology

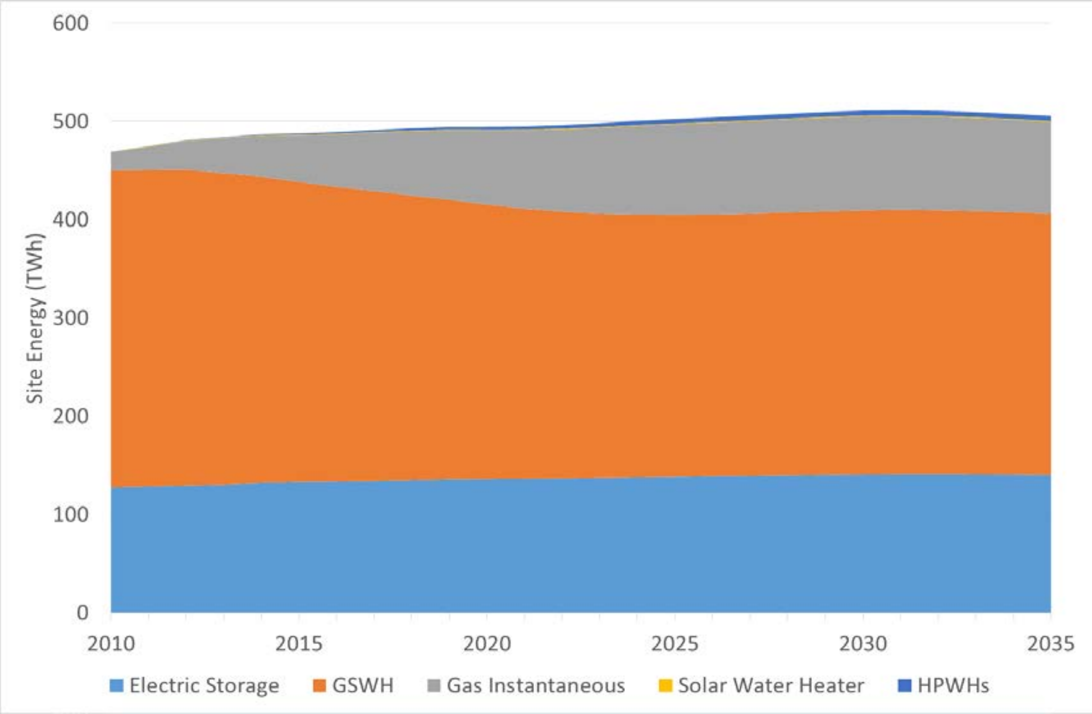


Figure 41. Estimated Water Heater Final Energy Consumption in the US for the Recommended Policy Scenario by Water Heater Technology

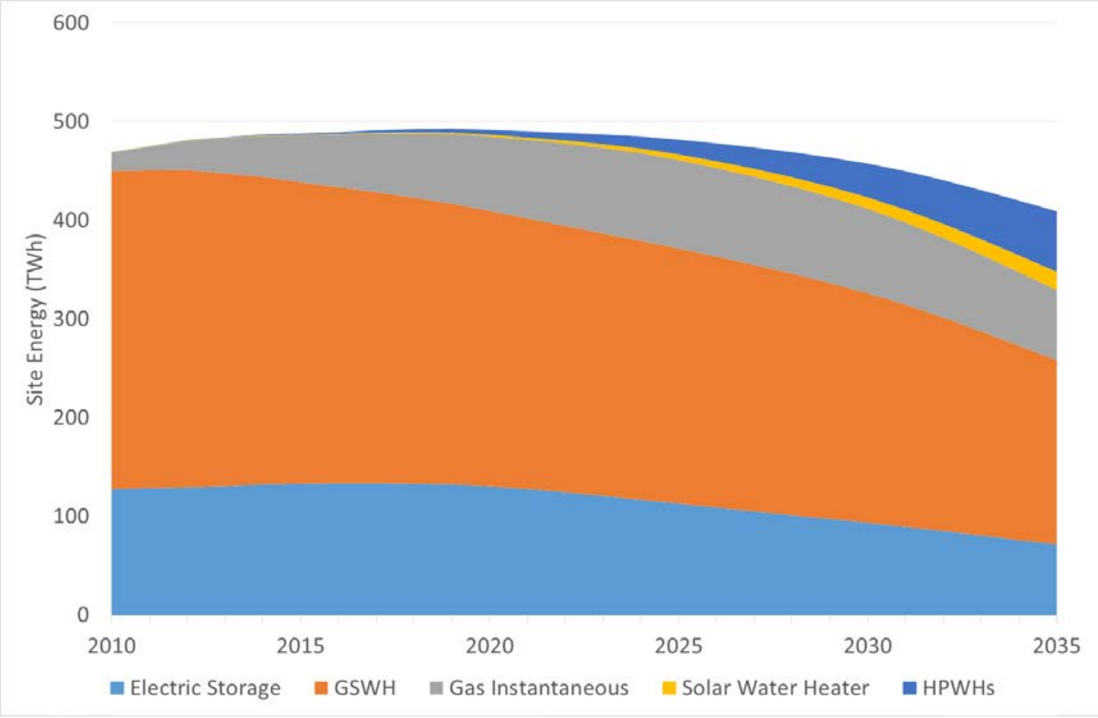
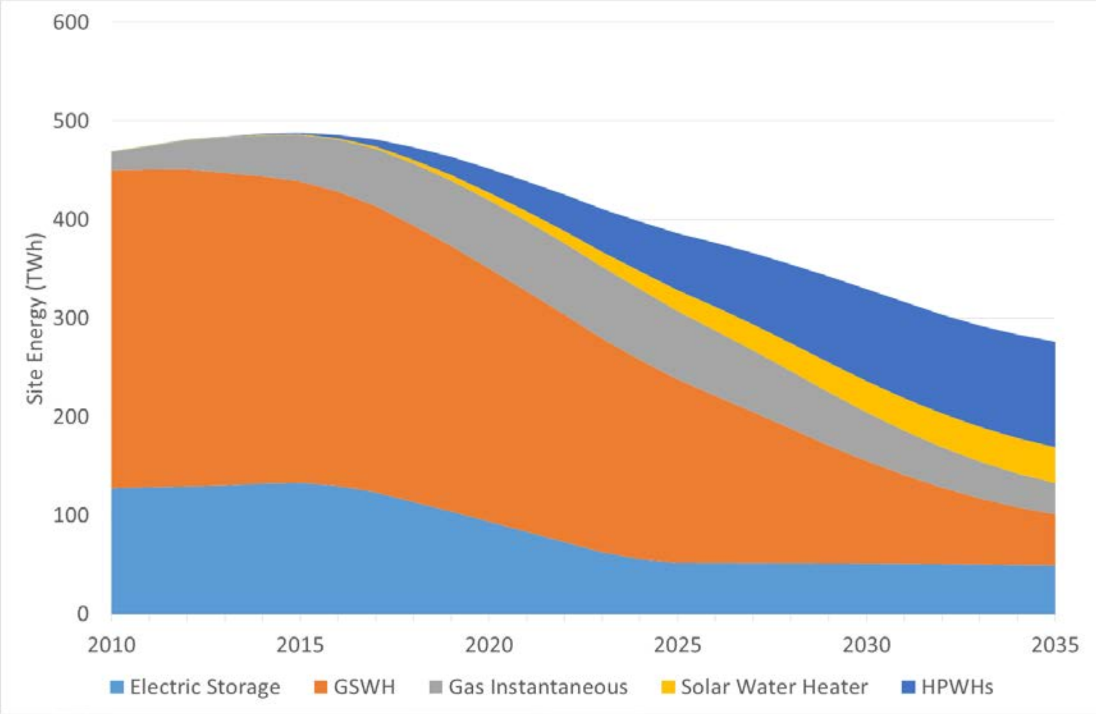


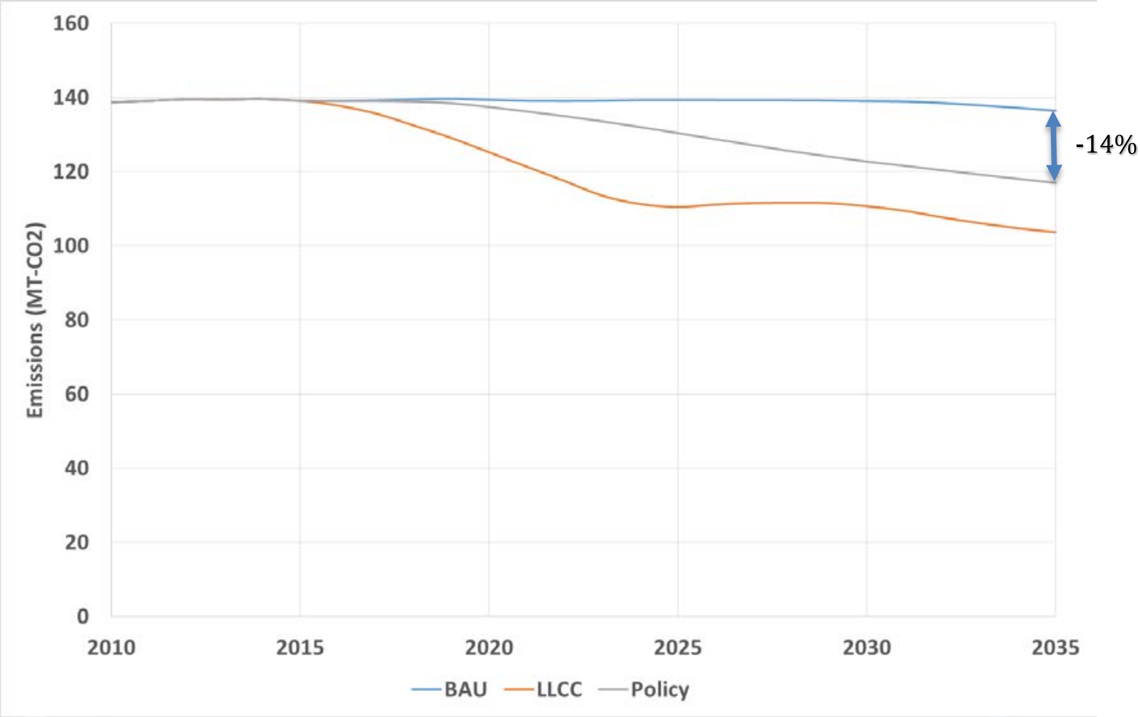
Figure 42. Estimated Water Heater Final Energy Consumption in the US for the Least Life Cycle Cost Scenario by Water Heater Technology



Environmental impacts

Figure 43 shows the impact of water heaters on energy-related CO_2 emissions. Under the BAU Scenario emissions vary from 140 to 136 Mt-CO_2 per year from 2015 to 2035. Under the LLCC Scenario they decline to 104 Mt-CO_2 in 2035. The Recommended Policies scenario sees emissions decline steadily, reaching 118 Mt-CO_2 in 2035. Cumulative emissions (2015-2035) in the policy scenario are 2743 Mt-CO_2, a reduction of 173 Mt-CO_2 (6%) from BAU emissions of 2916 Mt-CO_2.

Figure 43. Estimated Water Heater related CO_2 Emissions in the US for the BAU, Recommended Policy, and Least Life Cycle Cost Scenarios



06 Policy recommendations

Generic recommendations

Each of the three economies considered has a very substantial potential for additional fossil fuel energy savings from the adoption of more efficient water heater technology. In each case this will also reduce the cost of the water heating service and reduce environmental impacts associated with water heater energy use. To bring this market transformation about, however, will not be easy due to a mix of information, first cost, public perception and other barriers (of varying importance depending on the economy considered). Policies known to be effective are recommended to address each of these barriers.

The easiest issue to address is information. In all three economies there is a dearth of water heater energy labeling that indicates the relative energy performance of water heaters across technology types. The introduction of water heating energy labeling based on either primary energy consumption or estimated mean life cycle costs is recommended. It enables consumers to make informed choices across technology types and not just within them. The EU has shown how this can be achieved and there is no technical reason why this type of labeling approach cannot be adopted in China, India, or the USA. Ironically, it is the least efficient water heating technology (electric resistance storage heaters) that currently have energy labels in each of these economies while many of the other types do not. This practice risks confusing some consumers into believing that a water heater with a high label rating is more efficient than an alternative type of water heater without an energy label, when exactly the opposite may often be the case.

Information provided in the form of an energy label will also need to be supported by more general awareness raising efforts and communication campaigns. They need it to inform consumers and participants in the supply chain about how much they stand to gain in overall service cost reductions if they invest in the higher efficiency water heater technologies. Few energy labels are successful at communicating life cycle costs and hence there is a need to back up the more static information provided by a label with more comprehensive awareness raising efforts. Databases and smart-phone applications can assist in making information more widely accessible and personalizing savings opportunities. In some markets it may be necessary to address negative perceptions about high efficiency water heater technology. They can be perceived to carry too much risk or simply not have a positive image.

The high efficiency water heater technologies, such as solar and heat pump water heaters, have significantly higher initial cost compared with the less efficient alternatives. It is therefore critical to implement measures that help to alleviate this barrier. The choices are either to provide subsidies and favorable taxation or to create business models where payment is made in instalments that use the value of the energy saved to buy-down the first cost differential. Government can play a key role in fostering such business models through ensuring legal frameworks are compatible, helping to carry risk, acting as a sector aggregator, supporting quality and hence raising consumer confidence, and supporting capacity in the supply chain. Government can also help alleviate the price differential for high efficiency technologies through helping to build demand and aiding technology learning curve phenomena to improve the efficiency of production and supply and thereby lower costs. Subsidies and supportive taxation regimes can be used to help achieve these transformations, with eligibility criteria being linked to product quality and supply chain support measures (e.g. extended warranty and installer training). Supportive tax regimes can be used on anything from VAT to corporation tax and even on property taxes i.e. to act throughout or at different points in the supply chain. They can be favorable to encourage high efficiency options and punitive to discourage low efficiency options. Incentives can be funded through public expenditure or through revenues raised on energy tariffs. The latter have the advantage of directly linking energy bill revenues to energy savings and can usually be implemented on a more ambitious scale but they do require appropriate regulation of utilities to be in place.

Given the very high cost effectiveness of high efficiency water heater technology, such as solar thermal and heat pump water heaters, compared to investing in energy supply it makes sense for these incentives and/or tax regimes to be of a sufficient scale to effect a wholesale market transformation over time. That said, this financial support should also be temporary and only act long enough to secure the transformation while helping stimulate learning curve benefits. The objective should be to help ease or eliminate the first cost disadvantage and foster market conditions where this is sustained when direct financial incentives are ended.

A key component of high efficiency water heater strategy is ensuring that a high efficiency water heater is a natural choice at the moment a water heater is acquired. Policies need to address both new build and replacement purchases. When water heater markets transition from a new build driven to a replacement market it becomes harder to influence the replacement decision as the easiest choice is to fit the same type of water heater that has failed into the same space and fixture. Therefore, it is essential to focus on ensuring the choice of water heaters being installed in new construction or major renovations are efficient by default. This means creating supportive regimes in the construction sector so that developers opt to install efficient water heaters for their properties prior to placing them on the market. While, this type of focus will deliver faster results in economies with a high proportion of new build or first time water heater installations, such as India and China, it will also help affect systemic change in economies with much slower rates of first time installations (e.g. the USA).

Mandatory measures can be extremely effective and should be used where reasonable to help lock in energy efficient choices. These may be in the form of stringent building codes specifications, solar ordinances to apply to new build or conversely in the form of renewable energy or energy efficiency obligations on utilities structured so that measures addressing water heaters are expressly eligible as a means of meeting the obligation. In principle these should be technology neutral even if in practice the criteria are specified so that only certain types of existing technology can meet it. For example, it might be more appropriate to specify stringent minimum primary energy efficiency requirements on water heaters being installed in new construction than to require solar water heaters. In practice these may be set such that only solar water heaters or advanced heat pump water heaters can meet the requirement unless some innovative approach is adopted such as a very high efficiency district heating system.

Given the importance of the topic and complexity of the challenge the key first need is to develop a coherent, ambitious and viable national strategy for water heating. This requires developing program goals and actions and bringing together key stakeholders, including but not driven by the incumbent water heater industry, to help inform and implement it. The strategy will need to identify the magnitude of opportunities and identify and prioritize actions that will bring the greatest savings at least cost. This in turn requires relevant barriers to be correctly evaluated and ameliorative actions to be implemented on a scale that is adequate to overcome them. If near term stakeholder interests are among these barriers then means will need to be found to overcome these either through alignment of interests with the program benefits or provision of sufficient time for a successful transition.

Economy specific recommendations

China

China's water heater market appears to be at an inflexion point and there is considerable uncertainty about future levels of demand. Nonetheless, if China continues to follow hot water demand trends as a function of per capita GDP, then growth in demand of approximately 5.8% per annum can be expected by 2035, assuming the validity of mainstream GDP projections. From an economic and environmental perspective the key issue will be the degree to which this growth in demand is met by high efficiency and low carbon solutions such as solar, heat pump and to a lesser extent natural gas water heaters versus energy intensive resistance electric water heating. Traditionally China has a farsighted policy with respect to water heaters and has built up an impressive proportion of solar water heating in the overall water heater stock. It has also been proactive in stimulating improvements in fossil fuel powered heaters through the use of energy efficiency standards and labeling coupled with selective incentives.

The challenge China faces in minimizing the energy, economic, and environmental impact of water heaters is to find a route to promote the high efficiency, low carbon, low life cycle cost technologies against the background of some difficult structural changes. In particular, the solar water heater market is driven much more strongly by the rate of new construction than is the electric storage water heater market, because the former requires higher capital outlay, professional installation and access to external sites (which is easier to attain for new-build roof spaces for shared ownership buildings which are already occupied). Also, a higher percentage of low rise building occupants have access to solar resources than in high rise buildings so as a greater percentage of China's population moves from low rise rural locations to high rise urban locations it becomes more challenging to continue to provide such a large proportion of all hot water demand through solar water heaters. On the other hand heat-pump water heaters, while very promising, have high upfront costs and are more likely to be attractive to relatively affluent families that use greater than average amounts of hot water. Thus, it will take time and nurturing to support a substantial heat pump water heater market. Another challenge is the degree to which domestic sector energy tariffs are subsidized as these discourage consumers from investing in technologies that have the Least Life Cycle Cost from a societal perspective.

In the case of solar, it is an inexpensive industry for SME's to enter but the large number of such enterprises has raised concerns about product quality. Chinese industry has recently innovated balcony solar water heaters that are designed for installation on the sides of urban apartment blocks, and these hold out potential to increase the proportion of urban dwellings that can benefit from solar water heating, albeit with somewhat lower access to the solar resource than roof top systems would normally receive. Both solar and heat pump water heaters should expect to benefit from price reductions due to learning curve effects, with cost reduction rates of about 10% per doubling of the installed volume for solar water heaters and probably at least 18% for heat pump water heaters, therefore, sustained public-private efforts to drive up volumes could go a long way to develop a sustainable low carbon water heater market. The challenge in an economy such as China where hot water demand is still far from saturated and demand is highly sensitive to cost and income, is to find a policy which stimulates transition to the high efficiency low carbon technologies without strongly accelerating overall demand for domestic hot water.

The key will be in ensuring any stimulus helps reduce the first cost and structural disadvantages that impede high efficiency water heater technologies without artificially making them cheaper to acquire than the less efficient conventional water heater technologies.

Given these factors it is recommended that China:

- Introduce a common primary energy label applicable to all types of domestic water heater technologies,
- Extend high efficiency water heater ordinances to all residential new build and major renovations,
- Strengthen financial incentives for solar and heat pump water heaters,
- Foster innovative pay-as-you-save style business models to minimize first cost barriers,
- Raise public awareness of the life cycle cost benefits of high efficiency water heaters,
- Ensures sufficient high efficiency water heaters are of sufficient quality.

These are now discussed in turn.

Energy labeling based on primary energy

There is a need to develop an energy label that indicates the primary energy efficiency of all water heater types and thereby allows water heater consumers to compare options across technology types. China currently has separate energy labels for electric storage water heaters and for solar water heaters. It is not possible to compare performance across all types of water heaters. It is important that consumers should be able to see how the efficiency of these technologies compares to each other. Failure to do so may inadvertently give the false impression that a Grade 1 electric storage water heater is as efficient as a Grade 1 solar water heater and also gives no recognition to heat pump water heaters, nor to gas water heaters. Furthermore, it would be very helpful for the marketing of solar and heat pump water heaters if it was evident they are far more efficient than conventional electric water heaters. There is a broad difference in performance between high and low efficiency water heaters in primary energy terms. Meaningful labeling scale is likely to require more classes than China has used in previous energy labels i.e. more than 5 classes. Otherwise there is a risk of little measureable different between specific types of water heater technology. Label design mechanisms for addressing this issue were considered in the EU's recent review of its energy labeling Directive[12].

Building codes and ordinances

China has successfully implemented mandatory building energy performance codes and solar ordinances in many cities. It is recommended that both policies be extended to require the installation of high efficiency (i.e. low primary energy) water heaters such as solar or heat pump water heaters in all residential new construction or major renovation. This will lock-in an energy efficient water heater in all sites where water heaters are being installed for the first time and not only will save a substantial amount of energy for the lifespan of the water heater concerned but makes it much more likely that when these water heaters are eventually replaced that it is with energy efficient replacement units. The rapid extension of such measures will require coordination and cooperation between national and local authorities in order to ensure the scale of opportunity is realized.

Incentives, financing, promotion, and taxation

At present the two most efficient water heater technologies are those that have the highest capital expenditure demands. This will deter ordinary consumers from purchasing them unless the first cost price differential can be minimized. The fact that the high efficiency products have a much lower operating cost, lower life cycle cost, and greater storage capacity and hence greater user convenience is likely to be viewed as a luxury that most consumers would feel unable to afford due to constraints in their disposable income. Heat pump water heaters are currently about 3.2 times more expensive than electric storage water heaters in China and solar water heaters about 1.8 times more expensive once average capacity differences have been taken into account. Happily, the learning curve of both high efficiency water heaters is much steeper than for conventional water heaters. If their sales volumes are stimulated the price differential will be eroded more rapidly. This means that short term financial stimuli can help to create a fully sustainable long term market.

Stimulation of substantial market transformation therefore requires a strategy to remove the high first cost affordability barrier while simultaneously promoting the lower life cycle cost benefits of higher efficiency water heaters. Technical suitability factors mean that the most viable alternative high efficiency water heater type will depend on the specific market being considered. Solar water heaters are clearly the most suitable technology and Least Life Cycle Cost option for most low rise

12 For examples of how this can be achieved, see Figure 17 on page 129 of the final report at: http://www.energylabelevaluation.eu/eu/documents/

locations where there is a sufficient solar resource and an inexpensive roof or land space. In cities they are clearly the most viable for apartments within the top two stories of unshaded apartment blocks that are sufficiently close to the roof space. Predominantly south facing apartments can also use balcony solar water heaters to generate hot water. Other apartment types are likely to need alternative technologies such as heat pump water heaters. The recent contraction of the Chinese solar water heater market is likely to be due to a combination of a decline in new construction rates, coupled with the end of temporary state subsidies against a background of progressively more of the population moving into urban environments. If left unaddressed it is likely that sales of solar water heaters will continue to decline compared with low cost alternatives so there is clearly a strong case for government support of the sector. There are many ways this could be done from renewal of the recently lapsed subsidies to VAT or producer tax credits. Aware of the need to strengthen quality China sensibly tied its previous subsidy levels to the quality and energy performance of the solar water heaters and it would make sense to build upon this experience in the design of any new subsidies. To ensure such subsidies are compliant with WTO requirements they would need to be open to any producer, whether manufacturing locally or nationally and would also need to ensure they do not constitute an effective export subsidy. Some WTO compliant options include removal or lowering of VAT for eligible products and or provision of personal (i.e. consumer) tax breaks that can be offset against the cost of acquiring energy efficient technologies such as high efficiency water heaters.

Through structuring the subsidy scheme to avoid undercutting the upfront expenditure for a water heater in relation to conventional water heaters it will avoid excessive rebound effects where overall numbers of water heaters could increase faster than would have otherwise occurred; however, a modest rebound effect will still be expected due to the extra disposable income water heater users would have compared to the BAU scenario as a result of lower operating costs over the medium term. This is not a negative phenomenon, however, as it supports economic development objectives and helps transfer wealth from energy intensive and low employment sectors, such as energy supply, to those that better stimulate growth detached from negative environmental and national balance sheet impacts.

Fostering of innovative business models

A related but alternative means of overcoming the first cost disadvantage of high efficiency water heaters is to amend the vendor business model to allow consumers to time repayments to match the level and rate of energy bill savings. A pay-as-you-save repayment structure avoids imposing any cash flow disadvantage on consumers compared to the case where they would purchase a default electric storage water heater.

In particular, the state could actively encourage solar water heater and heat pump water heater manufacturers and retailers to provide upfront financing and leasing schemes to customers which would remove the first cost disadvantage. Repayment could be structured in terms of an upfront payment priced to be equivalent to that of a standard electric storage water heater followed by a set of regular instalments set at a level equivalent to the estimated value of the energy savings incurred. The state could support this by underwriting any default risk. If existing state budgets are insufficient the cost of the scheme to the state could be levied through taxation levied on fossil energy suppliers or even through differential taxation applied to less efficient water heater technologies. The term state here is used in the most generic manner and could refer to any level of political jurisdiction that has the authority and means to initiate such a scheme. In China, many of the most effective schemes are structured at the local Province or municipality level but these will strongly benefit from guidance, coordination and support (technical, political and financial) at the national level and hence the creation of a coalition of willing actors with national level support is likely to be the most viable pathway. A cascaded structure of risk sharing would be one means of achieving this wherein the national authorities would commit to cover a part of the default risk while local Provinces could supply another part and municipalities the remainder. Any such scheme would clearly require the establishment of appropriate eligibility requirements, clarification of obligations and securitization. The latter will be necessary to minimize default risk and therefore help the scheme to multiply its effects over as broad a market as possible.

Public awareness raising

Public awareness of the life cycle cost benefits of high efficiency water heater technology is key to driving up demand for such products. If consumers understand the life cycle costs savings they are much more likely to be willing to make the investment – especially if these investments are shown to be highly cost effective compared to other investments they could make. There would therefore be considerable value in launching a large scale general awareness raising effort to sensitize the public to these issues. This would be most effective were it to coincide with the introduction of a new primary energy label applicable to all water heaters.

Financial support and restructuring of the business model to buy-down the first cost increment by accruing profit via the operational cost savings will have much greater impact if supported by an effective public awareness raising effort. Most members of the public will be completely unaware of the balance between first and operating costs for water heater technology and of the relative rate of return from investing in efficient technology choices so if the market is to be built there will need to be a concerted effort to inform them. Purely private sector efforts to promote life cycle cost value propositions carry much less credibility with the public than those advanced by the state as the latter are seen to be motivated by issues of public good whereas the former are perceived to be motivated by profit. Thus if the state were to extol the lifecycle cost benefits of low primary energy water heaters, and this were supported by a primary energy based energy label which clearly indicated the actual distinction in primary energy performance, the value added of an investment in such technologies would be much more evident, credible and motivating to consumers. In China, the recent addition of QR codes to energy labels can be used to provide additional information to consumers on nature of the energy label and the benefits of high efficiency products.

Product quality and strengthening the industrial base

China's solar water heater industry is the largest in the world but it is widely reported that greater efforts are needed to eliminate low quality products if consumer confidence in the technology is to be maintained and strengthened. One reason for this is that only modest capital outlay is required to become a manufacturer and hence there are a large number of small manufacturers as well as several very large ones. This fragmented production base increases the probability of quality issues occurring and thus places greater importance on the need to have good quality management processes across the whole sector. The state can play a role to establish and police quality standards by making their satisfaction a requirement of participating in the market. In principle quality can also be graded and blended within an overall water heater rating. As well as making satisfaction of product quality requirements obligatory China may consider imposing general management quality requirements on participants within the sector to ensure the companies are well operated, that warranties are adequate and are backed by company insurance. There is clearly a need to find the right balance between the stringency of such requirements and the implications for final product price as it is important that these are not so onerous as to have an appreciable impact on producer costs that might discourage consumers from purchasing the product.

In the case of heat pump water heaters, which are a less mature technology than solar water heaters, the state may wish to provide targeted incentives to support manufacturers working in this sector including efforts to promote their R&D effort.

India

The energy used by domestic water heating in India is set to grow by 5.9% per annum to 2035 unless more proactive policy measures are introduced. The existing energy labeling scheme has been successful at transforming the market for electric storage water heaters towards energy label class 5 water heaters and thereby driving down storage heater standing losses by ~15% and overall storage water heater energy consumption down by ~4%; however, this is a modest improvement against the broader potential to save about 60% of water heater fossil energy consumption. In principle a substantial proportion of these savings can be achieved via a coordinated set of policy measures that target a sharp growth in both solar and heat pump water heating and a move towards natural gas instantaneous water heating in cases where these are not practical.

Energy labeling based on primary energy

There is a need to develop an energy label that indicates the primary energy efficiency of all water heater types and thereby allows water heater consumers to compare options across technology types. The current label only applies to the intrinsically least efficient water heating technology and inadvertently risks conveying a false impression to consumers that electric storage water heaters are the most efficient technology as only they carry an energy label and are currently eligible to be rated 5 stars. It would be very helpful for the marketing of solar and heat pump water heaters were it to be made evident that these are a far more efficient choice than conventional electric water heaters.

Building codes and ordinances

India's experience with building energy codes is less established than in China and the US and hence there may be less opportunity in the near term to successfully adapt these to support the installation of high efficiency water heaters in new residences. In particular, the national level building codes are voluntary where energy is concerned and currently only apply to commercial buildings. As a result it will be more productive to aim to influence local building codes, especially those applied in metropolis, where there is scope to impose minimum energy performance requirements on the installation of new water heaters. The extension of solar ordinances is one such method and these could be adapted to ensure that occupancy or sale of new construction is only permitted if the water heaters installed comply with energy performance requirements. The rapid extension of such measures will require coordination and cooperation between national and local authorities in order to ensure the scale of opportunity is realized.

Incentives, financing, promotion, and taxation

Information alone will only shift part of the market because much of the current market is constrained by limited access to capital and available expenditure. Unfortunately, the two water heater technologies that are far more efficient than the others are those that have the highest capital expenditure demands. Currently the price of a typical electric storage water heater is likely to be a factor of 8 times less than the price of a 100 liter heat pump storage water heater and 3 times less than the price of a 100 liters solar water heater. The fact that the high efficiency products have a much lower operating cost, lower life cycle cost and greater storage capacity and hence greater user convenience is likely to be viewed as a luxury that most consumers would feel unable to afford due to constraints in their disposable income. Stimulation of substantial market transformation therefore requires a strategy to remove the high first cost affordability barrier while simultaneously promoting the lower life cycle cost benefits of higher efficiency water heaters. Technical suitability factors mean that the most viable alternative high efficiency water heater type will depend on the specific market being considered. Solar water heaters are clearly the most suitable technology and Least Life Cycle Cost option for most low rise locations where there is a sufficient solar resource and an inexpensive roof or land space. The example from China shows how a high degree of solar water heater penetration can be attained with a robust policy framework, despite having slightly less favorable solar resources and much greater levels of urbanization and high rise living. Thus, there is substantial scope for India to enlarge upon the efforts undertaken thus far under the Jawaharlal Nehru National Solar Mission plan. In particular there is a powerful argument to substantially expand the ambition of the stage III implementation plans and to adapt and scale-up the measures under consideration.

Fostering of innovative business models

A logical approach is to actively encourage solar water heater and heat pump water heater manufacturers and retailers to provide upfront financing and leasing schemes to customers which would remove the first cost disadvantage. Repayment could be structured in terms of an upfront payment priced to be equivalent to that of a standard electric storage water heater followed by a set of regular instalments set at a level equivalent to the estimated value of the energy savings incurred. The state could support this by underwriting any default risk. If existing state budgets are insufficient the cost of the scheme to the state could be levied through taxation on fossil energy suppliers. The term state here is used in the most generic manner and could refer to any level of political jurisdiction that has the authority and means to initiate such a scheme. In India, as in China and the USA, it is clear that the most effective schemes are structured at the local State or municipality level but these will strongly benefit from decisions, guidance, coordination and support (technical, political and financial) at the national level and hence the creation of a coalition of willing actors with national level support is likely to be the most viable pathway. A cascaded structure of risk sharing would be one means of achieving this wherein the national authorities would commit to cover a part of the default risk while local states could supply another part and municipalities the remainder. Any such scheme would clearly require the establishment of appropriate eligibility requirements, clarification of obligations and securitization. The latter will be necessary to minimize default risk and therefore help the scheme to multiply its effects over as broad a market as possible. The Jawaharlal Nehru National Solar Mission plan has already been structured to support ESCO activity through cascaded financing and hence this experience could be adapted and scaled to better support the water heater transformation effort.

Public awareness raising

Financial support and restructuring of the business model to buy-down the first cost increment by accruing profit via the operational cost savings will have much greater impact if supported by an effective public awareness raising effort. Most members of the public will be completely unaware of the balance between first and operating costs for water heater technology and of the relative rate of return from investing in efficient technology choices so if the market is to be built there will need to be a concerted effort to inform them. Purely private sector efforts to promote life cycle cost value propositions carry much less credibility with the public than those advanced by the state as the latter are seen to be motivated by issues of public good whereas the former are perceived to be motivated primarily by profit. Thus if the state were to extol the lifecycle cost benefits of low primary energy water heaters, and this were supported by a primary energy based energy label which clearly indicated the actual distinction in primary energy performance, the value added of an investment in such technologies would be much more evident, credible and motivating to consumers.

The implementation of such a scheme has to strike the right balance between scale and quality and recognize the interactions between the two. Through structuring the scheme to avoid undercutting the upfront expenditure for a water heater in relation to conventional water heaters it will avoid excessive rebound effects where overall numbers of water heaters could increase faster than would have otherwise occurred; however, a modest rebound effect will still be expected due to the extra disposable income water heater users would have compared to the BAU scenario as a result of lower operating costs over the medium term. This is not a negative phenomenon, however, as it supports economic development objectives and helps transfer wealth from energy intensive and low employment sectors, such as energy supply, to those that better stimulate growth detached from negative environmental and national balance sheet impacts.

Any high efficiency water heater economic stimulus scheme that targets high efficiency water heaters (solar or heat pump) should also stimulate improvements in product and service quality and be structured so as to accelerate the learning curve effect. The learning rate for solar thermal water heaters has been at about 15% over the last two decades (STW 2012). This means that for each doubling of the cumulative number of water heaters delivered the price has declined by 15%. Much of the cost and value of solar water heaters is incurred in the delivery and installation thus regardless of whether products are manufactured within an economy or sourced from outside (especially China for solar water heaters) there is considerable scope to improve the efficiency of the supply chain at delivering and installing the products. As such increasing the market volume will create important economies of scale and lower supply chain/installer costs. The high efficiency water heater stimulus scheme should be structured to drive down these costs by driving up volumes within a competitive supplier market.

For heat pump water heaters a faster rate of improvement can be expected with each doubling of the volume of product delivered. While HPWHs still use some electricity and hence are not quite as attractive from a public policy perspective as SWHs they still need to be promoted to provide a high efficiency option for when SWHs are not viable. At the moment in India they are a very expensive option compared to SWHs so they will require stronger support in their early years if a market is to be built, however, as their lifecycle costs are competitive compared to electric storage water heaters a significant market could still be built by restructuring the business model to provide repayment through instalments as set out above. Initially, it may also be necessary to consider direct subsidies to give extra support to this transition. This type of state supported technology market transformation has been effectively implemented in other jurisdictions. An example being how the Netherlands and the UK helped to build the gas condensing water heater markets through providing incentives in the early years of the technology that were rapidly tailored back as the market volumes grew. In both markets impressive learning curves were achieved and once the condensing technology had attained an acceptably small price increment compared to less efficient conventional boilers it became possible to lock in their use through minimum energy performance regulations specified in building codes. As a result a technology which had a minimal market share and was more than twice as expensive as the incumbent technology became the dominant technology and was locked in via regulations within just five to six years. The state subsidies which had initially seemed high rapidly served their purpose and were phased out.

National Implementation Plan and Costs

There are several options for staged reimbursement of a capital acquisition purchase that could be used to provide a business model where the increment in upfront capital cost associated with a high efficiency water heater is obviated through staged repayments that are funded through their economy in operating costs. For example, there is a long experience of hire purchase in India that could be adapted to this opportunity. Similarly, the most recent experience with leasing could also be applied as could a rent-to-own business model. In practice then it is expected that several different business and financing models could be developed and trialled for viability to determine the optimal approach for a full scale program. The optimum approach may differ depending on the target community and technology being promoted (e.g. SWH or HPWH) so it may be appropriate to implement more than one approach. In terms of staged implementation the structure set out in Table 6.1 could be envisaged.

If the program is developed and implemented energetically and intelligently, with strong commitment from key stakeholders and with appropriate resources the energy, economic and environmental benefits that could be anticipated are set out in section 5. It is interesting to consider how little external funding might ultimately be required. For example, consider the cases in Table 6.2 where the scenarios consider: the upfront cost paid to participate in the scheme (set at the price of an average 21 liter electric storage water heater and expressed as a share of the price of the high efficiency water heater), the assumed repayment default rates (assumed to be 5% here), the proportion of the defaulter's asset (water heater) that are recovered (assumed to be 80% here), the time (in years) that the default occurs after entering in the agreement (either 0.1, 0.5, 1 or 2 years in these examples), the amortized value of the repayments made up to when the default occurs (Rs.) assuming repayments are set to match the value of the energy savings, the unit cost (i.e. price) of the water heater (Rs.), and the implied value of the public subsidy to cover the default risk expressed as a share of the water heater cost. If this last value is positive a net public subsidy is required equal to the percentage expressed, multiplied by the cost of a water heater and multiplied by the number of units sold; however, if the value is negative the program would be self-funding as on average the program would accrue value (money) from defaults.

Table 6.1 Prospective High Efficiency Water Heater Promotional Program in India

Action	Year from start date
Establish national committee comprising all key ministries and agencies needed to develop and steer the high efficiency WH promotional plan	Establish within 0.5 years and to work throughout the program implementation period
Develop and implement primary energy label for domestic water heaters	Developed and implemented within 3 years
Develop and implement holistic QA requirements for HPWH and SWHs to be eligible for the program and build laboratory testing capacity	Implemented within 3 years (less for SWHs building on JNNSM phase I and II experience)
Work with stakeholders to develop SWH staged financing business model	Max 1 year (building on JNNSM phase I and II experience)
Work with ministries, local jurisdictions and other relevant stakeholders (e.g. utilities) to develop funds to support financing	Secure funding for the pilot programs within 1.5 years and for the full-scale programs within 3 years for the SWH program and 4 years for the HPWH program
Roll-out SWH staged financing pilots	Completed and assessed within 3 years
Begin implementation of full-scale SWH staged financing program	Within 3.5 years
Work with stakeholders to develop HPWH staged financing business model	Max 2 years
Roll-out HPWH staged financing pilots	Completed and assessed within 4 years
Begin implementation of full-scale HPWH staged financing program	Within 4.5 years

Clearly, the actual values to be expected would need to be determined through the pilots to have a better idea of the actual level of program costs that would be needed; however, these examples indicate that there are good grounds to imagine only rather modest public funding may be required to operate the scheme over the medium to long term.

Table 6.2 Prospective High Efficiency Water Heater Promotional Program

Parameter	HPWH		SWH	
	Case 1	Case 2	Case 1	Case 2
Upfront payment (share of product cost)	13%	13%	33%	33%
Default rate	5%	5%	5%	5%
Product recovery rate	80%	80%	80%	80%
Product value after recovery and recovery overheads (share of product cost)	50%	50%	50%	50%
Default period (years)	0.5	1	0.1	2
Amortized repayment to default (Rps)	1361	2722	377	7534
WH unit cost (Rps)	55460	55460	21500	21500
Public subsidy as a share of product cost	1%	-2%	1%	-32%
Parameter	HPWH	SWH		

It should be noted, that the vision set out above is not the only means by which a transformation to a high efficiency water heater market could be secured in India. There is plenty of scope to reinforce the program objectives through judicious but energetic use of regulatory instruments such as solar ordinances and building energy codes, thus these should also be developed and implemented. One route to the creation of public funding could be the adoption of so-called bonus-malus or feebate type incentives. Under such a mechanism taxation on inefficient technology (in this case conventional electric water heaters and possibly LPG gas water heaters) would be increased and the revenues raised used to fund incentives given to high efficiency technologies (SWH and HPWHs). Another funding stream option for which there is already experience in India is via the utilization of Utility Energy Efficiency Portfolio Standards or Obligations. Alternatively, there is a strong rationale for India to consider strengthening its renewable energy sector through the adoption of Utility Renewable Energy Efficiency Portfolio Standards or Obligations which could also be adapted to create a funding stream for SWHs and HPWHs. As illustrated in principle in the analysis shown in section 5 if the public funds are used for some initial seed funding and to cover an acceptable proportion of the repayment default risk only modest sums are needed. The magnitude of actual support required can only be determined through a much more detailed assessment than it is possible to conduct here and ultimately would need to be based upon the outcome of stakeholder negotiations and pilot programs; however, the expectation is that a highly economically attractive and viable formulation should be achievable given the huge scale of downstream savings value that can be tapped into.

Given the high potential for undesired rebound effects, wherein were a stimulus program to lower the cost of any water heater technology below the current lowest cost of any water heater technology it would be expected to increase demand for water heaters overall and hence potentially drive up energy use (unless it were solar water heaters which were being targeted) it will be important for any stimulus program to be devised so that it does not lead to undercutting of conventional water heater prices.

USA

Unlike the situation in India and China, the water heater market in the US is mature. Hot water availability has been saturated in the residential sector for many decades and the BAU energy demand profile is relatively stable to 2035. In addition, new construction is a small part of the housing market and therefore the vast majority of opportunities to influence the choice of new water heater occurs when there is a replacement sale, often due to a failure with an existing water heater. As the residential infrastructure is largely in place, in most houses there isn't much option, except at large cost, to switch from electricity to natural gas. For this reason the market shares between the principal fossil fuel powered water heater technologies have changed very little over recent years.

MEPS and test procedures for water heaters have been in place for 30 years with periodic updates. The most recent MEPS updates took effect this year while the most recent test procedure update is still being implemented. As a result the current MEPS do not yet reflect the changes in the new test procedure. The new test procedure is based on a daily tapping pattern that varies by capacity of the water heater in a manner analogous to the new EU test procedures. The new MEPS effectively require large storage water heaters (>200L) be either heat pump water heaters if electric or condensing if gas-fired.

It is important to recognize that the hot water system in houses consists of not just the water heater, but also the hot water distribution system (plumbing), the hot water use points (showers, lavatories, dishwashers, and clothes washers), and the discharge. In the US efficiency standards on showerheads, dishwashers (in the US dishwashers are typically plumbed only to hot water), and clothes washers have become more stringent with each revision and thus reduced demand for hot water. At the same time the population continues to increase and per capita demand for hot water, while much more stable than in China or India, is still increasing with rising GDP. The net result is very little change in expected overall national water heater energy consumption under the current policy framework.

The MEPS in the US are different for water heaters of different fuel types and by technology type (storage/instantaneous). The US regulations specify that MEPS be developed separately for different product classes. Where product classes are defined by fuel type and other consumer utility. The efficiency metric used to rate water heaters, the uniform energy factor (UEF), is calculated with site energy and thus does not include the impact of any source (primary) energy conversion factor. The National Research Commission completed a study of applying full fuel cycle analysis to appliance standards.[13] They noted "[s]torage water heaters, … , are the "poster child" for the site versus full-fuel-cycle debate" and recommended a gradual implementation of the full-fuel-cycle metrics for appliance standards. In 2011 the US DOE issued a policy notice that it would start using full-fuel-cycle in its analyses.[14] However in the final rulemaking for the revised test procedure, the Department continued to use site energy for the uniform energy factor rating.[15] It stated that the annual consumer cost appearing on the energy guide labels are essentially accounting for the full-fuel-cycle differences between fuel types.

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13 Committee on Point-of-Use and Full-Fuel-Cycle Measurement Approaches to Energy Efficiency Standards; National Research Council. 2009. Review of Site (Point-of-Use) and Full-Fuel-Cycle Measurement Approaches to DOE/EERE Building Appliance Energy efficiency Standards--Letter Report. https://www.nap.edu/download.php?record_id=12670.

14 United States Department of Energy. 2011. "Statement of Policy for Adopting Full-Fuel-Cycle Analyses Into Energy
Conservation Standards Program." Federal Register 76 (160): 51281–89. http://www.gpo.gov/fdsys/pkg/FR-2011-08-18/pdf/2011-21078.pdf

15 United States Department of Energy. 2014. "Test Procedures for Residential and Commercial Water Heaters; Final Rule." Federal Register 79 (133): 40542–88. http://www.gpo.gov/fdsys/pkg/FR-2014-07-11/pdf/2014-15656.pdf

The DOE has created exemptions to the high efficiency MEPS of large electric storage water heaters for grid-enabled water heaters.[16] These are water heaters that are remotely controlled by the utility to allow operation only when electricity demand is low, during off-peak hours. During that off-peak operation, the electricity consumed is stored by the water heater as thermal energy for use during peak hours when the utility prevents the water heater from using electricity.

DOE has also proposed exemptions from the more stringent MEPS for solar-assisted storage water heaters.[17]

Many of the gaps in US water heater efficiency policy stem from a failure to treat residential hot water as a system. There are opportunities other than increasing water heater efficiency to reduce energy consumption. As previously mentioned hot water demand reductions have been made in the US by setting and updating the MEPS on showerheads, dishwashers, and clothes washers. Other options include changing building layouts to reduce distribution losses with shorter hot water pipe distances and lower pipe volumes. There are also opportunities to recover waste heat from the drain water. These techniques require modifications to the plumbing structure, and thus are more appropriately addressed in building codes.

In the US utilities often offer incentives to encourage the adoption of more efficient products. In many states the utility revenues are decoupled from the energy sales. This removes the incentive for utilities to sell more energy. The Consortium for Energy Efficiency (CEE) is a collaborative effort by utilities to coordinate the specifications of products promoted by their efficiency programs. Currently CEE has projects to coordinate the specifications for heat pump water heaters and condensing gas-fired water heaters that are promoted by the utility efficiency programs. CEE typically works with the Energy Star product labeling program to improve consumer understanding of product efficiency levels. Working with manufacturers, CEE has set up the Coalition for Energy Star Water Heaters to promote sales of high efficiency water heaters.[18]

The Northwest Energy Efficiency Alliance in collaboration with other northwest utilities has developed the Northern Climate Heat Pump Water Heater Specification.[19] This specification provides guidance to manufacturers who are interested in developing products that not only meet the Energy Star criteria but are able to provide high levels of consumer satisfaction and energy performance in cooler, northern climates. The objective of this effort is to accelerate the adoption of heat pump water heaters, with the goal of making them the standard product for the electric water heating market.

Building codes are local, such that most building energy efficiency codes are implemented at the state level. For decades, as part of its building energy efficiency code, California has encouraged the use of gas-fired water heaters. Inadvertently this has made it difficult to justify the use of heat pump water heaters given the relative energy tariffs and water heater energy demand in the state (noting, climate variations the most economical solution is likely to vary significantly depending on the specific location within some states).

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16 United States Department of Energy. 2015. "Definitions and Standards for Grid-Enabled Water Heaters ; Final Rule." Federal Register 80 (154): 48004–10. http://www.gpo.gov/fdsys/pkg/FR-2015-08-11/pdf/2015-19643.pdf

17 United States Department of Energy. 2015. "Definitions for Residential Water Heaters ; Notice of proposed rulemaking." Federal Register 80 (154): 18784–95. http://www.gpo.gov/fdsys/pkg/FR-2015-04-08/pdf/2015-07956.pdf

18 Coalition For ENERGY STAR® Water Heaters, http://www.eswaterheaters.com/

19 Northern Climate Heat Pump Water Heater Specification, http://neea.org/northernclimatespec/

The water heating market in the US has seen low levels of adoption of solar thermal water heaters. In response to this there have been several projects to develop roadmaps for solar thermal water heating. One of the earlier roadmaps was by the DOE in 2005.[20] According to the authors solar thermal water heaters have had disappointing market penetration because of: higher upfront costs; lack of familiarity with buyers and the building trades; and lack of product support. A similar list of market challenges and barriers to solar water heating were cited in a Low-Cost Solar Water Heating Research and Development Roadmap[21]. The Solar Energy Industries Association has also developed a roadmap for solar heating and cooling.[22] The recommendations from that report are intended to increase the quality and reliability of systems, reduce installation costs, expand the workforce, and foster private investment.

Two related roadmap studies were developed by Navigant for the US Department of Energy.[23] [24] These roadmaps are for R&D for technology development however, not policy changes.

By contrast, solar photovoltaic systems have experienced significant uptake in recent years, much more than solar thermal. In 2010 California added solar water heating to its solar initiative program and allocated $350M to fund the program. However as of 2013, the single-family solar thermal water heating program had achieved less than 1% of its target.[25] The discrepancy in the response of solar PV compared to the solar thermal initiatives is such that the California Energy Commission has funded a research project to investigate.

Some commentators have estimated that a grid-tied PV system with a heat pump water heater may actually be a more economical solar water heater than a solar thermal water heater in the USA.[26] [27] The reasons for this are related to the high equipment and installation costs for solar thermal water heaters in the US compared with the burgeoning PV market. Inherently though these benefits seem to be related to the respective scale of the two markets as solar thermal has substantially better conversion efficiencies than solar PV and therefore requires much less roof space (and collector areas) to achieve the same effect. Furthermore, they function better under diffuse sky conditions and hence are able to provide solar heated water for a greater proportion of the year. Total bill of material costs are likely to be similar or favorable for solar thermal under equivalent market

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20 Solar and Efficient Water Heating, a Technology Roadmap. 2005 , Developed by representatives of the water heating industry. Washington, D.C.: U.S. Department of Energy

21 Hudon, K, T Merrigan, J Burch, and J Maguire. 2012. Low-Cost Solar Water Heating Research and Development Roadmap. NREL/TP-5500-54793. http://www.nrel.gov/docs/fy12osti/54793.pdf.

22 Beebe, Chris. 2013. Solar Heating & Cooling: Energy for a Secure Future. Washington, DC. Washington, DC. http://www.seia.org/sites/default/files/resources/SEIA%20SHC%20Roadmap-Final-9.30_0.pdf.

23 Goetzler, W. 2011. Research and Development Roadmap for Water Heating Technologies. http://www.ornl.gov/sci/ees/etsd/btric/pdfs/WaterHeatingTechnologiesRoadmap_9-30-2011_FINAL.pdf.

24 Goetzler, William, Matt Guernsey, and Michael Droesch. 2014. Research & Development Roadmap for Emerging Water Heating Technologies. http://energy.gov/sites/prod/files/2014/09/f18/WH_Roadmap_Report_Final_2014-09-22.pdf.

25 California Public Utilities Commission Energy Division , Customer Generation Programs. 2014. Review of the Incentive Levels and Progress of the California Solar Initiative-Thermal Program. http://www.cpuc.ca.gov/NR/rdonlyres/B7D3D1AC-5C9A-49C9-81E1-8E03E471AA73/0/CSIThermalAB2249ReportFinalWebVersionJanuary292014.pdf.

26 Hal Slater. 2013. “Is PV Better Than Thermal Solar Water Heating?” CleanTechnica. September 20. http://cleantechnica.com/2013/09/30/pv-better-thermal-solar-water-heating/.

27 Martin Holladay. 2014. “Solar Thermal Is Really, Really Dead.” GreenBuildingAdvisor.com. December 26. http://www.greenbuildingadvisor.com/blogs/dept/musings/solar-thermal-really-really-dead.

volumes and installation costs need not be so dissimilar. Thus, this phenomena appears to be an effect of the current market prevalence of the two technologies and is indicative that solar thermal systems are likely to have as steep or steeper a learning curve (i.e. rate of reduction of costs with each doubling of installed systems) as PV in the USA.

Earlier this year a PV company had an electric resistance water heater connected to PV panels tested as a solar water heater and certified by SRCC.[28]

These circumstances indicate that there is a strong rational to promote the sale of HPWHs in place of electric resistance water heaters currently and gas-fired water heaters in the future as HPWH prices decline. Where space and other physical constraints mitigate against the use of HPWHs solar thermal and/or PV systems will often be cost effective over the installation life cycle and will progressively become more attractive as the levels of deployment increase and product/installation costs decline. Policy is therefore needed that will accelerate deployment of HPWHs and aggressively accelerate deployment of solar water heating technologies.

The following recommendations are proposed.

Adapt and develop generic policy frameworks to support high efficiency water heaters

At the federal level (or failing that at the state level) it is recommended that Renewable Portfolio Standards (RPS) be established to support renewable heat technologies such as solar water heaters. This would be consistent with approaches developed in other leading economies, such as the UK's Renewable Heat Incentive scheme, and is supported by the Solar Energy Industries Association. It would also help ensure that solar thermal technologies are supported in the US in a similar manner to solar PV and hence address an imbalance that has led to much greater deployment of PV systems and relative neglect of solar thermal systems. Furthermore, such RPSs also create a coherent and consistent framework to support all renewable heat technologies, including heat pump water heaters, as incentive formulae can be developed that reward technologies in proportion to the amount of heat they supply through renewable energy. The UK RHI scheme makes such differentiations and hence awards different levels of support to solar thermal water heaters, heat pump water heaters and heat pump heating systems depending on the renewable energy fraction they offer.

MEPS and energy labeling based on primary energy

It is recommended that the US water heater MEPS be finalized in accordance with the new water heater test procedure (Note that the DOE is currently working on this and it is expected to be completed in early 2016). In addition the UEF should be converted to be based on full-fuel-cycle so water heaters using different fuels can be easily compared.

It is further recommended that the DOE should require water heater manufacturers to report more information about water heaters in the ratings directories, including standby losses, recovery efficiency, and various other parameters which will allow more accurate energy calculation at conditions other than those specified in the test procedure. Apart from benefitting consumers directly, utility programs, state and local policies will benefit from being able to better estimate energy consumption at non-standard conditions appropriate to their locale.

In the case of energy labeling it is recommended that the EnergyGuide and Energy Star labels be updated so consumers will find it easier to make relative efficiency comparisons. Adoption of a clear, categorical comparison along the lines of the EU labels would be very beneficial as this would facilitate explanation of the true difference in efficiency between the existing water heater technologies. Were such a change, which has implications well beyond just water heater labeling

28 Sun Bandit, http://www.sunbandit.us/

considered to be too problematic, at a minimum it is proposed that the EnergyGuide and Energy Star labels be modified to apply across all water heater technologies so that consumers can clearly see which is the least and most efficient technology on the market and the position of specific models within the full spectrum of water heaters independent of the energy source used. This would require modifying these labels to address source (primary) rather than site energy efficiency; however, at present this would require modifying the law which requires energy specifications to be based on site (i.e. final) energy[29]. An alternative approach would be to base the ratings on average energy operating costs expressed in dollars as this will tend to reflect the difference in primary energy and be more pertinent to the consumer. Such a change will doubtless be difficult to implement and controversial with parties who would feel their products would be less well ranked, but would clearly better inform consumers and thus serve the public good.

Building codes and ordinances

The US has extensive building energy codes and model national buildings codes promoted through the DOE. These need to be updated to reward and/or mandate renewable energy and high efficiency (e.g. heat pump) water heater choices in new build or major renovations. It is beyond the scope of this report to go into all the details of how this could be designed and structured but there are numerous good practice examples that can be considered both within the US and beyond. It is recommended that the DOE works with the model code developers to consider how fit for purpose the current codes are in this regard and what options are available to enhance the promotion of high efficiency water heaters within the codes, noting that as water heaters are installed prior to occupation in all new and remodelled homes that it is best practice to include requirements which address their energy performance.

In the case of solar ordinances Hawaii is currently the only state to have adopted such measures and in part this reflects the high price of commercial energy within the state and the high cost effectiveness of solar options. Other island territories or locales with high energy prices, such as Puerto Rico, American Samoa, Guam, Northern Mariana Islands and the U.S. Virgin Islands, may wish to follow Hawaii's example. Some, such as Puerto Rico, already have RPS to support solar technologies, including water heaters, and hence could build upon an existing expertise in solar installations to broaden their application. Some mainland jurisdictions may also wish to consider adopting ordinances to promote solar and/or heat pump heating perhaps beginning in non-residential applications and then expanding them over time.

Incentives, financing, promotion and taxation

Capital constraints are less of a barrier to investment in efficient water heaters in the US than in China or India, however, given that:

- few consumers are used to making purchases based on life cycle costing, that there is a market failure because few home owners know how long they will own a property for and will therefore be reticent about making an investment that minimizes the lifecycle costs if they are not going to be beneficiaries of the investment,
- there is a legitimate perception of risk as while the price of technologies are clear at the moment of purchase the lifecycle costs remain to be proved;

there is, thus, a strong need for policy measures which buy down the difference in first costs of efficient water heater technologies compared with conventional technologies. It is recommended that US authorities at both the Federal, State and municipal level and including utility regulators should:

[29] The Energy Policy and Conservation Act (EPCA), (42 U.S.C. 6291(4)–(6), 6311(3)–(4), (18) requires that MEPS be based solely on the energy consumed at the point of use.

- develop and/or enhance incentive schemes to promote adoption of high efficiency water heater technologies (such as renewable heat portfolio standards, the modification of existing RPS to include solar thermal and heat pump technologies, and the adaptation of existing energy efficiency portfolio standards to promote such technologies). Specifically, include solar heating and cooling technologies as generating technologies that are eligible for Solar Renewable Energy Credits (SRECs) or Renewable Energy Credits (RECs) in state and federal Renewable Portfolio Standards (RPS) or Clean Energy Standards (CES). In particular, heat pump water heater installations should be given incentives whenever grid-tied roof top PV is installed.
- at the Federal level it is recommended that the 30% Innovation Tax Credit be extended for multiple years beyond 2016 while at local level states should also consider application of tax credits to support deployment of solar and heat pump water heaters
- examine means to provide easy financing mechanisms (on-bill payment (e.g. pay-as-you save), property tax assessments, etc.) to allow selection of higher first cost advanced water heaters in standard or emergency replacement situations.

With all of the above, it is imperative that the incentives be of such a scale as will trigger substantially accelerated adoption of the higher efficiency technologies. This will not only help increase penetration of the high efficiency water heaters directly supported and hence lead to immediate energy savings, but will develop industrial and commercial capacity, help establish greater familiarity and confidence in the technologies supported and lower perceptions of risk. The industrial and commercial capacity building will accelerate the learning curve effect for high efficiency water heaters and will thereby progressively lower the need for financial support over time, this also increases the viability and acceptability of ultimately locking them in via more ambitious mandatory requirements such as MEPS, building codes and ordinances. By the same token it is essential that the quality of user experience be assured through the continuing support[30] of quality assurance schemes and that only products and services that work through such schemes should be eligible for such support.

Fostering of innovative business models

The incremental first cost and life cycle benefit/performance risk of high efficiency water heaters can be mitigated through the propagation of innovative business models that allow repayment by instalments and hence follow a pay-as-you save formula. If strong financial incentives are also provided by regulators it could be appropriate to develop business models that emulate the experience of the solar PV sector wherein upfront costs in many countries have often been entirely paid by the service provider in exchange for remuneration over time from the accrued energy savings[31]. This completely removes the risk for the homeowner and is a proven model to deliver rapid technology adoption in affluent consumer economies. Policymakers have an important role to play to work with the private sector to help facilitate the creation of these business models. This may take the form of public-private risk sharing in the event of non-repayment, of endorsement and/or promotion of the model to end-users, of helping to pilot business models through social housing and or government contracts, etc.

Public awareness raising and quality assurance

Financial support and restructuring of the business model to buy-down the first cost increment by accruing profit via the operational cost savings will have much greater impact if supported by an effective public awareness raising effort. Most members of the public will be completely unaware of the balance between first and operating costs for water heater technology and of the relative rate of return from investing in efficient technology choices so if the market is to be built there will

[30] The Energy Star program includes quality assurance requirements within its specifications.
[31] This is already the case for PV panels in California. See for example http://www.solarcity.com/residential/states/california-solar

need to be a concerted effort to inform them. Purely private sector efforts to promote life cycle cost value propositions carry much less credibility with the public than those whose claims are also supported by the state as the latter are seen to be motivated by issues of public good, thus, there is value in the state extolling the benefits of lifecycle cost based procurement of water heaters and helping to provide informational aids to support this procurement practice. These will need to build on revision of energy labeling to apply across all water heater types equally. Part of this will be to continue to support high efficiency water heater quality assurance schemes and to tie promotions to products and services operating within these schemes.

07 Conclusions

Water heating accounts for a considerable proportion of domestic energy use in all economies and yet the most common technologies used to provide it are far from optimized from an energy performance perspective. While energy policy has been relatively successful in promoting relatively high efficiency water heater technologies compared to other water heater technologies using the same energy source (electricity or gas) it has been much less successful, with the exception of in China, at stimulating adoption of the most energy efficient technologies across all fuel types. There is a substantial potential in each of China, India and the US to save energy and CO_2 emissions through the promotion of policies that encourage the adoption of high efficiency water heating technology across all energy source types.

Adopting the Least Life Cycle Cost technologies is expected to save between 23% and 68% in primary energy compared to continuing with the BAU and to appreciably reduce the life cycle cost of the water heating service; however, stronger and more coherent policies are needed to achieve this. In particular, measures are needed that:

- Allow easy comparison of the overall energy performance of different water heater technologies across technology type to help clarify the value proposition of the different choices available
- Help explain and promote this value proposition to consumers so they feel informed and empowered to select the most efficient and cost effective technology choices
- Lower initial cost barriers to the adoption of high efficiency water heaters
- Support the deployment of high efficiency water heater choices, most notably solar and heat pump water heaters, so that their incremental costs compared to traditional less efficient choices decline due to learning curve effects
- Ensure quality is maintained in the technology, installation and servicing of high efficiency water heating technologies to build competence and confidence in the supply chain

While the specifics of the measures that are needed in each of the economies investigated (China, India and the USA) differs there are many common elements. Specifically, energy efficiency regulators need to adopt test procedures that measure and compare water heating efficiency across technology types. They equally need to implement energy labeling and other product rating, ranking and consumer awareness raising measures that facilitate easy comparison of product energy performance across technology and energy types. Public awareness raising efforts are required that will both clarify the value proposition of high efficiency water heater technologies and explain how best to acquire and use them. Measures are needed to remove the higher first cost barrier, through incentives or modified pay-as-you-save business models, and must be of a sufficient scale to promote wide spread adoption. Technology adoption risk needs to be minimized by supporting quality assurance schemes and through underwriting risk in the event of failures. Over the medium term the additional cost of the high efficiency solutions needs to be minimized through stimulating large scale deployment and accelerating learning curve effects. Once the quality of service is sufficiently reliable, the scale of delivery at a suitable level and the economic benefits established it may be appropriate to lock in the higher efficiency choices through mandatory regulatory measures such as minimum energy performance standards, building codes and ordinances.

Overall the development of a coherent program will require the conscious development and implementation of a high efficiency water heater strategy. While this may be steered at the national level, input and implementation will often be at the local level and thus resources will be required to help develop and roll out the strategy both nationally and locally. To achieve the high benefits from an effective program an ambitious and strongly resourced activity that aims at the long-term transformation of the water heater market towards the highest efficiency options will be needed. Broad-based stakeholder engagement combined with sustained public policy making efforts will be essential for the successful implementation of this strategy.

APPENDICES

A1 Definition of relevant product classes or categories

A broad overall definition of a water heater
The recent EU Ecodesign and energy labeling regulations provide a broad definitional scope of domestic water heaters as follows[32]:

"1. This Regulation establishes requirements for the energy labeling of, and the provision of supplementary product information on, water heaters with a rated heat output ≤ 70 kW, hot water storage tanks with a storage volume ≤ 500 liters and packages of water heater ≤ 70 kW and solar device."

The EU regulations do not apply to:

- water heaters specifically designed for using gaseous or liquid fuels predominantly produced from biomass
- water heaters using solid fuels
- certain kinds of combination heaters
- water heaters designed for making hot drinks and/or food only.

The EU regulations clarify the meaning of some of these terms through the following set of definitions:

"(1) 'water heater' means a device that:
(a) is connected to an external supply of drinking or sanitary water;
(b) generates and transfers heat to deliver drinking or sanitary hot water at given temperature levels, quantities and flow rates during given intervals; and
(c) is equipped with one or more heat generators;

(2) 'heat generator' means the part of a water heater that generates the heat using one or more of the following processes:
(a) combustion of fossil fuels and/or biomass fuels;
(b) use of the Joule effect in electric resistance heating elements;
(c) capture of ambient heat from an air source, water source or ground source, and/or waste heat;
(3) 'rated heat output' means the declared heat output of the water heater when providing water heating at standard rating conditions, expressed in kW;
(4) 'storage volume' (V) means the rated volume of a hot water storage tank, expressed in liters;
(5) 'standard rating conditions' means the operating conditions of water heaters for establishing the rated heat output, water heating energy efficiency and sound power level, and of hot water storage tanks for establishing the standing loss;

(8) 'fossil fuel' means a gaseous or liquid fuel of fossil origin;

32 http://www.eceee.org/ecodesign/products/water_heaters/Water_heaters_Ecodesign_Reg_814_2013.pdf

(9) 'hot water storage tank' means a vessel for storing hot water for water and/or space heating purposes, including any additives, which is not equipped with any heat generator except possibly one or more back-up immersion heaters;
(10) 'back-up immersion heater' means a Joule effect electric resistance heater that is part of a hot water storage tank and generates heat only when the external heat source is disrupted (including during maintenance periods) or out of order, or that is part of a solar hot water storage tank and provides heat when the solar heat source is not sufficient to satisfy required comfort levels;
(11) 'solar device' means a solar-only system, a solar collector, a solar hot water storage tank or a pump in the collector loop, which are placed on the market separately;
(12) 'solar-only system' means a device that is equipped with one or more solar collectors and solar hot water storage tanks and possibly pumps in the collector loop and other parts, which is placed on the market as one unit and is not equipped with any heat generator except possibly one or more back-up immersion heaters;
(13) 'package of water heater and solar device' means a package offered to the end-user containing one or more water heaters and one or more solar devices;
(14) 'water heating energy efficiency' (η_{wh}) means the ratio between the useful energy provided by a water heater or a package of water heater and solar device and the energy required for its generation, expressed in%;
(16) 'standing loss' (S) means the heating power dissipated from a hot water storage tank at given water and ambient temperatures, expressed in W;
(17) 'heat pump water heater' means a water heater that uses ambient heat from an air source, water source or ground source, and/or waste heat for heat generation."

A priori we consider the scope and definitions of water heaters to be considered in this project to be the same. However, we impose the following additional exclusions:

- combi-boilers, i.e. those that have a dual purpose of providing space heating and sanitary hot water heating
- devices using biomass
- devices using solid fuels.

We note that despite the broad definition applied here that most regulations and test procedures distinguish by type of water according to the characteristics previously described. We will therefore need to assess within and across type for the subsequent work.

The remaining text in this section considers distinctions between types of water heaters, water heater characteristics, their methods of test and the types of energy performance metric used.

Product classifications and configurations

Defining types of water heaters entails defining their classifications and this in turn requires their service and features to be characterized.

Water heaters can be classified in terms of:

- capacity
- fuel type
- whether they are of an instantaneous or storage type
- whether they are unitary or split into components
- whether they have more than one form of heating the water or not.

Capacity
Capacity can be defined in terms of rated power (either output heating power, or rated input heating power) or rated storage capacity (storage volume) for storage type heaters. A rated output heating power seems to be the most encompassing and logical approach because it embraces both storage and instantaneous types and it is defined in terms of the service delivered rather than the input power required. Domestic water heaters are usually defined to be those intended for domestic use, i.e. to supply sanitary hot water for domestic washing and bathing purposes, and thus they are typically constrained to smaller capacity units. Nonetheless the capacity ranges found in regulations can be quite large. For example the EU regulations set a limit at those units with a rated heat output ≤ 70 kW. The EU also specifies that in the case of storage tanks they should have a storage volume capacity of ≤ 500 liters.

Note that the definition of storage capacity is sometimes linked with the water storage temperature, which makes comparison across models and economies very difficult. In Europe the introduction of a new "MW40 : mixed water at 40 °C" classification means that effective storage capacity can be increased beyond the actual tank volume by storing water at a higher temperature than 40 °C and mixing in cold water to reduce the delivered temperature to 40°C and thereby increasing the effective rated capacity.

Energy source
All water heaters have a principal energy source used to generate hot water. In practice this can be:

- gas
- electricity
- oil
- solar energy
- solid fossil fuels
- biofuels.

Gas-fired water heaters often use electricity for ignition, controls, fans, etc. The electricity should be included as an energy input. The conversion of electricity to a common energy basis can be done either at site or can include considerations of source efficiency of the electricity generation.

Instantaneous or storage types
Water heaters may deliver instantaneous hot water on demand, i.e. water that is heated and supplied on demand, or they may heat off demand and store the water for use when demanded. The former are known as instantaneous water heaters and the latter storage type water heaters. Storage type water heaters will lose energy in the form of standing losses (thermal losses while waiting for demand), however, they can heat more slowly and hence require less heating power, which can bring benefits for solar water heaters or electric water heaters.

Sometimes instantaneous water heaters are designed to be smaller and to simply supply hot water requirements at a single point of demand. Storage type systems are usually plumbed into a network of demand points and are designed to meet all the water needs at the various demand points. This solution has the benefit of minimizing the number of individual water heaters required but does entail additional energy losses in the water distribution network as the water heater cannot be so proximal to each point of demand.

Configuration: unitary or split systems

Water heaters may be sold as unitary units or as assemblies of components. For example, in the case of heat pump water heaters (HPWH) this can include:

- unitary (refrigeration unit and water storage tank in the one cabinet)
- split – heat pump connected to tank by refrigerant lines, condenser inside water tank
- split – heat pump connected to tank by water lines, condenser housed in same cabinet as evaporator. This configuration may be designed as:
  - single pass ('one time') – water heated to desired temperature in one pass; and
  - multi-pass ('circulated') – water heated to desired temperature in stages.

The way in which HPWHs are defined varies significantly between standards. This means that products which are grouped together for testing under one standard may need to be separately tested under a second standard, because of some design difference that may not even be defined under the first standard. Furthermore, a product type defined in one standard may not even be testable under other standards, because there is no provision for them. For example, the European Standard EN16147 does not appear to provide for the testing of a unitary HPWH designed to be installed outside, whereas this product type is common in Australia.

Multiple heating options

While most water heaters have a single source of energy generators there are a number of possible combinations found in practice. Several of these are designed to take advantage of an intermittent renewable energy source and hence have a secondary heating source as a backup (auxiliary). Configurations include:

- Solar + Electric
- Solar + Gas
- Gas + Electric Heat pump
- Electric + Electric heat pump
- Biofuel + electric
- Biofuel + gas.

Controls

Water heaters are now being designed with control logic that can adapt to the pattern of household hot water use. For example, if the controller observes that hot water demand is concentrated at a certain time of day it can adapt reheat times to minimize heat loss or to make use of cheaper electricity rates (assuming that there is a capability for the controller to have tariff times programmed into it, or to monitor them in real time).

The European regulations for the energy labeling of water heaters (including HPWHs) allows models with 'smart controls' to obtain a rating one grade higher than would be indicated by energy efficiency alone (EC 2013). It defines 'smart control' as 'a device that automatically adapts the water heating process to individual usage conditions with the aim of reducing energy consumption'.[33]

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[33] Some new water heaters have the capability to change their mode of operation (i.e. to turn off, reduce load or turn on) in response to signals sent from the utility or other 'remote agent'. This is a separate capability that may have different impacts on energy consumption or energy efficiency.

While 'smart' controls may enable a water heater to reheat at times when electricity tariffs are lower use, and so reduce running costs, they complicate energy efficiency testing because the water heater may behave differently after 'learning' the draw-off patterns used in the first stages of a test.

Description of test types and energy performance metrics

Throughout the study, reference is made to the principal test types and performance metrics. Most of these tests and metrics are described briefly below. In addition, some terms particular to a given economy are described in the text.

Metrics

- **Energy efficiency**: means the ratio between the useful energy provided by a water heater and the energy required for its generation, expressed in%. It can be used for steady state behavior, for tapping cycles, on a daily or yearly basis, etc. The energy used for hot water generation can be gas, oil, electricity, or may be referred to primary energy using primary energy conversion factors (primary energy factor) given in regulations or test standards. Energy efficiency may be determined via a single test, or be obtained by calculation from the results of several tests.
  Energy efficiency may also be called water heating energy efficiency, thermal efficiency, or energy factor.
  Energy efficiency may be denoted by the following symbols: η, η_{wh}, EFF, EE, COP, PER, EF, COP_{DHW}
  Units:%
  Note: In some cases it may be a seasonal performance factor, like for heat pump (SCOP = seasonal coefficient of performance) or solar water heaters.

- Annual gas usage: calculated for a given daily water usage, using the measured values of thermal efficiency, start-up heat capacity and pilot gas consumption. For the purposes of energy labeling, it may be compared with the annual gas consumption of a reference storage water heater to give the relative performance.

- **Standby losses**: applies to storage water heaters. It is the energy or the power required to maintain a constant water temperature inside the tank when no hot water is being drawn off.
  It may also be called maintenance gas consumption, standing heat losses, tank standby losses, standing loss.
  It may be denoted by the following symbols: M, Q, S,
  Units: W, kWh/L-month, kWh

- **Hot water delivery capacity**: The volume of hot water a storage heater is able to deliver starting with the water in the tank at its standard hot temperature, referenced to a given temperature (generally 40ºC or 45ºC).

- **Pilot gas consumption:** gas consumption when there is no demand for heating

- **Monthly specific energy production:** solar water heaters (PMEe)

Tests

- Stationary (or steady-state): measurement of the energy input in steady-state conditions, in different conditions of water flow, water inlet temperature, water outlet temperature, standard energy consumption, used to measure the efficiency. Several tests may be performed to get the average results. It may include a reduced capacity test. It can be used for instantaneous heaters, or with the heating part of a split storage heater.

- **Standby energy consumption**: the electrical power input measurement while there is no heating demand.

- **Start-up heat capacity** (or steady-state warm-up, cold-start heat-up): for instantaneous heaters, the energy or the capacity necessary to rise the cold water temperature up to a given percentage (generally 90%) of the steady-state temperature rise. For a storage heater, it is the energy required to raise the temperature of the water in the tank from the cold water temperature up to a given temperature, defined in the standard or given by the manufacturer.

- **Hot water delivery capacity** (or diffusion test): for storage heaters. The test starts just after a recovery. Hot water is drawn off at a constant water flow rate or a constant energy rate until the outlet water temperature reaches a given value. Water inlet temperature is constant and the heater is connected. Water volume drawn off during the test is measured together with its temperature. The final result is the volume of water referred to a given temperature.

- **Tapping cycle** (or draw): test simulating "real" use of the hot water, with several hot water draw-offs at a given water flow rate, during a given time or until reaching a given energy. For storage heaters, this test starts after a recovery and a last recovery shall end the test after a 24h period. The number of draw-offs varies between countries (roughly between 6 and 20 per 24 h) and the draw-off characteristics may or may not be identical.

- 24 hour simulated use test: simulated composite 24 hours using results of different tests. This can be made by calculation or by the use of full simulation from component testing using TRNSYS software.

- Pilot gas consumption: gas consumption when there is no demand for heating.

- Steady-state standby loss test: this test starts when the water temperature in the tank is steady at a given hot water temperature, as defined in the standard or given by the manufacturer. During 48 h to 72 h depending on the test procedure, energy consumption is measured while the control device of the heater maintains a constant temperature within the tank.

- Coefficient of Thermal Performance: a measure of efficiency used for solar water heaters.

- Stationary, COP (coefficient of performance) at different outdoor temperatures/water inlet temperatures, constant outlet temperature. Weighted to a seasonal COP (SCOP) value.

A2.1 Listing and assessment of country data sources: China

Test procedures

The following test procedures apply for water heaters in China.

Table A2.1.1 Test procedures in China

Water heater type	Exist. std (Y/N)	Standard reference	Status	Comments
Gas				
Gas storage	Y	GB 18111-2000	Current	
Gas instantaneous	Y	GB 6932-2001 CJ/T 336-2010	Current	Separate test methods for condensing and non-condensing
Combi-boilers	Y	GB 25034-2010 CJ/T 395-2012 JJF 1261.9-2013	Current	Separate test methods for condensing and non-condensing
Gas + solar				
Gas + electric heat pump				
Electric				
Electric storage	Y	GB 21519–2008 GB/T 20289 – 2006	Current	MEPS, labels, and test procedure in same document
Electric instantaneous	Y	GB/T 26185-2010	Current	Labels and test procedure in same document
Electric heat pump	Y	GB/T 23137-2008	Current	

Table A2.1.1 Test procedures in China (continued)

Water heater type	Exist. std (Y/N)	Standard reference	Status	Comments
Oil				
Any				
Solar				
Solar water heater system	Y	GB/T 18708-2002 JJF 1261.11-2013	Current	
Solar collector				
Solar tank				
Tank				
Unvented				

Regulations

The following regulations apply for water heaters in China.

Table A2.1.2 MEPS in China

Type	Status	Organization	Standard	Link
Gas				
Gas storage	Current		GB 18111-2000	http://webstore.ansi.org/RecordDetail.aspx?sku=GB+18111-2000
Gas instantaneous	Current From 2016		GB 20665-2006 GB 20665-2015	http://webstore.ansi.org/RecordDetail.aspx?sku=GB+6932-2001
Combi-boilers	Current From 2016		GB 20665-2006 GB 20665-2015	
Gas + solar	None			
Gas + electric heat pump	None			
Electric				
Electric storage	Current		GB 21519–2008	
Electric instantaneous	Current		GB/T 26185-2010	
Electric heat pump	Current		GB 29541-2013	-

Table A2.1.2 MEPS in China (continued)

Type	Status	Organization	Standard	Link
Oil				
Any	None			
Solar				
Solar water heater system	Current		GB26969-2011	
Solar collector	None			
Solar tank	None			

Table A2.1.3 Mandatory labels in China

Type	Status	Organization	Standard	Link
Gas				
Gas storage				
Gas instantaneous	Current From 2016		GB 20665-2006 GB 20665-2015	http://www.energylabel.gov.cn/UserFiles/9%E7%87%83%E6%B0%94%E7%83%AD%E6%B0%B4%E5%99%A8%E8%83%BD%E6%95%88%E6%A0%87%E8%AF%86%E5%AE%9E%E6%96%BD%E8%A7%84%E5%88%99.pdf
Combi-boilers	Current From 2016		GB 20665-2006 GB 20665-2015	http://www.energylabel.gov.cn/UserFiles/9%E7%87%83%E6%B0%94%E7%83%AD%E6%B0%B4%E5%99%A8%E8%83%BD%E6%95%88%E6%A0%87%E8%AF%86%E5%AE%9E%E6%96%BD%E8%A7%84%E5%88%99.pdf

Table A2.1.3 Mandatory labels in China (continued)

Type	Status	Organization	Standard	Link
Gas + solar				
Gas + electric heat pump				
Electric				
Electric storage	Current		GB 21519–2008	http://www.energylabel.gov.cn/UserFiles/12%E7%94%B5%E7%83%AD%E6%B0%B4%E5%99%A8%E8%83%BD%E6%95%88%E6%A0%87%E8%AF%86%E5%AE%9E%E6%96%BD%E8%A7%84%E5%88%99.pdf
Electric instantaneous				
Electric heat pump	Current		GB 29541-2013	http://www.energylabel.gov.cn/UserFiles/files/035%20%E7%83%AD%E6%B3%B5%E7%83%AD%E6%B0%B4%E6%9C%BA%EF%BC%88%E5%99%A8%EF%BC%89%E8%83%BD%E6%BA%90%E6%95%88%E7%8E%87%E6%A0%87%E8%AF%86%E5%AE%9E%E6%96%BD%E8%A7%84%E5%88%99(1).pdf
Oil				
Any	None			

Table A2.1.3 Mandatory labels in China (continued)

Type	Status	Organization	Standard	Link
Solar				
Solar water heater system	Current		GB26969-2011	http://www.energylabel.gov.cn/UserFiles/29%E5%AE%B6%E7%94%A8%E5%A4%AA%E9%98%B3%E8%83%BD%E7%83%AD%E6%B0%B4%E7%B3%BB%E7%BB%9F%E8%83%BD%E6%BA%90%E6%95%88%E7%8E%87%E6%A0%87%E8%AF%86%E5%AE%9E%E6%96%BD%E8%A7%84%E5%88%99.pdf
Solar collector	None			
Solar tank	None			

Table A2.1.4 Voluntary labels in China

Type	Status	Organization	Standard	Link
Gas				
Gas storage				
Gas instantaneous	Current		GB 20665-2006 GB 6932-2001 CJ/T 336-2010 CQC61-448262-2009	http://www.cqc.com.cn/chinese/rootfiles/2011/08/02/1312218399827019-1312218399867761.pdf

Table A2.1.4 Voluntary labels in China (continued)

Type	Status	Organization	Standard	Link
Combi-boilers	Current		GB 20665-2006 CQC61-448262-2009	http://www.cqc.com.cn/chinese/rootfiles/2011/08/02/1312218399827019-1312218399867761.pdf
Gas + solar	None			
Gas + electric heat pump	None			
Electric				
Electric storage	Current		GB 21519-2008 CQC31-448173-2009	http://www.cqc.com.cn/chinese/rootfiles/2011/08/02/1312218400788920-1312218400881285.pdf
Electric instantaneous				
Electric heat pump	Current		GB 29541-2013 CQC31-439133-2013	http://www.cqc.com.cn/chinese/rootfiles/2014/03/18/1312218399615404-1395090129926954.pdf
OIL				
Any	None			

Table A2.1.4 Voluntary labels in China (continued)

Type	Status	Organization	Standard	Link
Solar				
Solar water heater system	Current		GB26969-2011 CQC61-448261-2012	http://www.cqc.com.cn/chinese/rootfiles/2013/08/08/1346864451423713-1375803709592612.pdf
Solar collector	None		CQC31-448314-2013	http://www.cqc.com.cn/chinese/rootfiles/2014/01/22/1387327610843607-1390338132338120.pdf
Solar tank	None			

A2.2 Listing and assessment of country data sources: India

Test procedures

The following test procedures apply for water heaters in India.

Table A2.2.1 Test procedures in India

Water heater type	Exist. std (Y/N)	Standard reference	Status	Comments
Gas				
Gas storage	Y	IS 5115-1969	Current	for use with LPG
Gas instantaneous	Y	IS 15558-2005	Current	for use with LPG
Combi-boilers	N			
Gas + solar	N			
Gas + electric heat pump	N			
Electric				
Electric storage	Y	IS 2082:1993	Current	
Electric instantaneous	Y	IS 8978-1992	Current	
Electric heat pump	N			

Table A2.2.1 Test procedures in India (continued)

Water heater type	Exist. std (Y/N)	Standard reference	Status	Comments
Oil				
Any	N			
Solar				
Solar water heater system	NA			
Solar collector	NA			
Solar tank	NA			
Tank				
Unvented	NA			

Regulations

The following regulations apply for water heaters in India.

Table A2.2.2 MEPS in India

Type	Status	Organization	Standard	Link
Gas				
Gas storage	None			
Gas instantaneous	None			
Combi-boilers	None			
Gas + solar	None			
Gas + electric heat pump	None			
Electric				
Electric storage	None			
Electric instantaneous	None			
Electric heat pump	None			-
Oil				
Any	None			

Table A2.2.2 MEPS in India (continued)

Type	Status	Organization	Standard	Link
Solar				
Solar water heater system	None			
Solar collector	None			
Solar tank	None			

Table A2.2.3 Mandatory labels in India

Type	Status	Organization	Standard	Link
Gas				
Gas storage	None			
Gas instantaneous	None			
Combi-boilers	None			
Gas + solar	None			
Gas + electric heat pump	None			

Table A2.2.3 Mandatory labels in India

Type	Status	Organization	Standard	Link
Electric				
Electric storage	None			
Electric instantaneous	None			
Electric heat pump	None			
Oil				
Any	None			
Solar				
Solar water heater system	None			
Solar collector	None			
Solar tank	None			

Table A2.2.4 Voluntary labels in India

Type	Status	Organization	Standard	Link
Gas				
Gas storage	None			
Gas instantaneous	None			
Combi-boilers	None			
Gas + solar	None			
Gas + electric heat pump	None			
Electric				
Electric storage	Voluntary	BEE	Schedule-10	http://220.156.189.29/Content/Files/Schedule_10.pdf
Electric instantaneous	None			
Electric heat pump	None			
OIL				
Any	None			

Table A2.2.4 Voluntary labels in India (continued)

Type	Status	Organization	Standard	Link
Solar				
Solar water heater system	None			
Solar collector	None			
Solar tank	None			

A2.3 Listing and assessment of country data sources: USA

Test procedures

The following test procedures apply for water heaters in the USA.

Table A2.3.1 Test procedures in the USA

Water heater type	Exist. std (Y/N)	Standard reference	Status	Comments
Gas				
Gas storage	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Revisions cover light duty commercial water heaters as well.
Gas instantaneous	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Revisions cover light duty commercial water heaters as well.
Combi-boilers	N			
Gas + solar	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Tested as gas water heater
Gas + electric heat pump	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Tested as gas water heater
Electric				
Electric storage	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Revisions cover light duty commercial water heaters as well.
Electric instantaneous	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Revisions cover light duty commercial water heaters as well.
Electric heat pump	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Revisions cover light duty commercial water heaters as well.

Table A2.3.1 Test procedures in the US (continued)

Water heater type	Exist. std (Y/N)	Standard reference	Status	Comments
Oil				
Storage	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Revisions cover light duty commercial water heaters as well.
Solar				
Solar water heater system	Y	SRCC 300-2013-09	current	Solar Rating & Certification Corporation
Solar collector	Y	SRCC 100-2013-11	current	Solar Rating & Certification Corporation
Solar tank	Y	10CFR430—Appendix E to Subpart B	Revised in 2014 (DOE)	Tested as electric water heater
Tank				
Unvented	N			

Regulations

The following regulations apply for water heaters in the USA.

Table A2.3.2 MEPS in the USA

Type	Status	Organization	Standard	Link
Gas				
Gas storage	Current, update takes effect 15 April, 2015	DOE	Code of Federal Regulations, TITLE 10—Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, §430.32 Energy and water conservation standards and their compliance dates (d) Water heaters.	http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf
Gas instantaneous	Current, update takes effect 15 April, 2015	DOE	Code of Federal Regulations, TITLE 10—Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, §430.32 Energy and water conservation standards and their compliance dates (d) Water heaters.	http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf
Combi-boilers	None			
Gas + solar	None			
Gas + electric heat pump	None	DOE	Code of Federal Regulations, TITLE 10—Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, §430.32 Energy and water conservation standards and their compliance dates (d) Water heaters.	http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf

Table A2.3.2 MEPS in the US (continued)

Type	Status	Organization	Standard	Link
Electric				
Electric storage	Current, update takes effect 15 April, 2015	DOE	Code of Federal Regulations, TITLE 10—Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, §430.32 Energy and water conservation standards and their compliance dates (d) Water heaters.	http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf
Electric instantaneous	Current, update takes effect 15 April, 2015	DOE	Code of Federal Regulations, TITLE 10—Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, §430.32 Energy and water conservation standards and their compliance dates (d) Water heaters.	http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf
Electric heat pump	Current, update takes effect 15 April, 2015	DOE	Code of Federal Regulations, TITLE 10—Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, §430.32 Energy and water conservation standards and their compliance dates (d) Water heaters.	http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf
Oil				
Storage	Current, update takes effect 15 April, 2015	DOE	Code of Federal Regulations, TITLE 10—Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, §430.32 Energy and water conservation standards and their compliance dates (d) Water heaters.	http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf

Table A2.3.2 MEPS in the US (continued)

Type	Status	Organization	Standard	Link
Solar				
Solar water heater system	None			
Solar collector	None			
Solar tank	Current, update takes effect 15 April, 2015	DOE	Code of Federal Regulations, TITLE 10—Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, §430.32 Energy and water conservation standards and their compliance dates (d) Water heaters.	http://www.gpo.gov/fdsys/pkg/CFR-2013-title10-vol3/pdf/CFR-2013-title10-vol3-sec430-32.pdf

Table A2.3.3 Mandatory labels in the USA

Type	Status	Organization	Standard	Link
Gas				
Gas storage	Current	FTC	Code of Federal Regulations, Title 16 - Commercial Practices , Part 305 — Rule Concerning Disclosures Regarding Energy Consumption and Water use of Certain Home Appliances and Other Products Required Under the Energy Policy and Conservation Act (''Appliance Labeling Rule'')	http://www.gpo.gov/fdsys/pkg/CFR-2013-title16-vol1/pdf/CFR-2013-title16-vol1-part305.pdf
Gas instantaneous	Current	FTC	Code of Federal Regulations, Title 16 - Commercial Practices , Part 305 — Rule Concerning Disclosures Regarding Energy Consumption and Water use of Certain Home Appliances and Other Products Required Under the Energy Policy and	http://www.gpo.gov/fdsys/pkg/CFR-2013-title16-vol1/pdf/CFR-2013-title16-vol1-part305.pdf

			Conservation Act (''Appliance Labeling Rule'')	

Table A2.3.3 Mandatory labels in the US (continued)

Type	Status	Organization	Standard	Link
Combi-boilers	None			
Gas + solar	None			
Gas + electric heat pump	None			
Electric				
Electric storage	Current	FTC	Code of Federal Regulations, Title 16 - Commercial Practices , Part 305 — Rule Concerning Disclosures Regarding Energy Consumption and Water use of Certain Home Appliances and Other Products Required Under the Energy Policy and Conservation Act (''Appliance Labeling Rule'')	http://www.gpo.gov/fdsys/pkg/CFR-2013-title16-vol1/pdf/CFR-2013-title16-vol1-part305.pdf
Electric instantaneous	Current	FTC	Code of Federal Regulations, Title 16 - Commercial Practices , Part 305 — Rule Concerning Disclosures Regarding Energy Consumption and Water use of Certain Home Appliances and Other Products Required Under the Energy Policy and Conservation Act (''Appliance Labeling Rule'')	http://www.gpo.gov/fdsys/pkg/CFR-2013-title16-vol1/pdf/CFR-2013-title16-vol1-part305.pdf

Table A2.3.3 Mandatory labels in the US (continued)

Type	Status	Organization	Standard	Link
Electric heat pump	Current	FTC	Code of Federal Regulations, Title 16 - Commercial Practices , Part 305 — Rule Concerning Disclosures Regarding Energy Consumption and Water use of Certain Home Appliances and Other Products Required Under the Energy Policy and Conservation Act (''Appliance Labeling Rule'')	http://www.gpo.gov/fdsys/pkg/CFR-2013-title16-vol1/pdf/CFR-2013-title16-vol1-part305.pdf
Oil				
Storage	Current	FTC	Code of Federal Regulations, Title 16 - Commercial Practices , Part 305 — Rule Concerning Disclosures Regarding Energy Consumption and Water use of Certain Home Appliances and Other Products Required Under the Energy Policy and Conservation Act (''Appliance Labeling Rule'')	http://www.gpo.gov/fdsys/pkg/CFR-2013-title16-vol1/pdf/CFR-2013-title16-vol1-part305.pdf
Solar				
Solar water heater system	None			
Solar collector	None			
Solar tank	None			

Table A2.3.4 Voluntary labels in the USA

Type	Status	Organization	Standard	Link
Gas				
Gas storage	Current, revision process initiated	EPA	ENERGY STAR Residential Water Heaters Specification Version 2.0	http://www.energystar.gov/products/specs/node/241 http://www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters_landing
Gas instantaneous	Current, revision process initiated	EPA	ENERGY STAR Residential Water Heaters Specification Version 2.0	http://www.energystar.gov/products/specs/node/241 http://www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters_landing
Combi-boilers	None			
Gas + solar	Current, revision process initiated	EPA	ENERGY STAR Residential Water Heaters Specification Version 2.0	http://www.energystar.gov/products/specs/node/241 http://www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters_landing
Gas + electric heat pump	None			
Electric				
Electric storage	None			-
Electric instantaneous	None			-
Electric heat pump	Current, revision process initiated	EPA	ENERGY STAR Residential Water Heaters Specification Version 2.0	http://www.energystar.gov/products/specs/node/241 http://www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters_landing
OIL				
Storage	None			-

Table A2.3.4 Voluntary labels in the US (continued)

Type	Status	Organization	Standard	Link
Solar				
Solar water heater system	Current, revision process initiated	EPA	ENERGY STAR Residential Water Heaters Specification Version 2.0	http://www.energystar.gov/products/specs/node/241 http://www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters_landing
Solar collector				
Solar tank				

A3 Mapping of product characteristics in the selected countries

China

The Chinese water heating market was estimated to be 48.2 million units in 2012, and had been growing quickly. In 2011, sales of solar water heating increased more slowly compared to previous years and 2011 also saw government increased support for appliance sales in rural areas.

Electric storage and gas instantaneous accounted for the large majority of non-solar water heater sales while solar accounted for ~37% of sale, Table A3.1; however, there is some uncertainty about the true volume of solar water heater sales as the industry association tracks production of solar thermal panels used for water heating and derivations need to be made to adjust for: domestic shipments versus exports, shipments per end-use sector (e.g. domestic, commercial, public and industrial) and for the average areas of panels sold per water heater. The figures presented in Table A3.1 use the best available information to derive the estimates of domestic solar water heater sales and stocks, while probably somewhat underestimating the value, but there is more uncertainty for these figures than for the other figures. In terms of trends solar seemed to peak around 2012 and would appear to be declining somewhat in relative market share since. Sales of gas fired water heaters are rising in relative terms; these are dominated by gas instantaneous water heaters but there is a small but significant share of gas combi water heaters too. Gas storage water heaters are not common in China due to large space requirements and complex installation. Electric storage water heaters continue to be much more common than electric instantaneous water heaters because the latter are considered to be more expensive to operate and there are believed to be safety concerns. Heat pump water heaters have a small market share but there is too short a time series to be clear about the trends.

Electric storage water heaters are used where there is no gas distribution infrastructure and in multi-story apartment building. In 2011, the most popular models had a capacity between 40 and 100 L, specifically in the 50 to 80 L range. Larger units are popular in the prosperous south and in larger dwellings. Gas instantaneous water heaters are common and growing with China’s gas distribution infrastructure. The most popular models have flow rates that vary between 5 and 13 liters per minute and have a fan-assisted open flue.

Sales of domestic water heaters in China grew at 19% per year from 2006-2012 but are thought to have stalled and even declined, since.

Table A3.1 Water heater sales and stock data for China

	Sales 2012		Installed (2012)	
China	Volume (1000 units)	Percent Sales	Current Stock	Percent Installed
Gas Instantaneous	9,980	20.7%	72,259	30.1%
Gas Storage	~193	0.4%	1,397	0.6%
Gas Combi Water Heaters	1,210	2.5%	4,130	1.7%
Electric Instantaneous	1,392	2.9%	5,488	2.3%
Electric Storage	17,638	36.6%	69,542	28.9%
Oil	~0	0%	0	0.0%
Solar*	17,220	35.7%	85,347	35.5%
Heat pump	590	1.2%	2,206	0.9%
Totals	48,223	100%	240,370	

Sources: CNIS (Chinese National Institute for Standardization) Energy Efficiency White Paper (2014 年我国热水器产品的总销售量已经超过 3600 万台，其中电热水器销量超过 1750 万台，燃气热水器销量达到 1180 万台，太阳能热水器销量为 700 多万台，热泵热水器销量近 30 万台), Solar Water Heater sales derived from data supplied by China Solar Thermal Industry Federation (CSTIF) at e.g. http://www.abi.com.cn/news/htmfiles/2015-1/152584.shtml; Alternative, earlier sources, include: http://www.aceee.org/files/pdf/conferences/hwf/2012/6C-Goetzler-Final.pdf. Note these CSTIF values produce higher estimates of solar water heating market shares than the CNIS sources and therefore the modelling exercise in Chapter 5 assumes an averaged value between the available sources.

India

Water heating in India varies by region and dwelling. In the urban areas it is common to have a water heater – and electric, gas, and solar are all common, depending on the region. In rural areas, hot water is generated by the use of open fires or an electrified hand-held stick (element) that heats water in a bucket. The vast majority of bathrooms do not have hot water piping, nor a bathtub, nor shower.

Overall, there is low penetration of water heaters in India, but the market is growing. In 2010 it grew by more than 10% and by another 6% in 2011. The Indian water heating market is dominated by electric water heaters. Gas water heaters are becoming more popular, but there is little infrastructure and (non-subsidized) gas prices are very high. However, there are constant electricity shortages in India, and gas and solar water heaters are one way to ensure hot water is available, so they are becoming more popular.

Electric storage water heaters are the primary water heating devices in India. Storage water heaters are the most common for large households. Preheated water from a storage heater can be used in case of a power cut. The most common sizes are between 6 and 30 liters and are installed in every bathroom. Larger units are used in commercial settings but their share is small. Big sizes are also used in the luxury residential segment.

Electric instantaneous heaters are the second biggest market segment in India and are mostly smaller units with a capacity of 3kW. Instantaneous heaters are primarily used in large cities, Mumbai being the largest regional market, where power outages are less common. In Mumbai, 4.5 kW units dominate. Larger units of 6, 9, 12 or 15kW are also on the market.

The market is expected to grow further in the years to come in line with the increase of India's GDP, disposable income, and construction market.

Table A3.2 Water heater sales and stock data for India

	Sales 2012		**Installed (2012)**	**Installed (2012)**
India	Volume (1000 units)	Percent Sales	**Current Stock**	Percent Installed
Gas instantaneous	255	9.8%	3,070	13.0%
Gas storage	0	0.0%	0	0.0%
Electric Instantaneous	568	21.7%	6,318	26.7%
Electric storage	1,432	54.8%	12,359	52.1%
Oil	0	0.0%	0	0.0%
Solar	360	13.8%	1,955	8.2%
Heat pump	0	0.0%	0	0.0%
Total sales	3,875	100%	23,702	

Sources: *TV Veopar Journal: http://www.tvj.co.in/index.php/hidden-menu/489-water-heaters-going-green.html, http://www.tvj.co.in/index.php/hidden-menu/25-flat-panel-displays/417-wh-gleaning-new-insights.html ;* Feedback (2014), MNRE (http://www.mnre.gov.in/); other sources: MNRE (2010), UNDP/GEF (2011), ICF (2013)

USA

In the US water heating is the second largest energy use in homes, accounting for 17% of residential energy consumption. The market size is approximately 11 million units per year. Type of water heating installed is dependent on infrastructure, so varies regionally. The share of installed units is mostly split between those fuelled with natural gas (56%), and those with electricity (43%). A small percentage of homes, primarily in New England and the mid-Atlantic regions, use fuel oil. Solar and heat pumps make up a small part of the market. Sales of solar thermal water heaters have been relatively flat while heat pump water heater sales are growing. Historically, the water heater market in the US grew consistently and was tied to new home construction. During the recession, the market fell by more than 20% from the 2004 peak. It is expected to rebound with the economy. The 2009 American Recovery and Reinvestment Act supported state sponsored appliance rebate programs that promoted both energy efficient conventional units and heat pumps and solar systems.

Table A3.3 Water heater sales and stock data for the USA

	Sales 2013		Installed (2013)	
USA	**Volume (1000 units)**	**Percent Sales**	**Current Stock**	**Percent Installed**
Gas Instantaneous	1,560	14.2%	8,856	7.5%
Gas Storage	4,189	38.1%	58,023	49.0%
Electric Instantaneous	0	0%	0	0%
Electric Storage	4,986	45.4%	50,196	42.4%
Oil	27	0.2%	355	0.30%
Solar*	66	0.6%	474	0.40%
Heat pump	160	1.5%	474	0.40%
Totals	**10,988**	**100%**	118,377	**100%**
***Source: http://www.aceee.org/files/pdf/conferences/hwf/2012/6C-Goetzler-Final.pdf**				

Sources: US DOE Technical Support Document, see https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27 ; Solar thermal shipments: http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb1007, other: https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_2010.pdf

A4 Test procedure comparison

A full comparison of the differences in test procedures would be part of the work expected in a full mapping and benchmarking study. However, prior to documenting and assessing these specific test and metric details, it's appropriate here to conduct a broader assessment of the differences in the approaches taken to testing water heater energy performance in different economies in order to help identify higher level incompatibilities between the different approaches. This assessment would require additional development in a complete benchmarking study. The parameters considered here are as follows.

- **Scope**: type of water heater (e.g. energy source, instantaneous/storage, etc.) and indication of any size limitations.
- **Size/capacity** classification and limits described in the standard? Y/N. If Y, what is the size metric considered? (For example, volume, flow rate, MW40, etc.)
- **Type of performance tests** used to rate efficiency: stationary, standby, cold/hot start, tested 24-hour tapping cycle, separate tests (standby, cycling, recovery) + simulated composite 24 hours, allows the use of full simulation from component testing (e.g. using TRNSYS software) and so on.
- Do the performance test conditions vary with water heater size (e.g. different draw-off patterns)? Y/N. Give the number of **different tapping patterns in each case**.
- **What is (are) the metric(s)** used to rate efficiency? Name and short definition e.g. EFF, EE, COP, PER (useful to know numerator and denominator and if refers to a specific test). Is it a final or primary energy efficiency indicator? Are electricity and the consumption of fossil fuels accounted separately?
- **Any other product design specifications** in the standard which could affect ratings? Y/N (could be for instance burner specifications for gas appliances, tests with or without storage for HPWH with default tank insulation, and so on).

These parameters are considered for each economy's test procedure below.

China

The Chinese test procedures for measuring the efficiency of residential water heaters are described in the following table.

Table A4.1 Description of water heater test procedures in China

Water heater type	Standard reference	Scope	Size/Capacity limits	Performance test type / size	Metrics	Other parameters
Gas						
Gas storage (1)	**GB 18111-2000**	heat input < 50 kW		**Cold Start heat up** **72 h standing loss @ ΔT=45K**	**thermal efficiency** **standing loss**	
Gas instantaneous	**GB 6932-2001** **JJF 1261.9-2013**	heat input < 70.0 kW		Steady draws at full & 50% rated capacity for 15 min **@ ΔT=40C**	thermal efficiency	
Combi-boilers	**GB 6932-2001** **JJF 1261.9-2013**	heat input < 70.0 kW		Steady draws at full & 50% rated capacity for 15 min **@ ΔT=40C**	thermal efficiency	
Gas + solar	N					
Gas + electric heat pump	N					
Electric						
Electric storage	GB/T 20289-2006			24 hour standing loss	**standing loss**	
Electric instantaneous	GB/T 26185-2010			Steady draw 9 min **@ ΔT=40C**	thermal efficiency	
Electric heat pump	**GB/T 23137-2008**	input < 10.0 kW		single-pass Steady draw 30 min **@ ΔT=40C** multi-pass cold start heat up Tin = 15 C, Tfinal = 55 C integrated cold start heat up Tin = 15 C, Tfinal = 55 C	COP	
Solar						
Solar water heater system	GB/T 18708-2002 GB/T 26971-2011 JJF 1261.11-2013	≤ 600 L		8 hour steady state test (4 hours before noon and 4 hours after noon) combined with measured average heat loss factor for tank	Coefficient of Thermal Performance	
Solar collector	N					
Solar tank	GB/T 28745-2012					

(1) GB 18111-2000, gas storage water heaters, references American National Standards ANSI Z.21.10.1:1998 and ANSI Z 21.10.3:1998, Australian National Standards AG 102:1998 and the Japanese Industrial Standard JIS S 2109:1996.

India

Currently India has voluntary test procedures for water heaters. Table A4.2 describes the test procedures. IS 2082-1993, Stationary Storage Type Electric Water Heaters (includes standing loss requirement, Table 1, amendment 4); IS 5115–1969, Specification for Domestic Storage Type Water Heaters for use with LPG; (provide a ready supply of hot water at a maximum water temperature of 85°C, having nominal capacities between 6 and 100 liters. Thermal efficiency shall be not less than 70 percent.) and IS 15558-2005, Mini Domestic Water Heater for use with LPG. (nominal useful less than 25 kW, thermal efficiency specified in section 16).

Table A4.2 Description of water heater test procedures in India

Water heater type	Standard reference	Scope	Size/Capacity limits	Performance test type / size	Metrics	Specific parameters of influence
Gas						
Gas storage	IS 5115–1969 (1)	hot water storage capacity 6 to 100 L		Heat up test	Thermal Efficiency	
Gas instantaneous	IS 15558-2005	nominal useful output < 25 kW		Steady state operation	Thermal Efficiency	
Combi-boilers	None					
Gas + solar	None					
Gas + electric heat pump	None					
Electric						
Electric storage	IS 2082-1993	hot water storage capacity 6 to 200 L		Standing Loss	kwh/24 h/45°C	
Electric instantaneous	None					
Electric heat pump	None					
Oil						
Any	None					

Table A4.3 Description of water heater test procedures in India (continued)

Water heater type	Standard reference	Scope	Size/Capacity limits	Performance test type / size	Metrics	Specific parameters of influence
Solar						
System Factory made	None					
System Custom built	None					
Solar collector	None					
Solar tank	None					
Tank						
Unvented	None					

1) Intended for LPG fired, vented tanks.

USA

Except for solar water heating systems, the same test procedure is used to rate the efficiency and effective capacity of all types of residential water heaters. The current test procedure is a 24 hour simulated use test with the same stylized draw pattern for all sizes of water heaters. The test procedure has been undergoing a revision and a new test procedure was released in 2014. It was due to become effective one year after its release but this was not notified in the Code of Federal Regulations for use with MEPs and energy labeling at the time of drafting this text.

The test procedure for solar water heating systems and components is developed by the Solar Rating and Certification Corporation. The method is similar to ISO 9459 in that components are tested and computer simulation is used to develop ratings.

Table A4.4 maps which water heaters are to be tested to the standards in the USA.

Table A4.4 Description of water heater test procedures in the USA

Water heater type	Standard reference	Scope	Size/ Capacity limits	Performance test type / size	Metrics	Specific parameters of influence
Gas						
Gas storage	10CFR430—Appendix E to Subpart B	V=76 L to 380 L input < 21.94 kW Tdel < 82 °C		24 h simulated use test First hour delivery capability	EF F_{hr}	
Gas instantaneous	10CFR430—Appendix E to Subpart B V=76 L to 380 L input < 21.94 kW Tdel < 82 °C	V< 7.6 L input = 14.7 kW to 58.3 kW Tdel < 82 °C		24 h simulated use test Maximum flow rate @ΔT=42.8 °C	EF F_{max}	
Combi-boilers	N					
Gas + solar	N					
Gas + electric heat pump	N					
Electric						
Electric storage	10CFR430—Appendix E to Subpart B	V=76 L to 450 L input ≤ 12 kW Tdel < 82 °C		24 h simulated use test First hour delivery capability	EF F_{hr}	
Electric instantaneous	N					
Electric heat pump	10CFR430—Appendix E to Subpart B	V ≤ 450 L input ≤ 6 kW Tdel < 82 °C		24 h simulated use test First hour delivery capability	EF F_{hr}	
Oil						
Storage	10CFR430—Appendix E to Subpart B	V ≤ 190 L input ≤ 30.56 kW Tdel < 82 °C		24 h simulated use test First hour delivery capability	EF F_{hr}	

Table A4.4 Description of water heater test procedures in the US (continued)

Water heater type	Standard reference	Scope	Size/ Capacity limits	Performance test type / size	Metrics	Specific parameters of influence
Solar						
Solar water heater system	SRCC Standard 300-2013-09 SRCC Document TM-1			24 h simulated use test and modelled using the computer simulation program TRNSYS to calculate the ratings	Solar Energy Factor (SEF_D) solar water heating system components tested to SRCC TM-1 as specified by SRCC 300 depending on type of system	alternative to ISO 9459 test methods. some of the methods have been adapted from the ISO tests.
Solar collector	SRCC Document RM-1				a table of Rating Temperature Differential/Rating Day Combinations	uses ISO 9806-1 or ISO 9806-3
Solar tank	10CFR430—Appendix E to Subpart B or SRCC Document TM-1					
Tank						
Unvented	N					

A5 Identification of potential issues in test results comparison

The same type of water heater may be tested according to different test standards in different economies, which therefore gives rise to various rating values, energy performance scales and MEPS values. Depending on the economies in question, test standards may only include a test method description, or may also include a description of the energy performance metrics. In practice, it is likely that only one rated value will be made publicly available in the product's technical specification sheet even if multiple points are recorded during a product test. Insufficient information from which to make energy performance comparisons is then a common issue when developing energy performance benchmarking exercises.

In order to identify the parameters which may lead to significant differences in tests results, test procedures first need to be screened by main water heater type. Any categories which are unique to a single country can be screened out of this process. For instance, instantaneous oil heaters are probably not very common, even in Korea, the only economy with a test standard to rate their performance.

To perform a viable benchmarking assessment, sufficiently reliable conversion formulae need to be determined between test results obtained under different economies' test procedures. This then allows comparison of different MEPS and labeling thresholds.

Differences in energy performance test results can occur due to several factors, some of which have a large influence and hence are critical to be able to normalize for if any comparison is to be viable. This is the case when there are differences in the energy performance metrics used, for instance steady state measurement versus tapping cycles. Differences in permitted measurement uncertainties or test condition tolerances can be important but are less likely to be critical and are more straightforward to factor into any test procedure conversion formula.

It should also be noted that sometimes it can be possible to convert a test result from a given test procedure to the other but the reverse action may not be possible because some critical data was not measured or cannot be deduced from one of the tests. This is the case for the electrical consumption of gas heaters in standby mode, which is measured and included in the energy efficiency calculation in some countries, but not measured in others.

Three techniques can be applied when trying to estimate the impact of a particular test procedure difference:

- sometimes a simple calculation can be applied that requires no additional tests: this is the case, for example, when converting between measurements made using a higher or lower calorific value (HCV of LCV) for gas
- the impact of differences in a physical effect can be modelled. While sometimes this can be done by considering known physical phenomena, in many cases additional testing will be necessary to derive quasi empirical factors to be used in a parametric model
- when data are missing from one of the test procedures and no theoretical relation can be found between both sets of results, the only possibility is to make an estimation of the effect of the missing parameter, using hypothesis or performing measurements and deriving an empirical conversion.

The main factors that have been identified as possible sources of difficulty in elaborating relationships between test results for water heaters are as follows.

- Energy source characteristics: energy supply characteristics can vary between countries and may be a source of differences. These are voltage and frequency for electricity, composition and use of higher or lower calorific value (HCV of LCV) for gas, and typical weather data for heat pumps and solar (climatic differences). Another difference for electricity is whether the primary or secondary (final) energy value is used in the calculations.

- A major potential issue affecting comparison of the results of different instantaneous heater test types are that tests can be performed in steady state conditions or using specific tapping cycles. Depending on the test procedure, a relationship may be readily derived e.g. in the case of the US where steady state test results and evaluation of the energy losses at the start and end of a draw-off are used together to calculate the energy efficiency for a tapping cycle, or not.
- The scope of coverage defining which water heaters a test procedure applies to may differ, so that a water heater of a certain storage volume or input capacity may be covered in one country, but not in another.
- There are several types of energy performance metrics used for storage heaters and generally only one is considered within a given S&L regulation. The metrics used include: standby losses of the tank, standby losses of the system, steady state efficiency, tapping cycle efficiency, and heat up duration. The behavior of this type of water heater is complex and although modelling is generally possible, the parameters required by the model may be difficult to determine with sufficient accuracy, especially if a given test procedure does not generate all the inputs required by the model.
- Impact of control parameters: some water heater control parameters may be determined by the test procedure, or can be set by the manufacturer. In particular for storage water heaters, parameters like the storage hot water temperature or storage water temperature hysteresis have a critical impact on performance factors such as standby losses of the system or the energy efficiency during a tapping cycle. It may be very difficult to compare results between a case where the control setting is given by the standard and a case where the manufacturer can freely choose the value. Control factors that affect the use of a backup heater (gas or electric) are also extremely important to account for if good conversion formulae are to be derived. Another important aspect is how the test procedure accounts for “smart” controls e.g. is the water heater given a chance to “learn” the tapping pattern of the test procedure and to optimize it's performance for that tapping pattern?
- Ambient air temperature and cold and hot water temperatures during test, daily hot water use, tapping patterns used for the test and how load is measured (volume of water or energy delivered) are also possible sources of difficulties when comparing results between different test procedures.
- Measurement uncertainty and test conditions tolerances: In general the effect is much lower than the previously mentioned sources of difference, but their effect has also to be assessed and, if possible, quantified.

After this general review of possible issues in test results comparison, it is relevant to describe in more detail the situation for each type of water heater, as follows.

Gas instantaneous water heaters

- Test type: steady state efficiency, which may include a reduced capacity test, and tapping tests. If a tapping test is used, the manner in which the initial cold water flow at the start of a draw is treated before the water starts being heated is important.
- Performance metrics: efficiency ratings with HCV or LHV, auxiliary energy can be accounted for in the final rated efficiency (e.g. in the EU test procedure).
- Other potential issues: gas composition is usually specified and may differ from one economy to another; differences in flow rates and water temperature requirements; how to account for electricity use as well as gas use; how to account for combined space heating where applicable are all possible issues affecting the comparability of test results.

Gas and oil storage type water heaters

- Test type: steady state losses; heat up duration; tapping cycles; or hot water delivery capacity.

- Performance metrics: standby power (gas/oil + electricity) needed to maintain hot water temperature in the tank; efficiency with tapping (can also be yearly consumption for a given output, or daily efficiency); steady state efficiency (e.g. in Australia); first hour rating or delivery ratio.
- Other potential issues: gas composition is usually specified and may differ from one economy to another; differences in flow rates and water temperature requirements; how to account for electricity use as well as gas use; air temperature.
- For condensing water heaters, the efficiency of water heating depends strongly on the temperature of the water in the tank and thus the efficiency of recovering from standby losses will be different from the efficiency of heating newly incoming cold water. The timing of draws in a tapping cycle can impact the efficiency of the water heater. This issue can also occur with heat pump water heaters.

Electric instantaneous water heaters

- Test type: steady state efficiency, which may include reduced capacity test.
- Performance metrics: thermal efficiency for steady draw.
- Other potential issues: cold and hot water temperatures.

Electric storage water heaters

- Test type: standing losses, may include tapping cycles, hot water delivery capacity.
- Performance metrics: standing losses, first hour rating or delivery ratio.
- Other potential issues: variation in tapping cycles, air temperature.

Electric heat pump water heaters

- Test type: steady state, standing losses, heat up duration, tapping cycles.
- Performance metrics: the final rating may be a seasonal performance SCOP (or equivalent value in primary energy) or a COP at a given heat source temperature condition. Comparison in that case is difficult if individual test performances are unknown. Performance metrics may include the consumption of auxiliaries. Here again, more data than a single figure of merit is necessary to compare different ratings but this data is generally not available.
- Other potential issues: the performance of heat pumps depends on the temperature of their sources. Different standards may use the same type of test but with different combinations of cold/heat source conditions. For heat up and steady test conditions, corrections may be feasible. To predict tapping performance from steady state tests requires identification of the control parameters of the unit, which may not be practical. Predicting performance becomes more difficult when the heat pump also controls a backup heater (which is generally the case). Some standards (the EU's for instance), allow the manufacturer to determine several settings of the control system, such as: the hot water temperature setting in the tank, hysteresis to restart the heat pump, and the use or not of an existing auxiliary electrical heater during the tests. As there are no constraints in the EU test procedure or the regulations regarding these settings, test results may be very different for the same system tested under different test procedures and making a comparison with test results derived using other economy's test procedures may become almost impossible. This issue may also apply to other storage water heaters using other types of energy.

Solar water heaters

- Test type: laboratory test of system, test of components with computer simulation for annual performance.
- Performance metrics: similar performance issues as with heat pump water heaters, with even more impact from climate.
- Other potential issues: many different types of solar water heating systems, backup heater type together with its control logic.

Appendix B Sources of market data

Table B.1 presents the market data sources that are available for water heaters in China.

Table B.1 Market data sources for China

Type	Source/ year	Report	Link	Comments	Can derive UEC?
Gas instantaneous	BSRIA/2012	Water Heating China	https://www.bsria.co.uk/market-intelligence/market-reports/publication/china-water-heating-world-market-for-heating-2013/	Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Gas storage	BSRIA/2013	Water Heating China	https://www.bsria.co.uk/market-intelligence/market-reports/publication/china-water-heating-world-market-for-heating-2013/	Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Solar	Research In China/2013	Global and Chinese Solar Water Heater Industry Report, 2013	http://www.researchandmarkets.com/reports/2387288/global_and_chinese_solar_water_heater_industry	Key topics: - Development of global solar water heater industry, referring to the industry status quo, market scale, development trends, etc. of the world and major optothermal-using countries. Development of China solar water heater industry, covering industry status quo, market size, business model, competitive features, exportation, sector planning, anticipated future trends, and so forth;	No

Table B.1 Market data sources for China (continued)

Type	Source/ year	Report	Link	Comments	Can derive UEC?
Electric instantaneous	BSRIA/2013	Water Heating China	https://www.bsria.co.uk/market-intelligence/market-reports/publication/china-water-heating-world-market-for-heating-2013/	Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Electric storage	BSRIA/2014	Water Heating China	https://www.bsria.co.uk/market-intelligence/market-reports/publication/china-water-heating-world-market-for-heating-2013/	Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Heat pumps	NO INFORMATION				
Oil	NO INFORMATION				

Table B.2 presents the market data sources that are available for water heaters in India.

Table B.2 Market data sources for India

Type	Source/ year	Report	Link	Comments	Can derive UEC?
Gas instantaneous	BSRIA/2012	Water Heating India		Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Gas storage	BSRIA/2013	Water Heating India		Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Solar	MNRE/2010	Solar Water Heaters in India: Market Assessment Studies and Surveys for Different Sectors and Demand Segments	http://mnre.gov.in/file-manager/UserFiles/greentech_SWH_MarketAssessment_report.pdf	Market size and projections by sector	No
Electric instantaneous	BSRIA/2013	Water Heating India		Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Electric storage	BSRIA/2013	Water Heating India		Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Heat pumps	No information				
Oil	No information				

Table B.2 Market data sources for India (continued)

Type	Source/ year	Report	Link	Comments	Can derive UEC?
Generic	Feedback business consulting/ 2014	Opportunity in the Indian Residential Water Heaters Market 2014	http://www.researchandmarkets.com/reports/2392674/opportunity_in_the_indian_residential_water	Includes market size estimates and Market Share Estimates and market size by the following: players, capacities, categories, sub-categories, end user segments, regions	No
Generic	Feedback business consulting/ 2015	Opportunity in the Indian Residential & Commercial Water Heaters Market 2014	http://www.researchandmarkets.com/reports/2339825/opportunity_in_the_indian_residential_and	Product categories include: Electric Water Heaters (Instant, Storage), Gas Water Heaters (Instant, Storage)	No

Table B.3 presents the market data sources that are available for water heaters in the USA.

Table B.3 Market data sources for the USA

Type	Source/ year	Report	Link	Comments	Can derive UEC?
Gas instantaneous	DOE 2009	2009-01-13 Preliminary Technical Support Document (TSD) Chapter 3	http://www.regulations.gov/contentStreamer?objectId=0900006480c7c942&disposition=attachment&contentType=pdf	Basic market share information by product type and volume, description of products and range of suppliers from 2010 DOE rule making.	yes
Gas instantaneous	D&R International, 2010	Energy Star® Water Heater Market Profile	http://www.drintl.com/publications.aspx#Mark_Prof	Market background for current Energy Star labels	yes
Gas storage	DOE 2009	2009-01-13 Preliminary Technical Support Document (TSD) Chapter 3	http://www.regulations.gov/contentStreamer?objectId=0900006480c7c942&disposition=attachment&contentType=pdf	Basic market share information by product type and volume, description of products and range of suppliers from 2010 DOE rule making.	yes
Gas storage	Appliance Magazine/2014	Appliance Magazine Market Research: Appliance Historical Statistical Review 1954-2012	http://www.appliancemagazine.com/marketresearch/editorial.php?article=2476&zone=108&first=1	factory sales by year	No
Gas storage	D&R International, 2010	Energy Star® Water Heater Market Profile	http://www.drintl.com/publications.aspx#Mark_Prof	Market background for current Energy Star labels	yes
Solar	D&R International, 2010	Energy Star® Water Heater Market Profile	http://www.drintl.com/publications.aspx#Mark_Prof	Market background for current Energy Star labels	yes
Electric instantaneous	NO INFORMATION				

Table B.3 Market data sources for the US (continued)

Type	Source/ year	Report	Link	Comments	Can derive UEC?
Electric storage	DOE 2009	2009-01-13 Preliminary Technical Support Document (TSD) Chapter 3	http://www.regulations.gov/contentStreamer?objectId=0900006480c7c942&disposition=attachment&contentType=pdf	Basic market share information by product type and volume, description of products and range of suppliers from 2010 DOE rule making.	yes
Electric storage	Appliance Magazine/2014	Appliance Magazine Market Research: Appliance Historical Statistical Review 1954-2012	http://www.appliancemagazine.com/marketresearch/editorial.php?article=2476&zone=108&first=1	factory sales by year	No
Heat pumps	DOE 2009	2009-01-13 Preliminary Technical Support Document (TSD) Chapter 3	http://www.regulations.gov/contentStreamer?objectId=0900006480c7c942&disposition=attachment&contentType=pdf	Basic market share information by product type and volume, description of products and range of suppliers from 2010 DOE rule making.	yes
Heat pumps	D&R International, 2010	Energy Star® Water Heater Market Profile	http://www.drintl.com/publications.aspx#Mark_Prof	Market background for current Energy Star labels	yes
Oil	DOE 2009	2009-01-13 Preliminary Technical Support Document (TSD) Chapter 3	http://www.regulations.gov/contentStreamer?objectId=0900006480c7c942&disposition=attachment&contentType=pdf	Basic market share information by product type and volume, description of products and range of suppliers from 2010 DOE rule making.	yes
Generic	Verify Markets/2010	U.S. Residential Water Heating Market	http://www.researchandmarkets.com/reports/1441323/u_s_residential_water_heating_market	Includes Market overview, drivers/restraints, revenues and forecasts and some distribution trends and market shares for gas tanks, electric tanks, tankless gas, tankless electric, heat pumps	No

Table B.3 Market data sources for the US (continued)

Type	Source/ year	Report	Link	Comments	Can derive UEC?
Electric instantaneous	BSRIA/2013	South Korea (World Market for Heating 2013)	https://www.bsria.co.uk/market-intelligence/market-reports/publication/south-korea-water-heating-world-market-for-heating-2013/	Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Electric storage	BSRIA/2013	South Korea (World Market for Heating 2013)	https://www.bsria.co.uk/market-intelligence/market-reports/publication/south-korea-water-heating-world-market-for-heating-2013/	Market sales data for electric storage, electric instantaneous, gas storage, gas instantaneous, indirect cylinder	No
Heat pumps	None				
Oil	None				

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