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LEDs Beware! The Rebirth of the Incandescent Light Bulb

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Supplement to *NASA Tech Briefs*

LEDs Beware!
The Rebirth of the Incandescent Light Bulb

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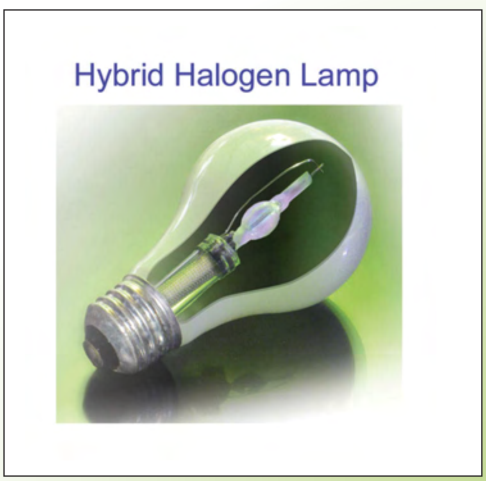
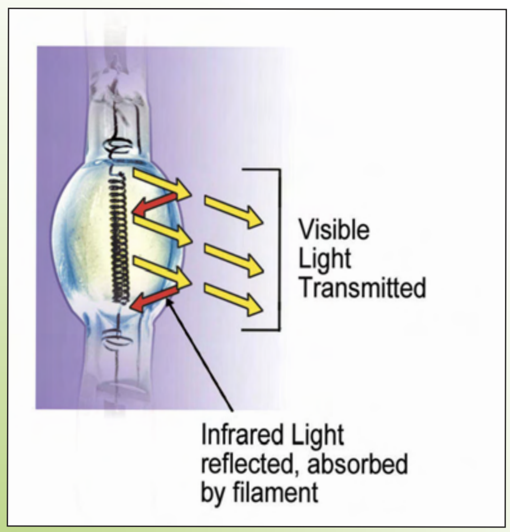
The incandescent light bulb, first commercialized by Thomas Edison in 1879, was a remarkable invention for its day. Edison found that when an electric current was passed through a carbon filament, the filament would glow, or incandesce. The incandescent light bulb was improved over the next three quarters of a century by using different filament materials and adding inert gas inside the outer jacket. It was mass-produced by the hundreds of millions in a seemingly endless array of shapes, sizes, and wattages, but the basic technology of the incandescent light bulb was largely unchanged.

In 1959, the first halogen incandescent light bulb was introduced. As the tungsten filament burns, small amounts of tungsten evaporate from the filament onto the bulb wall. Eventually enough tungsten will deposit onto the bulb wall that it will





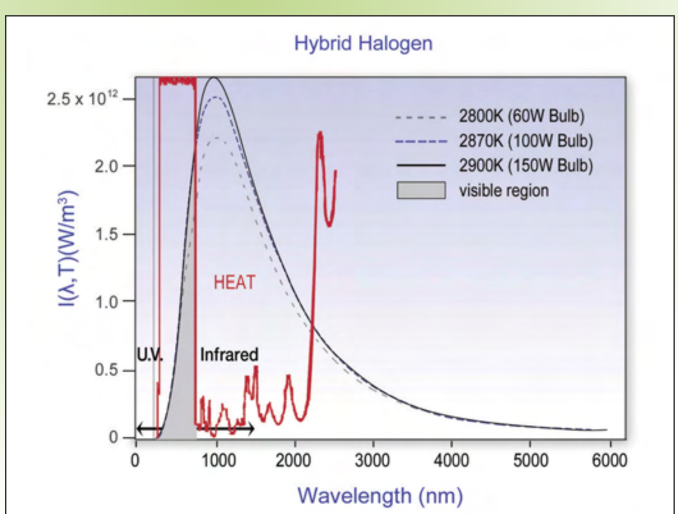


Figure 1. Performance of early hybrid halogen lamps.

visibly blacken and the lamp will fail. In halogen lighting technology, the halogen gas inside the bulb removes the tungsten that is deposited on the walls of the bulb. This scrubbing of tungsten is called the "halogen cycle". The addition of halogen gas allows the filament to operate at a high temperature, creating a brighter light. Because the halogen cycle prevents the bulb from blackening, the life of the incandescent light bulb is increased. While the halogen incandescent light bulb was brighter, it was not a significant change in the technology of the incandescent light bulb. An electric current is still used to heat the filament to a temperature that produces light.

In 1990, a halogen incandescent light bulb was introduced that used a new technology. An infrared (IR) reflecting, visible light transmitting optical coating, called a hot mirror, was deposited on the outside surface of the inner quartz envelope of a halogen incandescent light bulb. This hot mirror coating reflects a portion of the heat back to the filament where it reheats the filament. This recycling of the former waste heat allows the filament to reach the proper temperature using less electricity when compared to an uncoated halogen incandescent bulb (Figure 1). These early 'hybrid' halogen incandescent light bulbs achieved efficiencies of greater than 18 LpW (lumens per watt) for a 70 watt bulb. This gave the 70 watt hybrid halogen incandescent bulb the same light output as the 100 watt incandescent bulb.

The hybrid halogen incandescent light bulb is a more energy-efficient, direct replacement for the incandescent light bulb. It has all of the same features of an incandescent light bulb. The color can be designed to range from warm white to cool white. The hybrid halogen incandescent light bulb emits a continuous full spectrum with a color rendering index (CRI) of >97%. It can be dimmed by conventional dimmers. It can be switched on and off many times without compromising bulb life, allowing it to be used with occupancy sensors that deliver lighting when triggered. The hybrid halogen incandescent light bulb does not contain mercury or other toxic substances so it is RoHS compliant.

Since its introduction in 1990, the hybrid halogen incandescent light bulb has continued to improve in LpW and the cost for the hot mirror coating has gone down. The rate of improvement in LpW and the reduction in the cost of the optical coating has proceeded in a recurring pattern that is called *Bartolomei's Law*. Similar to the now famous *Moore's Law*, Bartolomei's Law states that "Every 4 years the micron per square centimeter deposition rate for IR coatings on halogen lamp burners doubles, while the coated burner performance (lumens per watt) increases by 20%". The improvement in LpW in the hybrid halogen incandescent light bulb is shown in the graph in Figure 2.

The 1.5X in Figure 2 is the 70 watt hybrid halogen bulb that equals the light output of the 100 watt incandescent light bulb (18 LpW). The 2.X in Figure 2 is a 50 watt hybrid halogen incandescent light bulb that has the same light output as a 100 watt incandescent (33 LpW). This 2X hybrid halogen incandescent light bulb was in limited trials in 2012 and set for commercialization by Venture Lighting International (VLI) in 2013. The 3X on Figure 2 represents laboratory results demonstrated by VLI and DSI (45LpW).

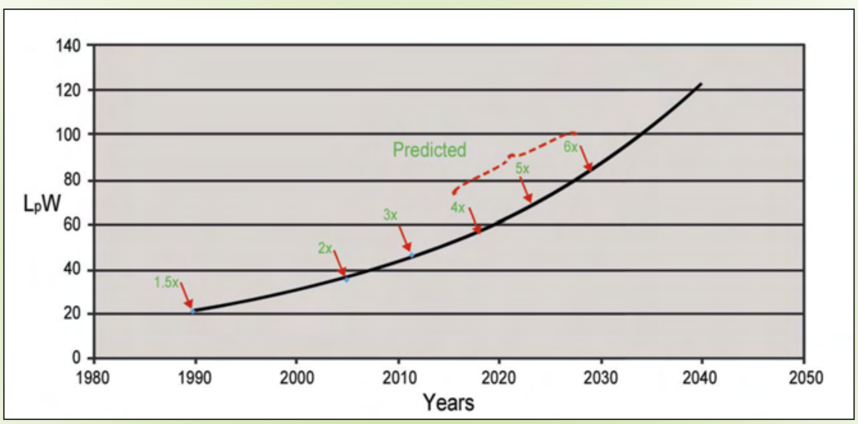


Figure 2. Applying Bartolomei's law, the graph shows the actual LpW output and the projected LpW output results (over time).

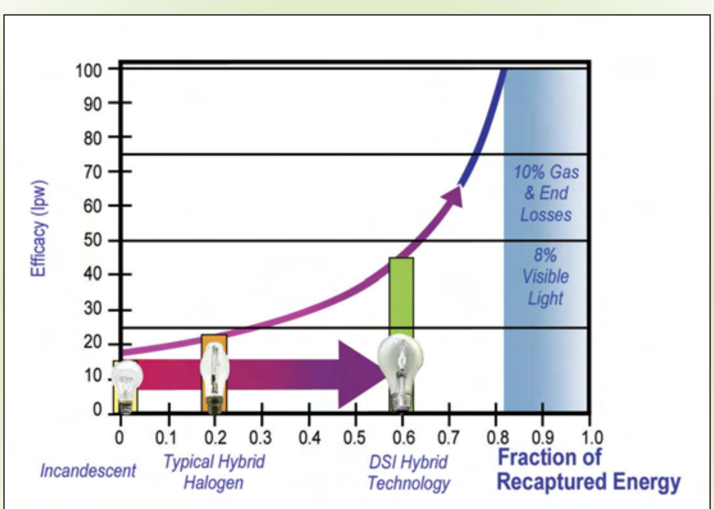


Figure 3. Comparison of light bulb efficiencies.

An incandescent light bulb produces 8% of its energy in the visible spectrum and 92% of its energy outside the visible spectrum as heat. Figure 3 shows how the efficiency, in terms of LpW, increases with the fraction of recycled heat energy. Note that as we move up the efficiency curve, small gains in recaptured energy produce proportionately larger gains in efficiency. Bartolomei's Law predicts that by 2018 the efficiency of a hybrid halogen incandescent light bulb will exceed that of the current compact fluorescent lamps (CFL) and equal light-emitting diodes (LEDs) on the market by 2023.

One key element contributing to the increased efficiency of the hybrid halogen incandescent light bulb is the work that is being done to increase the amount of heat recycled to the filament. This increase in the amount of heat recycled is the result of developments at Deposition Sciences, Inc. that have increased the infrared reflection of the thin film coating applied to the halogen capsule. Figure 4 shows the evolution of hybrid halogen coating design and coating performance at DSI.

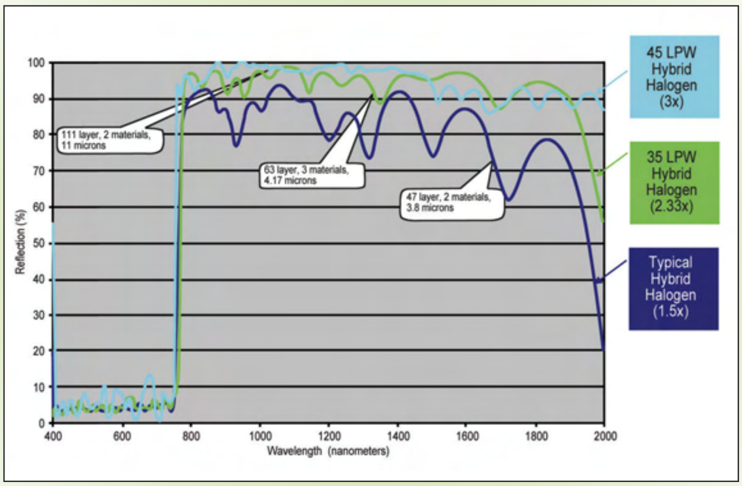


Figure 4. Evolution of hybrid halogen coating design and performance.

Each advance in thin film coating has increased the infrared reflection of the thin film coating, thereby increasing the efficiency of hybrid halogen incandescent lamps from the 1.5X to 2X and more recently to 3X.

The incandescent light bulb was commercialized by Thomas Edison over 133 years ago. It has been the light of choice for most of the industrialized world during that entire period of time. The incandescent light bulb (similar to the hybrid halogen light bulb discussed earlier) produces warm white to cool white light. They both emit a continuous full spectrum with a CRI of >97%, fit into the same socket, and can be dimmed by conventional dimmers. The incandescent light bulb and the hybrid halogen bulb can be switched on and off many times without compromising bulb life, allowing their use with occupancy sensors. Both the incandescent and the hybrid halogen light bulbs contain no mercury or other toxic substances, making them RoHS compliant. The drawback to the incandescent light bulb, however, has been its lack of energy efficiency. The new hybrid halogen incandescent technology has eliminated this drawback - 1.5X is on the market, 2X is entering the market, 3X has been demonstrated in the laboratory, and 4X is in development.

It took 110 years for the efficiency of the incandescent lamp to reach 18 LpW and only 21 years for the efficiency to be increased to 45 LpW using hybrid technology. The incandescent light bulb isn't dead; in fact it's alive and well. For more information, visit **http://info.hotims.com/45599-302**