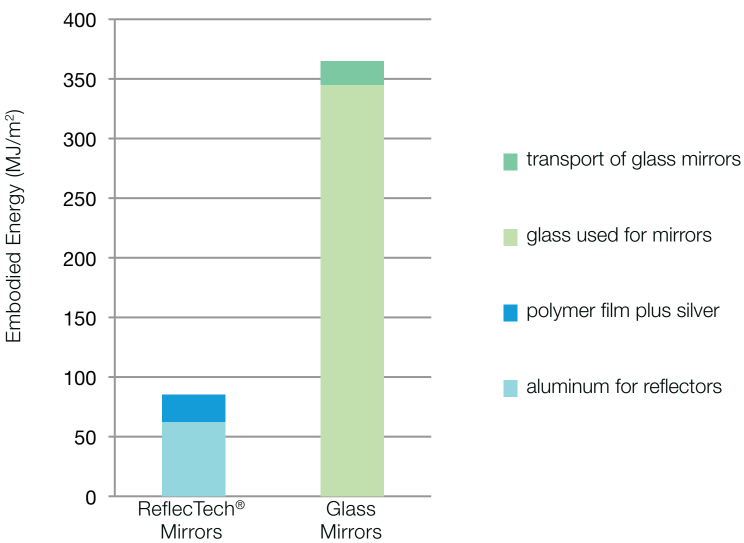
Embodied Energy

ReflecTech Mirror Film

Embodied Energy of Trough Mirrors
Including End-of-Life Impacts (MJ/m^2 of aperture area)



ReflecTech®- mirrors have a cradle-to-grave embodied energy that is **four times lower** than curved glass mirrors.

What is Embodied Energy?

Embodied Energy is the cumulative sum of the energy required to fabricate a given material or component, from extraction of raw materials to manufacturing, and all transport steps along this chain. In addition, "end-of-life" disposal options, including recycling, landfilling, and incineration, are accounted for. This is often referred to as "cradle-to-grave" accounting. Since the energy production potential is proportional to parabolic trough aperture area, the energy content of the troughs is presented on a per unit aperture area basis.

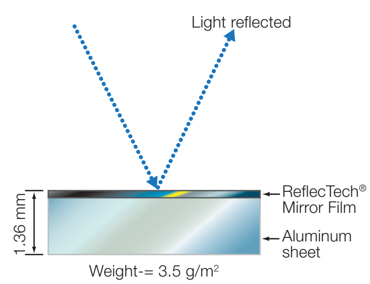
The National Renewable Energy Laboratory (NREL) analyzed the embodied energy of a parabolic trough solar concentrator made with ReflecTech® Mirror Film, and compared it to the EuroTrough, made with traditional curved glass mirrors (Heath, 2009). The analytical approach is described in the blue box on the next page.

Just the Mirrors

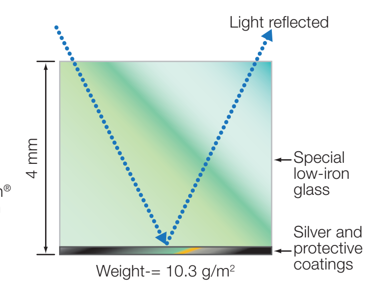
The embodied energy of the *ReflecTech®-based mirrors* is attributed to the aluminum support substrate (62 MJ/m^2), the ReflecTech® polymer substrate (22 MJ/m^2), and the ReflecTech® silver layer (1 MJ/m^2). The total is **85 MJ/m^2**.

The embodied energy of the *curved glass mirrors* is attributed to the curved glass (345 MJ/m^2, including the silver layer and the back-coated layers) and transportation of the mirrors to the project site (20 MJ/m^2). The total is **365 MJ/m^2**.

ReflecTech® Mirror Film on aluminum sheet



Traditional curved glass mirror



ReflecTech®-based mirrors have much lower cradle-to-grave embodied energy for two main reasons:

1. Weight

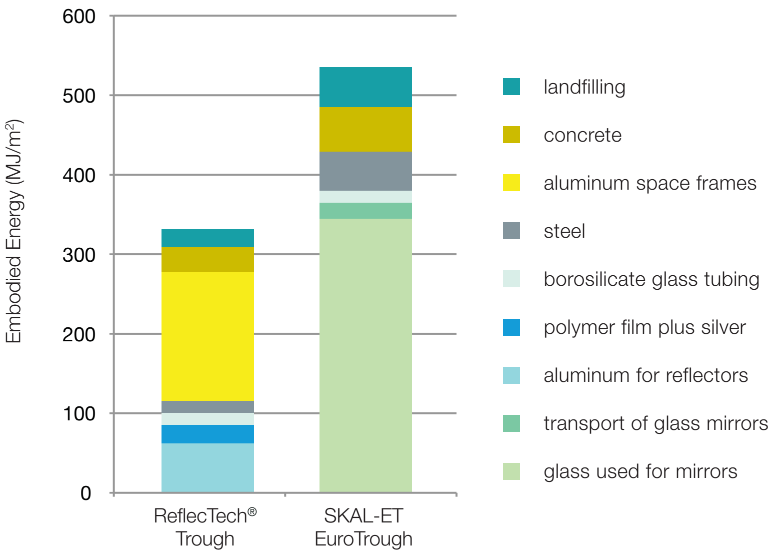
An aluminum-backed ReflecTech® mirror is about 3 times lighter than a glass mirror, as shown in the graphic above.

2. Recycled Content

The net impact of end-of-life disposal options is included in the analysis. Those components that are recycled (aluminum, steel, and glass tubing) receive credit for the embodied energy of the displaced virgin material. This factor is very important to aluminum, as it has high energy content and thus receives a large credit when accounting for recycling.

ReflecTech Mirror Film

Embodied Energy of Trough Collectors, Including End-of-Life Impacts (MJ/m² of aperture area)



The Whole Trough Collector

The effect on embodied energy of using ReflecTech®-based mirrors is also very significant when the entire parabolic trough is analyzed. The stacked bar chart shows the breakdown of embodied energy for each category.

The ReflecTech®-based trough uses less steel and concrete, but more aluminum, primarily for the space frame structure. The embodied energy associated with landfilling is reduced with the ReflecTech®-based trough because a greater proportion is made of recyclable materials.

NREL estimated that the embodied energy of the EuroTrough is 535 MJ/m² – **61% higher** than the trough using ReflecTech® Mirror Film (332 MJ/m²).

References:

R. Gee, Personal communication with Garvin Heath (National Renewable Energy Laboratory), SkyFuel, LLC, February 21, 2009.

G. Heath, Summary of Analysis of Embodied Energy per Square Meter Aperture Area for Trough Collectors, Accounting for End-of-Life Disposal Options, Internal NREL Correspondence, Strategic Energy Analysis Center, March 11, 2009.

G. Jorgensen, Personal Communication to Garvin Heath, NREL, February 17, 2009.

P. Viebahn, **S. Kronshage**, **F. Trieb**, and **Y. Lechon**, Final Report on Technical Data, Costs, and Life Cycle Inventories of Solar Thermal Power Plants, Co-funded by the European Commission within the Sixth Framework Programme under the New Energy Externalities Developments for Sustainability (NEEDS) RS 1a – WP12 Solar Thermal Power Technologies, Deliverable no. 12.2.

The Analytical Approach

The SimaPro v7.1 life-cycle analysis software platform (http://www.pre.nl/simapro/default.htm) was used for the calculations and comparisons. Material use for the trough designs came from the following sources: ReflecTech®-based parabolic trough (Gee 2009), and EuroTrough (Viebahn et al. 2008). Inventories of life-cycle energy use for materials came from the ecoinvent v2.0 database (http://www.ecoinvent.org). In the two cases where the ecoinvent database did not contain the exact material specified, the most relevant substitute was used: (1) for curved, mirrored, low-iron glass (trough glass), flat, clear, low-iron glass was selected as the proxy; (2) for galvanized steel, reinforcing steel was selected as the proxy. Both of these substitutions were for materials with lower embodied energy than the specified material.

To better estimate the embodied energy content in curved, mirrored, low-iron glass, it was assumed that the major difference in processing between flat glass and curved glass is the addition of energy to soften and form the glass. Thus, the difference in price between the two products should be approximately proportional to the difference in energy content. The mirroring (silvering) process was considered next. Since there are both material and energy costs associated with silvering, it was assumed that only half of the price ratio of silvering curved glass represents embodied energy. The ratio of prices for curved glass to flat glass is 1.3, and the ratio of curved clear glass to curved silvered glass is 3.0 (Jorgensen 2009). The net product of the two factors—1.95—was multiplied by the embodied energy content of flat, clear, low-iron glass to approximate the energy content of mirrored trough glass.

A similar approach was not applied to the case of galvanized steel. Therefore, the estimate of embodied energy of the galvanized systems likely remains underestimated, which results in a more conservative embodied energy estimate for the EuroTrough.

The embodied energy of each trough collector system is the sum of the embodied energy of each component. The embodied energy of each component accounts for all upstream processes required to manufacture the component, as well as the net impact of end-of-life disposal options.

- Those components that are recycled (aluminum, steel, and glass tube) receive credit for the embodied energy of the displaced material.
- The energy associated with incinerating is accounted for within the embodied energy figure for the ReflecTech® polymeric film material.
- Due to limitations of the life-cycle analysis software, the energy-related cost of landfilling concrete, trough glass, and silver could not be disaggregated by component, so it is reported as a total.

All materials except for the trough glass are assumed to be transported a negligibly short distance from place of manufacture to place of use. But because trough glass is primarily manufactured in Germany, transoceanic transport between Germany and the southwestern U.S. is modeled.

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