

Power that Changes the World



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Executive Summary

Sustainability and eco-design are now central to government regulations, corporate policies, and the manufacturing strategies of leading display companies.¹

A rare opportunity now exists to make non-incremental improvement by taking a systems approach to sustainability innovation. Key to this is leveraging both new-to-the-world and established optical film technologies to address fundamental and previously unassailable constraints.

This paper discusses how this systems approach affects the device, the factory in which it is manufactured, and the supply chain (Fig 1). First we discuss how lifetime energy consumption of a device can be reduced and how manufacturers can use low power to differentiate their devices. Next we discuss how the supply chain and factory can be greatly simplified via new optical film technologies that enable highly integrated optics, resulting in the elimination of light guides and free-floating films. An order of magnitude reduction of waste stream associated with the backlight optical components is possible.

Lastly we discuss how these developments present an opportunity for supply-chain-wide collaboration on Life Cycle Management to improve the environmental profile of LCD as a display technology.

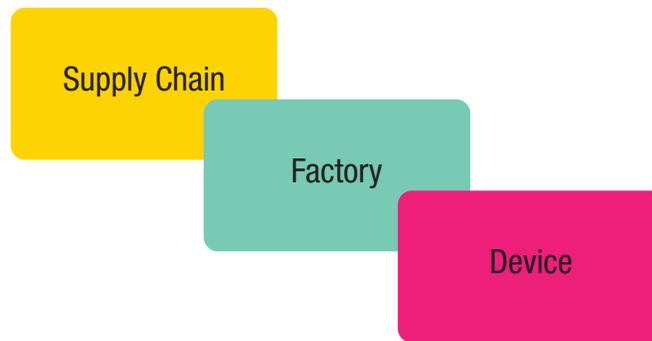


Figure 1: Components of Sustainability Strategy

Device Sustainability

The global share of energy consumption by consumer electronics is increasing,² as is consumer awareness of that increase. In addition to the often discussed bill of materials (BOM), new metrics are being proposed such as the greenhouse gas bill of materials (G-BOM), which has as its goal the quantification of the environmental impact of all aspects of a device's manufacture and use.³⁻⁴ Consumer awareness is increasing through multiple labeling and consumer education programs.

Energy consumption by televisions has been recognized, in particular, as a key opportunity for reducing residential power consumption. In the United States, televisions are among the top five energy consuming devices in the home.⁵ Several key trends are contributing to television's ever-increasing share of the household energy budget. The number and size of TVs per home are both increasing. Also, consumers are using their TVs for more hours per day and to do more things, especially with the advent of smart and connected TVs. As these trends continue, the industry can play an important role by developing lower power designs. In addition, the industry can benefit from the differentiation that sustainable designs provide. Figure 2 summarizes key considerations for device sustainability.

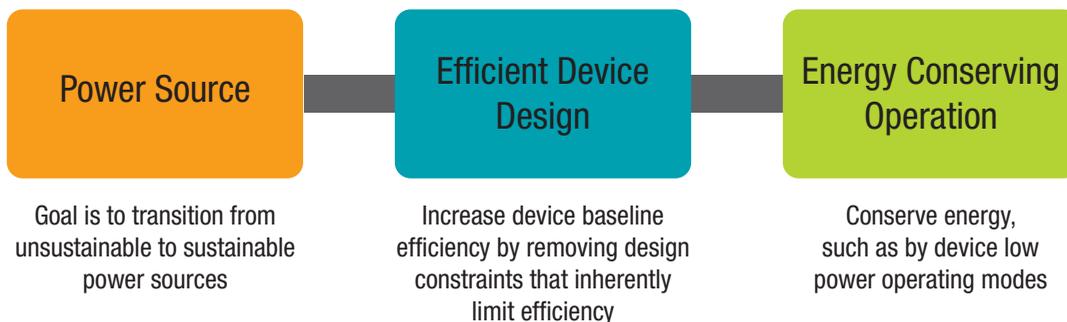


Figure 2. Key components of device energy sustainability

Television Power Reduction Programs

Because television energy consumption has a significant impact on the global demand for energy, governments and utilities around the world have created numerous programs and services around the world aimed at reducing the amount of energy that TVs consume. These programs provide benefit to the consumer, who can make more informed decisions, and to manufacturers who can use the programs to differentiate and promote their products. Table 1 lists the types of programs and regions where they are active, while Figure 3 shows TV power use compared to other residential power draws.

Table 1. Global Television Power Reduction Programs⁶⁻¹⁶

Type	Description	Programs
Minimum efficiency performance standards	Establish maximum legal power limits for TVs sold in a particular market	2009: Australia 2011: EU, China, California (US)
Mandatory Consumer Labels	Provide point-of-purchase power consumption information to consumers	2010: Australia 2011: China, US, EU
Voluntary Labeling Programs	Provide special recognition to TVs which meet specific eco requirements	US: Energy Star EU: Ecolabel Japan Top Runner
Financial Incentives	Private and Public funds available to manufacturers, retailers, or consumers for making, selling or purchasing energy efficient TVs	Utilities in North America have programs established since 2008. EU and China have programs under development.

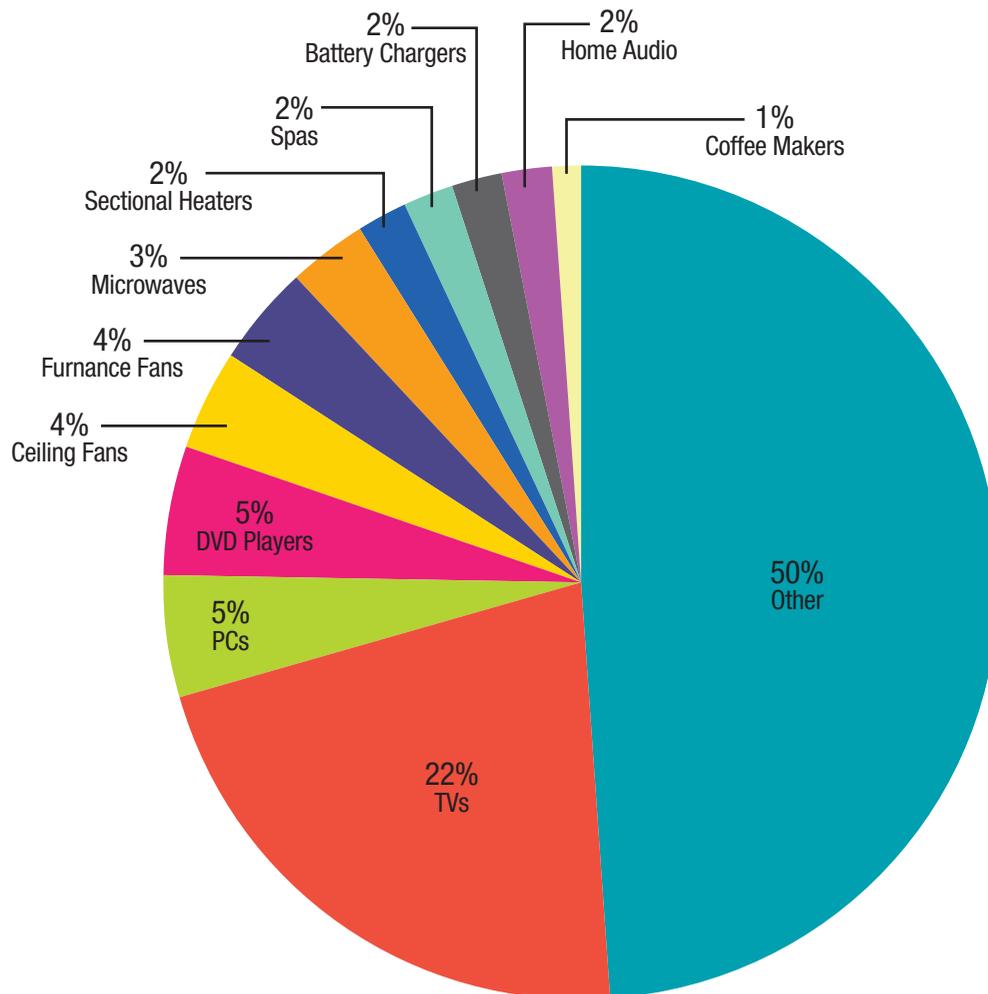


Figure 3. Power Consumption in United States North American Homes¹⁷

In addition to the programs listed in Table 1, there are a variety of resources available to consumers such as the Top Ten program and CNET's Juice Box to help them find the most energy efficient TVs. Additionally, proliferation of technologies such as smart meters will also help consumers make important adjustments once they get their TVs home. Google's PowerMeter (Figure 4) is an example of a tool that consumers can use to monitor, in real time, the effect that devices have on their utility bills.

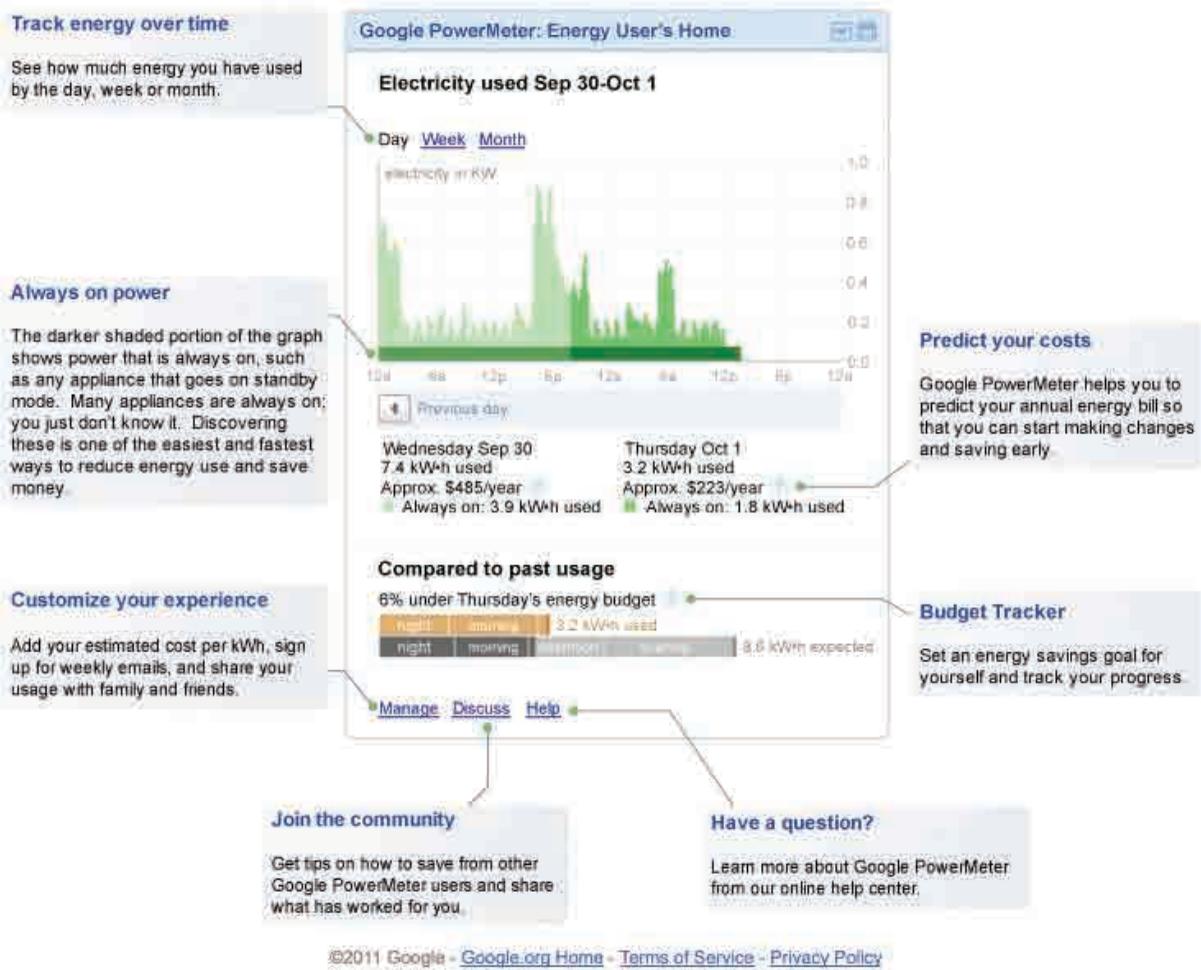


Figure 4. Example of Consumer Education and Engagement Google PowerMeter¹⁸

Evolution of Television Energy Consumption

The IEC test method¹⁹ has become the global industry standard for characterizing television power consumption in the active mode. ENERGY STAR adopted this test method in its television standard beginning in October, 2008. Figure 5 shows that manufacturers are delivering ENERGY STAR qualified sets in 2011 that consume 50% to 70% less power than their 2008 counterparts. For forward reference, the EU energy label is scheduled to introduce new voluntary levels over time. Figure 5 also shows the efficiency criteria that manufacturers must meet to earn the EU's highest energy rankings.

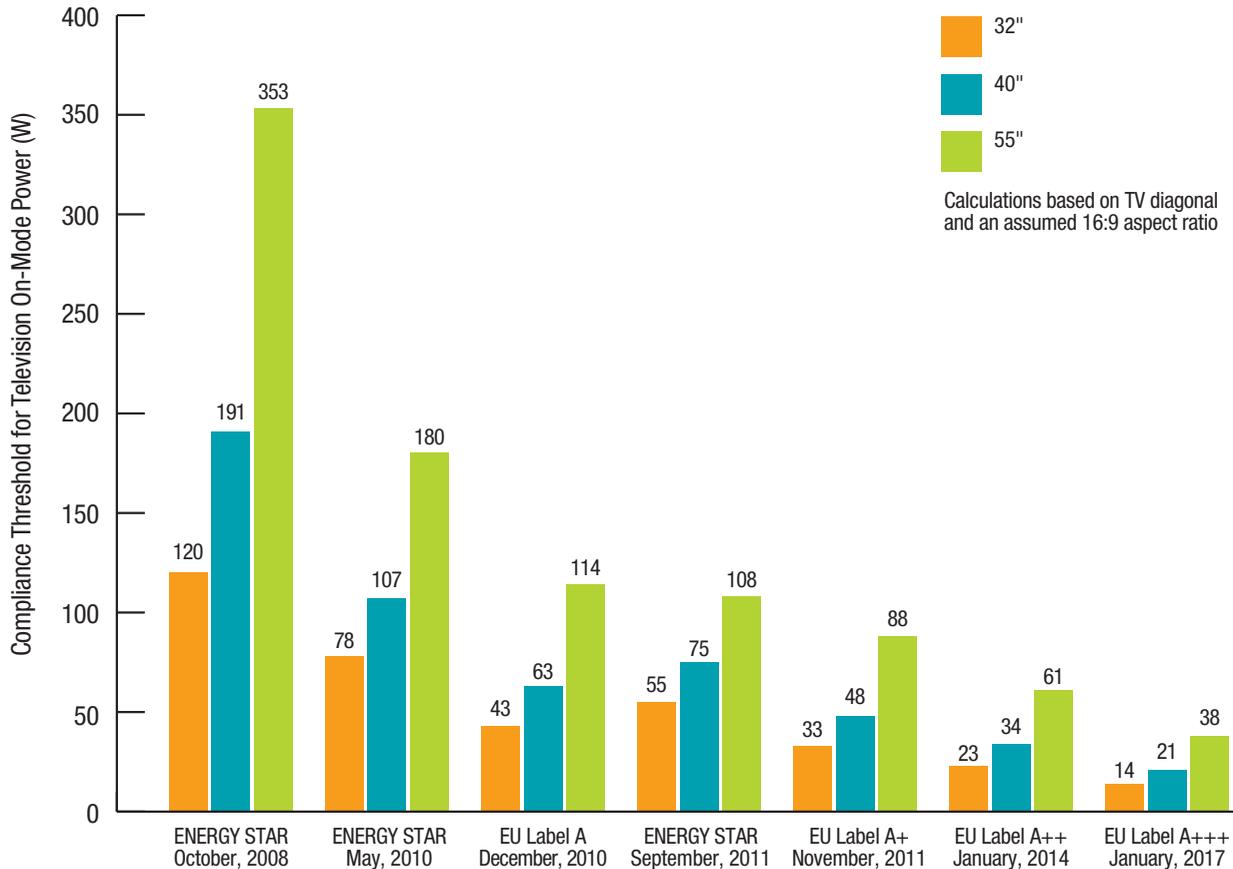


Figure 5. Compliance Criteria for ENERGY STAR and EU Energy Label

Energy Reduction Technologies in LCD TVs

Manufacturers have made great progress in reducing the energy consumed by their devices. Use trends, however, require even further reductions, and manufacturers have several technologies from which to choose.

Table 2 categorizes key technologies available to reduce the energy consumption of televisions. Many technologies focus on conserving output energy by altering the performance of the TV based on use conditions or user preferences. Automatic Brightness Control is an example of one such technology where the brightness of the display is automatically reduced (which reduces the required input power) based on ambient lighting conditions. A challenge with this kind of technology is that it can be disabled by users if it is perceived to compromise visual quality.

There are other technologies that fundamentally improve the efficiency of the TV itself. One example is light source efficiency improvements. Light Emitting Diodes (LEDs) used in TVs are now providing more than 80 lm/W, and there is still much room for further LED efficiency improvements.²⁰

Improvements in efficiency (as opposed to conservation efforts) offer power reduction benefits to users regardless of the required performance, and these efficiency improvements cannot be disabled – they are inherent to the device.

Strategy	Category	Description	Comment
Conserve	Dynamic Backlight Adjustments	Automatic adjustment brightness (and power) to save energy.	Can be disabled by the end-user. Effectiveness dependent on the algorithm logic for which there are no standards.
	Light Redistribution or Tailoring	Modifies the directional, spatial and/or spectral characteristics of the display to save power.	Power reductions can come at the expense of visual quality if designed poorly.
	User Backlight Adjustments	Manual (user) adjustment of display brightness (and power) to save energy.	Power savings inversely proportional to brightness. Without knowledge of how settings affect power consumption, users will likely favor brightness.
	Idle Shutoff	Places the TV in an idle mode when it is not in use.	Does not affect power consumption in use mode. Provides no additional benefit to a user who would ordinarily turn off the TV.
Improve Efficiency	Component Efficiency Improvements	Components which result in more output work for every input unit of energy. Results in less energy waste.	<ul style="list-style-type: none"> • Increases the system efficiency regardless of setting • Immediate power reduction without sacrificing visual quality

Table 2. Technologies for Reducing TV Energy Consumption.

3M's LCD Efficiency Solution

3M's award-winning²¹ Dual Brightness Enhancement Film (DBEF) has been used in LCDs since 1996 and is a well-know and proven efficiency solution for LCD televisions. DBEF takes light that would ordinarily be absorbed by the display and converts it into light that can be used by the LCD. The increased efficiency of the LCD with DBEF can be used to increase the luminance (brightness) of the display, to reduce the power used by the backlight, or a combination of luminance increase and power reduction.

In television applications where brightness is held constant, DBEF has been found to reduce power consumption by up to 32% (Figure 6). Any LCD TV that does not currently use DBEF can realize an immediate power reduction benefit on this order without sacrificing visual quality. Because DBEF increases the total amount of light available, brightness at all angles of view can be increased.

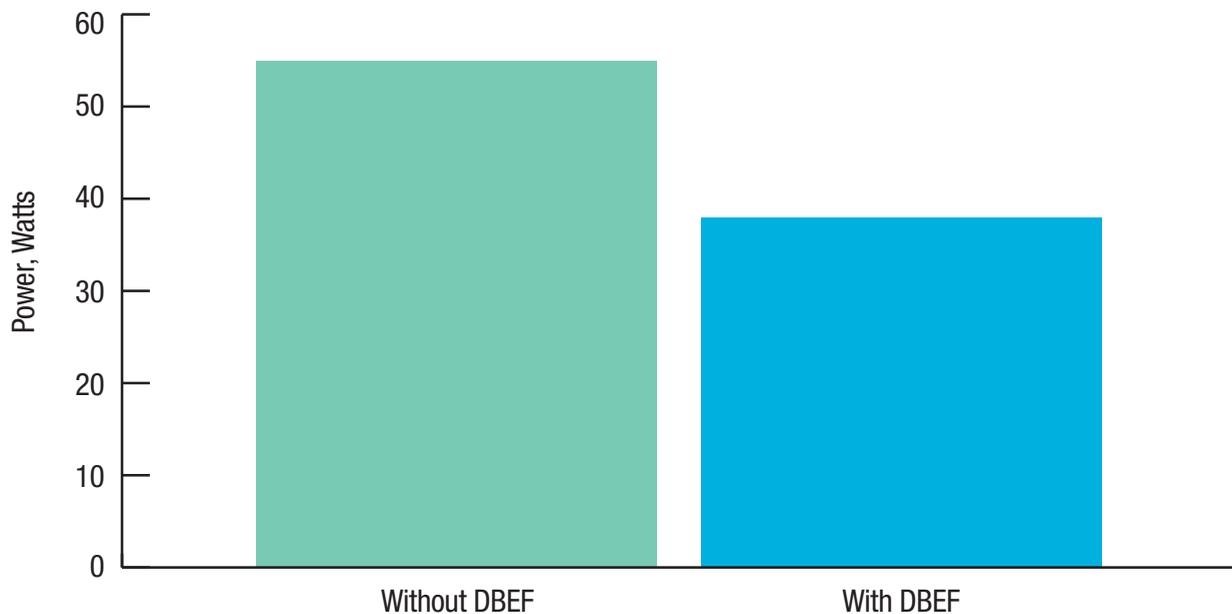


Figure 6.

New Paradigms Enabled by Increased Device Efficiency

In addition to reducing power, increasing the baseline display efficiency can create opportunity to establish a new range of features never before considered.

The desktop monitor market can serve as an example. By combining the most efficient light sources with the most efficient backlights, 3M has now demonstrated desktop monitors that consume less than 8 Watts of power (Figure 7). This is exciting because these monitors are now low enough in power to enable power and content to be delivered via a USB interface. This removes the need for internal power infrastructure in the monitors, simplifies and makes more universal the connection of monitors to computers, and enables users to use their desktop monitors in new ways. Further improvements in device efficiency will enable even larger systems such as TVs and LCD signs to be powered by this or other alternative power means.

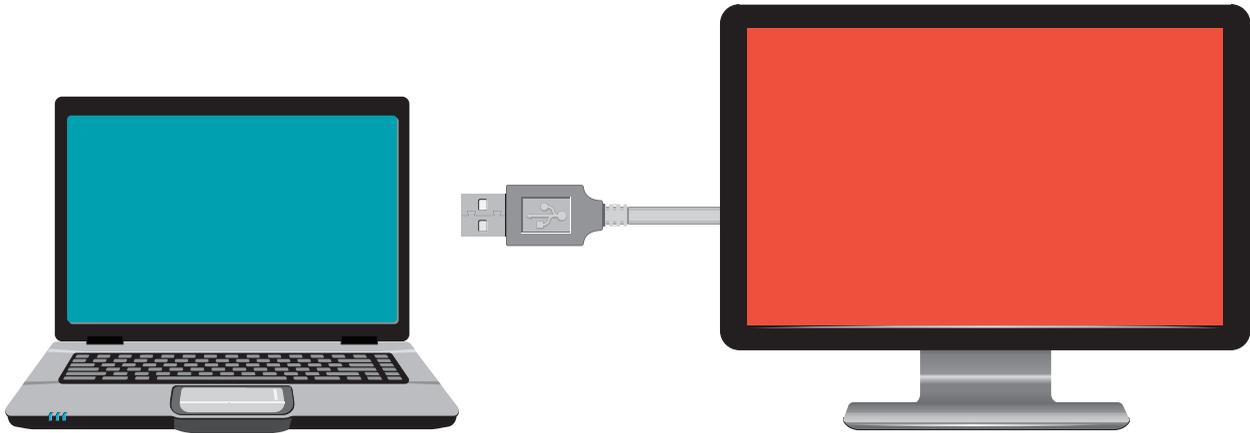


Figure 7. USB Powered Display Enabled by Low Power Requirements

Supply Chain and Factory; A Non-incremental Reduction in Material Usage

The conventional LCD backlight architecture is shown on the left of Figure 8. It consists of a back reflector, a light guide, one or more diffuser and prism films, and a reflective polarizer. These elements are between the LCD panel and the chassis. LEDs are positioned at the edge. This multi-component approach cascades through the supply chain, and it requires multiple factories, process steps, SKUs, shipping and packaging.

On the right are three backlight architectures enabled by Collimating Multilayer Optical Film (CMOF), a new integrated optics technology.²²⁻²⁵ These include: a polarized light guide comprised of one film integral with a solid light guide; a hollow cavity light guide (which we call the Air Guide) consisting of one film on the LCD panel and one film on the chassis; and a direct-lit design, which has a similar construction to Air Guide except for the location of the LEDs.

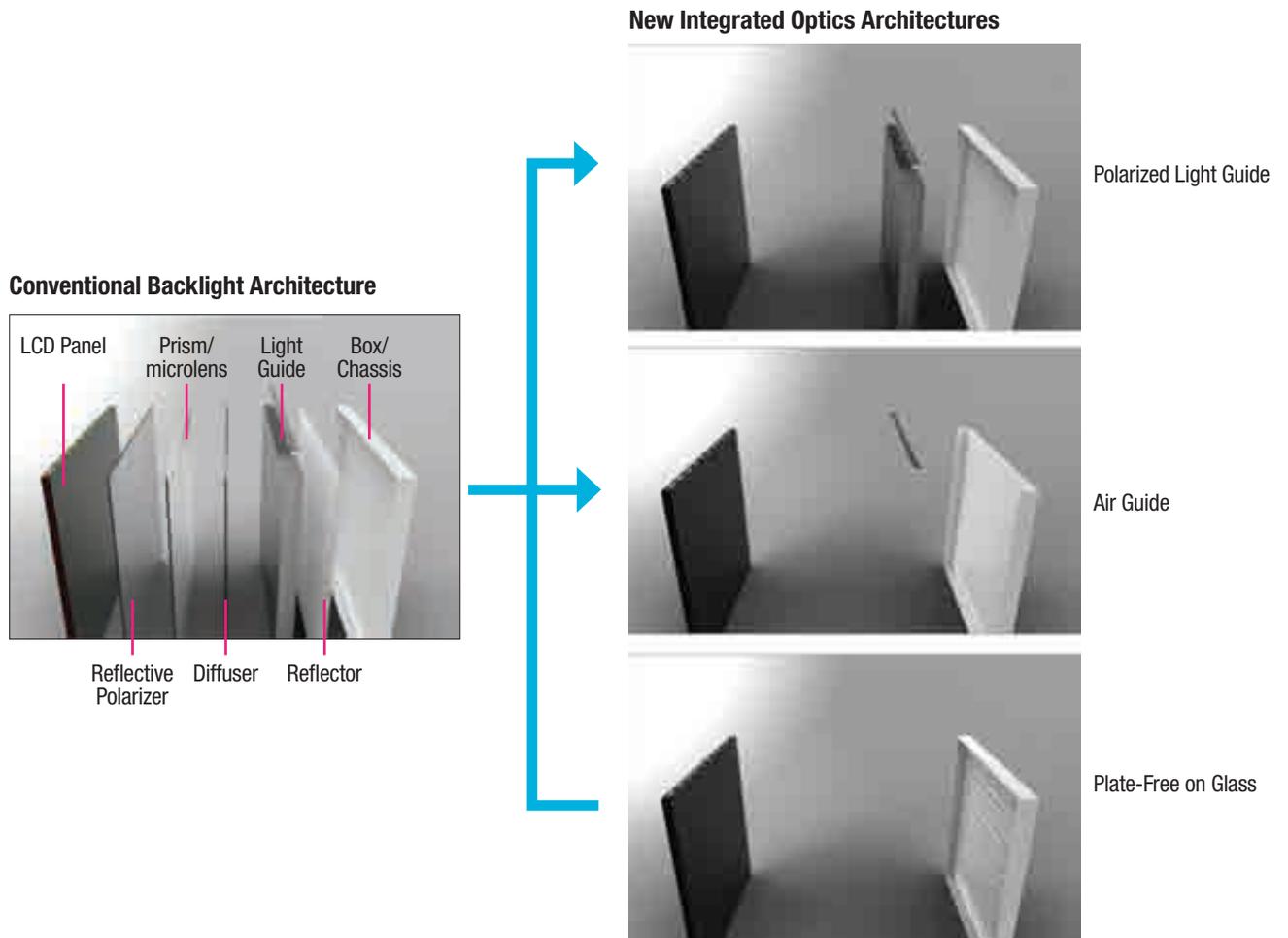


Figure 8 Conventional vs. Integrated Optics LCD Backlight Architectures

This shows a significant reduction in components including non-value added sub-components such as thick polycarbonate substrates, adhesives, and intermediates such as liners which are discarded during assembly.

3M's new Collimating Multilayer Optical Film (CMOF) is a single film that provides the function of diffuser, collimator, and reflective polarizer. CMOF can be paired with 3M's ESR (Enhanced Specular Reflector) film as a back reflector to provide the function of the solid light guide. CMOF technology has enabled demonstration of each class of display shown in Figure 8.

The resulting material reduction can be dramatic, particularly when the Air Guide is compared to a conventional solid light guide multi-film system. The chart below shows an example of the material reduction in a 52" diagonal television. A reduction of >90% is seen, with the bulk being realized by elimination of the PMMA light guide plate.

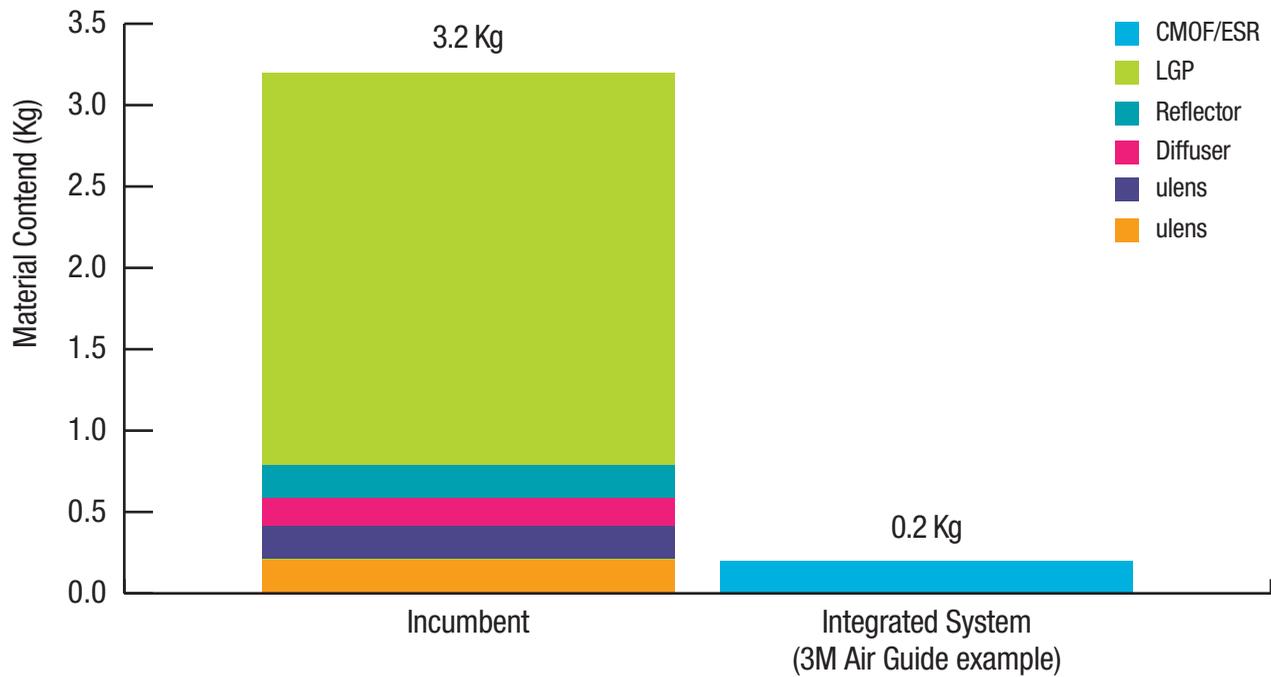


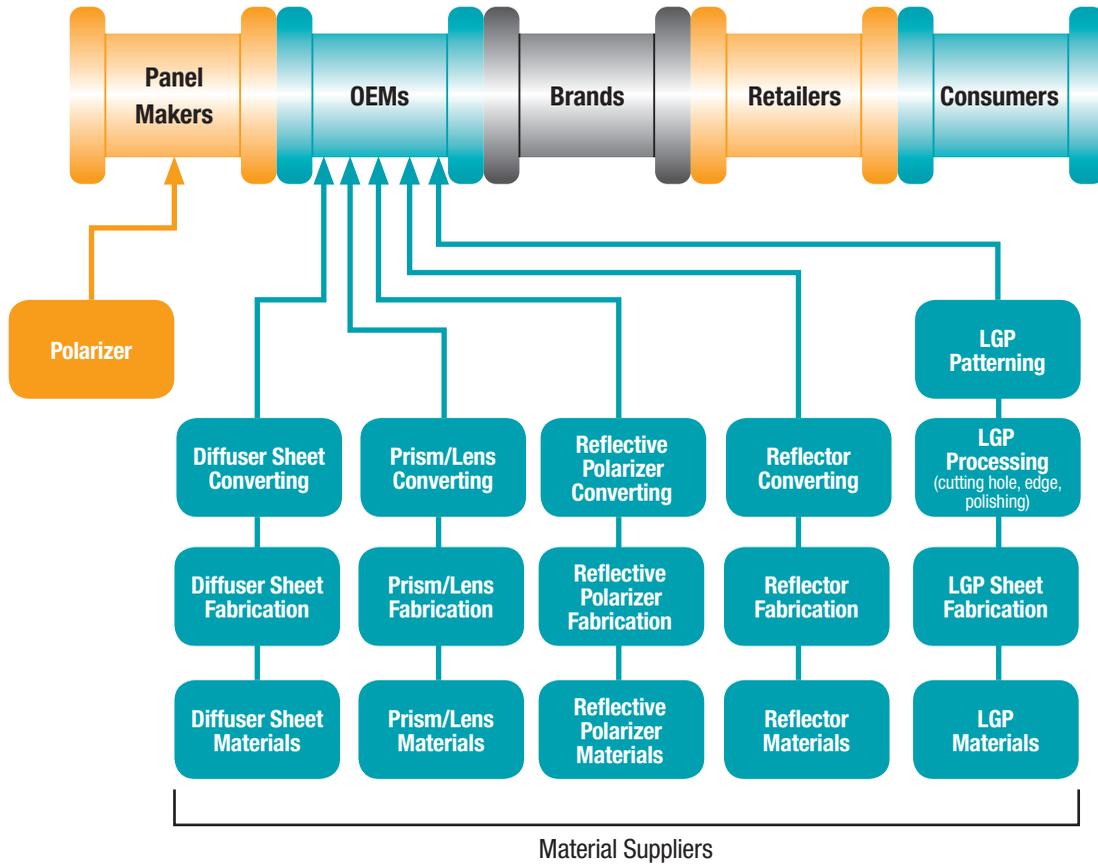
Figure 9. Material Reduction (Kg) for a 52" TV Conventional Backlight System vs Integrated System

Implications to the LCD supply chain are significant. The top schematic of Figure 10 shows the current LCD supply chain with focus on the backlight materials. Today, five different components are supplied to the OEM. For each there are multiple steps including raw material manufacture, yielded material losses in article fabrication, packaging and energy used for transportation. All modes of transportation are used: land, sea, and air.

In contrast, integrated systems provide the opportunity for significant simplification. In the scenario shown, the CMOF film is attached to the rear polarizer prior to its attachment to the LCD panel. ESR is provided as the chassis back reflector. This greatly streamlines the overall process, minimizing steps reducing the amount of materials, packaging and transportation required.

Supply Chain Today

Multiple materials, inspections, assembly steps, waste sources



New Supply Chain

Streamlined, minimal materials, minimal steps

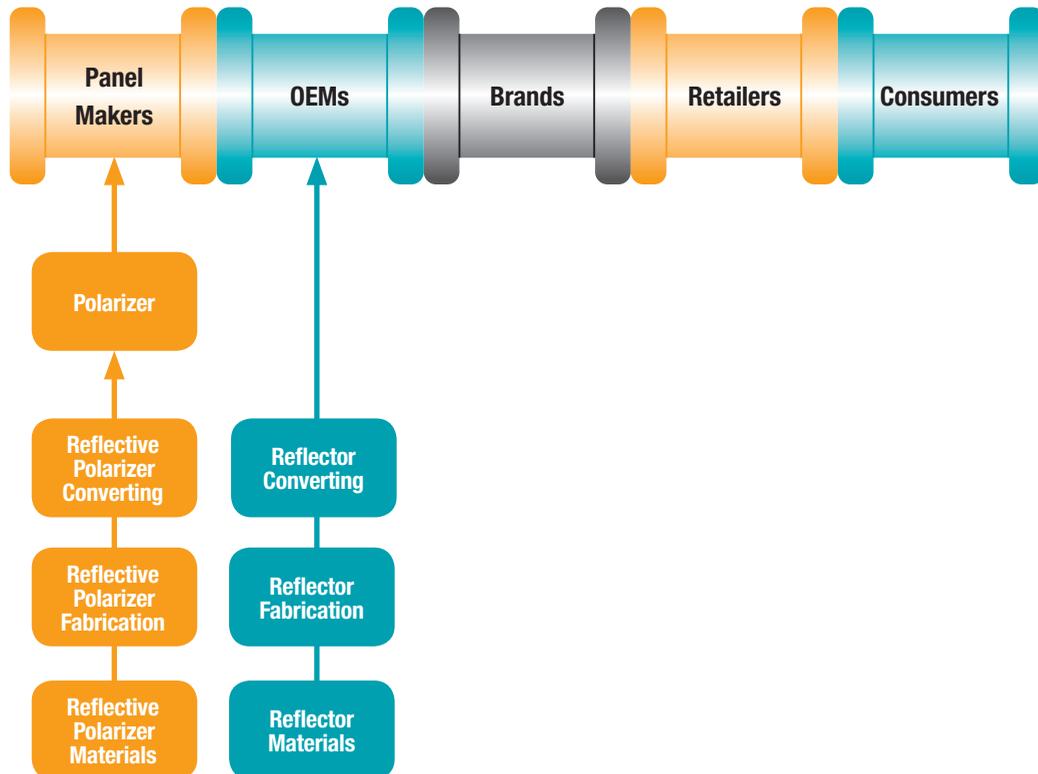


Figure 10. Traditional and New Supply Chain

Summary

From a device efficiency standpoint, we have presented here the importance of addressing the power consumption of televisions. Existing and emerging programs and consumer tools can enable manufacturers to differentiate on low power consumption the same way they currently differentiate on contrast ratio and refresh rate. 3M offers unique high efficiency and low power technologies available to meet the ever-increasing demands for sustainability. Increased efficiency also offers the prospect of adding new features to TVs, enabled by virtue of their small power consumption.

From a materials reduction standpoint, new integrated optics technology (CMOF) enables an order-of-magnitude reduction in the amount of plastic needed for the backlight. With the number of TVs sold globally and other backlit displays and signage, we estimate that the amount of material currently consumed in backlighting is approximately 1 billion pounds every year. Additional environmental impact come from the associated packaging and shipping materials, as well as the energy required to make all materials and ship them. Eliminating some 90% of these materials—a real possibility, given this breakthrough in integrated optics technology—would cascade through the supply chain greatly improving the overall environmental profile of displays, display products, and the industry as a whole.

As discussed in the United Nations Environment Programme (UNEP),²⁷ *Life Cycle Analysis* (LCA) is an integral part of a sustainability strategy. Instead of only focusing on the manufacturing process to control environmental, health, safety and energy effects, the spotlight is now on products throughout their entire life cycle, from manufacturing through customer use and disposal. The LCA process can serve as a collaborative tool at an *industry level* where leaders in each part of the supply chain can work together toward non-incremental, definable goals.

A Call to Action—Collaboration on Sustainability Across the Supply Chain

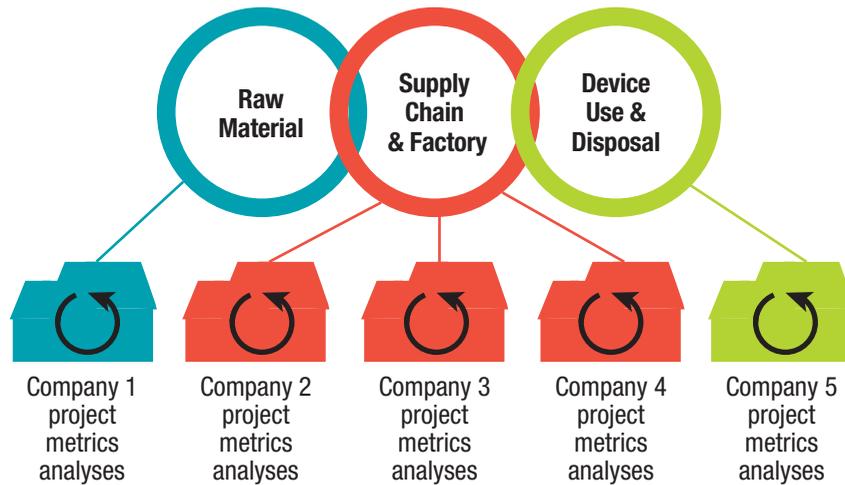
A rare opportunity now exists for collaboration toward non-incremental advancement in the area of sustainability for the LCD industry. The scope should be broad: supply chain, factory, and device (Fig. 11).

Key steps moving forward should be:

- Formation of an industry task force comprised of leading companies from across the supply chain as well as representatives from key standards committees engaged in quantifying device carbon footprint.
- Development of a quantified representation of where the industry is today regarding the energy and raw materials used.
- Development and implementation of prioritized improvements and a roadmap going forward.

Traditional Approach

Traditional approaches use company by company initiatives and metrics, but miss the opportunity for system-wide innovation



Proposed Approach

System Wide Innovation: Analyzes the entire system and implements improvement, based on a common set of metrics

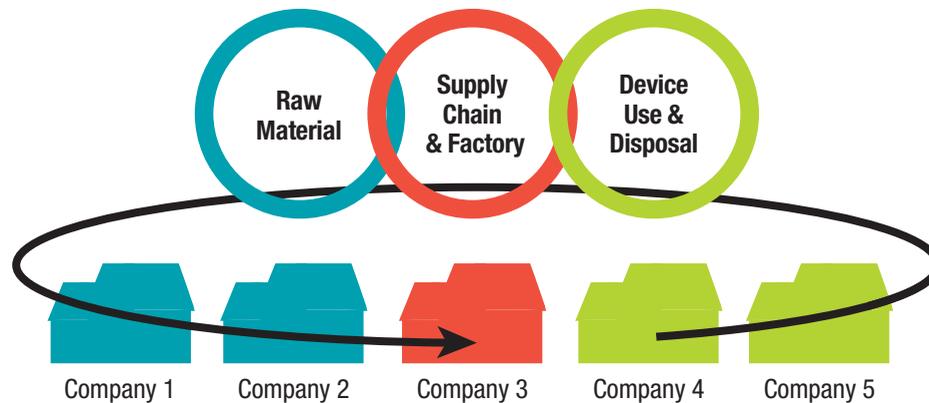


Figure 11

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