Global Patent Claim
Green Fire Stream Energy
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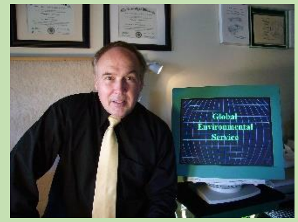

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U.S. Patent Standards

The United States of America has acquired a reputation of being the most inventive nation in history. Not surprisingly, U.S. standards for patenting inventions also are highest in the world. The subject matter of this invention has global application, so a globally valid patent is the right scope. Unfortunately, the low degree of refinement in patent law among nations has for some time compelled an expensive, time-consuming, piecemeal approach to obtaining global patent coverage that falls far short of uniform standards. Since the world situation with respect to energy resides in a state of emergency, there is compelling need to reform the extant patent process to assure access of all nations to this (or other) energy innovations capable of relieving global energy crisis. Given that U.S. patent standards are highest, it is prudent to begin the reformation process from that foundation. The following paragraphs review the U.S. standard, then speak to satisfaction of those standards with the present invention, "Green Fire Stream Energy." Later in the document, conditions supporting *globalization* of the U.S. kernel of patent law are added.

Subject Validity

Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title. (Title 35 Section 101 U.S. Code of Laws.)

Conditions of Invention

Useful   Novel   Unobvious

Conditions of Filing

Prior Art   Disclosure Sufficiency   Reduction to Practice

Analysis of Situation Evoking Need for Invention and Establishing Usefulness

Review of Global and National Energy Consumption Situation – Per capita energy consumption in the U.S.A. tripled during the last 150 years. The industrial age and multidimensional expansion of transportation were key driving forces for societal energy intensification. Seemingly limitless repositories of coal and oil increasingly tappable using automated extraction technology removed supply constraints to the high-energy, high-technology civilization emerging in developed nations. Envious life styles stimulated a global quest for energy that overdrew regional supplies and created a global energy shortage. Oil repositories vital to multidimensional transportation especially were reaching extinction at the end of the 20th Century Among nations, relationships deteriorated to lethal, multi-billion-dollar "oil wars" to settle who wins long-supply-line preference among the clusters of global energy fields. Even with relatively few energy-rich, technology-rich nations in the global community, their extreme workstyles and lifestyles destabilized global climate. This second war front (against a deteriorating natural environment) is marked by escalating events of billion-dollar property damage and extreme casualties. So perplexing has been the combined, globe-spanning societal and environmental upheaval that survival of entire nations and of Earth's environmental munificence has been fearfully questioned.

Review of Usefulness Criteria - A number of prescriptions for addressing the aforementioned global scene of dynamic instability compose a solution-demand *framework for innovation* especially relevant to advanced society.

Lifestyle Moderation & Regionalization – The past two centuries witnessed the rise of the U.S.A. from a colony to a global superpower. No nation in history had so rapidly developed. Its foundation in the Protestant Work Ethic yielded world-class extractive, agricultural, and manufacturing industries. American "Can Do" leadership led the world and furnished a lifestyle so prosperous that immigration composed a global melting pot. Unfortunately, hyper-growth momentum resulted in over-working and over-building: skyscrapers too high, homes too spacious, cars too fast, travel too busy, roadways infringing Green Nature, weapons too destructive, factories too busy, advertising too persuasive, trips too far, etc. Soon the American

Dream eclipsed affordability and replicability, overdrawing Nature's munificence to the point of environmental damage threatening broad-based societal shutdown.

Creeping awareness of lifestyle extremism hazards spawned grassroots social consciousness and an alarmist environmental movement. Resulting acrimony and public demonstrations registered frustration, but evoked few remedies. These lamentations are, however, tangible evidence of the general need to slow down, to consume less, to seek a moderate, sharable American Dream. The global breadth of tribulation also interprets as a need to draw in the scope of living to a more regional, family, and individual dimensionality.

Regionalizing Energy Sources – Advanced nations have organized the energy logistic around a world trade discipline. They have been the principal users of petroleum energy with wealth enhancement, so petro-rich underdeveloped countries have generally been open to trading energy resources for global currency. Producer countries have evolved into politically unstable "hot spots" for oil wars and poverty-driven terrorism. Long, critical international supply lines have raised business and financial risk, brought currency speculation, instigated piracy, heightened environmental damage, etc.

An alternate, Christian perspective on energy regards the global distribution of resources geographically efficient for the good of all. Nations confidently develop and energize their societies from reserves in their own back yard. Proximate energy thereby prospers regionally, simply, and safely. Energy over-consumption is foreclosed. No nation is driven to distant lands to satisfy extreme need. Underdeveloped countries receive proximate, God-given quotas to robustly build their societies, not just energy trade.

Repository-to-Stream Energy Transition – Wood, coal and petroleum may be regarded repository energy supplies. Once discovered, they are rather simply tapped. Unfortunately, supply richness brings over-consumption risk. Industrialized nations have generally over-used their endowments, pressing into sumptuous lifestyles, weapons development, environmental offenses, currency inflation, etc. As global reserves prematurely dwindle, nations are being driven to tap *perpetual energy* streams ultimately generated by the sun. The "millennial sun" patiently produced vast energy repositories modern society has swiftly squandered. But, the time has come to fuel the forward-looking global society on a *current basis*, from the ongoing, real-time stream of sun energy. Stream energy present in Earth's working fluids of air and water, or the landed living vine of Nature, may be *harvested continuously* using high technology. Present technological means deliver less than 10% of the present U.S. energy demand, but stream output is growing, and consumption eventually will moderate to establish a happy equilibrium.

Recycling Products of Industry – Prime materials of modern society (e.g., steel, aluminum) do not occur naturally. They are won from ores extracted from the earth and transformed into marvelous building materials using energy. Accordingly, products of advanced society *embody* much energy: they are an *energy bank*. Recycling such materials is a necessary obligation to God and Nature if society is to continue enjoying the remarkable qualities of these advanced materials. Aluminum highlights the fruitfulness of intelligent recycling policy. The metal does not occur naturally, but once made and fabricated into a long-lived product (aluminum does not corrode), it may be recycled at the end of its lengthy product life into a replacement product for only 5% of the energy required to produce the original.

Growth-to-Maintenance Societal Transition – Like human beings, societies progress from growth to maturity. Economic, industrial, and financial infrastructure especially change. Smooth transition from high-output, energy-intensive growth to low-output, energy-conserving maintenance is prescribed. Failure to navigate this *critical point* successfully is causing empires and nations to crumble. Wars, economic depressions, hyper-inflation, crime, and 20th Century unemployment testify to involvement in an uneasy transition.

Invention Claim of Discovery
Unobvious Energy Reserves & Flows of Requisite Magnitude

This patent claim identifies an unobvious but plentiful source of energy that responds to several of the aforementioned prescriptions for societal stability. In its simplest characterization, it amounts to tapping the perpetual flow of energy from the leaf product of Nature's abundant foliage. This product of the vine is reasonably termed Green Energy or Green Stream. It is available in the trees, shrubs, and grass of Green Nature, the most uniformly distributed living resource on Earth. This Green Power conveniently situates in the yard around every landscaped home. It bears no logistical burden to acquire. Present clippings and rakings are a disposal nuisance that carries a municipal solid waste (MSW) disposal charge of about $0.05 per pound or $100 per ton. As a combustion resource transformable to home-heating energy by the home owner or others, it may be thought of as coal or oil "above the ground," easily seen and harvestable, possessing substitution *value* rather than MSW *expense*. For example, residential combustion heating by various means (gas, electric, wood, oil, etc.), averages about $5 per million British Thermal Units (MBTU). One ton of leaf product with a heat content of 16 MBTU is worth about $80 in the general energy market. Retaining and converting residential leaves to home heating *on-site* entails a net benefit of $180/T.

Acronyms & Technical Shorthand

Municipal Solid Waste (MSW) British Thermal Unit (BTU)
Thousand BTU (KBTU) Million BTU (MBTU)
Quadrillion BTU (Quad) Cubic Foot (cf or Ft^3)
Trillion Cubic Feet (Tcf or TFt^3) Square Feet (Ft^2)
Ounces (Oz) Fluid Oz (fOz) Weight Oz (Oz or wOz)
Foot (Ft or ') Inch (") Mil=0.001" Hour (Hr or H)
Meter (m) Millimeter (mm) Square Inch (In^2) Cubic Inch (In^3)
Kilowatt-Hours (KWH) Pound (Lb) Short Tons (T) = 2,000 Lb
Mass Density Lb/Ft^3 Energy Density (BTU/Lb or BTU/Ft^3)
Energy Cost Density ($/BTU or $/MBTU also BTU/$ or MBTU/$)
Volume % (V%) Weight % (W%) Watts (W)
Temperature (T) Temperature Change (ΔT)
Degrees Fahrenheit (F° or °F or F)

MSW FACTS

In 2012, the U.S.A. recovered 250 million tons of municipal solid waste (MSW). About 87 million tons were recycled (35% rate). On a per capita basis, citizens produced about 4.4 pounds of solid waste daily, with 1.5 pounds recycled. Per capita trash magnitudes have declined 8% since the year 2000.

Trash collection in the U.S. for 2012 cost about $100 per ton net of recycling revenues. The energy value of MSW is about 4,300 BTU/Dry Lb. Were all MSW from a 3-person residence burned to warm the habitat, approximately 19 KBTU per day would be generated. Since a typical northern residence requires about 500,000 BTU per winter day, MSW offsets only 4% of the heating burden.

Yard trimmings compose 13.5% of U.S. trash. About 7.7% of the trimmings are recycled into products like compost. The energy content of dry trimmings is about 2,800 BTU/Lb. Paper is the largest component of MSW at 27%. Its energy content of 7,300 BTU/Lb is the largest energy prize of MSW capturable on-site by incineration to heat the home. Unlike trimmings, it associates a first-use expense (e.g., buying a newspaper) that potentially makes it *more* expensive than traditional heating fuels.

Leaf Power spares the precious wood of trees. It veils a fuel resource more plentiful than wood, yet similar in heat content. It is cleaner than coal or oil to burn (negligible sulfurous combustion products). Harvesting Leaf Fuel dispenses with laborious firewood felling, sawing, and splitting. Nature graciously drops Fall leaves, pre-seasoned and finely-divided, in an easily-recovered blanket over (not under) the earth surrounding preserved, precious trees. These flame-colored beauties surrender to the earth at the end of their *green season* of quietly providing life-giving oxygen at a rate 1,000 time greater than Nature's ubiquitous grass carpet. This invention addresses unobvious, perpetually recoverable heating value from Fall leaves of the tree. Considering the vital gifts of wood for construction, leaf-produced oxygen for breathing, and both wood and leaf heating value for home and industry, one is awed by the silent service to mankind from God's marvelous "tree soldiers" of the forest.

The State of Pennsylvania exemplifies the distributed wealth of Green Power. Named for Colonist William Penn and the sylvan splendor of a verdant forest now covering 60% of the State, Pennsylvania has a land area of 44,820 square miles and population of about 12,433,000. Annual leaf product on Pennsylvania's unequaled stock of hardwood trees is estimated at 1.25 pounds per woodland square foot. Given calorimeter assessment of dried leaf energy at 8,000 BTU/Lb, the annual forest energy endowment in Pennsylvania translates to 6.21quadrillion BTU (usually called "Quads"). Population density in Pennsylvania is about 2.31 acres per capita. The Green Energy endowment factors down to about 500 MBTU per capita, more than 1.5 times Pennsylvania's 327 MBTU per capita energy consumption. While other States may not be as well-furnished naturally with trees, the Pennsylvania endowment inspires a *Green Life Objective* States might embrace through *planned* forestation.

Grass is a complementary leaf product of Nature's vine. It differs from Fall-harvested tree leaves in that it grows throughout summer months and is harvested continuously by mowing. Homeowners cultivate beatific lawns, but Nature spreads its natural green carpet just about everywhere. By it, soil erosion is held in check, beast of the field are fed, and vital atmospheric oxygen is replenished.

Based on calorimetry data, the energy content of grass is 20% less than tree leaves, about 6,400 BTU/Lb. During one-half year of warm season growth, grass turf should produce about 0.37 pounds per square foot of clippings. Were 100% of Pennsylvania land area "grassy" for half the year, 3.54 combustion Quads would be produced. This translates to 285 MBTU per capita. While full grass coverage of the State is not practical, the magnitude is theoretically instructive for generalizing regional Green Energy potential. *Green Resources exhibit energy supply liberality* capable of meeting energy needs with a Factor of Safety approaching 2.4. Some Green Technology (hydroponics) raises natural grass productivity 800-fold, further validating leaf-basis Green Stream Energy as a *proximate, natural, living energy resource of substantial magnitude.*

"THE TREE"

Modeled After A Lovely Poem
"Trees"
By Joyce Kilmer 1913

I think that I shall never see,
A gift more lovely than a tree.
It stands so tall on legs of wood,
A means for building all things good.
On outstretched arms
It holds its leaves,
Small factories for air we breathe,
That are surrendered in the Fall,
To give, perhaps the best of all:
A life provision, eternally,
Power and energy to meet our need.
For years I only saw a tree,
As shade and beauty for you and me.
But now I wonder if ever there will be,
A fuller provision,
Than I find in this vision,
Of a common and wonderful,
Familiar and beautiful,
Most useful and elegant gift,
That we know as a tree.

William C. Patterson, Ph.D.

Key Technical Issues – While history records homeowners burning leaves in the Fall (mostly to dispose of them without having to cart them away), there is not evidence of intentional use for home heating as taught by this claim of invention. Residents have sought and paid for wood, coal, oil, natural gas, electricity, kerosene, etc., to heat their homes, but not leaves. Their presence in collected and potentially incinerated municipal waste has been too limited to support a claim of combustion heating preference or potency. In situ owner processing has not become significant because gathered leaves have very low bulk density and, therefore, low bulk energy density. Bulkiness also renders Fall leaf harvests intractable for storage. Furthermore, outside accumulations lose combustibility because of entrained moisture from rain or snow. Characteristically thin, isolated leaves weakly support combustion. It is hard to keep a leaf pile lit, and the typical over-carbonized (rich mixture) flame produces a lot of objectionable smoke. The modern U.S. real estate model emphasizes tree landscapes far less than grass, shrubs, bark, concrete, stone, brick, etc. On a land area basis, however, trees possess 15 times the energy density of lawns.

Evident from this review accounting for the historically low desirability of leaves as an energy resource is a need for *affirmative* rather than *casual* energy cultivation. Residential landscapes can be optimized for beauty AND energy yield. The naturally weak combustion behavior of Nature's leaves also can be technically modified to produce an ideal home heating product. A significant portion of this claim of invention associates with processing novelty to *technically optimize* energy capture from this otherwise unobvious, abundant, proximate, convenient, free, perpetual, energy legacy.

Potential Disqualifiers

Has Shale Energy Already Resolved the World's Energy Crisis? Beginning about 2008, the international energy crisis began relieving by the discovery of huge reserves of natural gas and oil in the deep shale deposits of the planet. New drilling technology, known as "fracking," proved capable of releasing tightly bound energy for distribution locally, nationally, and internationally. As of 2010, U.S. energy consumption was around 100 Quads, with 60% coming from oil and gas. Stream energies are rapidly growing in the energy mix, but currently meet only 8% of the energy need. Fisher-Pry Technology Forecasting Substitution Theory projections I have composed predict stream energy meeting 50% of demand by the year 2045. Shale energy flows are expected to peak around 2020 at 20 annual Quads. Subsequent exhaustion estimates from EIA, PCI, or Hubbert Peak Theory, vary from 8 to 92 years. Shale discoveries and drilling technologies bring merciful energy for a duration wrapped in uncertainty. The deep repository yield reasonably interprets as *bridging energy* that allows the nation(s) to reformulate energy policy for perpetuity around stream resources and lifestyle-workstyle moderation.

The Leaf Energy initiative at the core of this invention claim taps a perpetual energy stream potentially *double* the extant consumption flow. Scientific details of the transformation process for Green Power to be disclosed herein will demonstrate highly desirable qualities of simplicity, convenience, harmlessness, affordability, and generalizability. Leaf Fuel will not be as convenient as natural gas (now pipeline-delivered to the home), electricity (existing wire-grid infrastructure), or gasoline (automatic pump-delivered in the neighborhood). But it has supply proximity that will permanently eliminate shortages, terminations, inflation, cold weather hardships, explosion hazards, electrocution hazards, etc. By a merciful fine-grained implementation, only a husband's or father's light and prudent labor, not his wallet or employment status, determines continuity of wintertime home heating for his family.

Does Global Warming Preclude Further Use of Combustion Energy? Environmentalists have been warning industrial nations and their over-busy factories about global warming since the mid-20th Century. Cities have become air-polluted, CO_2-rich greenhouse domes owing to skyscraper-fed population hyper-density, coal-fired electrical grid overload, 24-hour lighting policy, 24-hour air-conditioning and heating, traffic jam automobile commuting, and hyper-active business air travel. Technical society has been overheating the air and water to such a degree that climate damage has occurred. Storm violence and damage is at an all-time high. Weather variability is rising, bringing drought and flood cyclicality, more extreme temperature highs and lows, and more wildfires. Polar ice is melting at an alarming rate, bringing predictions of sea level increase and destructive inundation of coastal cities.

Against this backdrop of societal overheating offenses to Nature, one might reasonably question the usefulness of innovations like Green Stream Energy that continue the combustion energy repertoire as petroleum, natural gas, and coal repositories lapse. Cool solar and wind technologies promise less climate destabilization and offer energy potential far above their present 8% of the U.S. portfolio.

The facts are that society continues to stand in great need of combustion heat, and that there are optimal geographic regions for situating *benign* combustion processes. Approximately 1/3 of the latitudes above or below the equator must be heated in winter months for humankind to survive. Clean winter heat to homes in these regions does not destabilize climate. It actually helps to even the thermal profile (a kind of "production leveling") that moderates weather patterns. The middle 1/3 latitudes (30°-60°) compose the world's industrial zone and are optimal for human work. In the post-industrial age, it will continue prudent to situate maintenance (low-activity, low-energy draw) industry there. Maintenance production might even be scheduled for winter months only, to avoid destabilizing temperature-intensification during already warm summer months. Industrializing cooler regions in the polar 1/3 of the planet engages a frigidly harsh work habitat where exhausting heat into West-to-East wind patterns can *directly* melt polar ice repositories.

Commuting automobiles are less essential in the post-industrial age. Office workers can live where they work and eschew commuting, which accounts for 57% of auto use. On a square foot (heat intensity) basis, the automobile is a much hotter feature of the global environment, generating 80 times the heat print of a home. Reigning in the auto "horses" looms as a much more sensible and fruitful policy path in a moderating, stabilizing U.S. and world energy future.

Invention Claim of Technical Merit
Novel & Practical Processing of Leaves to Create a Well-Behaved Solid-State Heating Fuel

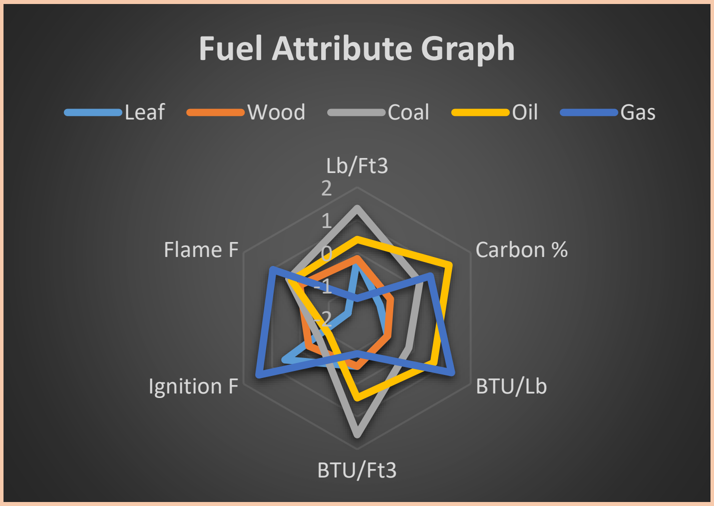
Table 1 - Characteristics of Leaves and Successful Home Heating Fuels

Fuels	1	2	3	4	5
Properties	**Leaves**	**Fire Wood**	**Coal**	**Heating Oil**	**Natural Gas**
Density Lb/Ft^3	37	37	84	55	0.05
Carbon %	46	52	69	86	75
Heating Value BTU/Lb	8,000	8,000	13,000	19,000	23,200
Heating Value BTU/Ft3	296,000	296,000	1,920,000	1,045,000	1,160
Ignition Temperature F	860	660	572	494	1,076
Flame Temperature F	1,800	3,600	4,000	3,900	4,600

Table 1 compares Nature's leaves to primary home heating fuels of U.S. history using key fuel attributes. Leaf Fuel is most like firewood, least like natural gas, and moderately similar to coal and oil. Leaf Fuel and wood exhibit lower density, heating value, and carbon content (element correlating most with heat value) than other solid or liquid fuels. Natural gas has low heat content, but is compressed about 2% above atmospheric pressure to stream BTU power into any combustion process. This light-weight fuel acquires its potency via throughput (flow). It currently qualifies as the cleanest (pure CH_4) and most convenient (piped to the home with fingertip or automatic valving) heating fuel of all. However, significant up-front investment was required to establish the huge underground natural gas delivery system. This fuel also possesses significant explosion hazard and lethal inhalation risk. Leaf Fuel has a lower flame temperature and higher ignition temperature than prime solid or liquid fuels. Accordingly, it is a little harder to start (only natural gas has a higher ignition temperature) and generates a cooler flame during combustion.

Figure 1 graphically transforms information from Table 1 to more easily comprehend the 5 x 6 space of fuel and property diversity. The 6-axis Radar-Screen (left) of standardized properties for each fuel creates a *property perimeter* or *property area* to simplify comparisons among the fuels. The Dendrogram (right) tree structure, derived from UPGMA Cluster Analysis (methodology in the field of *numerical taxonomy*), reduces the similarity-dissimilarity measures further, to a *single* dimension. Branches in the tree are at Euclidean distances of 0.79, 0.83, 1.41, and 1.62 (increasing order of dissimilarity). The Cophenetic Correlation Coefficient, assessing agreement between the original data's Resemblance Matrix and the Dendrogram, was acceptable at 0.86.

Figure 1 - Fuel Attribute Graphics

<table>
<tr><th>Radar Screen</th><th>Dendrogram</th></tr>
<tr><td>


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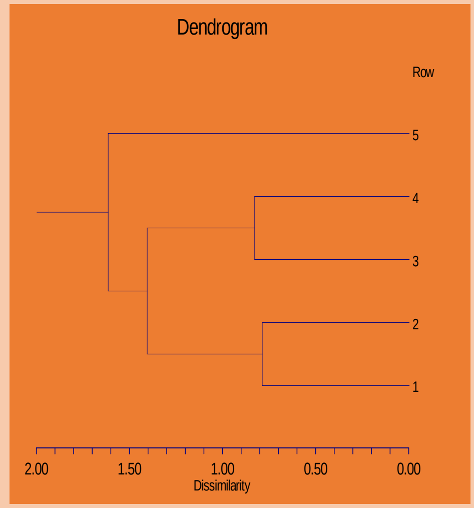
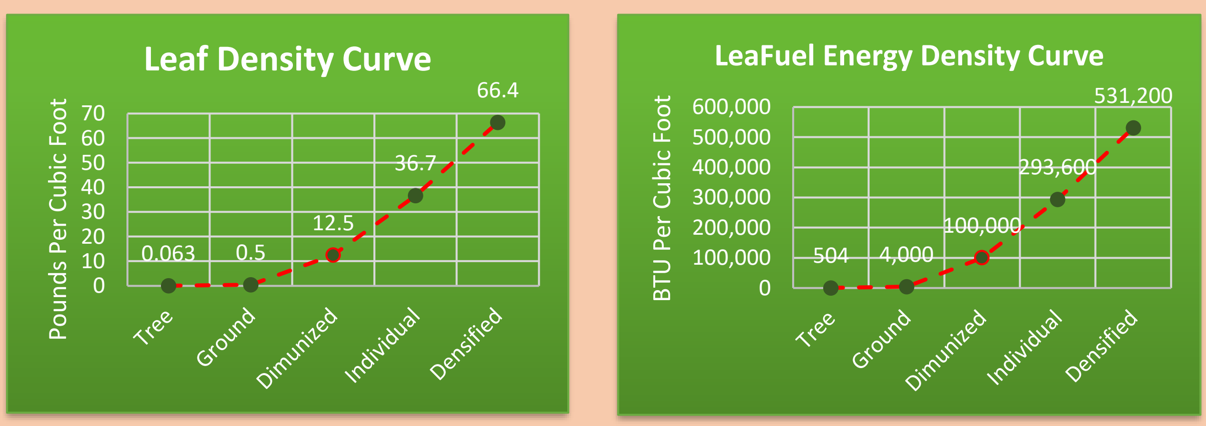


</td></tr>
<tr><td>Leaf Fuel, exhibiting one of the smallest footprints in 6-dimensional Fuel Attribute Space, characterizes as a milder heating fuel. Were cost included in the analysis, Leaf Fuel would achieve the greatest Benefit/Cost ratio.</td><td>Leaf Fuel and wood registered greatest similarity in the heating fuel array. Coal and oil were 78% different, and gas was more than 200% different.</td></tr>
</table>

Densification Need - On a volumetric basis, leaves are a bit like natural gas. One cubic foot of either contains less energy than early, weighty solid fuels. Natural gas overcomes its energy leanness by compression and streaming. Leaves as a fuel must compensate similarly. The graphs of Figure 2 show how the low natural density of leaves can be technically modified to elevate both mass density and energy density:

Figure 2 - Leaf Mass Density and Energy Density Curves



Although individual leaves have density similar to wood, their natural presentation on a tree or in a leaf blanket on the ground assembles them at a density 99% less. These airy bulk densities have traditionally proven less manageable for any type of energy harvest. Forest fires consume dry tree leaves in a flash of intense, destructive, non-manageable, non-practical heat. Ignited leaf piles tend to smolder and smoke, also attesting to non-functional leaf densities. Diminution produces a flowable leaf product about 1/3 the density of virgin leaf or wood. Like flowing natural gas, particulate leaf flows are able to concentrate the BTU benefit across time. Some home furnaces designed to burn wood chips could meter leaf particulate. However, the smaller, lighter particle size of diminized leaves might be risky to handle. A loose or aerated flow could present a flash hazard, like coal dust or natural gas (or even flour!).

Compressive densification of leaf fines can produce a leaf product denser than wood, even approaching mass densities of coal. My lab compression experiments repeatedly achieved a mass density similar to water (62.4 Lb/Ft^3). Upscaled, such densification could produce precisely molded products (logs, briquettes, wafers, rods, marble-size spheres, etc.) heavier and more energy-intense than wood. The energy density curve for 66 Lb/Ft^3 Leaf Fuel predicts a rather potent 530 MBTU/Ft^3. Such densified Leaf Fuel products will store easily and transport compactly.

Photographs of Leaf Fuel fines and MicroLogs in Figure 3 furnish evidence of process feasibility and practicality. It was necessary to lightly spray leaf fines before compaction-molding to achieve acceptable cohesion of the final MicroLogs. Aerosol sprays of either polyurethane or acrylic lacquer have yielded successful results. Evidence from these experiments suggest that any polymer with bonding quality will work. Non-exhaustive testing of oil-based and water-based paints and adhesives suggest that these broad realms of bonding agency are practical. Ideal hydrocarbon formulations economically bond, contribute energy value to the raw leaf product, and favorably alter oxidation behavior during combustion.

Figure 3 - Leaf Fuel Particulate and MicroLogs

Leaf Fuel Particulate (L)
Leaf Fuel taps the perpetual energy bank of U.S. forests, a standing stock covering approximately 820,525 square miles (22% of total land area). Resident leaf energy is estimated at 229 Quads. Were it cultivated to Pennsylvania's enviable Green Standard (60% land area), the U.S. leaf bank potential would be 621 Quads.

Sawdust Reference (R)
The U.S. produces 15 million tons of lumber mill fines annually with potential heating value of 0.13 Quads. It is a limited by-product wisely being tapped for mill heating via co-generation and home heating via products like Duraflame logs.

Leaf Fuel MicroLog
A light polymer spray was applied to leaf fines just before compression molding to a cylindrical shape 0.875"D x 1"L. Mineral oil and talcum powder were applied to the mold interior to facilitate extraction. Post-compression mass density was about 66 pounds per cubic foot. Energy density is estimated at 530,000 BTU per cubic foot.

Leaf Fuel Logs have the same energy density as wood logs, and are more geometrically precise. They spare the tree, and eclipse its one-time wood energy yield by 80-fold across tree lifetime.

Characteristics of Home Heating Fuels & Combustion Technology
Optimal Placement of Leaf Fuel within the Habitat Heating Realm

Individual dry leaves are similar to wood in energy content. Leaf Fuel particulate taps a free energy resource of multi-Quad magnitude. Efficient densification molding of particulate elevates energy content above wood, into the realm of coal, but without noxious, environmentally harmful sulfurous impurities. Densified Leaf Fuel contains as much energy as some coals, but it does not have as high a flame temperature. Accordingly, the rate of warming is less. Coal or wood is hard to start, and so is solid Leaf Fuel. Coal furnaces, once started, burn day and night, though cut back (damped or banked) in the evening. Fire places are lit with kindling, paper, gas pipes, etc., as needed, and extinguished at night.

The human habitat has dealt with warming rate diversity by generally locating hotter-flame coal furnaces further away, in a chilly basement. Lengthy ductwork delivers warmth to floor vents in each habitat room,

COMBUSTION HAZARDS

Solid fuels present generally less combustion hazard than fuels constituted as particulates, liquids or gases. Flame fronts on solid forms consume mass gradually, from the exterior, at the air interface. This 180-degree oxidation theater shrinks even further, to a 90-degree (or less) theater, to allow space for both O_2 intake and CO_2+H_2O exhaust processes.

Particulates, atomized liquids, or gaseous fuels are not so limited or unidimensional during combustion. The flame front is *spherically* active around the oxidizing species. When this tri-axial, 360-degree theater of combustion harbor critical species concentration, the three-dimensional flame fronts hyper-react, taking on the character of an explosion.

cooling the convection air to a temperature comfortably below the furnace proper during the transfer. Gas furnaces, also based upon high-BTU and high-flame-temperature fuel, usually are basement situated and fan-circulate hot air through lengthy ductwork with significant ΔT losses. A milder warming flow reaches habitat rooms at high or low registers. By contrast, tradition places wood-burning fireplaces **in** habitat rooms. The cooler wood flame temperature produces a more user-friendly, radiant heat or "glow." This distributed fireplace design does not lose heat to ductwork, nor surrender radiant heating from burning flames or embers to a chilly basement. Neither does it heat unoccupied rooms, as does central heating. Fireplace flues exhausting through the roof yield waste heat (secondary heat) to upper floors or attic space *after* their primary room-heating responsibility has been discharged.

It is interesting to observe that many heating devices entering the present marketplace are configured like little fireplaces, or improve upon the traditional fireplace. Once popular kerosene heaters have given way to safer electric filament conduction-radiant units, usually with integrated fans. The most common power rating of these is about 1,500 Watts or 5,000 BTU/Hr. They are marketed with claims of about 500 Ft^2 (room size) warming capability, and can be moved from room to room. Energy-conscious citizens owning homes equipped with traditional wood-burning fireplaces have retro-fitted using glass fronts, powered air circulation, special venting, etc. Such changes raise hearth temperature, increase combustion efficiency, tap radiant heating values, and generally deliver a warmer, cozier, prettier, smoke-free room (no duct losses, gas explosion hazard, open-valve asphyxiation, unaffordable energy bill, or risk of service termination). Room-specific heating, now supplementary, may become primary in the future . . . an old tradition re-born with perpetual Green Energy Streams.

Leaf Fuel Design: Optimizing Process & Product Attributes

Leaf Morphology – Fully dried, Fall leaves from Mulberry, Maple, and Oak trees were collected to furnish raw material for my research to compose suitable Leaf Fuel (Figures 4 and 5). Typical sizes and weights are reported in Table 2, with reference to a familiar, similarly thin combustible: copy paper. Tree leaves ranged 2X to 5X thicker than copy paper, but positioned on either side of paper density. Photomicrography (Figures 9, 10, 11) revealed small cellular texture within the leaf, typically 1.5 square mils in area (1 mil = 0.001"). Stems registering around 0.04" diameter can be as lengthy as the leaf, and often remain connected to fallen leaves.

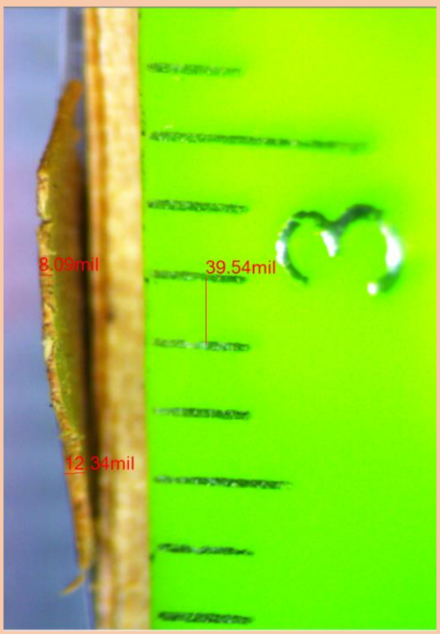
Table 2 - Leaf Morphology

Leaf	Length Inch	Width Inch	Area Sq Inch	Actual % (L x W)	Thickness Inch	Relative Thickness	Weight Oz	Density Oz/In^3	Relative Density
Oak	6	5	17	57%	0.02	476%	0.040	0.47	115%
Maple	5.5	6	17	52%	0.01	238%	0.035	0.21	51%
20# Paper (Ref)	11	8.5	93.5	100%	0.0042	100%	0.16	0.41	100%

Figure 4 - Leaf Graphics

		
Fall Mulberry Leaf	**Fall Maple Leaf**	**Fall Oak Leaves**

Figure 5 – Photomicrograph of Oak Leaf Edge (20X Magnification)



Quantitative photomicrography of leaves can understate thickness. The 20X magnified oak leaf edge displayed left next to a graduated rule registers 8.09-12.34 mils or 0.008-0.012." The pure edges at leaf margins or within the lamina varied 20% around an average thickness of 10 mils. Absent from the photomicrograph were thicker leaf structures of veins, midrib, and petiole (stem). Venation in dichotomous leaves progressively subdivides from the petiole root into a finely detailed cellular network towards the periphery. Micrometer readings of leaf thickness reported in Table 2 were derived by averaging several readings taken across the leaf surface. Accordingly, midrib and veins influencing those measurements *doubled* the estimate of average thickness to 0.02". All parts of a leaf, including the stem, possess energy values capturable via combustion. What intricately and efficiently serves the photosynthesis process of green leaves reverts to combustion fuel value as Nature colorfully "scraps" the leaves in the Fall. Like coal or wood, dead leaves can be chemically converted to liquid fuel, but the process is not very efficient. Maximal energy recovery derives from combusting the solid product. Preparing leaves and furnaces to win useful leaf combustion heat for societal use is the central subject of this invention.

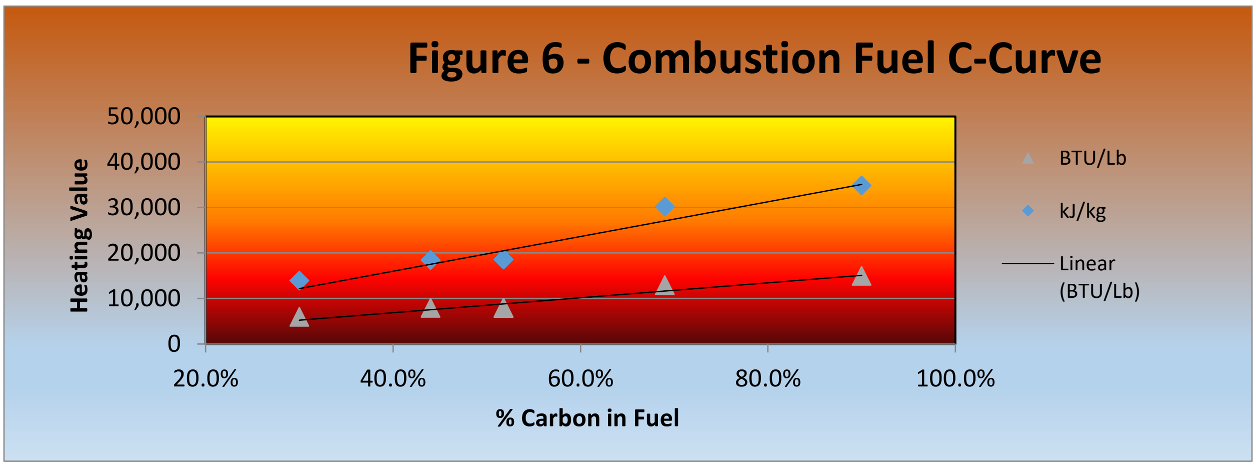
Table 3 - National Research Center for Coal Energy (NRCCE) Chemical & Calorimeter Analyses

Identification	%C	%N	%S	%H	Lb/Ft^3	BTU/Lb
Dry Mulberry Leaf Fuel	47.0	1.7	0	6.6	45.4	7,958
Cigarette Tobacco	42.0	2.5	0.3	6.2	15.9	6,733
Dry Grass Fuel	38.8	2.8	0.2	6.0	62.5	6,490
Hay	41.9	0.5	0.0	6.1	42.5	6,580
Paper	44.4	0.2	0.0	6.1	66.3	7,598

Table 4 - Coal Reference

Type	U.S. %	%C	%N	%S	%H	%H_2O	%Ash	Lb/Ft^3	BTU/Lb
Anthracite	<1	85-98	1-2	0.5-1	2	5	10-20	94	13,000-15,000
Bituminous	65	45-85	1-2	0.5-4	5	5-10	2-12	84	11,000-15,000
Lignite	10	25-35	1-2	0.5-2	5	30-60	10-50	50	5,500-8,300
(1) Subbituminous (~25% of U.S. market) omitted. (2) N and S in coal bring acid rain pollution. (3) Moisture reduces heating value. (4) Ash contributes to air pollution. (5) It takes 966 pounds of coal (nearly ½ ton) to light a 100W light bulb one year. I regard the extreme coal consumption required for illumination an encouragement to conserve night-time lighting. Essentially unoccupied commercial establishments (shopping malls, shopping centers, office buildings, factories, warehouses, etc.) can be dark or intermittently lit at night, saving precious energy resources and relieving climate damage.									

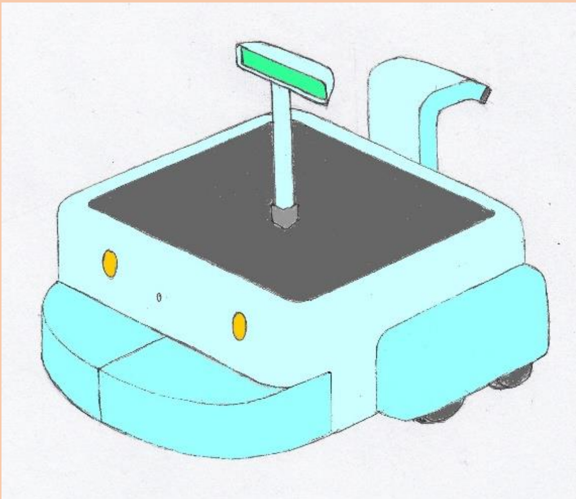
Carbon and hydrogen are prime reactants in hydrocarbon fuels. Since carbon presence affords the multi-dimensional attachment core for hydrogen in H-C fuels, there exists a relatively robust estimator of *heating value* based on carbon content only. My efforts to quantify this relationship (including Green Stream Energy Resources) is illustrated in the Figure 6.



Leaf Collection – Green Stream Energy harvest benefits from, but does not require, novel leaf collection. Manual gathering into bags or trash cans, and raking into piles for on-site burning or packing are among traditional means to handle Fall leaves. Among automated means, leaf blowers are widely used to "herd" leaves of the field to a point of disposal. I adapted my residential power mower for leaf diminution and pick-up by maximally jacking up the rolling clearance (I achieved about 5" ground clearance) and "mowing" the layer of fallen leaves spread over my dormant lawn. The standard grass catcher proved suitable for accumulating mowed leaves blade-reduced to about 1" x 1" size. The reduced leaf bulk compactly filling the grass catcher was transferred to plastic trash cans for dumping or packing into garbage bags for later municipal trash pick-up. Trash cans and garbage bags filled far more efficiently with blade-reduced leaves than raked or hand-gathered whole leaves.

I have designed special leaf-gathering-and-reduction equipment and process based upon positive experiences with leaf collection via power mower. One promising automated design (termed "Leaf Puppy" for its small size and retrieving prowess) is displayed in Figure 7 with explanation. Not illustrated, but interacting with the Leaf Puppy, is a self-propelled, self-guiding Follower Car. It electronically tethers to the Leaf Puppy, continuously receiving leaf particulate into its cargo bay. When filled, it programmatically navigates to an in-ground storage silo on the property to deposit its cache of leaf particulate. The Follower Car then returns to a trail position behind the Leaf Puppy to initiate another collection cycle. The 2012 introduction of a robotic home lawn mower, the Miimo, by Honda Motor Company, implies feasibility of robotic leaf collection.

Figure 7 - Leaf Puppy Robotic Leaf Retriever & Digester



Leaf Puppy Operation

About the size of a home lawn mower, the Leaf Puppy automates leaf gathering and diminution for home owners. It is self-navigating across the property for leaf pickup, akin to programmatic floor cleaning inside the home using the popular Roomba floor vacuum (iRobot Corp.). Front jaws open laterally, doubling the swept width of leaf collection. A series of rotating blades on the interior draw in and fragment the forward leaf blanket. Leaf particulate is expelled out a rear chute into an electronically tethered Follower Unit (not shown). As each Follower Car fills to capacity, it electronically disengages and a trained replacement Follower moves forward and electronically locks-on. Dual headlamps, like eyes, light the Leaf Puppy path ahead. A high-frequency horn "nose" warns away forest creatures. Easy-to-remove-and-service modular dual traction wheels on each side of the Leaf Puppy drive and steer it. Guidance electronics are housed in a top-mounted periscopic sensor that descends out of the way during storage. A solar roof panel furnishes electricity for the unit's electronics and trickle-charges the battery. Gas or alcohol (latter won from collected foliage) fuels the Pup's key-starting IC engine.

Bulk Leaf Fuel Pneumatic Transfer – Complementing automated collection and reduction of Fall yard leaves afforded by the Leaf Puppy and its trained Follower Car(s) is another of my design innovations intending clean, easy, focused transfer of leaf particulate. It involves use of a flexible hose of 2"D to 4"D that smoothly and neatly conducts leaf particulate pneumatically from one place to another (e.g., from storage silo to Leaf Fuel Log fabricating shed or garage, or from the storage silo directly into a home furnace capable of directly burning metered Leaf Fuel particulate). Since the harvest of dry leaf energy ideally occurs during a brief 4-6 week Fall season interval, yet the use of Leaf Fuel particulate or logs spreads over the entire cold weather season, capability to periodically and conveniently draw from weather-protected leaf reserves or silo storage is anticipated. Predecessor technology attesting to the feasibility of tidy bulk transfer of leaf fines includes (1) commercial leaf blowers that use a directed stream of air to diffusely herd fallen leaves into piles for bagging, and (2) pneumatic mail tubes used by department stores and other business establishments to propel mail capsules from one room to another in the same building.

On-property management of fallen dry leaves is an unavoidable burden to the homeowner. He must collect and dispose, usually through the MSW system which entails a cost of $100/T. Retaining leaves to harvest energy values avoids associated MSW expense. That savings subsidizes diminution, bonding, and molding cost necessary to make Leaf Fuel.

Leaf Particulate – Laboratory scale production of leaf particulate from gathered leaves was accomplished using a 450-watt 10-speed Osterizer. Diminution to about 0.02 square-inch or less particle size required 1-2 minutes at low speed. Mulberry and Maple leaves reduced more than Oak leaves. A *working model* for leaf particulate supporting over 200 laboratory experiments gave rise to a particle size distribution specification ranging from dust to about ¼" inch major length. This particulate characteristic successfully formed various aggregate Leaf Fuel products, including MicroLogs (nominally 0.8"D x 1"L), MiniLogs (nominally 0.8"D x 3"L), and Standard Logs (nominally 4"D x 13"L). Accumulated lab-scale experience validates the importance of reducing dry leaves to a free-flowing particulate stream for (1) transit/handling ease, (2) storage ease, (3) processing ease, and (4) to achieve *multidimensional combustion* behavior in solid Leaf Fuel products. Leaf stems, more resistant to diminution, often persist to final lengths of ½" or more. They were extracted by hand when seeming to interfere with molding smaller aggregate Leaf Fuel products. In Standard Leaf Fuel Logs or in free-flowing Bulk Leaf Fuel, entrained stem pieces appear not to compromise particulate flow, log integrity, or combustion quality.

The influence of leaf particulates on combustion quality deserves further elaboration here. It is generally understood and taught elsewhere in this document that solids burn more readily if they can be reduced to a more finely-divided form. For example, lighting a large log is more difficult than igniting kindling, or igniting a stack of paper is more difficult than igniting one thin paper sheet. It also is generally understood that thin, small leaves burn more readily than the wood of a tree, especially in propagating a forest fire. Furthermore, a pile of whole, dry leaves is known to be less completely combustible than an individual leaf lit by a match.

Tested in connection with my invention of Leaf Fuel was the combustion behavior of single dry leaves (see Figure 8). It was found that igniting single, horizontally-positioned leaves often did not consume the entire leaf. Even adding a lively hydrocarbon accelerator to the leaf surface (e.g., polyurethane) did not bring about total combustion. On the other hand, vertical positioning of individual leaves, making each act like a wick, did result in complete (and more rapid) burning. Low flame temperature of leaves with respect to other solid fuels explains much of the position sensitivity to leaf combustion. When the flame can preheat adjacent dry leaf material (as in the vertical "wick" position), it more readily and completely combusts.

Figure 8 – Whole Leaf Flame Propagation Study

Above is an example of a concluded flame propagation test on horizontally positioned whole Maple leaves. From left to right: (1) uncoated, (2) one-side polyurethane spray-coated, (3) 2-side polyurethane-spray coated. Results show benefit of poly coating, but reveal limited *horizontal* flame propagation.

Example of whole-leaf flame propagation with leaves set *vertical* prior to ignition. The same left-to-right pattern was used (1) uncoated, (2) one-side polyurethane spray-coated, and 2-side polyurethane spray-coated. Combustion was so accelerated that all leaves were consumed rapidly, burning even stems and masking tape hangers. Vertical flame quickly preheats upside leaf and coating to ignition temperature, with leaf behaving like a candle with a consumable wick.

Reducing leaf size via diminution puts dry leaf particles in closer proximity than in the case of piles of whole leaves. The small area of leaf particles creates less flame propagation distance to bring full combustion on the horizontal. Vertically-oriented particulate theoretically recreates the favorable *wicking effect* mentioned earlier. Combustion of a particulate pile is advantageous because it is free of flat laying leaves (blanket effect), as in a smoky burn pile. Leaf fines tend toward a circular form. In a loose pile (or within a log mold), particulates tend toward a blanket-free, random orientation (isotropism). Bottom ignition (common fireplace practice with a gas ignition tube under a fireplace grate) can be expected to bring a primary (higher velocity) vertical flame propagation and secondary (lower velocity) lateral flame propagation. The combined effect of particulate circularization and randomization favors efficient, complete, *multi-dimensional* combustion.

Figure 9 - Photomicrograph of Dry Bulk Leaf Fuel Particulate (20X Magnification)

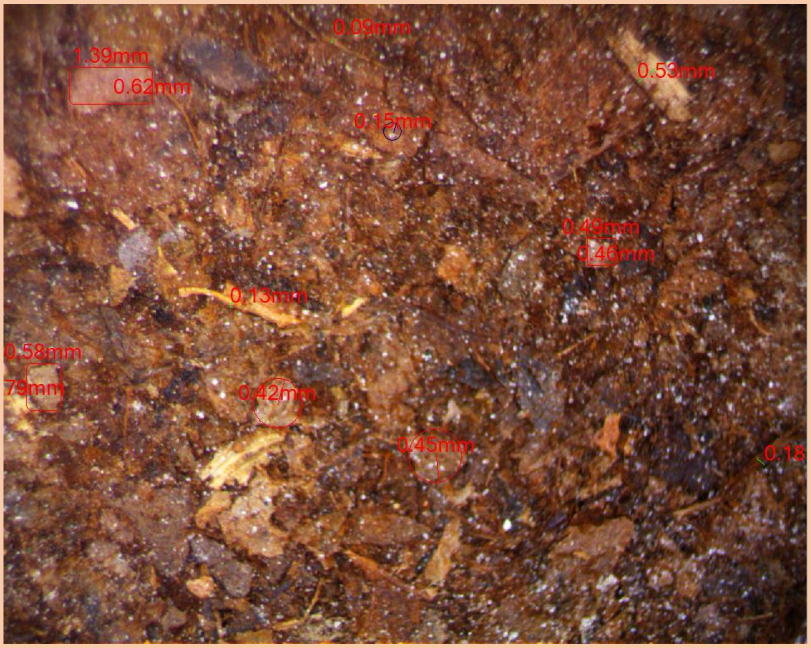
Dry, uncoated Oak Leaf Fuel particulate generally exhibit greater size diversity than Mulberry or Maple particulates. Large particles were typified by L=2.3mm (0.09"), L/l=130%, A=13mm^2 (0.02 in^2). Small particles were L=0.88mm (0.03"), L/l=122%, A=2mm^2 (0.003 in^2). A very small particle was 0.12mm^2 (0.0002 in^2). Oak cells were about r=0.2mm (0.008"), A=0.13mm2 (0.0002 in^2). Stem diameters were about 0.75mm (0.03").

Bonding Agents – Polyurethane and paraffin are among bonding agents for producing solid fuel rocket engines, that also are commonly and inexpensively available. They augment the lively burning of more expensive, often exotic rocket fuels they bind. All rocket fuels are rated for specific impulse (I_{sp}), a measure of fuel efficiency somewhat like miles per gallon. Polyurethane and paraffin register about I_{sp}=210-250. No thrust requirement exists for Leaf Fuel combustion, but higher I_{sp} values imply efficient flame production. Dry leaves are basically costless (even subsidized) combustion energy whose utility for home or factory heating rises to practicality by researching-discovering-experimenting-validating technically-optimized, minimum-cost-bearing processes for diminution and bonding. Accordingly, the prime array of binder "hopefuls" for leaf particulate were drawn from liquid or solid hydrocarbon species typified by (1) good leaf affinity, (2) low cost, (3) wide availability, (4) easy shipping & handling, (5) processing safety, (6) process energy rationality (energy output > energy input), (6) consumer safety, (7) combustion-enhancement, and (8) success in binding applications.

Two theories of particulate bonding are instrumental in the transformation of Leaf Fuel into solid combustion products, like fire logs. The first bonding system I developed can be called Thin-Layer Bonding because only a very light coating of hydrocarbon polymer is applied. Any air-dried, spray-applied combustible paint formulation, oil-based or water-based, usually clear (pigmented is not excluded, just not necessary), any specularity (gloss, semi-gloss, satin, or flat) will do. Air-dry glue, oil-based or water-based, will do, but these must be dilutable enough to blend into leaf particulate without clumping or producing more than a very thin overlay. Experiments performed on behalf of this invention have found spray paints faster to apply and easier to handle than glue admixtures.

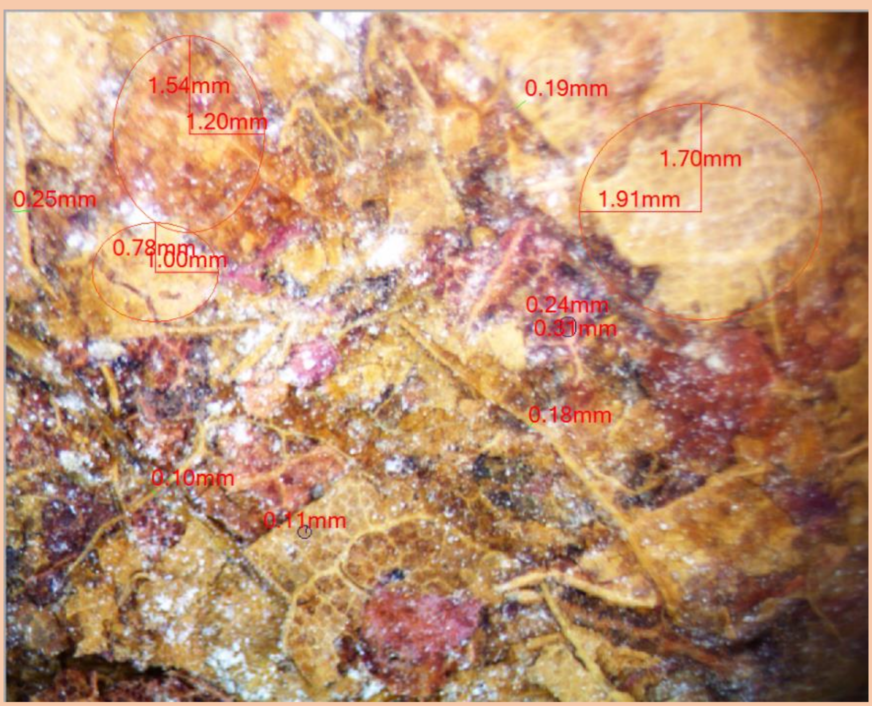
Most Thin-Layer Bonding work behind solid Leaf Fuel products has been in the polyurethane system. It is desirable for a bonding agent to burn as well as or better than leaf particulate. Polyurethanes are widely available, relatively inexpensive, and achieve a high degree of bonding in thin or thick layers. Thin Layer Bonding responds well to Densification, since compressive forces are readily transmitted from leaf particle to leaf particle, expelling air entrained from the bulk mass, and favoring a tri-axial stress state capable of raising the core density of solid leaf particulate.

Figure 10 – Thin Layer Poly Bonding of Densified Mulberry Leaf Fuel MicroLog (20X Magnification)



This photomicrograph reveals textural features at one end of a Mulberry Leaf Fuel MicroLog. Particulate parallel to the surface are generally fine-grained. Largest was 0.9mm^2 (0.001 in^2). Cell size was about 0.07mm^2 (0.0001 in2). A large stem is visible (D=.53mm or 0.02”), but most stem fragments were smaller (D=0.09-0.18mm or 0.004-0.007”). Spray-applied Thin-Layer poly bonding agent is not visible. White dust is residual talcum mold-release agent. Structure is free of voids and cohesive. Mass density was 45 Lb/Ft3. Energy density was 8,000 BTU/Lb.

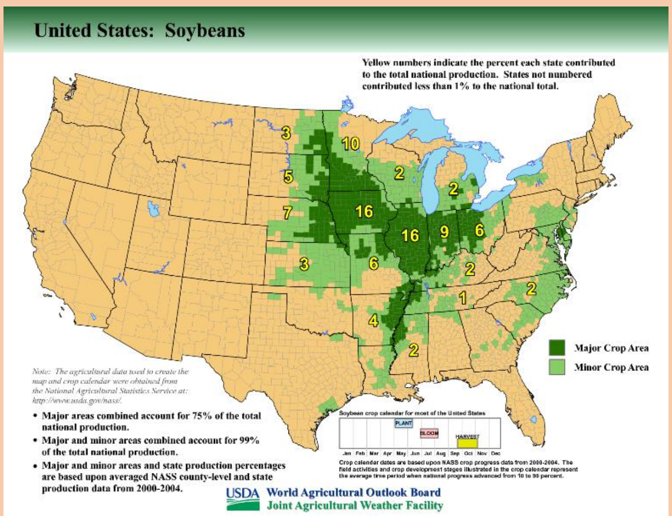
Figure 11 - Thin-Layer Poly Bonding of Densified Maple Leaf Fuel MicroLog (20X Magnification)



This photomicrograph reveals and measures particulate texture after Densification for a Maple Leaf Fuel MicroLog. An end view is shown because the longitudinal view was masked by talcum powder mold-release agent. Large dimensioned ovals sample particle size parallel to the surface [1.48mm. (0.06”) x 1.23mm (0.05”) or 120% D/d and A=5.8 mm^2 (A=0.009 in^2)]. Small circles sample cell size within a leaf fragment [r=0.16mm (r=0.006”) and A=0.08 mm^2 (A=0.0001 in^2)]. Green lineals sample stem diameter [d=0.18mm. (0.007”)]. White areas are talcum powder release agent. Poly bonding agent was not discernible. The sample exhibited good cohesion and achieved a compression density of 66.3 Lb/Ft^3.

The second system of bonding for Leaf Fuel solids can be called Hydrostatic Bonding. All Thin-Layer Bonding systems can be adapted to Hydrostatic Bonding by increasing binder thickness, or, more exactly, increasing their constituent volume or weight in the overall mix. Advantageously joining the preferred components of Hydrostatically Bound Leaf Fuel are candle waxes, like paraffin or soy. The former has high heat value (20 KBTU), derives from petroleum (a vanishing earth resource), and contains impurities. Soy wax, on the other hand, is a pure green vine product (soy beans) of perpetual availability (see Figure 12). The U.S.A. produces 60% of the world's supply in the strategically located, rail-intense Midwest and lower Mississippi Valley. Soy beans also can be grown on residential property as an attractive, low-profile homeowner energy crop. Residential Soy engages "free" real estate, affording a robust expansion policy for establishing Leaf Fuel. Farmland soybeans are a vital *food* product for man and animal that should not fall into shortage because of new uses. Food chain tension has risen by increasingly channeling agricultural corn into ethanol.

Figure 12 – U.S. Soy Bean Production

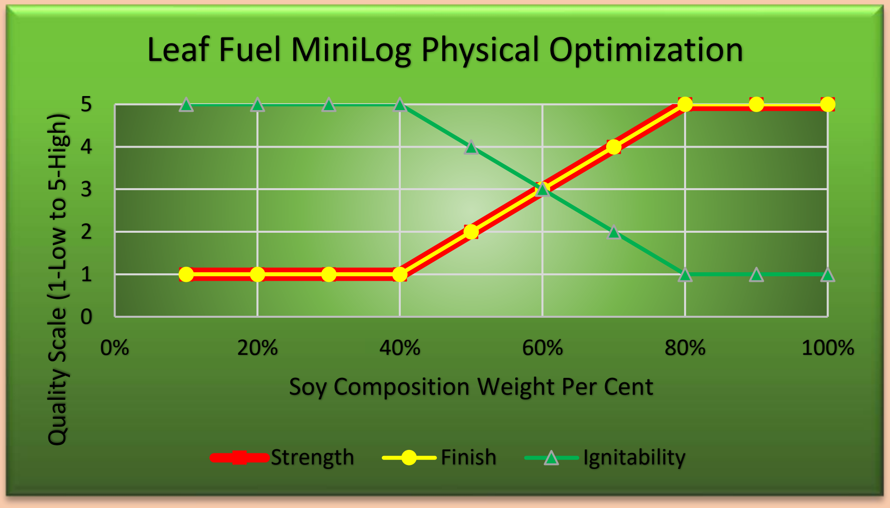


U.S. soybean production is ideally centered along the upper tier of States, convenient to Northern residents depending on combustion heat to survive winters. It also is convenient to the North East industrial core yet needing combustion heat to drive moderate-output, maintenance-level mature industry. Specific output is 44Bu/A, 0.53Lb/Yd2, or about 1 Oz/Ft^2.

Soy grows rather uniformly and densely into a level green foliage field 1'-3' tall. Such cultivation architecture confers to soy *home landscaping* potential, eliminating land expense and logistic expense from this vital energy crop. Owner seed-cycling and Leaf Fuel harvest creates *free home energy*. The food commitments of commercial soy would remain uncompromised by a well-constituted Residential Soy Policy. Furthermore, augmenting Residential Soy with small-footprint Hi-Tech Gardening should *more than double* historical agri-business soy productivity.

Leaf Fuel solids designed around Hydrostatic Bonding respond less to Densification. The bonding agent is solid at room temperature, so it must be added to leaf particulate in a molten state. Those who have engaged in-home candle-making are familiar with wax-melting procedures. It is reasonable to conceptualize the Leaf Fuel Log composed by Hydrostatic Bonding as a form of candle-making or candle-molding, with myriad leaf particles serving as a highly distributed, discontinuous wick. After intimately blending optimal amounts of particulate and molten wax, the mixture is fed into a compression mold. In this case, Densification is limited to driving entrained air from the solidifying mass. Leaf particulate does not become compressed (soy leaks out of mold seams under leaf-densifying pressure, instead of pressuring the particulate), so natural leaf mass density and leaf energy density do not increase.

Figure 13 – Optimizing Physical Properties of Leaf Fuel Logs

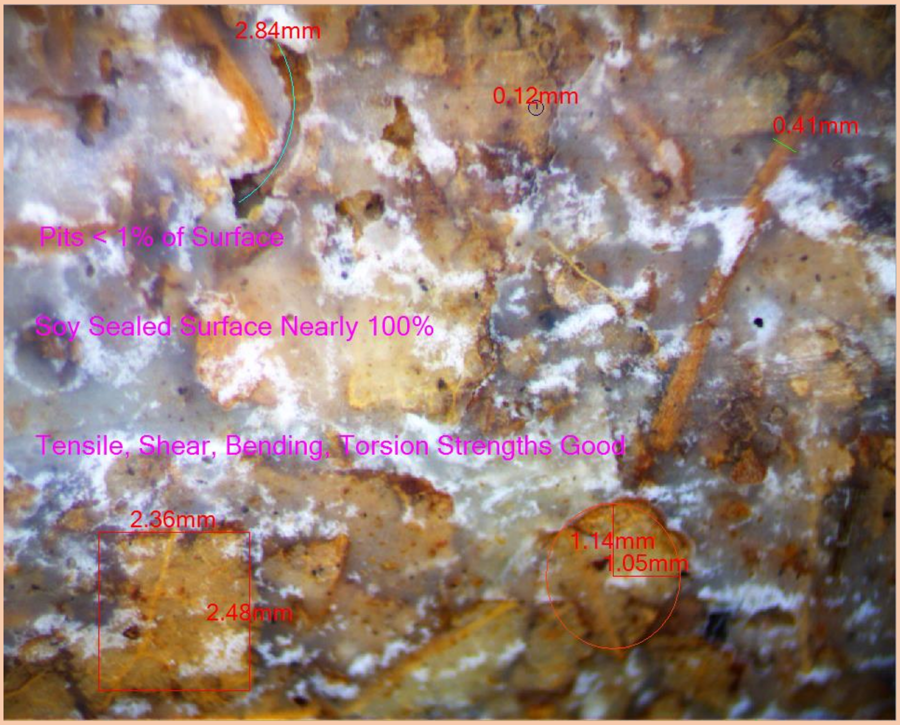


Soy is a low-strength binder for Leaf Fuel Logs. One aspect of physical optimization of the soy-bonded log is to include enough soy in the matrix to afford requisite cohesion. The graph above indicates that coherent logs can be fabricated when soy composition exceeds 40%. Surface quality tracks strength, implying that if soy has suitably infiltrated the particulate matrix for strength, log finish also improves (soy migrates to the surface, sealing it). Over-binding not only adds unnecessary cost to the Leaf Fuel Log, it inhibits ignition (soy becomes a wickless barrier to lighting). Accordingly, physical properties of soy-basis Leaf Fuel Logs macro-optimize at soy levels between 40% and 80% by weight, and micro-optimize at 60% to 70% by weight.

Table 5 - Some Bonding Agents for Leaf Fuel Particulate

Properties	Polyurethane	Polyurethane	White Glue	Paraffin	Soy
Solvent	Petro	Water	Water	N/A	N/A
Specific Gravity	0.84 wet/1.05 dry	1.0/1.05	0.76	0.80	0.627
Density Lb/Ft3	65.5 dry	65.5 dry	64.3 dry	49.9	39.1
Melting F	-	-	-	160	155
Flash F	104	104	N/A	395	350
Carbon %	64.3	64.3	50.7	85.2	78.3
Heating Value BTU/Lb	10,200	10,200	9,226	19,900	10,230
Heating Value BTU/Ft3	668,000	668,000	594,000	993,000	400,000
Ignition F	750	750	N/A	-	-
Flame F	2,400	2,400	N/A	2,600	<2,600
Tensile Strength PSI	3,000	3,000	3,600	200	800

Figure 13 – Hydrostatic Soy Bonding of Densified Oak Leaf Fuel MicroLog (20X Magnification)



This photomicrograph reveals and measures longitudinal particulate texture after compression molding optimal 64%Oak-36%Soy Leaf Fuel MicroLog using mineral oil for mold release (bulk volumetric percentages used). Oak particles parallel to the surface were generally larger than Maple particulate [example: L=2.5mm (0.1"), A=6 mm^2 (0.009 in^2)]. A sampled leaf cell was similar to Maple [r=0.12mm. (r=0.005") and A=0.05 mm^2 (A=0.00007 in^2)]. Stem lengths and diameters were generally larger than Maple (example D=0.41mm (0.02"). White area is solidified soy bonding agent, nearly sealing the surface 100%, and suggesting full expulsion of air within the particulate mass. Although soy tensile strength is not high, the MicroLog exhibited acceptable cohesion, tensile strength, and resistance to bending or torsion. Compression density was 49 Lb/Ft^3.

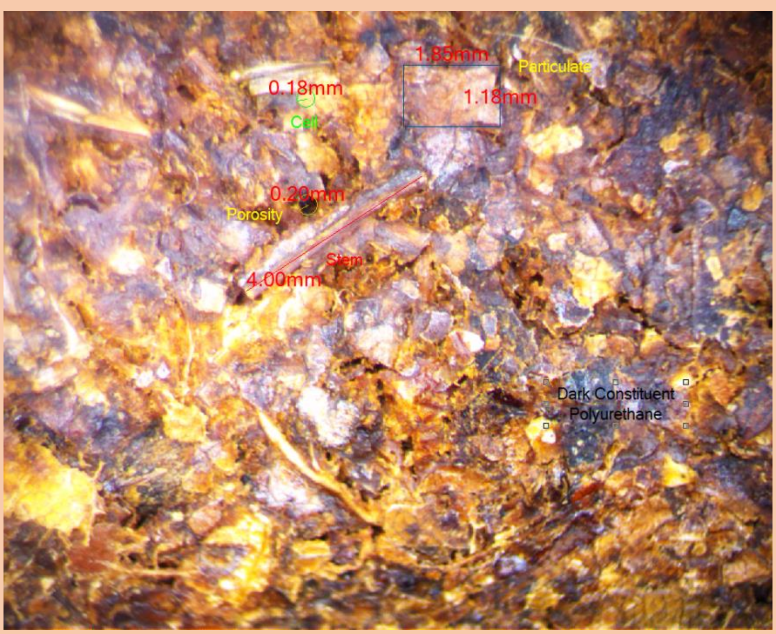
Figure 14 – Microstructure of Soy-Coated Oak Leaf Fuel Particulate (20X Magnification)

Coating dry Leaf Fuel particulate with a bonding agent results in compound particles of generally larger size. The photomicrograph at left depicts about 20 diminized leaf particles forming a 100mm2 (0.16in^2) oak-soy compound particle. Coated Leaf Fuel eliminates dusty fines while preserving bulk flow characteristics. It adds soy cost to fully natural Leaf Fuel particulate, but soy pays its way in terms of heating value. At 10,230 BTU/soy pound, thermal values are \$0.017/KBTU or 60 KBTU/\$. Of course, soy must have the wicking benefit of integral Leaf Fuel particulate to sustain burning.

Figure 15 – Soy-Coated Oak Leaf Fuel Particulate Natural Thickness Ratio (Photomicrograph @ 20X Magnification)

Instances of both leaf thickness and soy thickness are visible in this photomicrograph of a compound oak-soy particle edge. Oak leaf thickness averaged 0.25mm (0.01") and soy overlay averaged 0.42mm (0.017"). Absent densification, this thickness study infers how molten soy naturally spreads over (wets or coats) the leaf surface. The measured ratio of soy-to-leaf thickness was nearly 2-to-1 (actually 1.7). Were leaf particulate isolated particles, photomicrography implies that a coated leaf nearly triples its thickness, registering 77V% soy constituent. The more persuasive evidence of particulate *compounding* implies lamellar structure with a repeating unit of 0.25mm leaf mating to a 0.42mm soy layer, or 63V% soy. The latter postulates a natural optima for leaf+soy constituency in a large solid product, like a log.

Figure 16 - Hydrostatic Polyurethane Bonding of Densified Leaf Fuel MicroLog (10X Magnification)



This photomicrograph reveals and measures longitudinal surface texture of a polyurethane-bonded (35% by volume or 72% by weight of water-based poly) Leaf Fuel Minilog. Mineral oil was used for mold release. A variety of leaf types composed the Particulate. Particle size parallel to the surface was around 2.2mm^2 (0.003in^2). A sampled leaf cell was 0.10 mm^2 (0.0002in^2). Stem length was 4mm (0.16"). Dark areas on the photomicrograph are solidified polyurethane. Individual pits were about 0.13mm^2 (0.0002in^2), while total porosity appeared less than 5%. The MiniLog exhibited acceptable cohesion, strength, and resistance to bending. Compressed density was 57 Lb/Ft^3. Energy density was 9,500 BTU/Lb. At standard size, weight would be 6 Lb and energy content 57 KBTU. Pricing aqueous polyurethane at $1.00/pint or pound, a standard log would cost $4.50, and energy economy would be $0.08/KBTU or 13 KBTU/$. These economics favor polyurethane more for Thin Layer Bonding.

Densification – Dry leaves derive greater utility as a combustion fuel as they are densified. Thermo-mechanical properties of individual leaves resemble that of wood. However, too much chilling air surrounds tree or ground leaves to support focused, useful, controlled combustion. Leaf diminution to particulate improves combustion utility. For example, it can be optimally metered into an active flame hearth. Particulate heating value is about 1/3 of a natural leaf and 1/6 of densified particulate. Accordingly, there is a strong thermodynamic reward for densifying Leaf Fuel. Densified logs, briquettes, or wafers also ship far more space-efficiently than bulk leaf particulate.

When Thin-Layer Bonding is used to produce a solid Leaf Fuel product, energy density of the condensed mass can be raised above that of pure leaf or wood. Well-designed Densification can create a fire log with precise cylindrical geometry, full homogeneity (entrained air expelled), and energy potency *above* traditional fire wood. A Leaf Fuel Fire Log standardized at 4"D x 15"L can pack more orderly firepower than split firewood. It can reach fuel values in the lower ranks of coal without pollutants or dust hazards associated with coal.

Molding Leaf Fuel Logs - Solid fuels of great service to mankind have not been used in their natural state. Wood is sawn, chopped, and split to a manageable size, and seasoned. Veins of coal are broken down into transportable, more easily combustible lumps. Leaf Fuel may be thought of as an extension of tree wood, conveniently reduced by Nature to thinness of a leaf, seasoned on the vine during the Fall, and dropped to the forest floor for relatively easy recovery. Diminution of the already light leaf product yields a particulate with infinite molding opportunities to final form. The latter versatility associates with other molded products, like concrete, plastic, and ceramics.

At this stage of development, molding log forms from Leaf Fuel Particulate at the same scale as cord wood seems ideal. The consumer can easily relate a Leaf Fuel Log to its technical predecessor, the firewood log. Because split wood is non-uniform, the precise geometry of a molded log affords more predictable handling and heating experience. I like to think that the Leaf Fuel Log is a little prettier than Natures cut & split tree limbs, a little kinder to the hands of preparation (no splinters or blisters), re-directs yard clutter to a life-preserving home-heating product, and saves the precious, beautiful trees of Nature.

Three stages of mold development for Leaf Fuel Log fabrication were engaged in the Green Fire Project: The MicroLog, the MiniLog, and the Standard Log. This section chronicles molding process development in pictures and explanatory text.

The MicroLog Mold & Molding Process

Figure 17 – Molding Leaf Fuel MicroLogs

17a Basic PVC MicroLog mold 0.875"ID x 2.75"L with two 0.875"OD x 1"L wood compression ends. Wood ejector 0.875"D x 4"L shown parallel to the mold.

17b MicroLog Mold with interior oiled & powdered for mold release is filled with freshly poly-sprayed Leaf Fuel Particulate and densified using C-clamp leveraging.

17c Vertical MicroLog Mold after wood compression ends are removed reveals densified Leaf Fuel ready to be ejected using adjacent wood ejector.

The MiniLog Mold & Molding Process

Figure 18 - Molding Leaf Fuel MiniLogs

18a Molding station for soy-bonded Leaf Fuel MiniLogs. Upscaling log length is easier if the PVC mold cylinder is symmetrically parted longitudinally (see upper left). Log ejection force with a one-piece mold (as in Figure 17) becomes extreme as length increments upward. Invoking partability reduces ejection force 50%. Visible in this frame is a melting skillet for soy flakes (lower right), mixing cup with pre-measured leaf particulate charge (top left), and wood loading platform.

18b Lubed PVC MiniLog mold sections are hose-clamped together, assembly secured in the blind positioning hole at the center of the wood loading platform. Pre-measured soy flakes are heated above the melting point of 155F, but safely below the flash point of 350F, and intimately mixed with leaf particulate. The molten soy + leaf particulate mixture is funnel-fed into the vertical mold assembly, aided by a wood plunger rod (left), until full.

18c Wood compressors are inserted into each end of a charged MiniLog assembly, then hammered to achieve densification. Since soy is molten, densification mainly expels entrained air, producing a dual-phase matrix of leaf particulate and soy exhibiting perfect integrity. The densification end-point is reached when molten soy oozes from the mold parting line (there is no benefit to expelling cost-bearing soy to further densify costless leaf particulate). Soy-enriched log molds are refrigerated for 30 minutes prior to opening. Poly-enriched log molds are held at room temperature for 24 hours (initial set), then half-opened to air dry for 24 hours (final hardening).

The Standard Log Mold & Molding Process

Figure 19 – Molding Leaf Fuel Standard Logs

 19a Longitudinally split PVC mold 4"D x 15"L with mineral oil to interior for mold release.	 19b Hose-clamped PVC mold mounted in slide-in base	 19c Log mold with top joint and 18"L extension tube to accommodate compaction work space
 19d Preheating mold assembly, tamper (L) & compression tie-downs	 19e Pre-measured, dry Leaf Fuel Particulate charge	 19f Heat pre-measured soy sufficiently above melting point to allow time for mixing, molding, and compression
 19g Intimate contact between leaf particulate and molten soy is achieved during the mixing step. Visual signal is "glistening" throughout the blend, no bottom pool of excess molten soy.	 19h Improvised funnel (from plastic water container) is used to transfer soy-coated Leaf Fuel Particulate to the vertical mold assembly.	 19i At standard log size, a tamping tool was improvised to compact the coated Leaf Fuel Particulate. A screw-in or screw-down end cap or super-size c-clamp would make densification easier.
 19j To expeditiously solidify the molten soy and form a tight, solid-state leaf-soy matrix, the standard log mold was flash-chilled in a home refrigerator freezer for 30 minutes.	 19k The final Leaf Fuel Log extracted from the standard size mold came in near standard size: 4"D x 13.5"L.	

Photomicrography of Commercial Solid-State Combustion Products

Figure 20 – Comparative Microstructures of Familiar Combustibles (20X Magnification)

		
Charcoal – This coal-derivative is optimized for home grilling by compressing particulate into briquettes. Except for tiny fissures, the surface is monolithic and microporous. It requires general priming (petro distillate lighter fluid), and must array in a close-contact-pile to deliver precious heat value. 13 Lb/Ft3 13,000 BTU/Lb $0.47/Lb $36/MBTU or 28 KBTU/$	**Firewood** – Homeowners still use seasoned firewood, the home heating choice of antiquity. In this age of energy shortage, great forests of the world have been cut back strongly to harvest vital heat energy, altering global climate. A cellulosic material, wood microstructure is monolithic and requires priming to harvest heat. 37 Lb/Ft3 8,000 BTU/Lb $0.05/Lb $6/MBTU or 160 KBTU/$	**Cigarette** – Society's first widely-burned leaf product, tobacco is carefully cured (but not fully dried), diminized by shredding, and rather loosely wrapped into a cigarette (a log form). It requires match priming and forced horizontal aeration (puffing) for combustion. Burning tobacco is smoky and toxic. 16 Lb/Ft3 6,733 BTU/Lb $127/Lb $0.02/BTU or 53 BTU/$

Photomicrography studies above support concepts of seasoning for full moisture elimination, diminution for better flame propagation, and densification to concentrate heating value and raise economy. Cost-avoiding Leaf Fuel (it turns a waste product into valuable energy at the homeowner's fingertips) provides thermal units at little or no cost, especially if the consumer self-produces the product. Investing Leaf Fuel with an admixture like soy can add cost if the homeowner chooses to buy rather than grow his own soybeans. During 2015, soybean prices trended downward from $367/MT ($0.17/Lb) to $352/MT ($0.16/Lb). An optimized Oak-Soy Leaf Fuel Log weighing 5.5 Lb can be expected to furnish 52,500 BTU. Soy cost (leaves are free or subsidized) of the Standard Log is $0.52, yielding an energy price of 100 KBTU/$ or $0.01/KBTU. Of course, if the homeowner grows soy in situ, neither the soy nor residential leaf product bear cost.

Commercial Combustion Fuel Economics - The economics of Leaf Fuel *maximally available* to the homeowner reveal home business opportunity. An enterprising individual can participate in the world energy market out of his own back yard. Table 6 summarizes key heating fuel attributes bearing on the energy marketplace. Since leaves are a surplus product of Nature carrying a disposal charge of $0.05/Lb, Leaf Fuel production from residential leaves is subsidized. For soy-bonded Leaf Fuel Logs, even the soy can be home-produced, cancelling the soy market finance charge. In essence, you do not have to pay the energy market or your labor charge for home-grown leaves or soy to heat your home. If the homeowner can bring his Leaf Fuel cost below the threshold set by alternate commercial fuel prices, he could prosper selling his *surplus* Leaf Fuel to others. Of course, the micro-supply model for Leaf Fuel confers most competitive economics within a regional scope of production and use (the neighborhood market operates at minimum cost). Accordingly, the regional entrepreneur will do best within the region, but also has an annually-limited supply opportunity selling any regional surplus Leaf Fuel energy outside the region at the going rate.

Table 6 - Energy Market for Home Heating

Fuel	KBTU/Lb	$/Lb	$/MBTU	KBTU/$	Issues
Leaf Fuel (home produced) 45-60 Lb/Ft3	9.3	$0 Out-Of-Pocket	$0	nothing is superior to home-based self-supply	Perpetual Regional Supply $0.05/Lb MSW Cost Avoidance Can Be Home Labor-Dependent Only
Cord Wood 37 Lb/Ft^3 $175/Cord (90 Ft^3)	8.0	$0.05	$6	160	Undervalues Resource Climate Damage Can Be Home Labor-Dependent Only
Bituminous 84 Lb/Ft^3 $100/T	12.1	$0.05	$4	250	Finite Supply Pollution Obstacles Finance-Dependent
Natural Gas 0.05 Lb/Ft^3 $2.66/KCF	23.2	$0.05	$2	500	Vanishing Supply Environmental Obstacles Explosion/Fire Hazard Huge Distribution Infrastructure Finance-Dependent
Heating Oil 55 Lb/Ft^3 $2.50/Gal	19.0	$0.36	$19	53	Vanishing Supply Finance-Dependent Expensive

**If Leaf Fuel is bound with commercial soy, standard log cost is $0.52*
**If Leaf Fuel is bound with commercial polyurethane, standard log cost is $4.50*

Combustion Heating Process

Leaf Fuel is a hydrocarbon fuel, and follows well-known hydrocarbon stoichiometry during combustion (oxidation reaction). It is not as simple a hydrocarbon as natural gas (methane: CH_4), but fully gaseous methane oxidation is easiest to understand:

$$CH_4\,(g) + 2O_2\,(g) = CO_2\,(g) + 2H_2O\,(g) \qquad \Delta H = -761 \text{ BTU (exothermic)} \qquad \text{Eq. 1}$$

Cellulose ($C_2H_{10}O_5$) is solid material with 21% carbon content thought to be a key constituent of wood or leaves. Since elemental analysis shows the carbon content of Leaf Fuel to be about 47%, and very close to wood, it is evident that the cellulose C-H-O compound characteristic must be adjusted to depict Leaf Fuel. Based upon composition ratios already validated, a minimal molar expression of 1C-1.6H-0.75O or a rounded expression of 20C-32H-15O appears to characterize Leaf Fuel's lengthy molecular compound. Leaf Fuel appears 2.24 times more carbon-rich than common cellulose, more than double the energy potency. The associated oxidation reaction does not balance simply, but patterns other hydrocarbon fuels:

$$C_{20}H_{32}O_{15}\,(s) + {\sim}20\ O_2\,(g) = 20CO_2\,(g) + 16H_2O\,(g) \quad \Delta H = -8{,}000 \text{ BTU/Lb (exothermic)} \qquad \text{Eq. 2}$$

Because Leaf Fuel molecules bear oxygen, they do not draw as heavily from oxygen in the atmosphere to produce heat. Also, less water vapor is released per heating unit. The latter reserves more energy for habitat heating, since less is committed to moisture vaporization.

Analytical tests widely used for the evaluation of coal as a solid fuel were performed on Leaf Fuel specimens by the National Research Center for Coal Energy (NRCCE) at West Virginia University. The tests included bomb calorimetry (ASTM D5865), proximate analysis (ASTM 3172), and ultimate analysis (ASTM 3176). Some results are reported in the Table below:

Table 7 - National Research Center for Coal Energy (NRCCE) Calorimeter Reproducibility Tests

Leaf Fuel*	Lb/Ft3	BTU/Lb	%C	%N	%S	%H	Moisture	Ash	Volatile
Mulberry (L)	45.37	7,696	46.96	1.66	0.009	6.52	8.39	11.53	63.43
Mulberry (L)	45.37	8,035	47.13	1.75	0.000	6.80	8.06	19.72	58.44
Mulberry (L)	45.37	8,143	46.75	1.56	0.000	6.56	8.40	17.35	59.34
Mulberry (P)	12.5	8,070	46.00	1.80	0.000	6.20	9.90	6.00	65.50
Mean	**45.37**	**7,986**	**46.71**	**1.69**	**0.002**	**6.52**	**8.69**	**13.65**	**61.68**
Std Dev	**0.00**	**198**	**0.50**	**0.11**	**0.005**	**0.25**	**0.82**	**6.15**	**3.35**
COV	**0%**	**2.5%**	**1.1%**	**6.2%**	**200%**	**3.8%**	**9.5%**	**45%**	**5.4%**

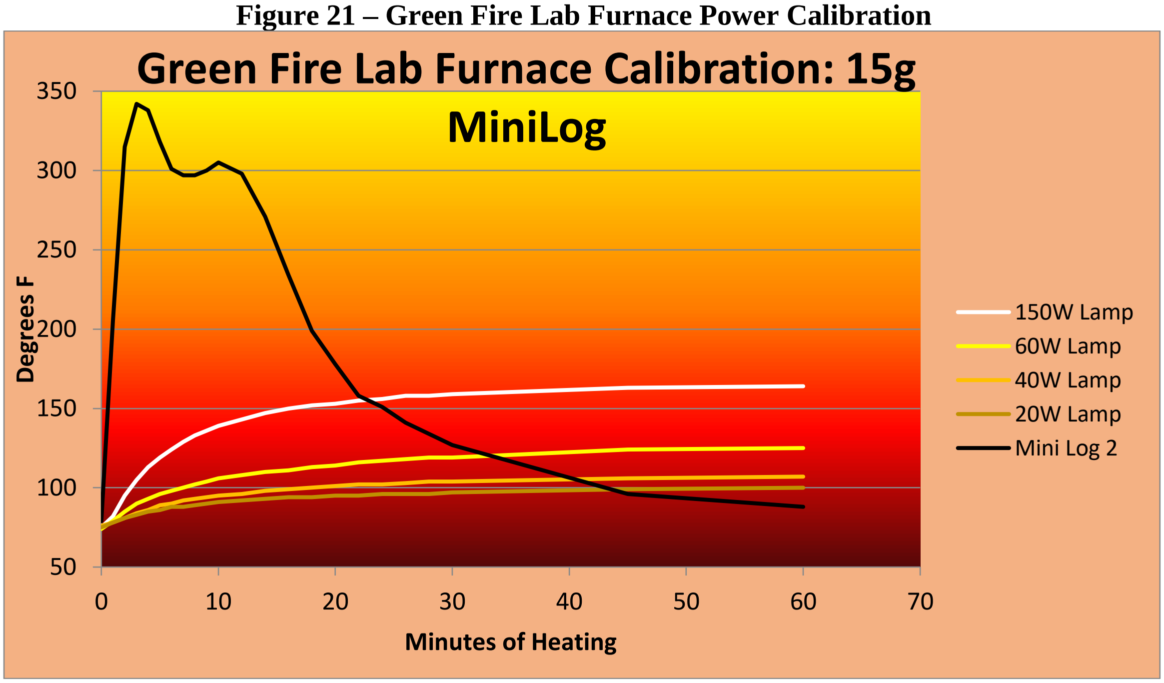
***MicroLog (L), Particulate (P)**

Table 8 - National Research Center for Coal Energy (NRCCE) Calorimetry Referencing Tests

Combustible	Lb/Ft3	BTU/Lb	%C	%N	%S	%H	Moisture	Ash	Volatile
Cigarette Tobacco	15.92	6,733	42.00	2.50	0.300	6.20	7.70	10.00	69.00
Grass Fuel	62.53	6,490	38.8	2.80	0.200	6.00	8.30	11.00	63.00
Hay Fuel	42.45	6,580	41.9	0.50	0.000	6.10	9.20	6.00	69.00
Newspaper	66.29	7,598	44.4	0.20	0.000	6.10	8.90	4.00	71.00

Based upon analytical results from WVU pertaining to combustion quality, Leaf Fuel specimens representing the perpetual Green Stream Energy exhibit characteristics of a viable solid fuel somewhat similar to wood. They were not equal to coal in heating value, but are free of sulfurous content (normally found in coal) that associates with acid rain. Relative to coals classified in ASTM 388, the heating value of Green Fire materials is approximately 50% of anthracite coal, 60% of bituminous coal, 80% of sub-bituminous coal, and on par with lignite.

Figure 21 – Green Fire Lab Furnace Power Calibration



The Green Fire Lab Furnace required calibration to assess heating rate or heating power (BTU/Hr) of Leaf Fuel Logs. Electric lamps of known but different wattage were used as standards for achieving a one-hour power signature (Watt-Hour or BTU/Hr) and equilibrium temperature (see Figure 21). The derived association between power and temperature allowed the time-temperature signature of Leaf Fuel MiniLogs to map instantaneous BTU/Hr (see Figure 23). Power output of the 15g Leaf Fuel MiniLog is seen to range between 0 and nearly 1,700 BTU/Hr, and average about 900 BTU/Hr. This information permits an estimate of the charge size for any desired *heating rate* (intensity) within the flame temperature envelope of Leaf Fuel (about 1,800F). For example, doubling the charge to 30g would about double the max heating rate to 3,400 BTU/Hr. In terms of log geometry, this weight increase can be conceptualized as an increase in log *diameter*. Similarly, the *hours of burning* can be controlled. If one 15g MiniLog delivers 900 BTU/Hr, adding a second 15g MiniLog would deliver another 900 BTU/Hr. Again, in terms of log geometry, the second hour of 900 BTU heating can be conceptualized as an increase in (doubling) Leaf Fuel Log *length*.

Typical hearth combustion is not so orderly as depicted above. Split firewood logs are not usually burned singly or from one end only. But, the exposited *geometric combustion model* mirrors reality better for precision-molded Leaf Fuel Logs than for split firewood. Given the standard Leaf Fuel log size of 4"D x 15"L, a diameter-based heating rate for a single log amounts to 18.8 KBTU/Hr. Estimating heat content of a standard 5.5 Lb Leaf Fuel Log at 53 KBTU, it would burn for about 2.8 hours. Another departure from assumed combustion reality associates with intrinsic variability of heating rate. Figure 18 reveals 100% variance in heating rate over the course of a single log's combustion campaign. Each log presents a saw-tooth curve of heating intensity. Burn a one-hour log and the room will be 2X hotter than average for the first 15 minutes (25% of heating time). The remaining 45 minutes (75%) of heating time will be increasingly below the average heating rate. Of course, any heat output during the lower cycle will warm the room. Relieving intrinsic cyclicality of hot-to-chilly episodes associated with any solid combustion fuel involves adding another log (or logs) to the fire during the chilly episode. Such tending for heat production levelling adds a little labor to the control process. Pellet furnaces now on the market precisely and automatically meter fuel into the combustion chamber. They should be able to process the finely-divided, Coated Leaf Fuel Particulate, and thereby relieve heat production levelling labor associated with discrete logs.

Figure 22 – Green Fire Lab Furnace Leaf Fuel Particulate Combustion Tests

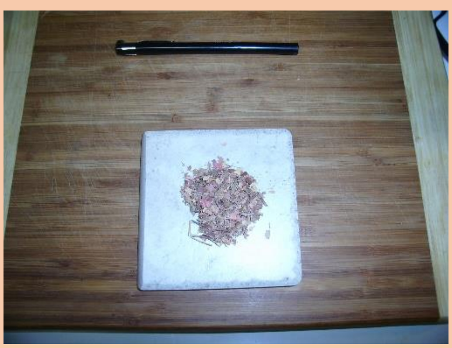
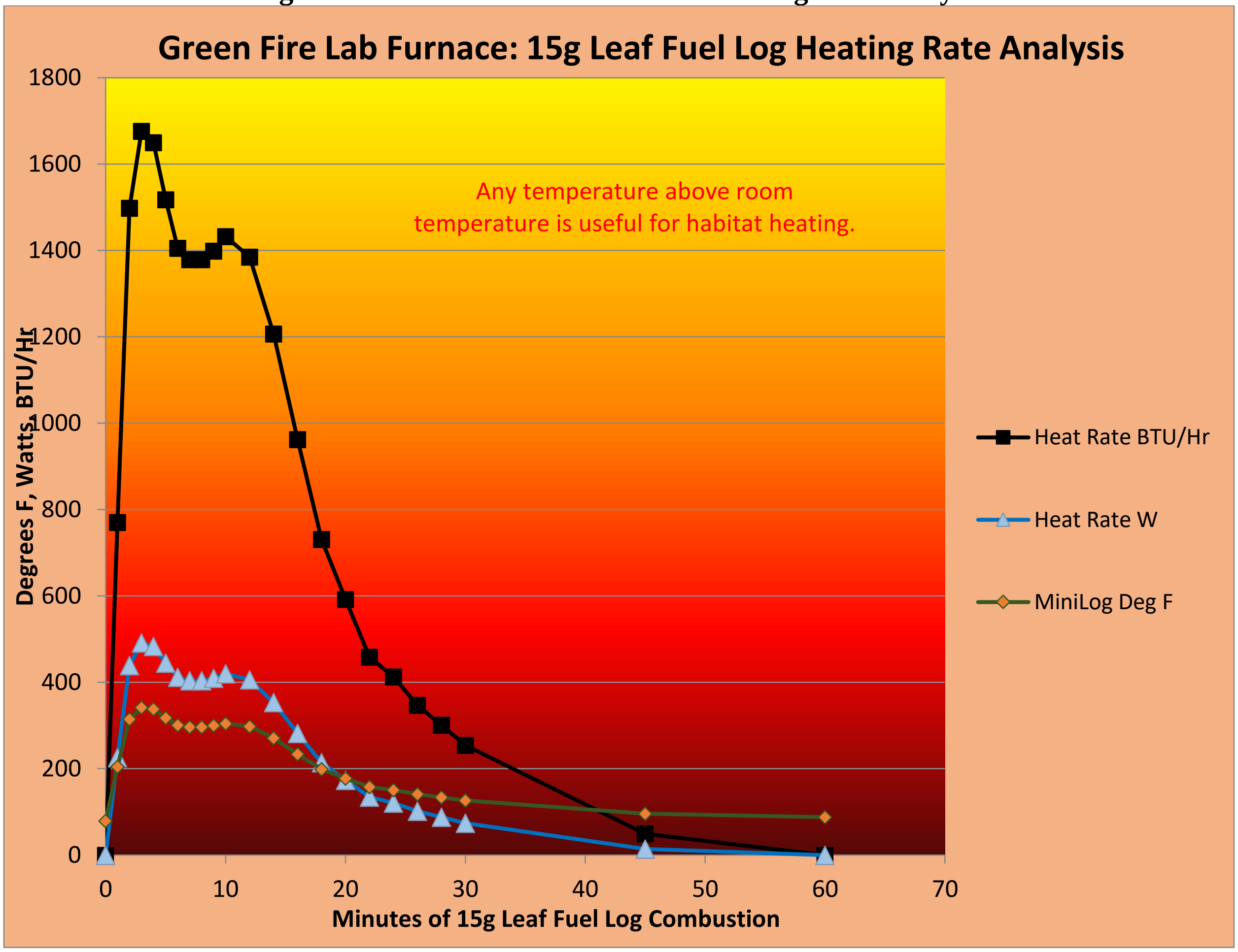
 Original Green Fire Lab Furnace testing of Leaf Fuel Particulate involved placing precision-weighed tablespoon Particulate charges on a 4"x4" ceramic hearth stone, priming with a tablespoon or less of lighter fluid or mineral spirits, positioning the burn table inside the Green Furnace at mid-zone, igniting with a grill wand, closing the furnace door, and opening 3 vent holes in the furnace door for natural drafting. Green Furnace parameters were varied by using powered air intake, powered exhausting, and small diameter copper fire rings to accentuate horizontal air flow directly over the burn pile.	 After up to 60 minutes of combustion activity, post-combustion Leaf Fuel Particulate withdrawn from the Green Fire Lab Furnace was carefully spread out in a circle on white paper for precision weighing and inspection. Combustion quality was assessed visually by estimating percentages of brown unburned, black burned, and white ash. Timers were used to mark combustion progress. Both optical and metal thermocouples were used to monitor exterior Furnace temperature at top-center and interior temperature next to (but not in) the burn pile.

Figure 23 – Green Fire Lab Furnace Heating Rate Analysis



When Leaf Fuel logs were scaled upward from MicroLogs to MiniLogs, combustion behavior was assessed using a small range-top skillet. The set-up allowed for controlled preheating, easy visual and photographic assessment of combustion progress (ignition, flame, ember glow, and smoke episodes), both optical and contact thermocouple data logging, and accurate timing. Figure 24 portrays typical Skillet Test conditions.

Figure 24 - Skillet Test Set-Up for Leaf Fuel MiniLogs

Skillet Tests were run range-top for combustion time-temperature profile logging. No auxiliary air intake or exhaust was used beyond the range exhaust. In this case, a laser-guided optical pyrometer is registering 383.9F on the skillet surface, immediately adjacent a preheated test log, 10 minutes after ignition. A voice recorder was used to register minute-by-minute readings for later transcription to an EXCEL electronic spreadsheet.

Table 9 - Correlation Matrix for Optimization of Leaf Fuel MiniLogs Via Skillet Test

Variables	Lb/Ft3	Wt% Soy	Burn Min	Max °F	Residual %	Soy T mm	Leaf/Soy T	ΔF°
Lb/Ft^3	1	0.82	0.57	0.69	0.00	0.69	-0.83	-0.28
Weight% Soy		1	0.74	0.55	0.33	0.97	-0.99	-0.45
Burn Minutes			1	0.21	-0.22	0.75	-0.70	-0.87
Max °F				1	0.04	0.49	-0.60	-0.21
Residual %					1	0.39	-0.33	0.45
Soy T mm						1	-0.97	-0.50
Leaf/Soy T Ratio							1	0.41
ΔF°								1

Red Values Significant at 0.05 Level

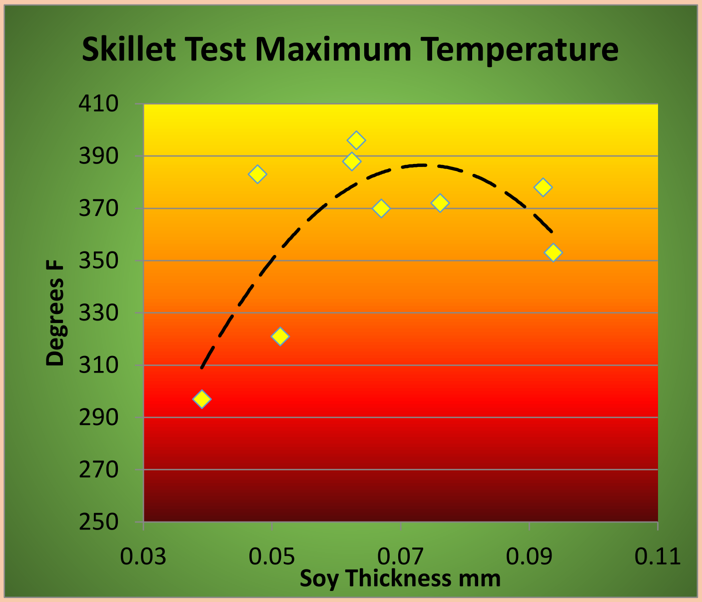


Figure 25a - Leaf Fuel MiniLog Soy Critical Point

A series of experiments varying Leaf Fuel MiniLog composition & density revealed existence of a *critical point* regarding soy content. Contemplating the Leaf-Soy system as lamellae, soy thickness in the vicinity of 0.07mm maximized skillet temperature. Oak particulate thickness averaged about 0.01" (0.25mm). This mode of composition analysis predicts an optimal Leaf/Soy Thickness Ratio of 3.6, and corresponding densified Leaf Fuel optimal volumetric composition of 78% Soy plus 22% Leaf Particulate. Densified microstructure allows far less soy volume than Coated Particulate (Soy/Leaf T-Ratio 1.7, soy thickness 0.42mm per Figure 15).

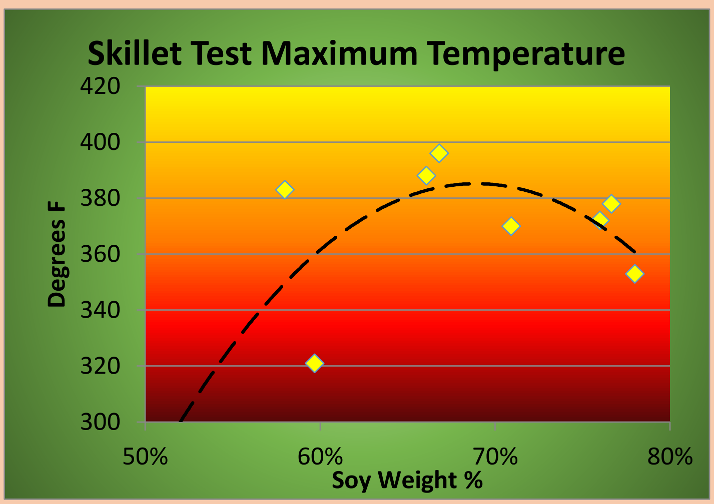
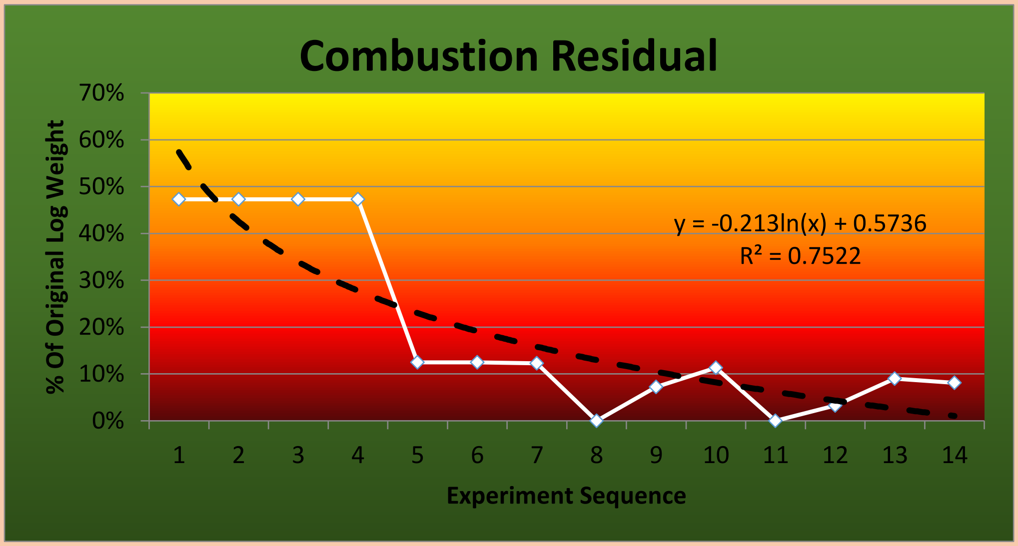


Figure 25b - Leaf Fuel MiniLog Soy Critical Point

Measuring Oak & Soy MiniLog constituents on a weight basis revealed existence of a Critical Point around 68W% Soy + 32W% Leaf Particulate. This is a more accurate basis for determining composition optimality than lamellar thickness (above).

Figure 26 – Green Fire Lab Furnace Parameter Improvement Curve



Operating the Green Fire Lab Furnace to maximally combust Leaf Fuel required progressive optimization of furnace parameters. Using combustion residue as the figure of merit, an Experimental Progress Curve towards minimizing ash or un-combusted residue was constructed. After the manner of Learning Curve methodology, the Experimental Progress Rate registers about 20%.

Leaf Fuel Log Scale-Up

Efforts to produce Green Fire Logs from Leaf Fuel Particulate began at a small scale with densified MicroLogs approximately 0.9"D x 1"L. Lab work advanced by mold process refinement and length increase that resulted in densified MiniLogs approximately 0.9"D x 2.5". The next scale improvement was directed towards log diameter increase to 4" and 4.5". The former proved more controllable for densification. Log lengths in the 4"D series were extended from 2" to 12.5". The largest lab-produced log reached about 83% of the Standard Green Fire Log commercial target of 4"D x 15"D. Firewood cords are assembled from cut-and-split lengths anywhere from 12" to 22". The molding standard for commercial Duraflame Fire Logs is 13"L.

Figure 27 - Progressive Scale Increase of Lab-Densified Leaf Fuel Logs

MicroLog

MiniLog

Standard 4”D Log @ 4.4”L

Standard 4”D Log @ 13.5”L

Laboratory scale-up of densified Leaf Fuel Logs occurred over a 5-year period. The original Leaf Fuel MicroLog was 0.875”D x 1”L (top left). MiniLogs (top right) basically extended log length to 2.5” for a 2.5X scale-up. After standardizing on 4” diameter, further length extension from 2” to 13.5” (bottom right) was achieved. Using volume (or energy content) as the scale factor, overall lab scale-up for Leaf Fuel Logs was 76X, about 90% of the targeted commercial size of 4”D X 15”L.

Figure 28 – Wrapped (Medium-Density) Leaf Fuel Logs

An alternative path to Leaf Fuel Log scale-up involved filling hollow cardboard cylinders 3"D x 1/16"T with dry Leaf Fuel Particulate. The combustible charge was manually compressed within the limited strength limitations of the combustible sidewall. Final mass density and energy density were about half that of Densified Leaf Fuel Logs, but above that of bulk particulate. Ends were sealed with clear plastic for product visibility. The cylindrical body was wrapped in forest green paper, symbolic of Green Fire Stream Energy. A small red leaf logo, signifying the unleashed fire power of leaves, adorned the exterior, along with a longitudinal light-green strip imprinted with combustion statistics. These Leaf Fuel Logs were designed to confine leaf odor, and be charged into a fireplace or furnace as-wrapped.

Furnace Design Issues

Based upon similarity between Leaf Fuel and wood, commercially available furnaces, stoves, grills, and fire places suitable for solid or pellet wood should be suitable to burn Leaf Fuel particulate or fabricated solid forms, such as Leaf Fuel Logs. After the similitude of wood, Leaf Fuel also should be suitable for making camp fires. Because Leaf Fuel affords greater freedom from polluting impurities, it should burn with greater success in equipment that accommodates coal, even though it is not as dense or potent regarding heating value or flame temperature as higher coal ranks (anthracite or bituminous). Because of Leaf Fuel's similarity to lignite, equipment that handles lignite should be able to handle Leaf Fuel with similar outcomes.

While hypothesizing that effective solid fuel combustion equipment (let such be generalized under the term "furnace") need not be modified to accommodate Leaf Fuel, the many combustion tests run in support of this invention do yield helpful guidelines for optimizing wood or coal or pellet furnace designs for Leaf Fuel. The following Table 10 compactly summarizes multiple regression analyses of numerous Green Fire Lab Furnace experiments fueled by Leaf Fuel Particulate.

Table 10 – Green Fire Lab Furnace Multiple Regression Analyses

Criterion Variable	Explanatory Variable Regression Coefficients				Coefficient of Determination (R^2)
	Ignition Primer Oz	Fire Ring Rotation°	Forced Air Input	Forced Air Exhaust	
Combustion Work (°F x Heat Minutes)	-38.62	-96.29	-143.78	718.72	0.79
Smoky Exhaust (% of Htg Minutes)	0.53	-0.71	0.09	-0.13	0.69
Fuel Combusted (Visual %)	0.01	-0.42	-0.04	0.06	0.96

Values in red significant at about 0.05 minimum probability

Accommodating Leaf Fuel's Higher Ignition Temperature and Lower Flame Temperature – There are a few procedural and technical adjustments to operating a furnace on Leaf Fuel that can improve the heating performance. Its higher ignition temperature might require more preheat support. Using a perforated natural gas ignition pipe under the grating (very common fireplace feature) can sustain a new charge of Leaf Fuel logs at elevated temperature longer during start-up. Increasing the amount of newspaper or kindling set under a new charge also can help to bridge the start-up temperature hurdle. Given the well-established modern tradition of electric heating appliances (ranges, hotplates, ovens, dutch ovens, toaster ovens), a Green Fire Furnace can integrate an electric hearth plate. Such can neatly replace a metal grating and gas ignition pipe.

Establishing a larger combustion mass by charging and lighting several logs at the same time will keep an ignited fire burning hotter, longer, and more completely. Soy-infiltrated Leaf Fuel logs can be set upon a steel catch-plate atop the cast iron grating to keep any melting soy within the hearth zone (and not dripping like a candle onto a cold fireplace floor). When furnace geometry options are feasible, opting for designs that promote horizontal drafting can naturally preheat a lit Leaf Fuel log. Instead of heat rising above the burning mass, it wafts longitudinally across the log charge before exhausting (see Figure 29).

Figure 29 – Horizontal-Draft Green Fire Lab Furnace Set-Up

The Green Fire Lab Furnace design favored longitudinal-horizontal drafting of logs, a geometry superior for preheating. It was modified to additionally allow power intake and power exhaust evaluation. The copper Fire Ring (lower left & lower right) enhanced the wind-tunnel effect of the basic furnace cylinder to better aspirate small Leaf Fuel MicroLogs or Leaf Fuel Particulate piles. The Ring also could be rotated during combustion to expose all elements of a burning log or particulate pile to air flow, for more complete combustion. Thermocouples atop the furnace and adjacent the Fire Ring were used to monitor combustion progress as both Leaf Fuel composition and Lab Furnace parameters were systematically changed.

Accommodating Powdery Fines in Leaf Fuel Particulate – Since Leaf Fuel is such a mild combustion product, furnaces operating on metered Leaf Fuel fines may not present any explosion hazard at all (keep in mind, even airborne flour dust has been known to explode in the presence of a flame). Taking the precaution to use *coated* Leaf Fuel particulate (e.g., soy or polyurethane) eliminates powdery leaf fines from the bulk mass. Coated product resolves to small, dustless agglomerations of leaf fines that flow (meter) freely. This form of Leaf Fuel somewhat parallels metered fuels based upon bagged lumber mill wood chips, granules, etc. I am unaware of companies bagging saw dust only as feed for furnaces. Such a finely-divided combustible would be expected to burn too rapidly, create a flash or explosion hazard, or be tricky to meter into a hearth zone.

Accommodating Unwanted Aroma of "Burning Leaves" – Seasoned fire place users know that gorgeously flaming, prime firewood can leave a stinky living room or family room. Burning Leaf Fuel or its ashes, even with aromatic additions, also amounts to leaving a stenchy open fire ring in the middle of your house, especially if raindrops descend the chimney. What might be considered modern high-tech fireplace design isolates the fire chamber from the living space. Glass front fireplaces preserve the view of dancing flames and project radiant energy into the habitat without a hint of smoke or ash. Full metallic enclosure of the combustion zone after the manner of Colonial Franklin Stoves is another refinement to in-room combustion heating that eliminates objectionable odor.

Fragrance Admixtures to Leaf Fuel

The fragrance of Fall leaves, dry or burning, is considered by many to be desirable. Admixtures of essential oils for a *desired* fragrance effect can be made to Leaf Fuel, somewhat similar to aromatic additions made to pipe tobacco or candles. Cherry, a popular fragrance choice for pipe tobacco, was tried. Essential oil additions of 0.25 fluid ounces per pound (about 1%-2% concentration) are aromatically detectable in molded Leaf Fuel logs. For inside, stand-by storage of Leaf Fuel logs, fragrance enhancement is pleasantly discernible. However, much higher concentrations may be needed to overcome natural, burning leaf aroma during combustion. Phthalate-free essential oil fragrances successful with candle making are safe. Many enticing fragrances are available, including Cherry Blossom, Fruit Slices, Gardenia, and Lemon Lavender. Aromatics are discretionary, sensory embellishments. At $1- $2 per fluid ounce, they are more expensive than any other Leaf Fuel raw material. Fragrance enhancement adds about $2 to a standard Leaf Fuel Log. Fragrance oils *do not* enhance space heating performance.

Flame Color Admixtures to Leaf Fuel

It is a characteristic of combustion that flame color decodes flame temperature. Dry leaves burn with a characteristic yellow color. For hydrocarbon fuels, a yellow flame associates with a flame temperature of about 1,800F. This is a relatively cool, comforting, and safe flame, ideal for close-range, in-room heating according to the fireplace tradition. Persistent use of fireplaces in modern homes equipped with gas or electric heating associates with the artistic and romantic dance of yellow flames before the eye. No doubt, many fireplaces have been installed in modern times just because of the mid-winter nostalgia value of warm, yellow flames.

There are ways to diversify the flame color of habitat fireplaces or windowed hearths. Various salt additions to burning logs can confer a rainbow of colors to please the eye. These same salts may be incorporated into the formulation of a composite log, like the Leaf Fuel Log. Since Leaf Fuel is an energy product from the limitless "Green" Stream, investing either Particulate or molded logs with salts capable of producing green flame is both artistic and highly symbolic. Among common salts that can be added to a composite fire log or to a burning log for green flame effect are boric acid and copper sulfate.

I received the initial idea of using the leaf product of trees for meeting the world's voracious appetite for energy during the Christmas season. It was not my first intellectual work in the realm of energy production (that came in the South West "Sunbelt" of the nation, and had to do with solar power), but it was driven by the expectation that homeland Pennsylvania would be mercifully gifted with needful energy for these difficult days (world-class energy-intensive steel industry was being terminated here because of energy-shortage fears). To me, Leaf Fuel was a heavenly Christmas gift as well as a timely work of knowledge. Symbolically, it sprang from a re-defined Christmas tree (deciduous rather than evergreen). Contemporaneously, many establishments were stringing decorative electric lights on barren deciduous trees to illuminate the winter night, even as electric utility power supply was becoming less certain. The hint of a new power source [tree leaves] strikingly persevered. Leaf Fuel also was a red and green Christmas offering, like Christmas poinsettias many churches use to decorate the Christmas alter. To me, the brilliant red leaves atop green leaves became a striking symbol of leaf "flame" power unfolding during these energy-uncertain times. Finally, the traditional red and green colors of Christmas are played out seasonally as forests of green leaves transform to brilliant Fall colors: flaming red, orange, and yellow among the most vivid hues. In a time of heightening combustion energy shortage, it does seem that God wisely adorned

Mother Nature to point the way towards a peaceful, hopeful, faithful transition from vanishing finite (fossil fuel) supplies to perpetual "green stream" resources.

Figure 30 – Fire "Sign" of the Christmas Poinsettia Leaf

At left, a Christmas poinsettia is displayed next to an early Leaf Fuel Log sample made by tamping Leaf Fuel Particulate into a cardboard cylinder to raise energy density. In keeping with the Christmas and Church poinsettia tradition, the Leaf Fuel Log was gift-wrapped in green and adorned with a fire-red Maple leaf logo. Ends were sealed in clear plastic to render visible the core Leaf Fuel energy "gift." One might say that God "pointed" the way to a secure heat energy future via "leaves" by a long-standing winter-weather tradition of displaying beautiful red-topped ("warming fire image") poinsettias on the Christmas alter of His Church.

Users of Leaf Fuel Logs might not, for economy sake, choose to invest in flame coloration for daily heating. However, red or green flame enhancements at Christmas time could become a fitting way to especially commemorate the inspirational origin of Leaf Fuel. Letting red or green fire light and warm the ever-abiding Christmas holiday season reminds us of God's faithfulness in supplying all our need: including heat for His children to enduringly abide freezing, cold winters on planet Earth.

Figure 31 – Examples of Commercial Combustion Products Based Upon Flame Coloration

Shown above left are examples of safe and attractive yellow, red, and green flame effects in tea light candles. Above right is a fireplace log sprinkled with salts producing a rainbow of flame colors. Lower left is a campfire to which green flame crystals were added. Coloring hearth flames of combustion increases the cost of habitat heating to survive the winter cold, but is an undeniable marvel of beauty from the world of chemistry that carries heartwarming Christian symbolism.

Packaging Leaf Fuel

Experiments involving Leaf Fuel dealt with a variety of product forms (fine and coarse particulate, wafers, MicroLogs, MiniLogs, Standard Logs, oversize (larger diameter) logs, and short logs. Defining product dimension for the heating fuel marketplace is a matter of wide discretion. One might trickle particulate into a furnace after the fashion of wood pellets. Or logs of almost any size could be molded. Firewood merchants have begun to offer single, heavy, large-diameter logs that burn vertically from a central wick cavity for long hours. Split firewood, the overwhelming open-fire tradition, requires a greater measure of tending: incrementally adding log fractions to the fire to sustain longer-term heating. Curtailing later night additions avoids wasting heat and firewood after the family has retired.

Molding flexibility of Leaf Fuel could easily accommodate a trend towards large mass, one-time charging of home fireplaces (furnaces). Rather than try to anticipate that trend, I have chosen to keep the home heating unit of merit a log approximating the size of traditional firewood. Dimensions of 4”D x 15”L are close to split wood dimensionality. Cylindrical precision of this Standard Leaf Fuel Log in some respects improves upon Nature regarding geometric refinement and shape regularity. It is a size easy to make and handle. It presents a familiar product form and heat content families will know how to manage for incrementing fuel additions for a heating day. Package size was less a matter of ideality, more a matter of convenience. Unlike wood or coal or gas or oil, however, Leaf Fuel possesses intrinsic geometric flexibility. Accordingly, size and shape can change any time society wants it to change.

Multi-year experience with experimental Leaf Fuel logs of various sizes indicates that they are stable indefinitely indoors in an as-fab, uncovered condition. Clear shrink wrap, colored paper, and cardboard sleeves have been tried successfully. Clear plastic shrink wrap bags or tubing suitable for sealing individual Leaf Fuel logs are available commercially for rather low cost (about $0.10 each for 1 mil thickness). Polyolefin, PVC, polyethylene, and polypropylene are plastics commonly used. A loose sleeve will retract snugly around a log when heated to 180F-250F, a range reachable by a hand-held hair dryer. Intelligent packaging renders Leaf Fuel Logs easier to carry, may serve as an inspection window revealing surface quality, limits handling damage, provides added protection when stacking up a seasonal inventory, and furnishes an odor barrier during in-home storage. Combustible packaging allows Leaf Fuel Logs to be loaded directly into a fireplace or furnace without unwrapping. Packaging affords labeling space for identifying particulars of the product (price, heating value, burn time, aromatic enhancements, weight, production date, production source, instructions, type of leaf or binder used, chemical analysis, exhaust analysis, etc.).

Figure 32 – Shrink-Wrapped Leaf Fuel Log

Shown above is a 4"D x 6"L Leaf Fuel Log shrink wrapped using a 1-mil, clear polyolefin bag. Tight conformance to the precise geometry of the Leaf Fuel Log afforded by this packaging system allows the pleasing color and surface integrity of the product to be seen and appreciated. A simple tie seals the open end.

Leaf Fuel MiniLogs for Commercial Evaluation

A few dozen Leaf Fuel MiniLogs composition-optimized with respect to binder-leaf constituents have been prepared for distribution to potential commercial producers for scientific evaluation of combustion quality, surface quality, and handling ease. Both water-based polyurethane and soy bonding agents were used. These were packaged in small sealable semi-clear plastic vials. Inserted with the Mini-Logs were green labels containing product details for MiniLogs and corresponding Standard Logs.

Figure 33 – Leaf Fuel MiniLogs for Commercial Evaluation by Candidate Producers

Leaf Fuel MiniLogs for Evaluation
Soy Bond (Left) and Polyurethane Bond (Right)

Green Fire MiniLog Sample 2014C1-1

16g	2.3"L	0.8"D
334 BTU	98 WH	51 Lb/Ft3

Standard Green Fire Log 4"D x 15"L

9.5 KBTU/Lb	5.5 Lb	140% Wood Mass
53 KBTU	15 KWH	120% Wood Energy

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Example Data Card Accompanying MiniLogs

Figure 34 – Archival Display Case for Green Fire Project Experimental Samples

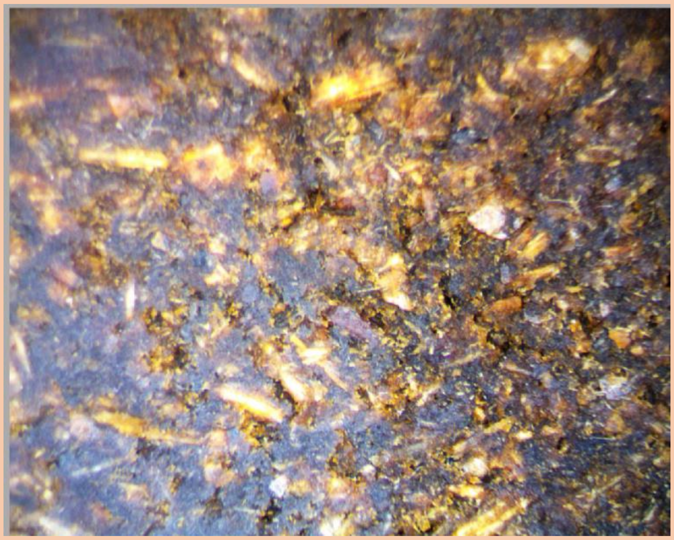
An attempt was made to preserve experimental samples from the Green Fire Project. These included Green Fuel Particulate, MicroLogs, MiniLogs, as well as shrink-wrapped scale-up samples aimed at producing a Standard Leaf Fuel Log (4"D x 15"L) approximating cord wood dimensionality. Solid fuel alternatives also are included in the display. The archival display case is not hermitically sealed, but does afford a degree of isolation from ambient conditions in the residence. Outward appearance of experimental samples from this multi-year project has remained rather stable.

Commercial Combustion Products Functionally Similar to Leaf Fuel

Duraflame logs appeared in the marketplace during the period of Leaf Fuel research & development. There is resemblance to Leaf Fuel logs in the sense that combustible particulates are molded into a log form through the use of a combustible binder. Duraflame raw material is drawn from the wood scrap of lumber mills. Earth's tree population is not put in jeopardy by producing Duraflame logs, but wood scrap is a limited supply stream. Cost effectiveness derives from the surplus nature of lumber mill scrap. A lumber mill disposal expense is forgone by channeling the wood scrap into an effective solid fuel heating product.

The Duraflame log uses a rather hot, petroleum binder. A $4.79 composite log weighs 5 Lb, contains 70,000 BTU, and burns for 3 hours. Clean burning is advertised, but the product bears a heavy petro odor. Cohesion is marginal. A photomicrograph from a commercial Duraflame log appears in Figure 35.

Figure 35 - Photomicrograph a Commercial Duraflame Log (Longitudinal Surface at 20X Magnification)



Yellow fragments in the photomicrograph are finely-divided lumber mill wood scrap reclaimed for combustion service in Duraflame Logs. Black matrix is a petroleum residual binder. The 5 Lb log measures about 3" x 4" x 13." Mass Density is estimated at 55 Lb/Ft^3. Energy Density is estimated at 14,000 BTU/Lb. Energy economics are estimated at 14.6 KBTU/$ or $0.07/KBTU. Duraflame, Inc. was established in 1986. It associates with the cedar industry of California, and traces the Duraflame Fire Log innovation back to 1968. They estimate the present fire log industry at $250 million annually.

Scientific Instruments for Singleton Innovation

Development of Leaf Fuel is a singleton scientific work begun in the midst of global energy crisis that would not have been possible without the increasing availability of affordable instruments for scientific investigation. The U.S.A. began its distinguished nation life with a growing reputation for individualism, American ingenuity, and can-do perseverance. Becoming the most inventive nation in history can be attributed to genuine faith in God and matchless freedom to pursue useful ideas to their proper conclusion.

*Every **good gift** and every **perfect gift** (**including creativity, inventions**) is from above, and cometh down from the Father of lights, with whom is no variableness, neither shadow of turning. James:1.17*

*If the Son therefore shall make you **free** (**to do right things at right times**), ye shall be free indeed. John:8.36*

Modern America hosts the largest organizations in world history, rich in financial capability and marvelous laboratories. Yet answers for a safe and secure energy future increasingly have come from the singleton tradition of risk-bearing entrepreneurs. Green Fire Stream Energy innovations hearken to that fine-grained *Heritage School of Progress*. It is, therefore, fitting to conclude this summary of my original work on behalf of energy process & product invention & development with a personal tribute to key movers in the re-born, micro-inventivity stream. A few photographs close this document as a *Collage of Inspiration* promising positive, peaceful American progress in the years to come from an ever widening assembly of creative *individual* servants armed with affordable tools of inquiry as potent as the world has ever known. Catching this *vision of the future* motivated me to launch the Global Environmental Service for *Preserving the Balance of Nature*, and the Priesthood of Science & Technology to shepherd global millennial peace:

*But ye are a **chosen** generation, a **royal priesthood**, an **holy nation**, a peculiar (**unique**) people;*
*that ye should show forth the praises of him who hath **called you out of darkness** into his marvelous **light**.*
1Peter:2.9

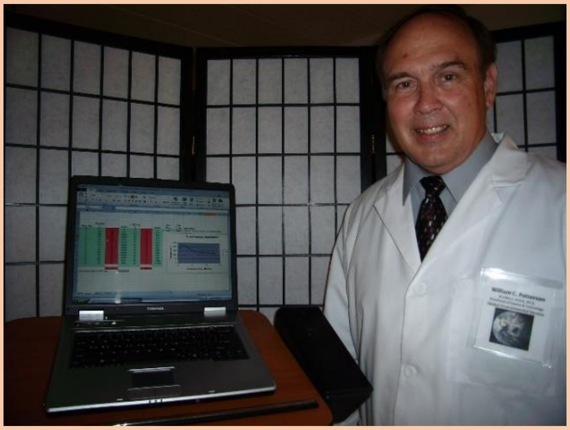
As historical endowments of energy, peace, time, and wealth seem to be fleeting, it is comforting to recall our Lord's sobering reminder about societal service in His power. It does not depend on the state of finances. It does not surrender to fear. It does not fall to deception, prejudice, aggression, crime, or war.

The thief cometh not, but for to steal, and to kill, and to destroy: I am come that they might have life, and that they might have it more abundantly. ***I am the good shepherd****: the good shepherd giveth his life for the sheep. But he that is an hireling, and not the shepherd, whose own the sheep are not, seeth the wolf coming, and leaveth the sheep, and fleeth: and the wolf catcheth them, and scattereth the sheep. The hireling fleeth, because he is an hireling, and careth not for the sheep. I am the good shepherd, and know my sheep, and am known of mine. John:10.10-14*

In these days, preciously bought by forefathers of faith and good works, is it not amazing that God unswervingly supplies His answers through (1) individuals of the most affordable kind (heavenly shepherds who serve whether paid or not), empowered to work with (2) high-tech tools of the most amazing yet affordable kind.

If ye abide in me, and my words abide in you,
ye shall ***ask what ye will****, and* ***it shall be done*** *unto you.*
John:15.7

Figure 36a – Instruments for Singleton Scientific Service ***Collage of Inspiration***



Lab Stand-Up Computer Station

Scientific Measurement Station

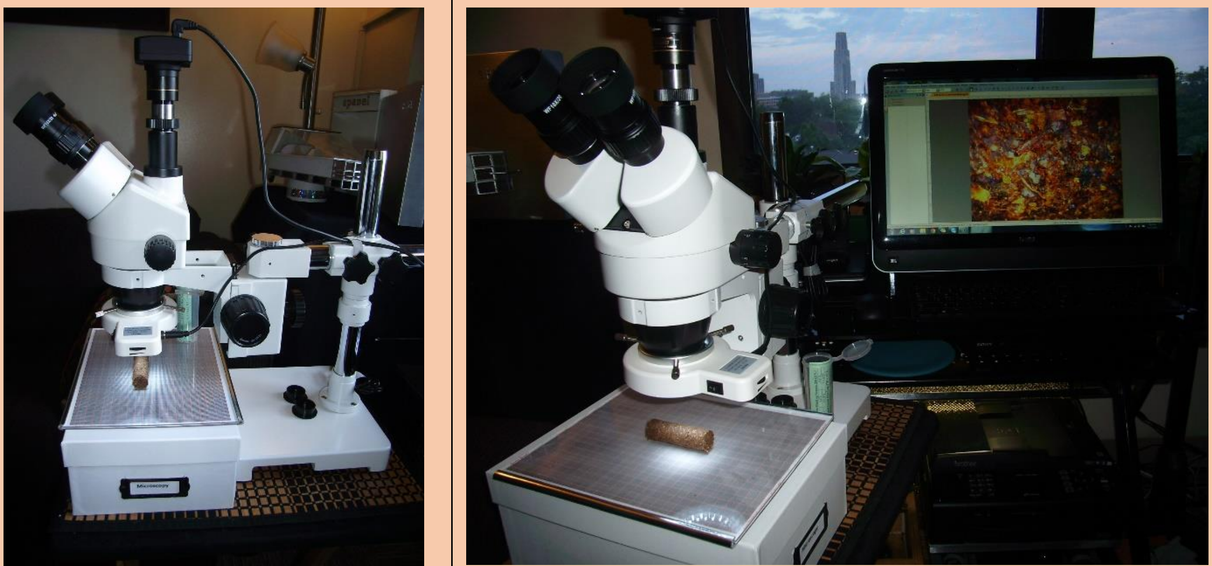
Green Fire Lab Furnace

Fire Safety Glasses & Lab Coat

Leaf Collection Nature Care Wear

Fall Leaf Collection

Figure 36b – Instruments for Singleton Scientific Service ***Collage of Inspiration***
Digital Stereo Photomicroscopy Station for Leaf Fuel R&D



Photomicroscopy contributed important detail to understanding the power potential of Nature's leaves. An AmScope© stereo microscope was used to investigate the structure of leaves, Leaf Fuel Particulate, Leaf Fuel Logs, and associated solid combustion materials and products. Still and motion digital image recording and measurement marvelously expands the observational realm and economizes record-keeping, both very important to the advance of scientific work. Stereo microscopy was particularly helpful in optimizing composition of two-phase (leaf+binder) Leaf Fuel Logs.

Globalization of U.S. Patent Process

More is known about creative thought and invention now than in the time when most of the U.S. patent law was written. There is general evidence that great ideas come to the minds of individuals more so than to groups or organizations. Yet, the increasing value ascribable to inventions in a populous world has organizations in hot pursuit of patent property, not always careful to protect rights of originating individuals with respect to name recognition (attribution) or financial reward. Accordingly, modern America harbors the false notion that big organizations are the real source in invention progress. Indeed, organizations are vital to *implementation* of useful ideas, but it is the individual who gives birth to them in the first place. In the recent past of organization curtailment (e.g., down-sizing, right-sizing, de-layering, etc.), it was risk-taking entrepreneurs who increasingly filled the innovation gap to provide both progress and jobs.

Spiritually, God is identified as the source of all good ideas, faithfully fathering the thought life of individuals to positive ends; and tending to glorify the character, faith, training, and good works of those He gifts. That associated *purposefulness* distinguishes true invention from lucky guesses.

Every good gift and every perfect gift is from above, and cometh down from the Father of lights, with whom is no variableness, neither shadow of turning. James:1.17

This matter of divine inspiration and God-chosen inventors is critical. It can be said that God has a purpose for each invention (gift), and that His choice of inventor *decodes* that purpose. I'll cite one easy example: the Wright Brothers invention of the powered airplane. Both Orville and Wilber were Christian men, sons of a Christian minister. This three-fold Christian family context is rather potent and rare. Was not God encouraging development of the invention along lines of peace, in accord with the Prince of Peace: the Lord Jesus they dearly loved and their father pastorally served? The sons also were bicycle men, a trade obviously orienting their thoughts about mobility or flight towards the lightest of moving platforms. Bicycle work groomed them for success in heavier-than-air flight platforms. Consider how quickly this marvelous gift of flight was turned to war by the call of the U.S. Government rallying for World War I. Had the Wright's faith and family values been taken into account, there could have been national and international purposefulness *never* to use such emergent power of the heavens to bring destruction or war. Warplanes could have been banned nationally and globally before there ever were any.

The U.S. and world since the mid-20th Century have been living at the edge of total destruction on account of the marriage of nuclear weaponry to extraordinary flight (warplanes and missiles). Hope of limiting the proliferation of nuclear weapons is thin. How much easier it would have been to exclude warplane and missile delivery platforms from all nation's armaments, before there were nuclear warheads. International inspection teams and other cooperative surveillance would have been uncontroversial if only aircraft were the objects of concern.

Comprehensive Benefit and Benefit Asymmetry Avoidance

Another mark of Spiritual invention is its capability to bring comprehensive benefit. The present system of patenting caters to novel ideas that may benefit many or few. Its close connection to financial interests engages a natural bias for inventions of interest to wealthy nations, like the High-Technology Triad (Europe, U.S.A., and Japan). Underdeveloped nations are in greatest need of useful, novel inventions, yet go wanting for quality-of-life innovations because they have not the money to pay for them. This asymmetry of benefits resolves to a smaller, more needful, unfulfilled world. Consequentially, there are too many poor houses and poor places on earth festering in unrest, and birthing terrorism towards the few wealthy nations they so resent.

*Do good unto **all** men, especially unto them who are of the household of faith. Galations:6.10*

From whence come wars and fightings among you? come they not hence, even of your lusts that war in your members? Ye lust, and have not: ye kill, and desire to have, and cannot obtain: ye fight and war, yet ye have not, because ye ask not. Ye ask, and receive not, because ye ask amiss, that ye may consume it upon your lusts. James:4.1-3

Ask, and it shall be given you; seek, and ye shall find; knock, and it shall be opened unto you.
For every one that asketh receiveth; and he that seeketh findeth;
and to him that knocketh it shall be opened. Matthew:7.7-8

Good Works Test

Not all inventions are equal. Many in modern times come under the heading of "Design Patents." These address the way something novel looks, rather than functional originality. In advanced societies that have met the core of human need, new things increasingly come from artistic augmentation of the core. Beauty of such artistry can command great market price for "form" inventions, but they lift "function" and physical well-being very little. The Bible would label such "idols" or "idolatry." Better are inventions and patenting that extends the range of good and fair living to include all peoples of the Earth, especially the huge array of underprivileged nations. Better are works guided by God to bring an *inclusive* global kingdom of peace and *universal* prosperity.

Work out your own salvation with fear and trembling,
*for it is God which **worketh in you** both to will and to do of His good pleasure. Philippeans:2.12-13*

*Little children, keep yourselves from **idols**. Amen. 1 John:5.21*

And he (Jesus) spake a parable unto them, saying, The ground of a certain rich man brought forth plentifully: And he thought within himself, saying, What shall I do, because I have no room where to bestow my fruits? This will I do: I will pull down my barns, and build greater; and there will I bestow all my fruits and my goods. And I will say to my soul, Soul, thou hast much goods laid up for many years; take thine ease, eat, drink, and be merry. But God said unto him, Thou fool, this night thy soul shall be required of thee: then whose shall those things be, which thou hast provided? So is he that layeth up treasure for himself, and is ***not rich toward God****. Luke:12.16-21*

Publication, Licensing, and Royalties

Patents are published by the U.S. Patent Office to register existence of useful inventions for advancing American society. It is a supermarket of ideas inventors and lawyers oversee, but only implementers actually prove regarding merit. Unfortunately, it is expensive to file a patent, and such filing does not guarantee that the inventor is first or sole, or that the invention actually works or is unique. They hope it is, but only litigation ultimately validates a patent. Furthermore, disclosing original work in this way leaves the door open for unscrupulous implementers to take what is disclosed and use it secretly, giving no license or royalty opportunity to the inventor. Ultimately, policing of invention use is left to the inventor: a responsibility that can steal years from any inventor's life and rob him of vital financial security.

As imperfect as the U.S. system is, it remains the best in the world. With the internet, countries and companies from anywhere on earth can scour the U.S. patent literature for something they need. Unfortunately, the U.S. invention benefit focus may not be global or embrace vastly unmet needs among undeveloped nations. Better would be a *Global Patent Office*, perhaps on the internet, that would showcase ideas the whole world can use. An inventor could explain his invention, with opinions on originality and evidence of practicality. The database could *automatically* (via search engines) identify similar inventions, listing possible contenders for originality. Implementers could choose what is best for themselves, even begin using it for commercial gain. The database could report the number of known users, thereby helping to identify lower-risk, practice-validated inventions. As the invention prospers its user, royalty payments to the inventor could subsequently begin from a place of user surplus. This voluntary use and eventual reward to the inventor parallels the system God uses with His people. They are counseled to voluntarily and even cheerfully return a tithe (1/10) or offering (more or less than 1/10) to God's work as He prospers them. That *honor system* has built up the Body of Christ (God's Corporation) on earth and raised Christian nations to unparalleled wealth and quality of life.

Characteristics of the U.S. Patent System Needing Globalization Reform

Timetable – Several inventor or invention disincentives have woven into the U.S. patent law regarding *time*. If an inventor conceives an original idea and discloses it to the public in any way, he starts a clock that has a very short deadline to file a patent application: ONE YEAR. Putting the idea before the public before the inventor has had sufficient opportunity to develop the invention to the finality of "practice" invites preemption. The much desired "reduction to practice" stage gives society a more sure innovation, but usually requires disclosure to collaborative others that may be construed as public disclosure. This *de facto* secrecy qualification and subsequent stopwatch to commercialization is neither fair nor practical for individuals. It inhibits invention refinement and puts the inventor in jeopardy of losing the "child of his mind." Impatient financial interests have pressed for the "countdown" mentality, so investment capitalists, always hungry for money-making ideas, may acquire a controlling interest in something they did nothing to spawn, and keep inventors from achieving financial success or maintaining management control in a business they righteously fathered. Since God's gifting of ideas is predicated upon morality, character, values, calling, etc., surrendering management control to others pretty much voids realization of any divine premise for the invention "gift."

Patent policy would do better to remove all clock pacing of invention development and refinement. Let the father of the idea take as much time as he must or pleases (many inventors are individuals of limited means). A poor man may raise his children more patiently than a rich man, but the rich man has no right to seize control of a poor man's family just because he can offer greater opportunity to them. Respecting the family unit of love, the kernel of every society, is far more important. Likewise, respecting a man's right to his own God-managed mind (integrity) is far more important than implementation of any intellectual property misappropriated from his creative mind.

Setting the lifetime of a patent to 17 or 20 years is another arbitrary tradition, again seeming to wrestle intellectual "progeny" from the fold of the inventor. Better is letting the patent and its associated rights (licensing and royalties) live as long as the inventor lives. Gracious God gives to His children enduringly, and does not withdraw His benefits. A God-respecting society should do the same.

Trivial Inventions – With the march of progress, it can be generally said that the really big (fundamental or radical) advances have already been made, and that myriad derivative and incremental advances dominate the modern invention menu. The patenting system attends to incremental innovation because it still is quite prospering. The auto industry provides anecdotal evidence of this. Henry Ford's assembly line invention revolutionized auto production, bringing purchase of an automobile within the economic reach of every American household. Today, with auto production at millions of units, an inventor need only conceive a cost savings for ONE of the 10,000 or so parts going into a single modern automobile (e.g., wheel re-design that saves weight and energy, or fastener re-design that cuts assembly time) to produce a multi-million-dollar invention. Save a penny through invention and reap perhaps 1/10 (if that were the inventor's royalty share) of 12,000,000 pennies every year. That's $120,000/year for 17 years (or a lifetime, per my proposal). The huge size of modern markets can make fine-grained, incremental, secondary intellectual property contributions bear very large rewards.

The hazard of today's finer-grained inventions is that many weave into "empty," cosmetic advances (for a car: brighter finish, sleeker curves, more thrilling engines, etc.). A wealthy public loves these and buys them. But average global society is steered away from efficient, affordable, world-car designs than every man and nation can use beneficially, without compromising world energy supply or offending global climate. The "wealthy few" drive the whole industry, and the "poor majority" is left unsatisfied. Globally scoping the invention agenda, and giving more voice to Spiritual men (God's shepherds of society) can bring the status of invention into better balance with universal human need through far more general sharing of wealth and effectiveness.

Litigation Barrier – The legal profession makes litigation the ultimate test of a patent's worthiness. The adversarial quality of the process is a consequence of programmatic thinking by great legal minds. Their world view envisions elegantly worded, expensive documents; expensive court contests; expert adversarial debate on behalf of litigants; extreme and expensive grasp of legal precedent; and dramatic power of persuasion by sagacious legal counselors. Is this the only way innovations can come to benefit society? Must there be an expensive, time-consuming fight. Must society and inventors pay so heavily for the disagreement burden?

There is a more excellent way: God's way. He abidingly helps all of mankind through creative enlightenment, and relies on a repayment system of gratitude through tithes and offerings, cheerfully given. He prospers the people with, say, $10, and they are invited to repay $1 from that surplus, via tithing. As men become more cognizant that the good life, the abundant life, indeed comes from God, they happily re-invest in God's Kingdom by both tithing and charitable service. It functions as a voluntary honor system, and it works. In fact, looking back on Judeo-Christian history, nothing has worked better. Peoples and nations that cheat or "rob" God ultimately do not prosper. He stands strong as the flawless judge on that.

Review the Old Testament "law book" of Malachi and you will gain confidence in the infallible, divine process for advancing society, and appreciate its relevance for intellectual property management.

Understanding that good ideas come from God in the first place gives further strength to the case that His *charitable agenda* also should govern the invention process. All the good and perfect ideas are His! Should He not be prime counselor on how these intellectual gifts are developed and shared with the world He loves?

Expense Barrier – It is well known in the realm of business strategy that if it is very expensive for a company to enter an industry, new entrants are deterred. Likewise, if it is very expensive to patent a new idea, society will receive fewer implemented ideas. Why are patenting costs so high? In a highly inventive nation like the U.S.A., there is an expansive body of patent literature. Patent lawyers (highly degreed, well-paid individuals) must examine this huge archive of patents to discern merit of a claim. The product of increasing review time and increasing reviewer cost keeps patenting expensive. Furthermore, it has become a standard of patent attorneys NOT to share the risk borne by inventive entrepreneurs by discounting or deferring attorney expense. Inventors must pay attorney cost UP FRONT.

Regarding an invention as a "child of the inventor's mind," a nation that removes the expense barrier to bearing such "children" will have more of them. Pressing the progeny metaphor further, if a nation makes it easy to marry, conceive, and bear children, the will be many children. But, not all may turn out to be good children. It depends on upbringing, and not all families are equal on this. Christian family heritage is a priceless gift to bestow upon children, those becoming entrusted with continuing family name and Christian heritage of the nation. Fathers strive for it. God requires it. Good inventions (children from the Mind of Christ), will entail less investigation burden, cross-checking validation, etc., because invention lineage traces back to the infallible mind of God of heaven. Such gifts will be clean and appropriate for present need. God handles ALL his gifting that way. So divinely creative ideas will always be worthy and suitable for the times. As Godly men come into reputation as sound invention sources, names worthy of trust, there will be less controversy, expense, and litigation burden. Setting the cornerstone for societal advance in the Will of God opens creative windows of heaven that will pour out blessings so profusely that the nation will not be able to gather all of it in (Malachi:3.10).

War and Peace – Invention in the U.S.A. during the Knowledge Age continues a strong orientation towards weapons of violence and war. Some claim nuclear weapons originally conceived in the 20th Century have advanced and proliferated to where they now possess the capacity to destroy the Earth ten times over. Furthermore, there is grim realization that any nuclear war will swiftly and uncontrollably converge to mutual, global suicide. Obviously, it is reasonable and imperative to reorient modern, brilliant, creative minds towards peace and away from war. This posture of human maturity finds clear Biblical endorsement:

And He shall judge among the nations, and shall rebuke many people: and they shall beat their swords into plowshares, and their spears into pruning hooks: nation shall not lift up sword against nation, neither shall they learn war any more. Isaiah:2.4

Globalization of invention provides the right occasion to finally confine the focus of creative ideas to the realm of PEACE ONLY. The human mind is the sole gateway to earthly power, and should be restricted to a repertoire of heavenly peace. When God says there should be peace, He supplies inspiration necessary to it. It can be conversely said that pressing minds for war in these pivotal days arises from a spirit of fear, not of Holy Spirit. The infrastructure of invention is therefore wise to promote *heavenly wisdom*, and eschew further excursions into the unenlightened realm of war.

There is no fear in love; but perfect love casteth out fear: because fear hath torment. He that feareth is not made perfect in love. 1 John:4.18

The wisdom that is from above is first pure, then peaceable, gentle, and easy to be entreated, full of mercy and good fruits, without partiality, and without hypocrisy. And the fruit of righteousness is sown in peace of them that make peace. James:3.17-18

Spiritualization - Perhaps the greatest omission from extant patent procedure is due regard for Deity. A patent is more than an original idea, more than logical rigor, more than historical grasp, more than novelty, more than usefulness. It packages something sent from God (James:1.17). It is a divine gift with good purpose. The patent claim must not fail to give due respect to the true origin and true purpose, or the document robs God and falls under adverse judgement (see Malachi).

Things of divine origin usually evince the character and ways of our Creator. They are "signed" by God. Men in good standing with the Almighty should be able to discern the *Signature of God*. Keys in this regard include consonance with Biblical law or promises, answer to prayer, universality of benefit, evidence of general prospering, healing of divisions, auguring for peace, discernible love in action, accompanying affirmative "signs," accompanying "acts of God," or authorship by one in especially good or favored relationship with God (a holy man). These should be explicated in the global patent claim to confer Spiritual authentication and give God the glory. I do not include miracles or speaking in tongues in the Signature of God. Such had their place in Biblical history, but we who live in these consummate days of fulfillment can look more to facts of Spirituality, tried and proven through more than 2,000 years of validation in and by the Body of Christ, and made clear to us by the Lord Jesus Christ. In this sense, we understand God as author of reality, seen darkly in earlier times, but now visible through an unfragmented, flawless mirror (1 Corinthinians:13).

Claim of a global patent, then, has both earthly and heavenly matters to explicate. The tradition has been to address only the earthly issues. Giving true and complete regard for reality beckons acknowledging with preeminent respect the heavenly dimensions of the invention gift from God. Fixing this matter looms as a crown to U.S. patent law, and the righteous thing to do as the global age of living is upon mankind. There is a filled earth, tamed wilderness, and evangelized human population by the great decrees of God. It is only fitting to usher the highest, most refined law into this grand global civilization. Modern man rides a crest of historical innovation achievements that further motivates completing the patent law to bestow high honor to Almighty God. His gifts have been sustained, enriching, and of a magnitude greater and greater. Certainly thanksgiving is reasonable accompaniment to any invention of this age, as it reflects upon the abundance of predecessor inventions that have lifted mankind to its present, lofty stature. So let the patent of the future be marked with thanksgiving, adoration of God, and attention to His loving kindness and tender mercies in what has been given. Let there be validation and praise in words and poetry, even song. Let there be pictures of beauty and light, honoring creation past and present. There is no good thing in life that has not come from the Hand of God. Let us beneficiaries of such a continuous flow of blessing return some His way on these wonderful patent occasions.

Enter into His gates with thanksgiving, and into His courts with praise.
Be thankful unto Him, and bless His name.
Psalm:100.4

Bless the Lord, O my soul, and all that is within me, bless His holy name.
Psalm:103.1

In Christ

William C. Patterson
B.S.Met.E., M.B.A., Ph.D.

Summary Review of Patent Claims

One: Discovered an energy resource of large enough magnitude to perpetually meet the global human need for winter season habitat heat.
Two: Discovered that the heat content of tree leaves is more than equal to the heat content of the wood of the tree.
Three: Discovered a combustion energy resource able to perpetually meet the global human need for winter season habitat heat that is unencumbered by pollutants intrinsic to traditional petroleum or coal heating fuels.
Four: Discovered an energy resource plentiful enough to perpetually meet the human need for winter season habitat heat regionally and more affordably than any repository heat source tied to lengthy, expensive logistical supply lines (coal, oil, natural gas). In a Pennsylvania woodlands setting, total per capita energy need can be met within 150 feet of the residence. Such localization of energy supply eliminates transportation energy and cost from residential heating expense (some present energy logistical lines are global, politically sensitive, and draw down critically short transit fuel).
Five: Discovered an energy resource plentiful enough to perpetually meet the regional human need for winter season habitat heat with less waste heat rejected to the environment and lower radiation hazard than potent nuclear power.
Six: Discovered an energy resource plentiful enough to perpetually meet the regional human need for winter season habitat heat without endangering the bird population, as is the case with wind energy and some forms of solar energy.
Seven: Discovered an energy resource plentiful enough to perpetually meet the family need for winter season habitat heat within the affordability envelope of *family labor* only (no out-of-pocket expense). Accordingly, no family need suffer or freeze due to lack of financial means to buy commercial energy in the winter.
Eight: Discovered an energy resource plentiful enough to perpetually meet the family need for winter season habitat heat within the affordability envelope of *family labor* only (no out-of-pocket expense), without sacrificing the tree population of the planet. Shifting the traditional energy focus from the wood of the tree to the leaves of the tree increases the energy harvest 80-fold while preserving precious standing wood stock and avoiding consequential destabilization of earth's climate.
Nine: Discovered and refined a process involving diminution, functional bonding admixtures, and densification, for transforming massive leaf energy into a well-behaved combustion product suitable for home heating and other controlled heating needs.
Ten: Developed furnace or hearth designs and modifications for horizontal air flow better able to accommodate the lower flame temperature and higher auto-ignition of leaf combustion products.

Eleven: Developed ways to improve the aroma of in-home leaf combustion products beyond the natural fragrance of Fall leaves.
Twelve: Developed ways to colorize the natural yellow flame color of leaf combustion products for in-home artistic or symbolic enhancement.
Thirteen: Developed affordable packaging systems for leaf combustion products that ease handling burden, limit release of odor, improve product quality visibility, and impart an environmentally friendly "green signature."

Reserved Words and Definitions Helpful to Understanding This Original Work

Leaf Fuel or **LeaFuel** – Combustion heating fuel derived from tree leaves according to processes and materials described in or derived from this invention document. Associating product name with technology should help to deliver predictable, reliable, safe performance to users of Leaf Fuel.

Green Fire – Useful heat associated with combustion, oxidation, burning, flame, embers, etc., that derives from and harmonizes with Nature, especially the living green vine of Nature.

Green Energy – Energy of any form derived from Nature. Usually associates with efficient energy conversion, minimal adverse environmental impact, and safety for producers and users.

Green Life – Lifestyle associated with living in accord with Nature, harm-free to the environment.

Green Season – Time of year when the green vine is flourishing towards harvest of food (for human or animal health, strength, and stamina) or energy to propel society forward.

Green Signature – Inventions, inputs, designs, processes, equipment, and effects, usually involving benign energy transfer, and exhibiting a high degree of harmony with and preservation of Nature.

Stream Energy – An energy resource that flows continuously. The term derives from river systems of the earth, ever-streaming due to the global water cycle. Driving the water cycle is the Sun, which streams over 1,000 watts of power on every square meter of earth surface. Even with modern society's voracious appetite for energy, nations use less than 0.1% of earth-incident energy from the Sun. Accordingly, there never was an energy crises, only a technical failure to suitably *transform* solar abundance to earthly need.

Perpetual Energy – An energy resource that lasts forever. Engineers counsel that there is no perpetual motion (energy in action), therefore no perpetual energy. Practically speaking, however, sunshine, planetary orbits, seasons, flowing rivers, and wind currents are enduring enough to be regarded as perpetual energy and motion. In Christian theology, God is considered Almighty, all-powerful, never-failing. Accordingly, He overwhelmingly transcends Creation's standard of durable energy, lifting our comprehension of power and energy into the realm of everlasting. Under-appreciation of God's eternal power (and love) has led many nations into predicting doomsday as the petroleum era was ominously drawing to a close.

Repository Energy – A finite energy resource. Fossil fuels like coal, petroleum, and natural gas fall into this category. Usage rate depends on how rapidly the store of energy is harvested. Repository energy fueled the industrial age. However, overuse of fossil treasuries has brought pollution to air, water, and land. It also is the root cause of global warming and derivative climate destabilization and damage. From a Christian perspective, petroleum can be interpreted as *anointing* energy purposed by God to complete evangelization of earth's people in Christ (the *anointed one*), globalizing the Kingdom of God. Diversion of petroleum to war-making and non-essential travel has wasted much of global petroleum, leaving many nations underdeveloped and under-Spiritualized.

Diminution – Act of reducing (diminishing) the particle size of bulky mass. Solid chunks of coal broken from the vein by miners are reduced to small, transportable lumps via diminution. Large stones broken away from quarries can be reduced to gravel by diminution. Leaves of a tree are reduced to fine particulate suitable for Leaf Fuel by diminution.

Diminize or **Dimunize** – Non-conventional forms of the word "diminution" to render it a verb. Such wording allows statements about diminution to be composed simpler and comprehended a little easier.

Densification – Label for a process step in making Leaf Fuel that raises mass density (Lb/Ft^3) and energy density (BTU/Ft^3) of leaf particulate (i.e., diminized leaves). Mechanical means are used to compress bulk leaf particulate to (1) drive out entrained air and, in some cases, (2) compact (cold work) the leaf particulate into a solid mass more dense than the natural leaf. Densification makes Leaf Fuel a more potent energy product, especially when logs are the final product form.

Inventivity or Creativity – Gross or per capita national production of intellectual property (creations of the mind). Includes inventions, patents, industrial designs, trademarks, and copyrights (literary and artistic works, such as music, plays, books, films, paintings, drawings, photographs, sculptures, architecture, and computer programs). With dawning of the Knowledge Age, historians and researchers were finding the U.S.A. to be the most inventive nation in history.

Leaf Energy – Energy derived from the leaf product of trees. Leaves contain about 8,000 BTU/Lb of combustion energy. Over the lifetime of a tree, leaf energy harvest is about 80 times greater than the wood energy harvest.

Leaf Power – Power derived from the leaf product of trees. Terminology patterned after other flowing (often called Alternative) energy sources: hydro power, solar power, wind power, etc. Can also use the term Leaf Energy, but the flow nature of seasonal leaf production favors the "power" connotation. Leaves and Leaf Energy will flow perpetually (they are an infinite power source), but the *rate of flow* is limited by the extant tree population of the planet. Raising Leaf Power requires protecting the present standing stock of trees AND augmenting Earth's present tree inventory via planting.

Leaf Puppy – Special name applied to robotic equipment for gathering leaves with integral diminution, designed by Dr. William Patterson. The "puppy" reference associates the automated equipment with characteristically tireless canine *retrieving* behavior. Gathering and disposing of Fall leaves has been a long-standing manual labor of homeowners the Leaf Puppy finally relieves. Little puppies warm the heart; Leaf Puppies warm the home.

Electronic Tethering – Novel, non-mechanical means for coupling the Leaf Puppy to a ferry load vehicle that transports leaf particulate to a storage silo or other collection site on the property. Electronics are used to "lock-on" to a reflector at the rear of the Leaf Puppy without establishing a complicated mechanical hitch. It is an invisible way the powered follower vehicle trails the Leaf Puppy, somewhat after the fashion newborn puppies amazingly follow their mother, without a leash.

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