ABSTRACT
A method for manufacturing solid fuel, including estimating a heat value for at least a portion of a combustible waste stream. At least one type of combustible polymer is added to the combustible waste stream as needed to raise the estimated heat value of the portion of combustible waste stream to a desired heat value. The combustible waste stream is heated and mixed with the at least one type of combustible polymer to increase the structural integrity of a solid fuel formed from the mixed combustible waste stream and to increase the hydrophobic properties of the solid fuel. The heated and mixed combustible waste stream is pressed into objects of solid fuel, such as briquettes, which are substantially hydrophobic.
PROCESS AND SYSTEM FOR MANUFACTURING IMPROVED HEAT VALUE SOLID FUEL FROM SOLID WASTE

CROSS-REFERENCE TO RELATED APPLICATIONS


FIELD OF THE INVENTION

This invention relates to the conversion of solid wastes, such as Residential Solid Waste (RSW) and/or Municipal Solid Waste (MSW), to a fuel that has an improved heat value and stability, preferably for use as a fuel supplement.

BACKGROUND OF THE INVENTION

While recycling of MSW has increased dramatically over the last 15 years through incentives and community education, MSW itself has grown in volume during that same period to over 220 million tons in North America alone. Recycling has increased 42% during this period, but has plateaued at approximately 30% of the total waste. This problem has affected municipalities, states and the federal government, from a financial, as well as capacity of volume perspective. Landfilling is the prominent way of disposing of MSW. This presents significant problems for municipalities including present landfill sites at or near capacity, and they are faced with significant post-closure costs and maintenance. There is a lack of new land for landfilling and, even where land is available, permitting processes are expensive and time-consuming, and the social issue of not in my backyard (NIMBY) exists.

Currently, waste to energy (WTE) is the most prevalent method for addressing both issues. In WTE, the MSW is directly placed into the boiler and incinerated with heavy metals falling through the grate to be recycled in the bottom ash. Due to the varying nature of MSW, the moisture content is in excess of 20%, with an average British Thermal Unit (BTU) value of between 4,500-6,000 BTU’s. As EPA regulations become more detailed and geared to reducing air pollution, the WTE field is faced with a very costly solution of emission reduction. Typically specialized bag collectors and scrubbers are installed at a very steep capital expense.

WTE facilities have had limited success in reducing emissions, and enhancing BTU values. Source separation is one method for enhancing the BTU value and refuse derived fuel (RDF) is another method of increasing BTU value of fuel. RDF or more commonly called ‘fluff’, is a product that has been separated and shredded after being screened for metals and glass. The resulting product is finely ground to produce a loose “fluff”. This product is blown into boilers to reduce moisture and increase BTU. This is usually produced onsite or within a short distance, as the product cannot be exposed to moisture, rain, etc. These factors render the RDF a very ineffective low-value fuel. One process for preparing a combustible pellet from fluff is disclosed by Philipson in U.S. Pat. No. 7,252,691.

Biogas systems have seen a greater use in the United States, typically in segments of a landfill that has been capped. Biogas produces a methane gas from the decomposing waste. Although this produces a limited amount of methane, the reduction of MSW to a landfill is 0%, and does not provide front-end value.

Anaerobic digestion is a method of producing methane gas using organic waste streams from MSW. Organic waste is subject to a specialized decomposition process and the resultant gas is put through the Fisher/trophic process to remove impurities. Although effective in producing various quality gases, the solids used are typically 90-98% of the input waste, which must be landfill. The process is effective in producing economic value, but does not optimize waste reduction.

Plasma arc gasification and fluidized bed coal or gasification are other methods of utilizing the waste stream in reducing the amount landfilled. Plasma arc is still in development stage and has limited commercial success. Development continues to produce a commercial product and has little impact on the reducing the waste stream. Fluidized bed gasification has been used commercially by the coal industry for a number of years. Fluidized bed boilers use a technique where pulverized coal is burned in various levels of the boiler, resulting in a more complete burn, and effecting emissions on a limited basis. Currently the technology is utilizing coal only as its feedstock and has no significant impact on the waste stream.

There is an unmet need for a fuel that will utilize the majority of post recycled waste stream. While various conventional processes use mainly light and organic fractions of the waste stream, the majority of the waste stream still needs to be landfilled. The majority of RSW (residential solid waste) commonly referred to as the “green or white bags” currently is collected and immediately landfilled. The focus of reducing disposal quantities in significant volumes of MSW can be solved by manufacturing a high BTU value (10,000-13,000 BTU’s) solid fuel that can be consumed exclusively or be co-fired with either coal or biomass.

Typically the majority of engineered fuels are produced through a pelletizing system. These systems include the pelletizer and methods of receiving raw MSW, with separations and grinding techniques, then feeding the actual pelletizing machines. The average pelletizing machine is typically limited to 3-5 tons per hour of production. Once the pellet is created it is subject to a cooling chamber to solidify the pellet. To achieve an effective commercial production rate of 25 tons per hour, a minimum of 5 systems would be deployed, resulting in an extremely capital intensive operation. Pelletizing also produces pellets that are subject to degradation and structural changes to the pellet. To prevent moisture absorption, the majority of pellets need to be dried, which requires capital expenditure for the plant. Pellet applications are more prevalent in the biomass industry, using mainly agricultural components to make up the blend of feedstock.

Certain fuel pellets and production processes are disclosed by Johnston in U.S. Pat. No. 4,236,897, by Warf et al. in U.S. Pat. No. 5,387,267, by Myasoedova in WO1999/055806, and by Parkinson et al. in U.S. Pat. No. 6,165,238. More recent solid fuel disclosures are provided by Bohlin et al. in U.S. Patent Publication No. 2010/00118113 and by Calabrese et al. in U.S. Pat. No. 8,349,034. Other engineered fuels are disclosed by Benson et al. in U.S. Pat. No. 5,429,645, by
SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved solid fuel from a solid waste stream which can be utilized in current boilers and burners without retrofitting. Another object of the present invention is to provide such a solid fuel which is substantially impervious to water, minimizes or eliminates leaching, and is easy to handle and store without flaking or other degradation. This invention features a method for manufacturing solid fuel, including removing non-combustible and hazardous materials from a waste stream of substantially solid materials to produce a substantially combustible waste stream, and estimating a heat value for at least a portion of the combustible waste stream. At least one type of combustible polymer is added to the combustible waste stream as needed to raise the estimated heat value of the portion of combustible waste stream to a desired heat value. The combustible waste stream is heated and mixed with the at least one type of combustible polymer to increase the structural integrity of a solid fuel formed from the mixed combustible waste stream and to increase the hydrophobic properties of the solid fuel. The heated and mixed combustible waste stream is pressed into solid fuel objects which have at least one shape and are substantially hydrophobic.

In some embodiments, the at least one type of combustible polymer includes recycled resins such as plastic water bottles. In certain embodiments, at least two combustible polymers are added, such as from two separate receptacles, preferably about 3 weight percent to about 7 weight percent of polystyrene and about 30 weight percent to about 40 weight percent of at least one different type of combustible polymer, and the mixture is heated to slightly below a temperature at which the combustible polymers begin to char, typically above 200 degrees F. and about 350 degrees F. at least during mixing with the combustible waste stream. In a number of embodiments, the waste stream of substantially solid materials is obtained from at least one of residential solid waste and municipal solid waste. In some embodiments, the desired heat value for the combustible waste stream is between 10,000 BTU to 13,000 BTU. This invention also features briquettes of solid fuel made by one or more of the above embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

In what follows, preferred embodiments of the invention are explained in more detail with reference to the drawings, in which:

FIG. 1 is a diagram of one embodiment of the present invention;

FIG. 2 is a diagram of initial processing to make solid fuel according to the present invention;

FIGS. 3A and 3B are diagrams of further processing to make solid fuel according to the present invention;

FIG. 4 is a schematic block diagram of a system and method according to the present invention;

FIG. 5 is a more detailed block diagram of a system according to the present invention;

FIG. 6 is a still more detailed diagram of a system according to the present invention with a plant control system;

FIG. 7 schematically illustrates an improved manufacturing process according to the present invention;

FIG. 8 is a schematic block diagram of another system and method according to the present invention; and

FIG. 9 is a more detailed block diagram of a system according to the present invention.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

This invention may be accomplished by a system and method which performs thermodynamic analysis on a waste feedstock stream, adds combustible polymeric material to adjust at least the BTU or other heat value as well as hydrophobic properties, mixes the adjusted feedstock, and then directs the mixed feedstock into at least one product forming machine to produce fuel having a substantially consistent BTU value and other preselected parameters as desired. Preferably, the waste stream is initially subjected to a novel process of taking the raw RSW (residential solid waste), commercial solid waste and/or selected MSW (municipal solid waste), as received at a facility. A novel, sophisticated manufacturing process according to the present invention preferably includes: separation, shredding, one or more optional drying steps, dynamic analysis during manufacturing, and a specialized process of adding combustible polymers, to produce a solid fuel. The resultant process preferably produces at least one type of solid shape of fuel, as such as a fuel cube or briquette, that is consistent in BTU value (such as 10,000-13,000 BTU’s), is hydrophobic, is capable of being mass produced (preferably at least 30 tons per hour), is capable of being transported by rail, barge or truck hauling, produces significantly reduced emissions as compared to coal or current biomass, exhibits minimal leaching, and can be co-fired with coal and/or biomass such as in either coal or biomass boilers.

In other words, fuel according to the present invention typically is derived primarily from RSW, which has been processed in such a manner that most inert and metals have been removed. Further processing removes elements that potentially create environmental issues, resulting in a desirable combustible waste stream designated as “WERC-2 Mix” in FIG. 1 that is mixed, heated, and preferably pressurized, to form an engineered solid fuel that will provide equivalent or higher fuel value compared to coal and most current biomass alternatives. The final solid fuel product preferably is a briquetted fuel with one or more of a variety of final shapes, which is hydrophobic and may be stored outside without degradation or leaching, and can be shipped in the same manner as coal. The order and techniques that comprise the finishing step preferably are capable of mass production. The final finishing process preferably utilizes commercially available equipment from various industries.

The term “additives” as utilized herein, also referred to as “supplements”, includes one or more combustible poly-
mers that are preferably obtained from a waste stream, either on site or from another location. Referring to the Resin Identification Coding System developed by the Society of the Plastics Industry, suitable resins to serve as supplements or additives are Numbers 1 (polyethylene terephthalate), 2 (high-density polyethylene), 4 (low-density polyethylene), 5 (polypropylene), and 6 (polystyrene). Number 3 (polyvinyl chloride) is generally not acceptable for combustion due to the chlorine atoms. Suitable resins may also include 7 (other plastics) and 9 (acrylonitrile butadiene styrene) if their combustion will not exceed emission standards. Preferably, the combustible polymers utilized according to the present invention as additives or supplements are waste plastics otherwise destined for a landfill or potential recycling; such supplemental waste plastics now become part of an improved solid fuel with enhanced thermal, handling, and storage properties.

[0031] One manufacturing process 10, illustrated schematically in FIG. 1, utilizes solid waste processed as described in more detail below to become WERC-2 Mix, step 20a. According to the present invention, the WERC-2 mix in this embodiment further includes one or more types of recycled resins such as water bottles and other non-chlorinated plastics. The WERC-2 Mix is further ground or shredded as needed to reduce particle size to below three inches in average diameter, preferably below one inch. The mixture is heated and compressed, step 40. Ram-type compression against a steel brace 60 is depicted in FIG. 1 to schematically illustrate pressurized formation of a final solid fuel shape 70 such as a cylinder labelled WERC-2 MRDF, also referred to as MEFF (Manufactured Engineered Fuel Feedstock). Solid fuels 70A, 70B, 70C, 70D, and 70E, each of which may weigh one ton or more, are shown in storage, awaiting transport. After arrival at a combustion site, the entire MEFF can be burned as a single, log-type unit, or sliced or ground into pieces of desired shapes and sizes.

[0032] Manufactured solid fuel according to the present invention preferably is produced to significantly decrease CO2, S, Cl, M, SO2 and heavy metals emissions during combustion by itself or when mixed with coal or other fuels. The impact preferably is quantitative and demonstrates the effects of using the product. The finished fuel preferably has a moisture content of 2% to 12%, more preferably 4% to 10%, and most preferably 7% or less. The structural composition of the fuel preferably allows for a non-crushing capability or resistance to breakage, flaking or other separation while being handled or mixed. The fuel preferably requires no modifications of the existing boilers; in other words, no retrofit is required before using the fuel.

[0033] The current invention utilizes a change in design and preferably is suitable to produce commercial quantities of at least 35-50 tons per hour. A blend or mix of the final feedstock preferably has specific parameters that ensure a stable, reusable product. The manufacturing line that supplies the final feedstock typically incorporates: screening, crushing, shredding, forced air separation or wind sifting, potentially drying via microwave or other energy source, separation of ferrous from non-ferrous materials using devices such as magnets and eddy currents, as well as specialized optical/visual equipment to analyze the feedstream. The object of the manufacturing line is to remove virtually all non-combustible and potentially hazardous materials such as metal, glass, selected inerts, PVC, mercury, chlorine, heavy metals, etc. from the waste stream.

[0034] One system 100 according to the present invention, FIGS. 2-3B, has a receiving area 80 with railroad tracks 82 or other transportation system, doors with X-ray equipment 84 to detect rejectable items, liquid drains 86, 88, 90 and 92, hazardous materials bunkers 94 and 96, and oil-water separator 98 leading to a water treatment plant 99. Receiving area 80 also has negative air filtration closed-loop systems 102 and 104 in this construction. A plant control room 110 preferably receives inputs in this construction from at least heat sensors 112 to detect hot spots caused by spontaneous combustion or other potential thermal problem, ion mobility spectroscopy 114 to detect certain particulate matter, carbon nanotube gas ionization sensors 116 to detect certain poisonous gases, xenobiotic detection system 118 to detect various chemicals, and enzyme detector 120 to detect certain toxins and furans. Incoming RSW, commercial solid waste, MSW and/or other solid waste is inspected and sorted based on sensor and human quality control. The solid waste is initially ground by pre-shredder 132 and then passed to long parts separator 130 where pipes, gutters, boards, shafts and other elongated items are removed. Waste density is analyzed, density control 122, and manual quality control occurs at sort table 134. The heat value of the waste is determined by optical sensors and/or manual input to BTU data base 136. Further sorting occurs in production area 138 by screening step 140, preferably separating items below two inches in diameter for additional processing by magnets 150, eddy currents 152 and specialized detectors 154 for X-ray analysis, PVC, metals and inerts detection and removal, as well as near infra-red, PVC and metals detectors 156 and 158 for heaves 141 and mediums 143 separated by air separation such as wind sifters 142 and 144, respectively. Typical quantities are indicated in FIGS. 3A and 3B in TPH (Tons Per Hour) leading to non-fuel rejects 145, FIG. 3A, ferrous metals 160, FIG. 3B, non-ferrous metals 162, optional chlorine separation 164, and waste fines 166 separated by screen 168.

[0035] Useful fuel products waste streams 170 and 172, FIG. 3B, preferably are combined with useful fines 178 into a feed stream 179 which is passed through final grinders 176 and thermodynamically analysed, step 180. Alternatively, the useful small-diameter fuel are diverted as indicated by dashed line 178a and combined before or after analysis step 180. Fuel products stream 178 optionally is heated and dried by a heat source 174 in this construction. The combined fuel products waste stream 182 is collected in hopper 190, the BTU value is adjusted by additives in step 192 and mixed in step 194 leading to final process 198 including briquetting or other shape formation. In some processes according to the present invention, the ECOTAC material with additives in mixer 194 is similar to the WERC-2 Mix of step 20a, FIG. 1. Heat is applied as by ultrasound 196, FIG. 3B, or other source of thermal energy. BTU adjustment 192 and heating via ultrasound 196 are controlled by plant control room 100 in this construction.

[0036] Prior to the finishing step, the use of computerized controls and software, designed to accomplish the processes described herein, preferably provides monitoring, controls, fail-safes, data tracking and reporting, in addition to a quality assurance and quality control function, but more importantly provides a periodic, repeated chemical analysis of the feedstock to identify impurities and utilizes thermodynamic analysis to establish its burning capabilities in various size and type of boilers for the fuel. This data also directs the use of additives in the product. These additives are from existing...
waste streams. The whole manufacturing process allows for a series of checks and balances prior to entering the final process. Smaller-scale operations can be directed manually, including periodic sampling and analysis.

For simplicity and illustrative purposes, the principles of the present invention are described below in relation to FIGS. 4-9. The combination of inorganic and organic components may be used either singularly or with multiple components to produce the new solid fuel. The compounds may be used for stabilization and integrity of the solid fuel.

A method and system 400, FIG. 4, for manufacturing solid fuel according to the present invention includes removing non-combustible and hazardous materials from a waste stream of substantially solid materials, such as described above, to produce a substantially combustible feed waste stream 402, and estimating a heat value for at least a portion of the combustible waste stream, thermodynamic analysis 404. At least one type of combustible polymer is added, step 406, to the combustible waste stream 402 and/or to a mixer 408, as indicated by dashed line 407, as needed to raise the estimated heat value of the portion of combustible waste stream to a desired heat value, such as between 10,000 BTU to 13,000 BTU, and to increase the structural integrity of a solid fuel formed from the mixed combustible waste stream. The combustible waste stream 402 is heated and mixed in mixer 408. The heated and mixed combustible waste stream is pressed by product forming machine 412 into objects 414 of solid fuel such as briquettes which are substantially hydrophobic.

The starting point of the present invention is the information received from the thermodynamic analysis of the feedstock which is assembled prior to final shredding. The thermodynamic analysis preferably is capable of measuring and quantifying the chemical composition of the various components of the feedstock. One system for identifying and quantifying feed stream composition includes TTECH autosort multielemental sorting systems with DUOLINE scanning technology for visible and near-infra-red wave-lengths, available from Van Dyk Recycling Solutions of Stamford, Connecticut. By utilizing different spectral sensitivities, the atomic density of the material can be identified, preferably regardless of color, thickness, dust, or other contaminants. Different materials can be separated or sorted as desired.

It is preferred that the thermodynamic unit has the following minimum capabilities:

- perform mass balance calculation on manufactured feedstock;
- specify pre-selected chemical and physical properties of the feedstock; and
- estimate combustion of feedstock material reactions within a furnace.

The use of these tools, which in one construction utilizes known look-up tables for various constituents, provides predictable data to ensure that the characteristics of the feedstock will perform to their optimum capabilities, while ensuring the ability to maintain consistency of the finished product. The present invention may be contrasted with the typical methodology for establishing the value of feedstock which is subject to outside ASTM testing laboratories, where minimum baseline values of BTU’s, elemental solid and limited gases are identified. These traditional efforts only provide a baseline with limited ability to fully define the solid fuel combustion characteristics. The conventional situation relies on trial and error or “art” to manufacture the blend. In using this conventional approach the data ultimately limits the boiler operator’s ability to maximize efficiency due to variations of the fuel’s BTU value and resulting emissions. Also, the composition of waste streams often varies over the year, especially around holidays when extra packaging materials are disposed.

In preferred constructions for systems 500 and 600 illustrated in FIGS. 5 and 6, respectively, the invention comprises the following features. The entire process is considered carbon neutral. The process may use varying sizes of equipment and the order of the process may be adjusted to meet the requirements of the BTU value and blend.

The baseline product material is established during the manufacturing process, and the results of the thermodynamic analyses prior to the final shed by grinders or shredders 502, FIG. 5, and grinders or shredders 602, FIG. 6, such as shredders available from Metso Denmark A/S, Horsens, Denmark, with weighing on weigh belts 504, 604, such as weigh belts available from Thayer Scale-Hayer Industries, Inc., of Pembroke, Mass., will determine if automated or manual addition of selected material mix is necessary to ensure that the final product meets desired, pre-selected tight tolerance specifications including acceptable ranges of BTU values. The type, amount and rate of additional materials to be added preferably are calculated in “real time” manually or by plant controller 610, FIG. 6, based on the weight and identified constituents on weigh belts 504, 604. The process controls then initiate the appropriate flow and timing of one or more supplements or additives, such as plastic chips from water bottles and other recycled polymers in surge containers 512, 612 and Styrofoam (polystyrene) in surge containers 514, 614, also referred to as receptacles 512, 612 and 514, 614, as “boostering” or adjusting materials to alter BTU or other values up or down as desired and to increase hydrophobicity and integrity of the final solid fuel product. Although the additives can be delivered in heated liquid form, weighing and handling is simplified for chips or other particulates in solid form.

In some embodiments according to the present invention, it has been recognized that weighing and metering of the combustible polymer additives is simplified and more accurate when Styrofoam, having a high volume, low density, and high BTU properties, is delivered separately from other plastics. Typically, shredded Styrofoam, Resin Recycling # 6, has a heat value of about 17,000 BTU/lb, while mixed plastic chips selected from other Recycling Numbers generally have a heat value of about 14,000 BTU/lb. By comparison, shredded paper is about 8,000 BTU/lb.

The manufacturing line preferably is designed for substantially continuous operation for at least 20 hours per day. All material used as additives preferably comes from the RSW waste stream or very selective municipal and/or commercial waste streams.

The fuel mix post final shredding moves to the primary weigh conveyor belt 504, 604. The weigh belt measures the weight, such as in tons per hour, of the mixture to ensure a substantially uniform, paced flow and minimize undesired surges or pulses of the mix into the system. The mix passes through and over an electronic loadcell 506, 606, and the data is transmitted to the plant control system 610. The electronic loadcell may be operated in continuous reading mode or can
be set to measure in periodic intervals such as every 15 seconds. The primary weigh belt 504, 604 preferably has a capacity of 0-50 TPH.

[0050] The mix moves via gravity feed to the secondary weigh belt 520, 620 which is proceeding on the horizontal, but is intersected on the vertical axis, as illustrated in FIGS. 5 and 6, by variable speed weigh belts 516, 518 and 616, 618. These belts move from the additive surge tanks 512, 514 and 612, 614. With the use of at least two storage tanks or bins, the additives may be custom mixed to meet the requirements of the specific fuel. In certain processes according to the present invention, at least two combustible polymers are added, preferably about 3 weight percent to about 7 weight percent of polystyrene, more preferably about 4 weight percent to about 6 weight percent, most preferably about 5 percent, and about 30 weight percent to about 40 weight percent of at least one different type of combustible polymer, more preferably about 32 to 38 weight percent, most preferably about 35 weight percent, and the mixture is heated to slightly below a temperature at which the combustible polymers begin to char, typically above 280 degrees F. to about 350 degrees F. at least during mixing with the combustible waste stream. Less polystyrene may need to be added at certain locations or at certain times of the year, such as around the Christmas holidays when an increased amount of Styrofoam packaging material is discarded.

[0051] The belts 516, 518 and 616, 618 preferably have a capacity of 0-10TPH and may be operated singularly, that is, independently separately or simultaneously, or in tandem. The electronic loadcell 522, 622 located at the end of secondary belt 520, 620 provides real time data to the control system 610 and operates in the same parameters as the primary weigh belt 504, 604. The feed stream is then delivered, typically by gravity feed, to mixers 530, 630.

[0052] Once the additives have been added to the feed stream, preferably prior to or within the mixer, such as plug mill or twin screw mixer 530, 630, mixing occurs in a heated environment, preferably with both the wall of the mixer 530, 630 and the interior of auger 532, 632 heated to at least 200 degrees Fahrenheit, using steam, electric heat, or recirculating hot oil in this construction. In general, the heating is more typically about 320 degrees to 550 degrees F., most preferably slightly lower than the temperature at which polymers in the mixed waste stream begin to char. The temperature and time of material placed in each mixer will be established to transfer the material from a solid to a somewhat pliable and sticky state, with at least the combustible polymers softened. The temperature range will allow for the mix to become generally pliable and sticky. Mixing of the product allows for the additives to be blended substantially uniformly and the spread, that is, the elongated length, of the mixing will affect the rate at which the temperature of the mix is raised within mixers 530, 630.

[0053] The at least one combustible polymer additive not only provides structural integrity to the finished product, but makes the final product hydrophobic, that is, impervious to water, allowing for ease of transportation and storage. Additionally, the final solid fuel product preferably exhibits minimal odor, virtually no leaching, and resists degradation during handling. In some constructions, controllers are attached to sensors which check for temperature, pressure, and/or residency time. Once the fuel has achieved the proper parameters, it proceeds to the splitting system when throughput is greater than the capacity of an individual forming machine. The splitting system directs the mix into one or more hoppers. Once in the hopper or hoppers, the material is divided substantially equally into two or more streams.

[0054] The splitter 550, 650 moves the mix by conveyor belt to the respective receiving hoppers 552, 554 and 652, 654. The mix preferably is transported between stations at a rate, and with additional heating and/or increase in pressure as needed, that minimizes cooling of the product to avoid undue solidification prior to the final “briquetting” or other forming process. Each receiving hopper 552, 554 and 652, 654 feeds the material into a respective final screw feeders 556, 558 and 656, 658, preferably oriented vertically to utilize gravity, which increases pressure and meters the rate that the material is being placed into the product forming machine 560, 562 and 660, 662.

[0055] The product forming machine 560, 562 and 660, 662 preferably has an operation rate of 2-25 TPH. The finished fuel object preferably is a briquette that is substantially square or lozenge-shaped with tapered sides and ends. Each briquetting machine, such as those available from Koppers Equipment, Inc., Charlotte, N.C., preferably is capable of making various sizes from approximately 1"x1.5" to a maximum of 2"x2.5".

[0056] The product forming process is comprised of the following components in this construction:

[0057] Receiving hopper;

[0058] Screw Feeder, preferably at least a vertical feeder into the briquetting machine;

[0059] Roller press for compaction and shape formation;

[0060] Self-Cleaning press rollers; and

[0061] Various screen configurations.

[0062] Upon the final mix passing through the briquetting machine, the fuel is ejected into a hopper or other receptacle 570, 670 in some constructions and, in other constructions, is deposited directly onto load out conveyor 572, 672 to be stored or loaded to transportation equipment 574, 674 (truck, railcar, barge) for shipment.

[0063] FIG. 7 schematically illustrates an improved manufacturing process 700 according to the present invention. Initial RSW and/or MSW arrives by transport 702, such as by truck or railroad car, and initial recycling 704 typically removes approximately 15 percent of the total materials as PVC 706, optionally wood 708, glass 710 and metals 712, both ferrous and non-ferrous, which can be sold to recycled materials buyers 714. Arrow 720 represents processing of the remaining 85 percent of the total materials by methods and systems according to the present invention as described above, with further separation therefrom of approximately three percent of the total materials: first items 722 such as heavy metals, mercury, chromium, arsenic; second items 724 such as chlorine and selected organics, third items 726 such as metals, both ferrous and non-ferrous; and fourth items 728 such as glass and inserts, all items 722-726 preferably diverted for appropriate separate processing 730. After processing of solid engineered fuel as described above to make ECOTAC manufactured product 740, approximately two percent unusable fraction 750 of the total materials is diverted to landfill 752 or other suitable disposal. In other words, approximately 80 percent of the total solid waste arriving by transport 702 becomes usable combustible fuel 740 according to the present invention, with an even higher usable percentage when wood is added to combustible fuel 740. By comparison, after typical conventional recycling, approximately 70 percent of RSW and MSW is directed to landfills.
Another system 800 according to the present invention is shown in FIG. 8 positioned in a final processing area measuring approximately 110 feet in width and 200 feet in length in one construction. Main feed belt conveyors 802 and 804 are each approximately 10 feet wide and 20 feet long in overall floor space. Surge tank or receptacle 806 containing shredded polyethylene is approximately 12 feet in diameter while surge tank or receptacle 808 is approximately 10 feet in diameter. Polystyrene is selectively transported and weighed on belt conveyor 810, approximately 10 feet wide and 20 feet long, while mixed plastics are selectively transported and weighed on belt conveyor 812, approximately 4 feet wide and 5 feet long.

In this construction, the enhanced waste stream is separated into at least three streams 814, 816 and 818 which are directed into chutes 820, 822 and 824 of screw conveyors 826, 828 and 830, respectively, each approximately 3 feet wide and 30 feet long. The initially mixed feed streams are then directed to pig mills 832, 834 and 836, respectively, for thorough mixing, and then delivered to a single receiving hopper 840, approximately 10 feet wide and 20 feet long, which directs the feed stream through chute 842 into heated screw conveyor 844, which is approximately 3 feet in width and 30 feet in length. Temperature and pressure are increased on the mixed feed stream as it is delivered to one or more product forming machines 846. Final product, preferably in briquette shapes as described above, passes over screen 848, approximately 5 feet wide and 10 feet long, and onto belt conveyor 850, approximately 3 feet wide and 80 feet long. Any scraps or unformed waste is recovered by screen 848 onto belt conveyor 852, approximately 3 feet wide and 50 feet in length, which returns the mixed combustible scraps to belt conveyor 804 to be reused.

A more detailed illustration of a system 900 according to the present invention with plant control 902 is depicted in FIG. 9. Final grinders 904 and 906 shred a combustible waste stream, with non-combustible and hazardous materials removed as described above, onto a primary weigh feeder 908 where composition of the waste stream is detected by sensors 910. Detected information is conveyed over wire 917 in one construction or is wirelessly transmitted in other constructions. A thermodynamic analysis is performed, step 912, and a BTU analysis, algorithm step 914, with initial weight input from electronic loadcells 915, determines how much of different combustible polymer additives are to be metered through gating systems 916 and 918 for plastic chips surge container or receptacle 920 as one additive and Styrofoam surge container or receptacle 922 as another additive or supplement onto weigh belt feeders 924 and 926, respectively, to achieve a combined BTU value on secondary weigh belt feeder 928 within desired ranges as described above. Final combined weight is checked by electronic loadcell 930, which also relays information to plant control 902, such as via wire 931.

The final, adjusted waste stream is fed to pig mill mixer 940, where it is heated and mixed, and then fed through receiving hopper 942 to screw feeder 944 and into one or more product forming machines 946. Formed briquettes and possible unformed waste are discharged, stream 947. Formed briquettes are conveyed via load out conveyor 948 to transportation 950, such as a tractor trailer truck or railroad car, while unformed waste preferably is screened away and transported as stream 949 back into mixer 940 to be recirculated.

Although specific features of the present invention are shown in some drawings and not in others, this is for convenience only, as each feature may be combined with any or all of the other features in accordance with the invention. While there have been shown, described, and pointed out fundamental novel features of the invention as applied to a preferred embodiment thereof, it will be understood that various omissions, substitutions, and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art without departing from the spirit and scope of the invention. For example, it is expressly intended that all combinations of those elements and/or steps that perform substantially the same function, in substantially the same way, to achieve the same results be within the scope of the invention. Substitutions of elements from one described embodiment to another are also fully intended and contemplated. It is also to be understood that the drawings are not necessarily drawn to scale, but that they are merely conceptual in nature.

It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto. Other embodiments will occur to those skilled in the art and are within the following claims.

What is claimed is:

1. A method for manufacturing solid fuel, comprising:
   removing non-combustible and hazardous materials from a waste stream of substantially solid materials to produce a substantially combustible waste stream;
   estimating a heat value for at least a portion of the combustible waste stream;
   adding at least one type of combustible polymer to the combustible waste stream as needed to raise the estimated heat value of the portion of combustible waste stream to a desired heat value;
   heating and mixing the combustible waste stream with the at least one type of combustible polymer to increase the structural integrity of a solid fuel formed from the mixed combustible waste stream and to increase the hydrophobic properties of the solid fuel; and
   pressing the heated and mixed combustible waste stream into objects of solid fuel which are substantially hydrophobic.

2. The method of claim 1 wherein the at least one type of combustible polymer includes recycled resins.

3. The method of claim 1 wherein at least two types of combustible polymers are selectively added to the combustible waste stream.

4. The method of claim 1 wherein the combustible polymer is heated to a temperature between 200 degrees F. to about 350 degrees F. at least during mixing with the combustible waste stream.

5. The method of claim 1 wherein the waste stream of substantially solid materials is obtained from at least one of residential solid waste, commercial solid waste, and municipal solid waste.

6. The method of claim 1 wherein the desired heat value is between 10,000 BTU to 13,000 BTU.

7. Briquettes formed as solid fuel objects according to the method of claim 1.

8. A method for manufacturing solid fuel, comprising:
   removing non-combustible and hazardous materials from a waste stream obtained from at least one of residential
solid waste, commercial solid waste, and municipal solid waste to produce a substantially combustible waste stream;
estimating a heat value for at least a portion of the combustible waste stream;
adding at least one type of combustible polymer to the combustible waste stream as needed to raise the estimated heat value of the portion of combustible waste stream to a desired heat value;
heating and mixing the combustible waste stream with the at least one type of combustible polymer to increase the structural integrity and to increase the hydrophobic properties of solid fuel objects formed from the mixed combustible waste stream; and
pressing the heated and mixed combustible waste stream into objects of solid fuel which are substantially hydrophobic.

9. The method of claim 8 wherein the at least one type of combustible polymer includes recycled resins.

10. The method of claim 8 wherein the desired heat value is between 10,000 BTU to 13,000 BTU.

11. The method of claim 8 wherein the at least one combustible polymer is heated to a temperature between 200 degrees F. to slightly below a temperature at which the combustible polymer begins to char, at least during mixing with the combustible waste stream.

12. The method of claim 8 wherein at least two types of combustible polymers are selectively added to the combustible waste stream.

13. The method of claim 12 wherein at least one of the combustible polymers is a type of polystyrene.

14. Briquettes formed as solid fuel objects according to the method of claim 8.

15. A method for manufacturing solid fuel, comprising:
removing non-combustible and hazardous materials from a waste stream obtained from at least one of residential solid waste, commercial solid waste, and municipal solid waste to produce a substantially combustible waste stream;
estimating a heat value for at least a portion of the combustible waste stream;
selectively adding at least one type of polystyrene as a combustible polymer from a first receptacle and at least one different type of combustible polymer from a second receptacle to the combustible waste stream as needed to raise the estimated heat value of the portion of combustible waste stream to a desired heat value;
heating and mixing the combustible waste stream with the at least two types of combustible polymers to between 300 degrees F. to about 350 degrees F. to increase the structural integrity and to increase the hydrophobic properties of solid fuel objects formed from the mixed combustible waste stream; and
pressing the heated and mixed combustible waste stream into objects of solid fuel which are substantially hydrophobic.

16. The method of claim 15 wherein about 3 weight percent to about 7 weight percent of the polystyrene is added.

17. The method of claim 16 wherein about 30 weight percent to about 40 weight percent of the at least one different type of combustible polymer is added.

18. The method of claim 15 wherein about 4 weight percent to about 6 weight percent of the polystyrene is added and about 32 weight percent to about 38 weight percent of the at least one different type of combustible polymer is added, and the mixture is heated to slightly below a temperature at which the combustible polymers begin to char.

19. The method of claim 18 further including increasing pressure on the heated and mixed combustible waste stream as it is fed into a product forming machine for forming the solid fuel objects.

20. Briquettes formed as solid fuel objects according to the method of claim 19.

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