

Creosote-Treated Ties

An End-Of-Life Tie Evaluation

By Steve Smith & Chris Bolin

The full life cycle of creosote-treated railroad ties includes the growth of trees on forested land; harvest of logs; milling to create ties and lumber; treatment of ties with creosote; use of the ties by the railroads as part of the railroad bed; and, at the end of their use lives, disposal or use as an energy source. End-of-life alternatives include recycling ties to produce useful energy, disposing ties in landfills, and legacy ties along the railroad's right-of-way. This paper reports some of the energy and environmental consequences of these end-of-life options. This paper presents a simplified analysis of creosote treated tie life cycle and disposal and is not a Life-Cycle Assessment.

Description of Creosote-Treated Ties

Crossties are primarily made of hardwood species, mostly species of oak, with approximately eight percent of Douglas fir. "Dry" ties average approximately 40 to 50 percent moisture on a dry wood basis.

Ties are treated by pressure impregnation of creosote preservative. Most ties are treated to a gauge retention of seven (7) pounds per cubic foot (pcf) of wood with refractory species, such as white oak and Douglas-fir, being treated to refusal. The actual U.S. average creosote retention in ties is probably in the range of 5 to 6 pcf. 5.5 pcf is assumed in this evaluation.

Ties vary in size depending on use. The standard or "typical" tie measures 7-inches high by 9-inches wide by 8.5-feet long. The volume for this size tie is 3.72 cubic feet. Thus, the average new tie contains approximately 20 pounds of creosote (5.5 lb/ft³ x 3.72 ft³).

Ties spend their use life in an extreme environment—placed horizontally, the top surface fully exposed to sun and weather, the sides and bottom embedded in ballast rock, repeatedly heated, cooled, wetted, and dried, in varying climates, while being subjected to repeated compression and bending stresses as they support the transport of millions of tons of freight each year. A portion of the creosote is lost

due to volatilization and biological and photo-chemical degradation that takes place on the surface of the ties and to a lesser extent in surrounding ballast. The estimated "average" composition of ties at life stages are shown in Table 1.

Impact Indicators

As noted above, each end-of-life option has consequences. The following indicators of potential impacts (consequences) are evaluated for each option.

Fossil Energy Use - Fossil energy is a non-renewable resource. Use of fossil energy is a measure of resource depletion. When renewable resources, such as wood, are beneficially used, they offset fossil fuel use and reduce resource depletion.

Greenhouse Gases -

Global warming is thought to be at least partially caused by human (anthropogenic) releases of gases that trap heat within the earth's atmosphere, called greenhouse gases (GHG). Carbon dioxide is the reference compound used to assess warming impact. Methane is released in much smaller quantities, but is estimated to have 21 times the warming potential of carbon dioxide on a mass basis. Wood is biogenic, rather than fossil fuel. The use of wood fuel is considered carbon neutral. Use of wood fuel therefore does not increase GHG emissions.

Acidification - Combustion of fuel results in emissions that contribute to acidification. Factors have been applied to standard emission rates for natural gas, wood, and coal combustion boilers to evaluate the potential acidification impact of each disposal option.

Tie Impact Indicators Prior to End-of-Life

The wood in each tie contains 71 pounds of carbon that equates to the removal of 260 pounds of carbon dioxide during tree growth. Each tie also contains 13 pounds of fossil carbon in the creosote. Thus, treated ties begin with negative 260 pounds of CO₂ and this value increases through life as the fossil components decay or are combusted. While in use, 5 percent of the wood and 35 percent of the creosote are converted to carbon dioxide, raising the GHG emissions by 34 pounds for a net of negative 226 pounds.

Recycle Ties for Energy Recovery

Each tie offers approximately 1.4 million BTU (MMBTU) of heat energy. Ties may be used as fuel in a facility designed specifically to burn ties, in industrial wood fired boilers, in utility boilers co-

Table 1 - Composition of Ties by Life Stage

Tie Components	Untreated, green (lb/tie)	Treated (lb/tie)	Loss/ change in Use	Used Ties (lb/tie)
Wood (dry mass)	148	148	5%	141
Water (% of dry mass)	70%	40%		20%
Water mass	104	59		28
Creosote Mass	0	20	35%	13
Whole Tie	252	228		182

fired with coal, or other solid fuel combustion systems, such as cement kilns. With new technology, ties are being used in gasification facilities to produce electric energy or liquid biofuel. When ties are burned beneficially as fuel, they offset fossil fuel that would otherwise have been used to produce the same energy. The energy value of one tie is approximately equal to that of 125 pounds of coal.

Since the wood fuel is carbon neutral, for each tie burned for energy recovery, only the creosote portion is considered a fossil fuel that results in the addition of approximately 39 pounds of carbon dioxide to the atmosphere. The carbon dioxide from burning coal of equal energy would be approximately 288 pounds. Thus, each tie used for energy results in a net offset

of carbon dioxide emissions of approximately 249 pounds.

Acidifying emissions from burning wood are less than for burning an equivalent amount of coal; thus, use of ties for fuel results in lower net acidifying emissions.

Landfill Disposal of Ties

Following removal from the railroad bed, ties are placed and buried in landfills with other construction and demolition (C&D) waste and/or municipal solid waste for long term disposal. Within the landfill, some of the wood and creosote will degrade anaerobically, producing both carbon dioxide and methane. The carbon dioxide from wood degradation is considered carbon neutral, but the methane is considered a GHG. This evaluation considers ties being disposed in an assumed "average" landfill. Component fates and emissions from the modeled landfill include carbon dioxide, biogenic from the wood and fossil from creosote, and methane.

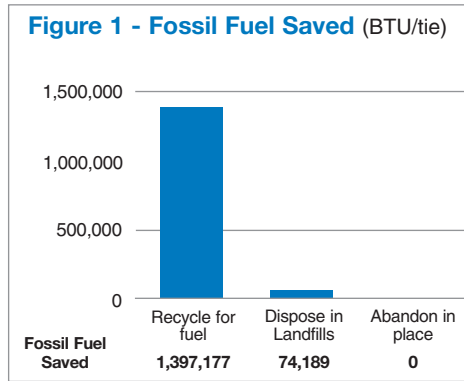
From the model, each tie disposed in a landfill will have 5.5 pounds of methane released to the atmosphere, 4.9 pounds of methane captured, of which 1.9 pounds are burned in a flare, and 3.0 pounds are used beneficially offsetting the use of an equal amount of natural gas. Approximately 44 pounds of biogenic carbon dioxide and 7.0 pounds of fossil carbon dioxide will be emitted. However, the GHG emission of methane and fossil carbon dioxide will be 116 pounds of CO₂-equivalent less 8 pounds of CO₂ for offset natural gas combustion for a net of 108 pounds CO₂-equivalent of GHG.

Legacy Ties in the Right-of-Way

It is unknown to what extent legacy ties exist along the right-of-way. Assuming that following removal from the rail bed a small number of used ties remain along the railroad within the rights-of-way land, then those ties will decay through aerobic bacterial action on the soil surface. Complete decomposition is

assumed to occur over approximately 40 to over 100 years. In areas where access is practical, some ties may be reclaimed by residents for landscape or fence uses, but the ties would still decay in about the same time. Since decay is aerobic, no methane emissions result.

The used tie wood decays to produce approximately 247 pounds of biogenic carbon dioxide and the creosote would decay to produce approximately 39 pounds of fossil carbon dioxide. No fossil fuel offsets would occur.



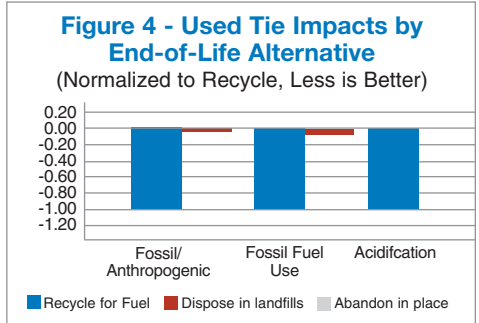
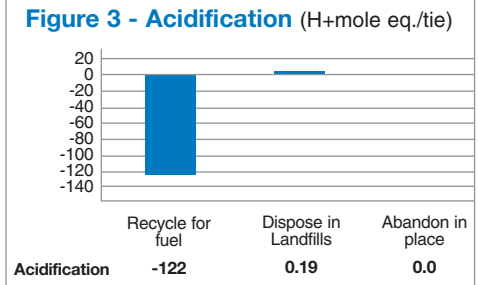
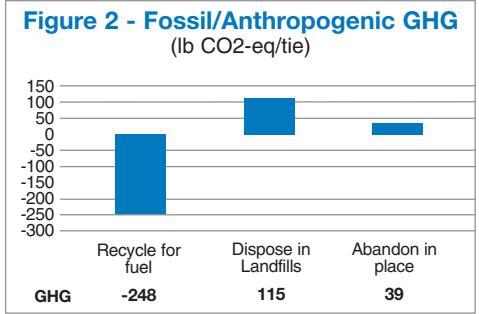
Comparison to National Energy Use

In the U.S., the average energy use per capita is approximately 337 MMBTU, of which 286 MMBTU are fossil fuel. Each tie recycled is estimated in this calculation to yield 1.4 MMBTU of energy. Thus,

each tie recycled represents approximately 0.5 percent of the annual U.S. per capita fossil fuel usage. Furthermore, the average GHG emissions per capita are estimated at 51,600 pounds of CO₂-eq. Each tie recycled results in the elimination of approximately 225 pounds of CO₂-eq. and represents approximately 0.5 percent of the annual per capita GHG emissions.

Comparison of End-of Life Alternatives

Use of fossil fuel is reduced, or offset, by the amount of fuel value in each tie that is used beneficially. The amount of fossil fuel saved for each tie recycled,



disposed, or abandoned is shown in Figure 1. The largest fuel savings results from recycling ties to energy production. Only a small fraction is beneficially used in landfill disposal and none is recovered when ties are abandoned.

The GHG balance resulting from each end-of-life alternative is shown in Figure 2. Recycling for energy results in a decrease in GHG emissions, because only the fossil (creosote) fraction of ties burned ➤



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contributes to GHG while all of the energy (biogenic and fossil) is used to offset combustion of fossil fuel. Landfill disposal increases GHG the most. For abandoned ties, the fossil (creosote) carbon fraction of tie mass is converted to fossil CO₂.

Releases potentially causing acid precipitation for each end-of-use alternative are shown in Figure 3. Recycling ties for energy produces a negative acidification indicator because combustion of wood results in lower emissions of acidifying gases than combustion of coal. The acidification caused by burning ties is small, so that when credit for the higher coal emissions are subtracted, the result is negative. Landfill disposal results in a negligible increase related to methane combustion and abandoning ties has no impact to acidification.

Comparison of all impact indicators for the full life cycle is shown in Figure 4. Rather than indicating actual indicator values, these have been normalized to show the recycle option as a negative 1, since all indicators for this option are negative. Values for disposal in a landfill and abandonment are relative to the recycle option.

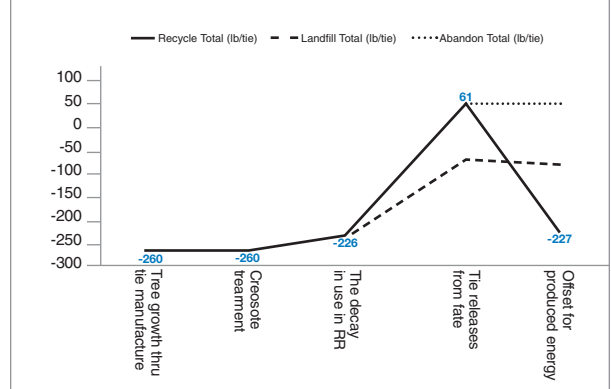
While previously shown figures address only emissions that occur due to the disposal method applied, this figure includes the full life cycle, beginning with growing the trees. Negative values mean that releases causing the indicator are reduced by implementing the disposal option. Positive values indicate the disposal method increases the impact indicator values.

Another way to consider the full life cycle is to consider the flux of GHG interchange with the atmosphere as depicted in Figure 5. All end-of-life alternatives start with the same GHG values from tree growth through the end of tie use. The flux begins at negative 260 pounds of CO₂-eq. due to the CO₂ removed from the atmosphere and stored in the tie wood and remains unchanged as tie is treated. Injection of creosote does not result in a change since it is not released as CO₂ or methane. During the tie's use the GHG value increases by 33 pounds CO₂-eq. per tie due to decay (creosote and wood

loss) while in use.

Values for the three alternatives diverge at the end-of-life stage. The recycle for energy and abandon alternatives increase to a positive 61 pounds CO₂-eq. per tie as all carbon remaining in the ties is converted by combustion or decay, respectively, to carbon dioxide. The landfill option results in less CO₂ emissions, but includes methane emissions (with CO₂ equivalent at 21 times those of CO₂), raising the landfill alternative GHG total to negative 59 pounds CO₂-eq. per tie. At the end-of-life, offsets to fossil fuel use are applied as shown in Figure 5. Abandoned ties have no offset. Recycled ties have a large offset that brings

Figure 5 - GHG (CO₂ - Eq) Flux by Life Stage



the final CO₂-eq. per tie value to a negative 227 pounds. Landfilled ties have a small offset, due to methane capture and energy recovery, bringing the final to negative 67 pounds of CO₂-eq. per tie.

Conclusions

Recycling for energy recovery provides clear and significant benefits of conserving fossil fuel resources, reducing greenhouse gas levels in the atmosphere, and reducing emissions that lead to acid precipitation.

The fuel offset gained by recycling creosote-treated ties for energy recovery is 20 times greater than energy recovery from landfill disposal. Offsets result in a significant decrease in GHG emissions when ties are recycled for energy compared to a slight increase in GHG emissions when landfilled. If ties are abandoned, no change results to fossil fuel use or acidification and GHG emissions are increased approximately one-third as much as by landfill disposal.

If all ties replaced annually in the U.S., approximately 20 million ties, were recycled for energy, the result would be to offset the GHG and fossil fuel use equivalent to a city of nearly 100,000 people. §

EDITOR'S NOTE

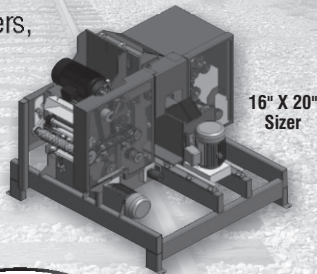
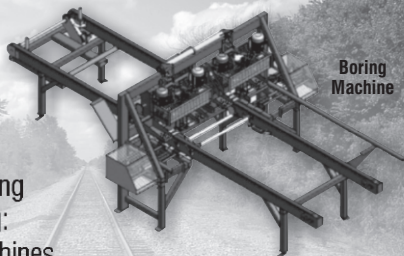
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The Authors:

Stephen Smith, P.E. AquAeTer, Helena, MT.
E-mail: stephentsmith@earthlink.net
Chris Bolin, AquAeTer, Centennial, CO.
E-mail: cbolin@aquater.com

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