Efficiency Improvement Opportunities in TVs: Implications for Market Transformation Programs

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Efficiency Improvement Opportunities in TVs: Implications for Market Transformation Programs

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Executive Summary

This report presents the results of an analysis, commissioned by the U.S. Department of Energy, of television (TV) efficiency in support of the Super-efficient Equipment and Appliance Deployment (SEAD) initiative.[1] SEAD aims to transform the global market by increasing the penetration of highly efficient equipment and appliances. The objective of this analysis is to provide the background technical information necessary to improve the efficiency of TVs and to provide a foundation for the voluntary activities of SEAD participating countries.

We assess the market trends in the energy efficiency of TVs that are likely to occur without any additional policy intervention and estimate that TV efficiency will likely improve by over 60% by 2015 with savings potential of 45 terawatt-hours [TWh] per year in 2015, compared to today's technology. We discuss various energy-efficiency improvement options and evaluate the cost effectiveness of three of them. At least one of these options improves efficiency by at least 20% cost effectively beyond ongoing market trends. We provide insights for policies and programs that can be used to accelerate the adoption of efficient technologies to further capture global energy savings potential from TVs which we estimate to be up to 23.5 TWh per year in 2015.

Motivation for this Study

The total global TV electricity consumption was estimated to be more than 250 terrawatt hours [TWh] in 2008, i.e., more than 5% of total global residential electricity consumption (International Energy Agency (IEA) 2009). Since the mid-2000s, the global TV market has undergone a major transition from traditional cathode ray tube (CRT) TVs to other types, particularly flat panel display (FPD) TVs such as liquid crystal display (LCD) and plasma display panel (PDP).

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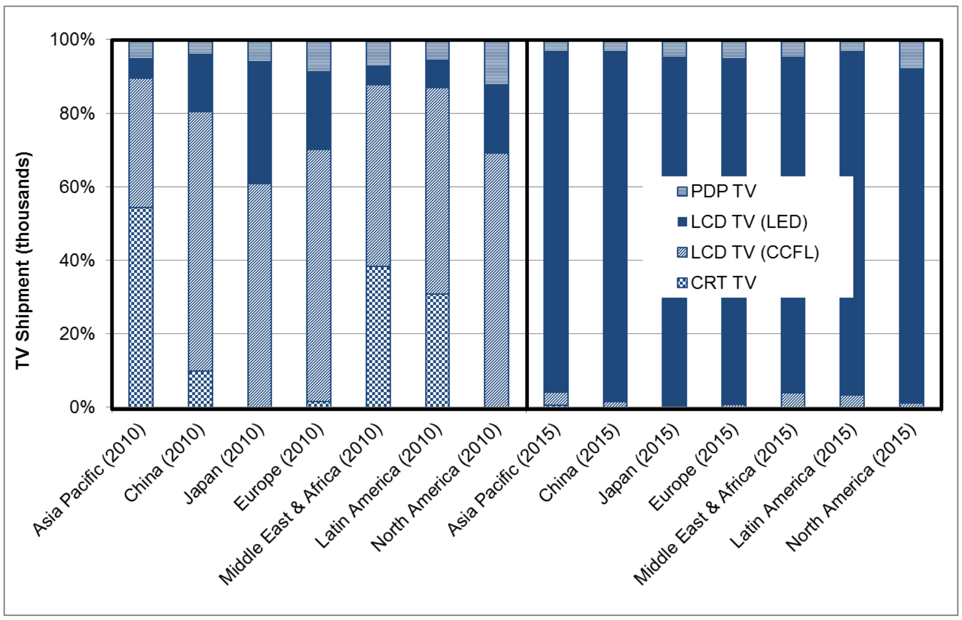
[1] As one of the initiatives in the Global Energy Efficiency Challenge, SEAD seeks to enable high-level global action by informing the Clean Energy Ministerial dialogue. In keeping with its goal of achieving global energy savings through efficiency, SEAD was approved as a task within the International Partnership for Energy Efficiency Cooperation (IPEEC) in January 2010. As of April 2011, the governments participating in SEAD are: Australia, Brazil, Canada, the European Commission, France, Germany, India, Japan, Korea, Mexico, Russia, South Africa, Sweden, the United Arab Emirates, the United Kingdom, and the United States. More information on SEAD is available from its website at http://www.superefficient.org/.

An assessment of efficiency improvement opportunities for TVs is needed for three reasons - *first*, to correct market failures such as uncaptured economic and environmental benefits available from TV energy consumption reduction through cost-effective[2] efficiency improvements, and *second,* to account for the ongoing large scale transition from cold cathode fluorescent lamp (CCFL) backlit liquid crystal display (CCFL-LCD) TVs to light emitting diode (LED) backlit LCD (LED-LCD) TVs in designing market transformation programs such as standards, labels or incentives in a timely manner. TV manufacturing is highly globalized, and LED backlit LCD TVs are likely to increase significantly, from 50% to 90% of the TV shipments in 2012 and 2015 respectively (DisplaySearch 2011a). *Third,* there are only limited regional differences and global similarity in TV screen (i.e., LCDs) and LCD backlight technology (see Fig. 1), although there are regional differences in screen size preferences and market share of TVs with additional 3D or network features. Major brands distribute similarly designed TVs with similar energy consumption characteristics across many regions. Accordingly, the research presented in this paper is applicable to TVs in most countries.



Source: DisplaySearch, 2011a

Figure 1. Actual (2010) and Forecasted (2015) TV Market Transition by Region and Screen Technology

Objective and Scope

The objective of this analysis is to identify potential TV efficiency improvements and their incremental costs, as well as to provide initial global and country-specific estimates of total energy savings potential. The overarching goal is to provide relevant and appropriate information to support design of appropriate policy programs that will accelerate the penetration of super-efficient TVs.

This paper focuses on LCD TVs since they are expected to dominate worldwide sales, amounting to an expected 95% of global TV shipments by 2015 (DisplaySearch, 2011a). Although large Organic Light Emitting Diode (OLED) TVs (larger than 40 in.) are expected to be on the market in 2013, they are not expected to be cost competitive against LCD TVs at least until 2015. PDP TVs are expected to remain viable but to decline steeply in market share as both LCD and OLED TV production costs decline. We consider efficiency improvement options for LCD TVs that are technically feasible, practical to manufacture, and could be realized

[2] In this analysis, cost-effectiveness is defined as cost of conserved electricity (CCE), the annualized investment in more expensive equipment or component needed to provide a unit of energy saved (kWh), less than electricity price.

in the short term (over the next three years), as the rapid evolution of technology in the display market makes a forecast over a longer time scale highly uncertain and therefore less useful from a policy perspective.

Data Sources and Analysis Method

We obtained the data for this paper primarily from the following sources: a review of the literature including technical reports, DisplaySearch reports and data sets, the ENERGY STAR database for TVs that meet the Version 4 or 5 specifications, international conferences and interviews with manufacturers and experts in the field.

Analysis Results

A. Efficiency improvement options and trends

Efficiency improvement options - which also lead to concurrent improvements in other desirable product characteristics (e.g., LED backlighting leads to thinner/lighter TVs and better picture quality in color reproduction capability) or lead to reduction in overall costs (e.g., high efficiency LCD panels require fewer optical films or backlight lamps) - are more likely to be adopted on their own without additional policy intervention in comparison with options which predominantly improve only efficiency, or which increase manufacturing cost. Furthermore, electricity costs for TVs and corresponding savings are relatively a minor component of the total costs over the lifecycle of the TV in many countries. Thus efficiency is unlikely to be a primary consideration in price-sensitive consumer's selection of TVs in many countries, presenting an additional rationale for policy intervention to improve efficiency. Table 1 summarizes LCD TV efficiency-improvement options.

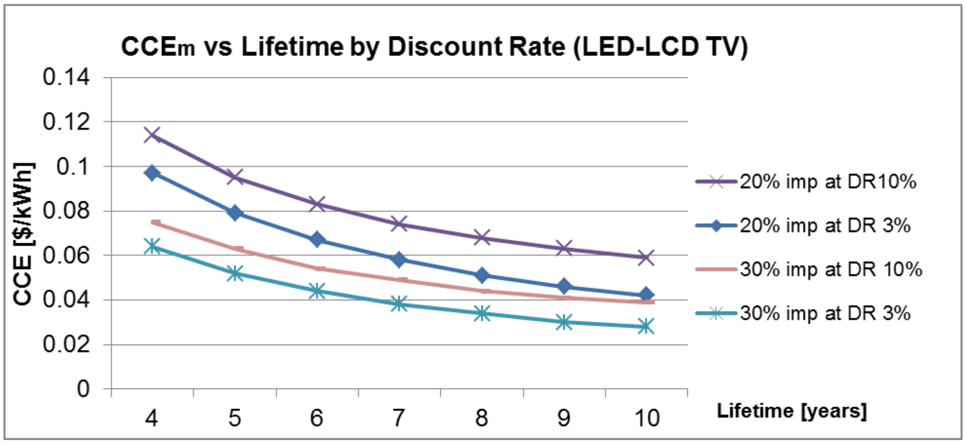
Table 1. LCD TV efficiency improvement options

Components		Improvement options	*Notes*
Backlight Unit	Backlight Source	· CCFL to LED transition	· Cost increase · Adopted by manufacturers due to improved product quality (BAU)
		· High LED efficacy	· Cost reduction in the longer term (BAU) · Technical barrier in thermal management and short term cost increase from adoption of much higher efficacy LEDs than BAU trajectory
	Optical films	· Optimized combination of films · Multi-function film	· Trade-offs in material cost, ease of manufacture, and efficiency (BAU)
		· Reflective polarizer (e.g., DBEF[a])	· Cost increase, proprietary technology
LCD Panel		· Improvement in panel transmittance by optimizing pixel design, functional layers, e.g., polarizer, color filter, and data line	· Proprietary technology · R&D investment required but driven by potential for total cost reduction.
Power management		· Brightness control (local dimming) by image signals	· Cost increase · The effect varies with backlight structure, input images, and algorithm.
		· Brightness control based on ambient light condition	· Cost increase · The effect varies with settings and ambient light condition
Other		· Power Supply Unit (PSU) Efficiency	· Trade-off between cost and efficiency
		· Color gamut (by color filter or light source)	· Trade off with efficiency

[a] Dual brightness enhancement film produced by 3M

B. Cost-effectiveness Analysis

A reflective polarizer improves TV efficiency by 20-30% regardless of backlight source. Backlight dimming can reduce LCD TV power consumption by at least 20%. Ambient light sensors are commercially available and their material cost does not vary with screen size or resolution, implying that cost-effectiveness of this option increases with screen size While backlight dimming in relation to ambient light conditions, i.e., auto-brightness control (ABC), can be generally regarded as part of backlight dimming, more research is needed to estimate the precise effect of these options on household TV energy consumption. Fig 2 and 3 show CCE for LED-LCD TVs versus lifetime at various combinations of discount rates and efficiency improvement potential.



Assumption: daily usage=5 h.
Note: imp=improvement potential, DR=discount rate.

Figure 2. Sensitivity to lifetime and discount rates of the cost per unit of conserved electricity (CCEm) for reflective polarizers

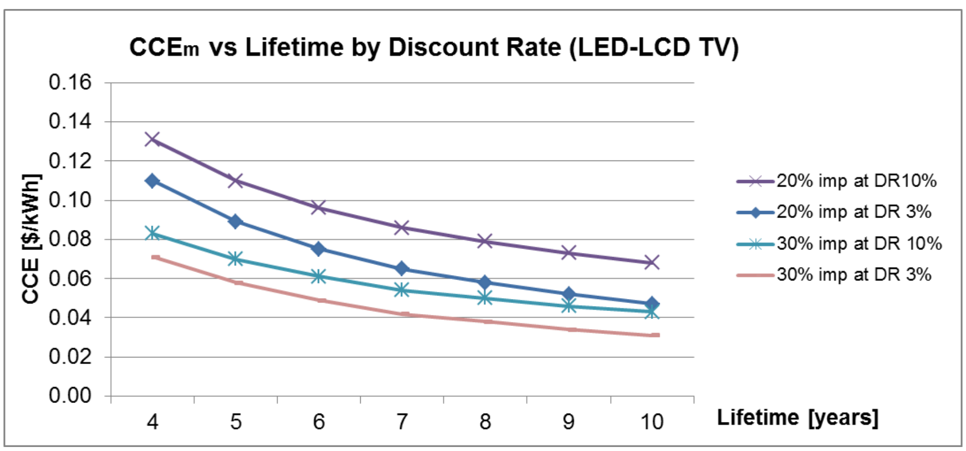
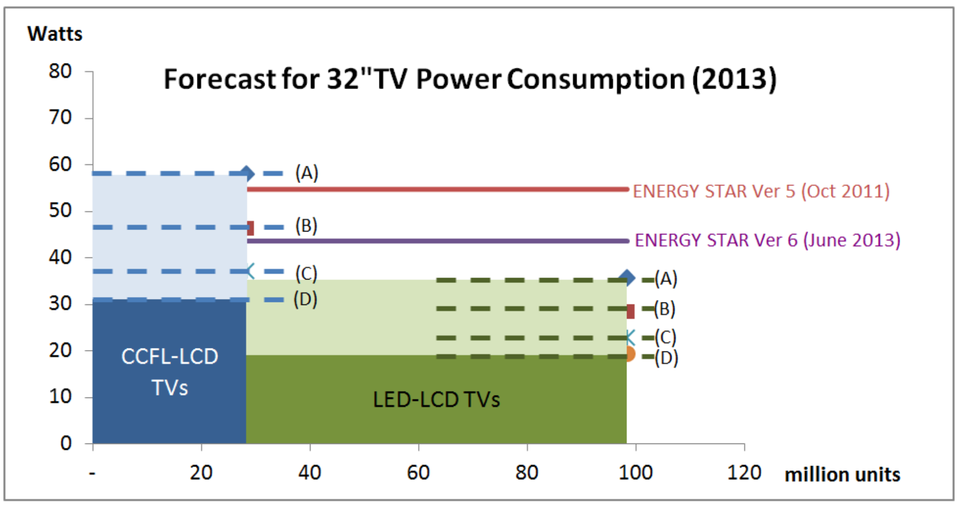


Figure 3. Sensitivity to lifetime and discount rates of cost per unit of conserved electricity (CCE_m) for 1D backlight dimming

C. Insights for Market Transformation Programs

As LED-LCD TVs are expected to account for more than 75% of global TV shipments from 2013 onward, energy efficiency programs need to account for the performance of LED-LCD TVs. Standards programs need to define much more stringent efficiency targets than are currently in place in order to exploit the maximum available cost effective energy efficiency potential and re-evaluate these targets regularly as the market evolves. A labeling or incentive program going into effect after 2012 may need to consider even more aggressive levels than, for example, the ENERGY STAR Version 6, due to the rapid evolution in TV energy efficiency.

Standards or entry levels of labeling programs setting specifications in 2013 could target an on-mode power consumption level about 15% below ENERGY STAR Version 5 while still remaining technology neutral and thereby capturing the additional savings potential (see Fig. 4). CCFL-LCD TVs can meet this level by employing cost-effective efficiency improvement options, while LED-LCD TVs will likely meet the level without any further efficiency improvement options. *Labeling and incentive programs* setting specifications for 2013 could target an on-mode power consumption level 50% below ENERGY STAR Version 5 (see Fig. 4). LED- LCD TVs (which are likely to be about 80 % of the market in 2013) can achieve this level by adopting cost effective technologies equivalent in cost and energy savings terms to reflective polarizers or backlight dimming. This level is about 36% more stringent than ENERGY STAR Version 6.



(A) Estimated average power consumption in a BAU scenario.
(B) Power consumption possible with *either* reflective polarizers *or* backlight dimming.
(C) Power consumption possible with *both* reflective polarizers *and* backlight dimming
(D) Power consumption possible with four options: reflective polarizers, backlight dimming, ambient light sensor and occupancy sensor
Each shaded area represents total power consumption by global shipments in the corresponding scenario.

Figure 4. Possible levels for standards, labeling and incentive programs

D. Global Savings Potential for Efficiency Improvements in LCD TVs

This analysis compares future TV energy consumption for three major scenarios: a base case with efficiency improvement expected in BAU (Base Case), an efficiency case and a super efficiency case with two sub-cases; one is the case with the two cost-effective efficiency improvement options (i.e., reflective polarizer and backlight dimming) and the other is the case with the other two efficiency improvement options (i.e., ambient light sensors and occupancy sensors) that can be additionally adopted by manufacturers. In addition to the three major scenarios, we include one additional case which assumes a market transition from CCFL-LCD to LED-LCD in the LCD technology with no further efficiency improvement within each technology from 2011 onward in order to give the reader a sense of the rapid improvement in TV efficiency expected even in a BAU scenario.

If in every year the efficient designs discussed in this paper reach an average of 40-90% of the market varying by technology type and efficiency improvement option, the energy savings potential would be up to 23.5 TWh per year in 2015. Fig. 5 shows the results of forecasted global TV electricity consumption in on-mode. The energy savings potential contributed from 2012-2015 TV shipments by each scenario and corresponding policy programs are summarized in Fig. 6.

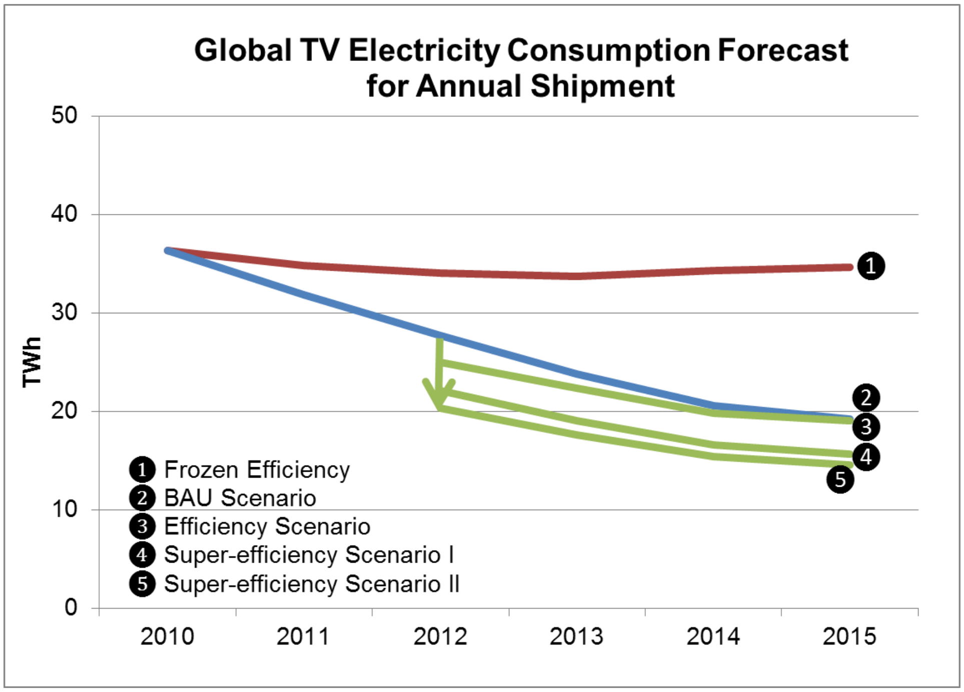
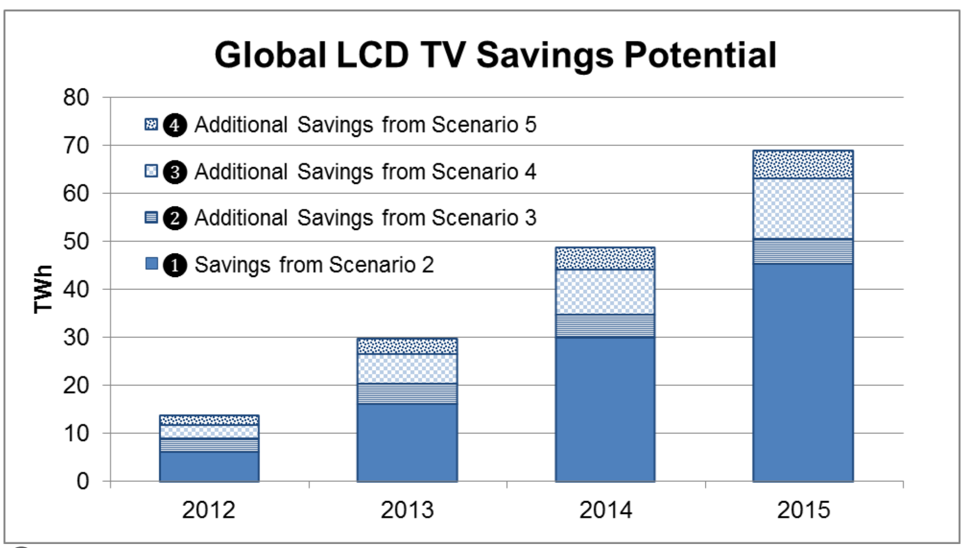


Figure 5. Global TV electricity consumption forecast for annual shipment



❶: Possible savings by BAU improvement.

❷: Possible savings by standards.

❸+❹: Possible savings by incentives and labeling programs.

Figure 6. Global LCD TV Annual Savings Potential for 2012-2015