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Standard Practice Guide for Use of Scrap Tires as Tire-Derived Fuel¹

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1. Scope

1.1 This practice covers and provides guidance for the material recovery of scrap tires for their fuel value. The conversion of a whole scrap tire into a chipped form for use as a fuel produces a product called tire-derived fuel (TDF). This recovery practice has moved from a pioneering concept in the early 1980s to a proven and continuous use in the United States with industrial and utility applications.

1.2 Combustion units engineered to use solid fuels, such as coal or wood or both, are fairly numerous throughout the U.S. Many of these units are now using TDF even though they were not specifically designed to burn TDF. It is clear that TDF has combustion characteristics similar to other carbon-based solid fuels. Similarities led to pragmatic testing in existing combustion units. Successful testing led to subsequent acceptance of TDF as a supplemental fuel when blended with conventional fuels in existing combustion devices. Changes required to modify appropriate existing combustion units to accommodate TDF range from none to relatively minor. The issues of proper applications and specifications are critical to successful utilization of this alternative energy resource.

1.3 This practice explains TDF's use when blended and combusted under normal operating conditions with originally specified fuels. Whole tire combustion for energy recovery is not discussed herein since whole tire usage does not require tire processing to a defined fuel specification.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

- 2.1 ~~ASTM Standards:~~² <https://www.astm.org/standards/sist/4b2fc0ce-c4aa-4184-8d07-5a110d2ec09c/astm-d6700-19>
- ~~D2013 Practice for Preparing Coal Samples for Analysis~~
 - ~~D2361 Test Method for Chlorine in Coal (Withdrawn 2008)~~³
 - ~~D2795 Test Methods for Analysis of Coal and Coke Ash (Withdrawn 2001)~~³
 - ~~D3172 Practice for Proximate Analysis of Coal and Coke~~
 - ~~D3173 Test Method for Moisture in the Analysis Sample of Coal and Coke~~
 - ~~D3174 Test Method for Ash in the Analysis Sample of Coal and Coke from Coal~~
 - ~~D3175 Test Method for Volatile Matter in the Analysis Sample of Coal and Coke~~
 - ~~D3176 Practice for Ultimate Analysis of Coal and Coke~~
 - ~~D3177 Test Methods for Total Sulfur in the Analysis Sample of Coal and Coke (Withdrawn 2012)~~³
 - ~~D3178 Test Methods for Carbon and Hydrogen in the Analysis Sample of Coal and Coke (Withdrawn 2007)~~³
 - ~~D3179 Test Methods for Nitrogen in the Analysis Sample of Coal and Coke (Withdrawn 2008)~~³
 - ~~D3682 Test Method for Major and Minor Elements in Combustion Residues from Coal Utilization Processes~~
 - ~~D4239 Test Method for Sulfur in the Analysis Sample of Coal and Coke Using High-Temperature Tube Furnace Combustion~~

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

~~D4326 Test Method for Major and Minor Elements in Coal and Coke Ash By X-Ray Fluorescence~~

~~D4749 Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size~~

~~D5468 Test Method for Gross Calorific and Ash Value of Waste Materials (Withdrawn 2016)³~~

~~D5865 Test Method for Gross Calorific Value of Coal and Coke~~

~~E873 Test Method for Bulk Density of Densified Particulate Biomass Fuels~~

~~2.2 Other Standards:~~

~~SW-846-5050 Bomb Calorimeter Preparation~~

~~SW-846-9056 Ion Chromatography~~

3. Terminology

~~3.1 Definitions:~~

~~3.1.1 all season radial, n—a highway tire designed to meet the weather conditions in all seasons of the year, that meets the Rubber Manufacturers Association⁴ definition of a mud and snow tire.~~

~~3.1.2 altered tire, n—a scrap tire which has been modified so that it is no longer capable of retaining air, holding water, or being used on a vehicle.~~

~~3.1.3 analysis, n—the activity to determine the proximate and ultimate analysis, fuel value and size specification of TDF.~~

~~3.1.4 bead, n—the anchoring part of the tire, which is shaped to fit the rim. The bead is constructed of high tensile steel wires wrapped by the plies.~~

~~3.1.5 bead wire, n—a high tensile steel wire, surrounded by rubber, which forms the bead of a tire that provides a firm contact to the rim.~~

~~3.1.6 bear claw, n—the rough-edged bead wire sticking out from a shredded tire.~~

~~3.1.7 belt, n—an assembly of rubber coated fabric or wire used to reinforce a tire's tread area. In radial tires, also constrains the outside diameter against inflation pressure and centrifugal force.~~

~~3.1.8 belt wire, n—a brass-plated high tensile steel wire cord used in the steel belts.~~

~~3.1.9 bias ply tires, n—a tire built with two or more casing plies, which cross each other in the crown at an angle of 30 to 45° to the tread centerline.~~

~~3.1.10 body, n—tire structure not including the tread portion of the tire. (See also casing and carcass.)~~

~~3.1.11 carcass, n—See casing.~~

~~3.1.12 casing, n—the basic tire structure excluding the tread. (See also carcass.)~~

~~3.1.13 chip size, n—the range of rubber particle sizes resulting from the processing of whole tires.~~

~~3.1.14 chipped tire, n—a classified scrap tire particle that has a basic geometrical shape, which generally is 2 in. (5.08 cm) or smaller and has most of the bead wire removed. Also referred to as a tire chip.~~

~~3.1.15 chopped tire, n—a scrap tire that is cut into relatively large pieces of unspecified dimensions.~~

~~3.1.16 classifier, n—equipment designed to separate oversized tire shreds from the desired size.~~

~~3.1.17 combustion, n—the chemical reaction of a material through rapid oxidation with the evolution of heat and light.~~

~~3.1.18 combustion unit, n—any number of devices to produce or release energy for the beneficial purpose of production by burning a fuel to include, but not limited to, units such as industrial power boilers, electrical utility generating boilers, and cement kilns.~~

~~3.1.19 commercial tire, n—truck and industrial tires.~~

~~3.1.20 compound, n—a mixture of blended chemicals tailored to meet the needs of the specific components of the tire.~~

~~3.1.21 converted tire, n—a scrap tire that has been processed into a usable commodity other than a tire.~~

~~3.1.22 cords, n—the strands of wire or fabric that form the plies and belts in a tire.~~

~~3.1.23 dewired, n—the absence of exposed wire on the perimeter of the tire chips. Belt wire typically remains in the chip, but it is embedded in the chip.~~

~~3.1.24 discarded tires, n—a worn or damaged tire that has been removed from a vehicle.~~

~~3.1.25 end user, n—the facility which utilizes the heat content or other forms of energy from the combustion of scrap tires (for energy recovery). The last entity who uses the tire, in whatever form, to make a product or provide a service with economic value (for other uses).~~

~~3.1.26 energy recovery, n—a process by which all or part of the tire is utilized as fuel (TDF) to recover its entire value.~~

~~3.1.27 energy value, n—the assignment of a value to the tire-derived fuel as measured in British thermal units per pound or calories per gram.~~

- 3.1.28 *fabric*, *n*—textiles cords used in tire manufacturing.
- 3.1.29 *fishhooks*, *n*—strands of belt or bead wire exposed from a processed scrap tire or an individual piece of belt or bead wire. (See also *bear claw*).
- 3.1.30 *stuff*, *n*—the fibrous, nonrubber, nonmetal portion of a tire that remains after the scrap tire is processed (that is, cotton, rayon, polyester, fiberglass, or nylon).
- 3.1.31 *fuel value*, *n*—the heat content, as measured in British thermal units (Btu)/lb or cal/g.
- 3.1.32 *hair*, *n*—wire protruding from the perimeter of a tire chip or shred. (See also *fishhooks*).
- 3.1.33 *heavy-duty tires*, *n*—tires weighing more than 40 lb (18.1 kg), used on trucks, buses, and off the road vehicles in heavy-duty applications.
- 3.1.34 *horsetail*, *n*—a rough piece of shredded tire with a width of 2 to 4 in. (5.1 to 10.2 cm) and a length greater than 6 in. (15.2 cm).
- 3.1.35 *innerliner*, *n*—the layer or layers of rubber laminated to the inside of a tire and which meets the Rubber Manufacturers Association⁴ definition of a mud and snow tire.
- 3.1.36 *light duty tires*, *n*—tires weighing less than 40 lb (18.2 kg), used on passenger cars and light trucks.
- 3.1.37 *light truck tires*, *n*—tires with a rim diameter of 16 to 19.5 in. (40.6 to 49.5 cm), manufactured specifically for light truck use.
- 3.1.38 *logger tires*, *n*—a special tire designed for the logging industry.
- 3.1.39 *minus*, *n*—the sieve designating the upper limit or maximum size shall be the sieve of the series with the largest opening upon which is cumulatively retained a total of less than or equal to 1 % of the sample.
- 3.1.40 *mucker tire*, *n*—a flotation type of tire specifically designed for use in soft grounds.
- 3.1.41 *natural rubber*, *n*—the material processed from the spa (latex) of *Hevaca Brasiliensis* (rubber tree).
- 3.1.42 *new tire*, *n*—a tire that has never been mounted on a rim.
- 3.1.43 *nominal*, *n*—commonly used to refer to the average size product (chip) that comprises 50 % or more of the throughput in a scrap tire processing operation. It should be noted that any scrap tire processing operation also would generate products (chips) above and below the “nominal” range of the machine.
- 3.1.44 *off the road tire (OTR)*, *n*—tire designed primarily for use on unpaved roads or where no roads exist, built for ruggedness and traction rather than for speed.
- 3.1.45 *passenger car tires*, *n*—a tire with less than an 18 in. (45.7 cm) rim diameter for use on cars only.
- 3.1.46 *pneumatic tires*, *n*—a tire that depends on the compressed air it holds to carry the load. It differs from a solid tire in which the tire itself carries the load.
- 3.1.47 *processed tire*, *n*—a scrap tire that has been altered, converted, or size reduced.
- 3.1.48 *passenger tire equivalent (PTE)*, *n*—a measurement of mixed passenger and truck tires, where five passenger tires are equal to one truck tire.
- 3.1.49 *radial tire*, *n*—a tire constructed so that the ply cords extend from bead to bead at a 90° angle to the centerline of the road.
- 3.1.50 *rim*, *n*—the metal support for the tire and tube assembly on the wheel.
- 3.1.51 *rip-shear shredders*, *n*—a tire shredder designed to reduce a scrap tire to pieces. The size and shape of the rubber particle is dependent on the processing action of the shredder (that is, by cutting blades, rotary shear, or rip shear).
- 3.1.52 *rough shred*, *n*—a piece of a shredded tire that is larger than 2 in. (5.1 cm) by 2 in. (5.1 cm) by 2 in. (5.1 cm), but smaller than 30 in. (76.2 cm) by 2 in. (5.1 cm) by 4 in. (10.2 cm).
- 3.1.53 *rubber*, *n*—an elastomer, generally implying natural rubber, but used loosely to mean any elastomer, vulcanized and unvulcanized. By definition, rubber is a material that is capable of recovering from large deformations quickly and forcibly and can be, or already is, modified to a state in which it is essentially insoluble in a boiling solvent.
- 3.1.54 *scrap tire processing*, *n*—any method of size reducing whole scrap tires to facilitate recycling, energy recovery or disposal.
- 3.1.55 *screen*, *n*—an apparatus for separating sizes of granules.
- 3.1.56 *secondary material*, *n*—fragments or finished products or leftovers from a manufacturing process which converts a primary material into a commodity of economic value.
- 3.1.57 *sectioned tire*, *n*—a tire that has been cut into at least two parts.
- 3.1.58 *shred sizing*, *n*—generally refers to the process of particles passing through a rated screen opening rather than those which are retained on the screen. Examples include:

3.1.58.1 *1 by 1 in. (2.5 by 2.5 cm), n*—a sized reduced scrap tire, with all dimensions 1 in. (2.5 cm) maximum.

3.1.58.2 *2 by 2 in. (5.1 by 5.1 cm), n*—a size reduced scrap tire, with all dimensions 2 in. (5.1 cm) maximum.

3.1.58.3 *X in. minus, n*—sized reduced scrap tires, the maximum size of any piece has a dimension no larger than X plus 1 in. (X plus 2.5 cm), but 95 % of which is less than X in. ($2.54 X$ cm) in any dimension (that is, 1 in. (2.5 cm) minus; 2 in. (5.1 cm) minus; 3 in. (7.6 cm) minus, and so forth).

3.1.59 *shredded rubber, n*—pieces of scrap tires resulting from mechanical processing.

3.1.60 *shredded tire, n*—a size reduced scrap tire. The reduction in size was accomplished by a mechanical processing device, commonly referred to as a *shredder*.

3.1.61 *shredder, n*—a machine used to reduce whole tires to pieces.

3.1.62 *sidewall, n*—the side of a tire between the tread shoulder and the rim bead.

3.1.63 *single pass shred, n*—a shredded tire that has been processed by one pass through a shear type shredder and the resulting pieces have not been classified by size.

3.1.64 *specifications, n*—written requirement for processes, materials or equipment.

3.1.65 *squirrel foot, n*—exposed, rough pieces of belt or bead wire. (See also *fishhooks*).

3.1.66 *steel belt, n*—rubber coated steel cords that run diagonally under the tread of steel radial tires and extend across the tire approximately the width of the tread. The stiffness of the belts provides good handling, tread wear and penetration resistance.

3.1.67 *supplemental fuel, n*—a combustible material that displaces a portion of traditional fuel source. It refers to the product being used in conjunction with another conventional fuel but typically not as a sole fuel supply.

3.1.68 *TDF, n*—See *tire-derived fuel*.

3.1.69 *tire, n*—a continuous solid or pneumatic rubber covering encircling the wheel of a vehicle.

3.1.70 *tire chip, n*—See *chipped tire*.

3.1.71 *tire-derived fuel, n*—the end product of a process that converts whole scrap tires into a specific chipped form. This specified product then would be capable of being used as fuel.

3.1.72 *tire shreds, n*—See *shredded tire*.

3.1.73 *tread, n*—that portion of the tire which contacts the road.

3.1.74 *tread rubber, n*—compounded, natural, or synthetic rubber, which is placed on a buffed casing and vulcanized to it to provide a new wearing surface.

3.1.75 *trommel, n*—a mechanical device that sorts size-reduced scrap tires.

3.1.76 *truck tire, n*—tires with a rim diameter of 20 in. (50.8 cm) or larger.

3.1.77 *used tire, n*—a tire removed from a vehicle's rim, which cannot be described legally as new, but which is structurally intact and has a tread depth greater than the legal limit. This tire can be remounted onto another vehicle's rim without repair.

3.1.78 *waste tire, n*—a tire that is no longer capable of being used for its original purpose, but has been disposed of in such a manner that it can not be used for any other purpose.

3.1.79 *whole tire, n*—a scrap tire that has been removed from a rim, but has not been processed.

3.1.80 *wires, n*—high tensile, brass plated steel wires, coated with a special adhesion-promoting compound, that are used as tire reinforcement. Belts or radial tires plies and beads are common uses.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *quality control, n*—the activity to collect samples of TDF, prepare the samples for testing, and to test the samples to determine compliance with size and fuel value specifications.

3.2.2 *relatively wire free, n*—TDF that has a bead wire content not greater than 1 % by weight, and a total wire content of 2 % or less by weight.

3.2.3 *scrap tire, n*—a pneumatic rubber tire discarded because it no longer has value as a new tire, but can be either reused and processed for similar applications as new or processed for other applications not associated with its originally intended use. A tire that no longer can be used for its original purpose, due to wear or damage.

3.2.4 *standard size specification, n*—the size specifications with the broadest application when blending with other solid fuels and requiring minimal adjustments or retrofits to existing solid fuel combustion units.

3.2.5 *variable size specification, n*—the size specification that would differ from the standard size specification and usually is specific to uniquely qualified applications where either a standard specification is too restrictive, or where a standard specification is inadequate, or both. Variation may occur in size requirement, wire removal requirement, or both.

3.2.6 *wire free, n*—TDF that is free of all inherent wire.

4. Significance and Use

4.1 When considering the specification of fuels for a boiler, issues to evaluate are the fuel’s combustion characteristics, handling and feeding logistics, environmental concerns, and ash residue considerations. A thorough understanding of these issues is required to engineer the combustion unit for power and steam generation; however, TDF has demonstrated compatible characteristics allowing it to serve as a supplemental fuel in existing combustion units based on cumulative experience in many facilities originally designed for traditional fossil fuels, or wood wastes, or both. When used as a supplemental energy resource in existing units, TDF usage is generally limited to blend ratios in the 10-30 % range based on energy input. This limit is due to its high heat release rate and low moisture content, which differ significantly from other solid fuels, such as wood, refuse derived fuel, coal and petroleum coke.

4.2 New combustion units dedicated to the use of TDF (or whole tires) as the sole fuel source are rare. The generation and availability of scrap tires is ultimately determined by market conditions for new tires and the depletion rate of scrap tire inventories (stockpiles). Scrap tires account for approximately 1 % of the municipal solid waste stream. Based on a national scrap tire generation rate, there are roughly 2.5 to 3 million tons (annually available for all uses to include fuel, crumb rubber, engineering projects, and so forth). Some dedicated combustion units have been built, however, competition for the scrap tires as other existing sources begin to use TDF will determine the ultimate viability of these facilities. Although most regions can supply TDF demand as a supplemental fuel, a dedicated boiler in the range of 500,000 lb/h (227,000 kg/h) steaming capacity would require over 66 000 scrap tires/day to meet its fuel demand. Such demand may strain a region’s ability to supply and put the fuel supply at risk. Some design projects have incorporated TDF as a supplemental fuel with wood, coal, coke, sludge, or some combination of multiple fuels where demand is consistent with supply availability.

4.3 It is important to understand what objectives may lead to TDF’s choice as a supplemental fuel in existing power units. Several model objectives may be as follows:

- 4.3.1 To increase boiler efficiency in a co-fired boiler using wood, sludge, and coal;
- 4.3.2 To procure a competitively priced fuel;
- 4.3.3 To supplement limited supplies of an existing fuel;
- 4.3.4 To use a high quality fuel;
- 4.3.5 To achieve environmental benefits by using a fuel with a relatively low sulfur content in comparison to certain coals or petroleum coke, and;
- 4.3.6 To provide a public and social benefit that solves a regional solid waste problem.

4.4 Boilers generally are engineered around fuels that will be available through the amortized life of the power unit. Boiler design discussions here are limited as TDF standard size specifications have been developed to assure TDF’s performance in existing systems. TDF is mined from the solid waste stream as a whole tire, then engineered via processing techniques to fit a new or existing combustion unit. A major modification or re-engineering of the combustion unit to accommodate TDF normally would make its use uneconomical as a supplemental fuel. TDF’s use is economically dependent on the following two issues:

- 4.4.1 A combustion unit’s existing ability to use the fuel without modification (other than minor operational changes in oxygen grate speed adjustments, and feed/material handling) and;
- 4.4.2 The ability of a supplier to economically collect, process and transport TDF to the combustion unit.

4.5 Once an economic decision has been made to develop TDF as a fuel source for a particular unit, issues of fuel specifications including size, proximate and ultimate analysis, combustion characteristics and environmental concerns must be evaluated properly to determine whether TDF is an appropriate supplemental fuel resource without major system modification.

5. Tire-Derived Fuel Analysis—General Description

5.1 TDF is defined as a scrap tire that is shredded and processed into a rubber chip with a range in size and metal content. Size normally varies in a range from 1 in. (2.5 cm) to 4 in. (10.2 cm). Metal content ranges from wire free, to relatively wire free, to

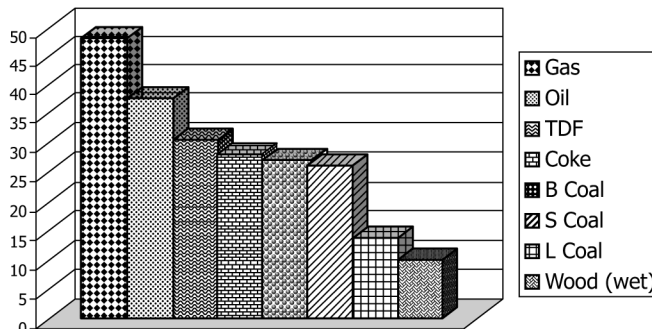


FIG. 1 Relative Energy Comparison of Fuels (Scale in Btu/ton)

only bead wire removed, to no wire removed. TDF's tolerable wire content is determined by a combustion unit's design considerations. TDF's wire removal is determined by production process capabilities. Some combustion units such as cement kilns can tolerate all inherent wire, so no removal is necessary. Circumstance where no effort is made to remove wire, TDF must be cleanly cut with minimal exposed wire protrusion from the chips to facilitate mechanical handling.

5.2 Unless temperatures in a combustion unit are sufficient to oxidize the wire, the energy contribution from the wire is nonexistent and will account for a lower product energy value than that of either a wire free or relatively wire free TDF product. Cement kilns typically burn at sufficient temperatures to oxidize the wire and benefit from both the energy release from oxidation and the resultant iron oxide that becomes a critical component in cement chemistry. Depending on the amount of wire removed, the TDF has an energy content ranging from 14,000 to 15,500 Btu/lb (7770 to 8600 cal/g).

5.3 Combustion efficiency for TDF generally is understood to be in the 80% range. TDF represents an ideal fuel source in that its moisture content is low (1-3%), and its energy value is high. Low moisture content uses less energy for moisture vaporization and lowers combustion gas mass flow rate. TDF has a volatile content of roughly 66%, which indicates rapid heat release. Relatively low ash content (3-5%) maximizes heat absorption and decreases ash disposal costs. As rubber is non-absorbent, moisture swings during seasonal periods of rainfall in ambient weather conditions are limited to a range of 1-8%. The smaller the TDF chip size, the greater the storage pile surface area and its concomitant ability to hold moisture on its surface. **Table 1** identifies the energy content of common fuel types currently used singularly or in some combination.

5.4 The specifications for TDF are somewhat customer specific as this material will be fed into an existing combustion unit. A highly refined product with the wire removed is more expensive to produce, but provides more energy per ton and fewer operating problems in many units. Problematic areas to evaluate to determine true specification requirements are fuel feed system, grate maintenance, ash circulation/handling, and ash disposal systems. Since roughly 10-15% of a tire is comprised of radial and bead wire, any TDF that is not relatively wire free will have a fuel value 10-15% less than the values reported for TDF in **Table 1**. TDF specified to have a lower wire content is more expensive to produce. The increased cost is attributable to further refinement expense and ultimate disposal, or recovery cost for the wire residue generated from TDF production, or both.

5.5 In addition to radial steel wire, nylon and polyester may be used in tire construction. Nylon and polyester plies are found in both steel radial and non-steel radial tires, passenger, truck, and off the road tires. Approximately 3% of a tire is made up of these types of non-steel plies. When a tire is processed into TDF, these synthetic plies will typically stay in the TDF. Both nylon and polyester are petrochemical products with an energy content similar to that of rubber. Due to the plies' extremely low ash and high energy content, its fuel value is relatively consistent with that of the rubber.

5.6 A representative analysis of TDF is presented in **Table 2**. This table identifies key combustion issues. The high amount of fixed carbon (29.96%) suggests particulate concerns and ash (4.22%) suggests solid waste concerns. Other elements of concern include sulfur (1.92%) and zinc (1.52%).

6. Handling Considerations Conveying, Grate, and Ash

6.1 TDF can be produced with the wire left in or taken out. Either way, one must balance the trade off(s). To remove a greater percentage of inherent wire the chip size must ultimately be smaller, in the 5/8 in. (1.6 cm) to 2 in. (5.08 cm) size range. Both smaller

TABLE 1 Energy Content

Fuel Type	Energy Content (million Btu/short ton)
Tire-derived fuel (TDF)	28-31 MBtu/ton
Petroleum coke (PC)	26-28 MBtu/ton
Bituminous coal (BC)	18-27 MBtu/ton
Subbituminous coal (SC)	17-25 MBtu/ton
Lignite coal (LC)	12-14 MBtu/ton
Wood fuel (WF)	8-17 MBtu/ton
Relative Comparison of Non-Solid Fuels	
Oil	34-38 MBtu/ton
Gas	42-48 MBtu/ton

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