ALTERNATIVE ENERGY AND FUELS

FINAL REPORT

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ABSTRACT

Alternative energy and alternative fuels have received considerable attention the past few years as traditional fuels have risen in cost. What are alternative energy and alternative fuels? What is the relative cost between traditional fuels and alternative fuels? Can a common comparative cost of "dollars per million BTUs" be used to compare traditional, alternative, solid and liquid fuels? What are the pros and cons of alternative fuels? What are users options given an existing boiler or furnace? What are the air emission comparisons? Are there bottom ash issues to deal with? Do alternative fuels offer a better carbon footprint than traditional fuels? This paper covers these questions and more to provide the reader with a high-level overview of alternative fuel options. These fuels include:

Coal	Biomass	Sulfur
#2 oil	Waste Wood	Natural Gas
#4 oil	Animal Waste	Synthetic Gas
#6 oil	Hogged Tree Wood	Solar Thermal
Petroleum Coke	Landfill Methane Gas	Solar Photovoltaic

Table 1: Alternative Fuels

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INTRODUCTION

Energy prices have risen dramatically over the past 30 years and many of us can remember when we filled our automobile tank with 23¢ per gallon gasoline and now we pay close to $4.00 per gallon. Electricity was 2¢ per kWh when I was growing up and today we pay over 16¢ for that same power.

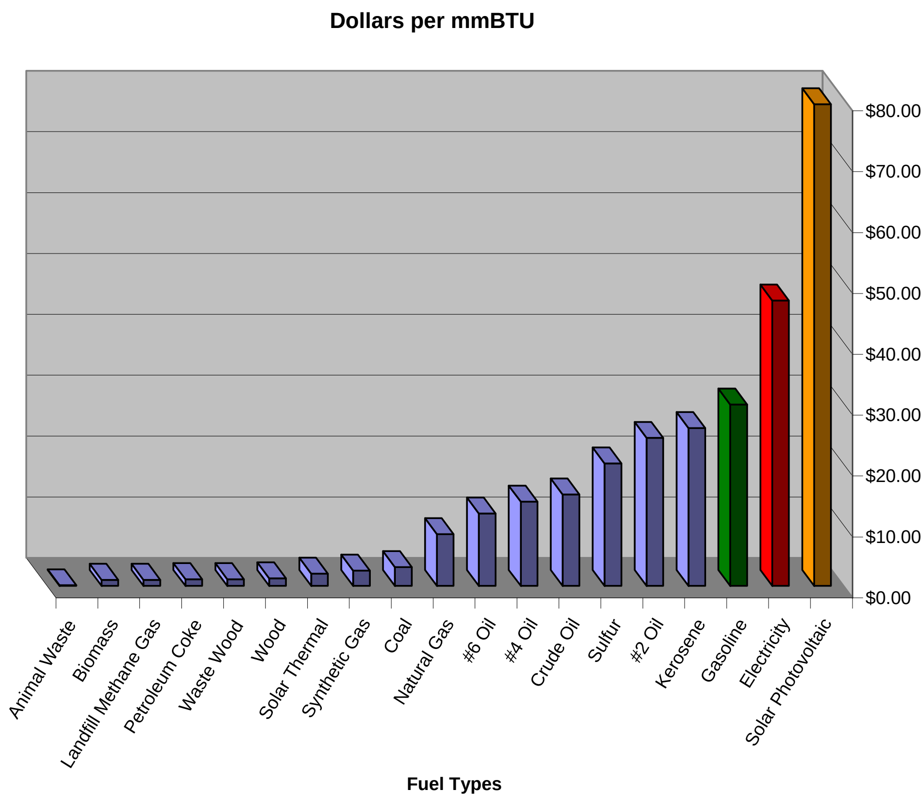
Energy and fuels are, as economists say, an elastic market. In an elastic market, if coffee prices rise people switch to tea. If sugar prices rise consumers make use of honey and artificial sweeteners. In the case of gasoline, oil, natural gas and electricity some people are able to purchase and use alternative fuels.

As Georgia Tech energy professor Sam Shelton said "There is no single silver bullet for our energy situation, however, there are 100 brass bullets and we just need to find the right match." With this in mind, let us think beyond the three major fuel sources of; the all electric house, natural gas, and gasoline. Let's think about some of those "100 brass bullets." The following table is a short list of some of the energy/fuel sources within easy reach with a proven history of application.

Fuel	Commonly Quoted Price	Commonly Used Units of Sale	Dollars per mmBTU
Animal Waste	$1.00	$ per Ton	$0.11
Biomass	$8.00	$ per Ton	$1.00
Landfill Methane Gas	$0.10	$ per Therm	$1.00
Petroleum Coke	$1.10	$ per mmBTU	$1.10
Waste Wood	$10.00	$ per Ton	$1.11
Wood	$12.50	$ per Ton	$1.25
Solar Thermal	$2.00	$ per mmBTU	$2.00
Synthetic Gas	$0.25	$ per Therm	$2.50
Coal	$80.00	$ per Ton	$3.08
Natural Gas	$0.85	$ per Therm	$8.50
#6 Oil	$1.75	$ per Gallon	$11.88
#4 Oil	$2.00	$ per Gallon	$13.84
Crude Oil	$100.00	$ per Barrel	$15.03
Sulfur	$160.00	$ per Ton	$20.10
#2 Oil	$3.20	$ per Gallon	$24.31
Kerosene	$3.50	$ per Gallon	$25.93
Gasoline	$4.00	$ per Gallon	$29.79
Electricity	$0.16	$ per kWh	$46.88
Solar Photovoltaic	$0.27	$ per kWh	$79.11

Table 2: Fuel Prices

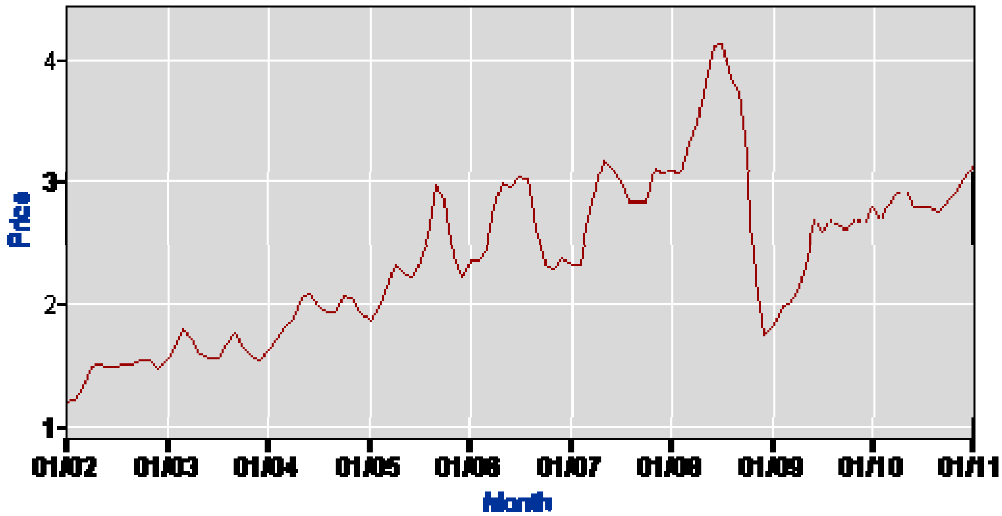
The following graph presents the same data from the table above and clearly shows why alternative energy and fuel sources are gaining in popularity. Fuel choices have the power to break an OPEC oil cartel and wean the United States from expensive oil, gasoline and electricity. Notice where gasoline (green bar), electricity (red bar) and solar Photovoltaic electricity (orange bar) are on the graph. Notice that 16 other (brass bullets) have a lower cost.



Graph 1: Fuel Prices

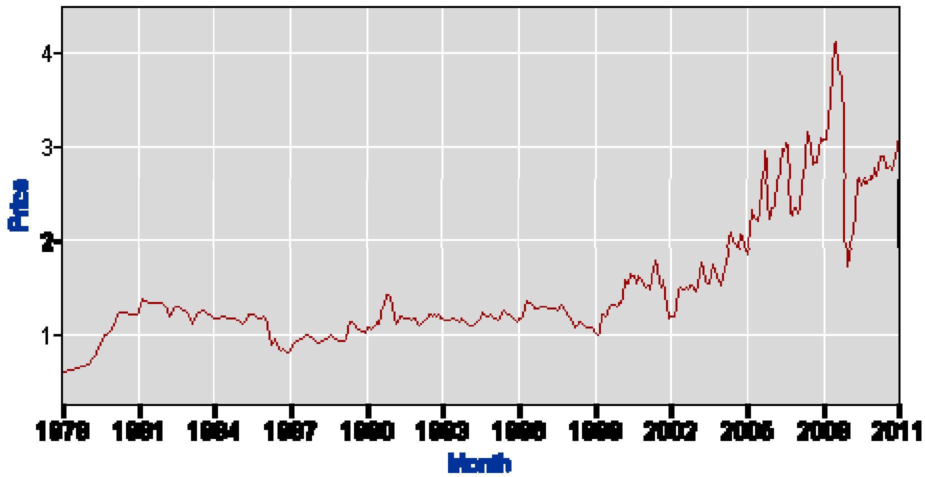
HISTORICAL GASOLINE PRICES

Some of us are old enough to remember when fifty cents would buy two gallons of gasoline. The younger of us thinks fifty cent is a singer. In just the past ten (10) years automobile gasoline has risen from just over $1.00 to over $4.00 per gallon and then fallen to $3.00 for the last two years. As of this writing, we're heading back up to $4.00 per gallon.



Graph 2: 10 Year Gasoline Prices

Contrast this recent volatility with the long term gasoline price stability of just over $1.00 which lasted 20 years from 1979 through 1999.



Graph 3: 30 year Gasoline Prices

Least we think we have it bad here in the United States, consider these prices from various parts of the world.

<u>**Country**</u>	<u>**Price in US $/Gal**</u>
Norway	9.25
Liverpool, United Kingdom	8.42
Israel	8.00
Nairobi, Kenya	6.16
Canada	5.25
Colombia	4.21
United States	**4.00**
Nigeria	1.85
Iran	0.33
Venezuela	0.12

Table 3: Gasoline Price by Country

You may prefer to see the globe and the prices by continent of Europe, Asia, Africa, South America and so forth.

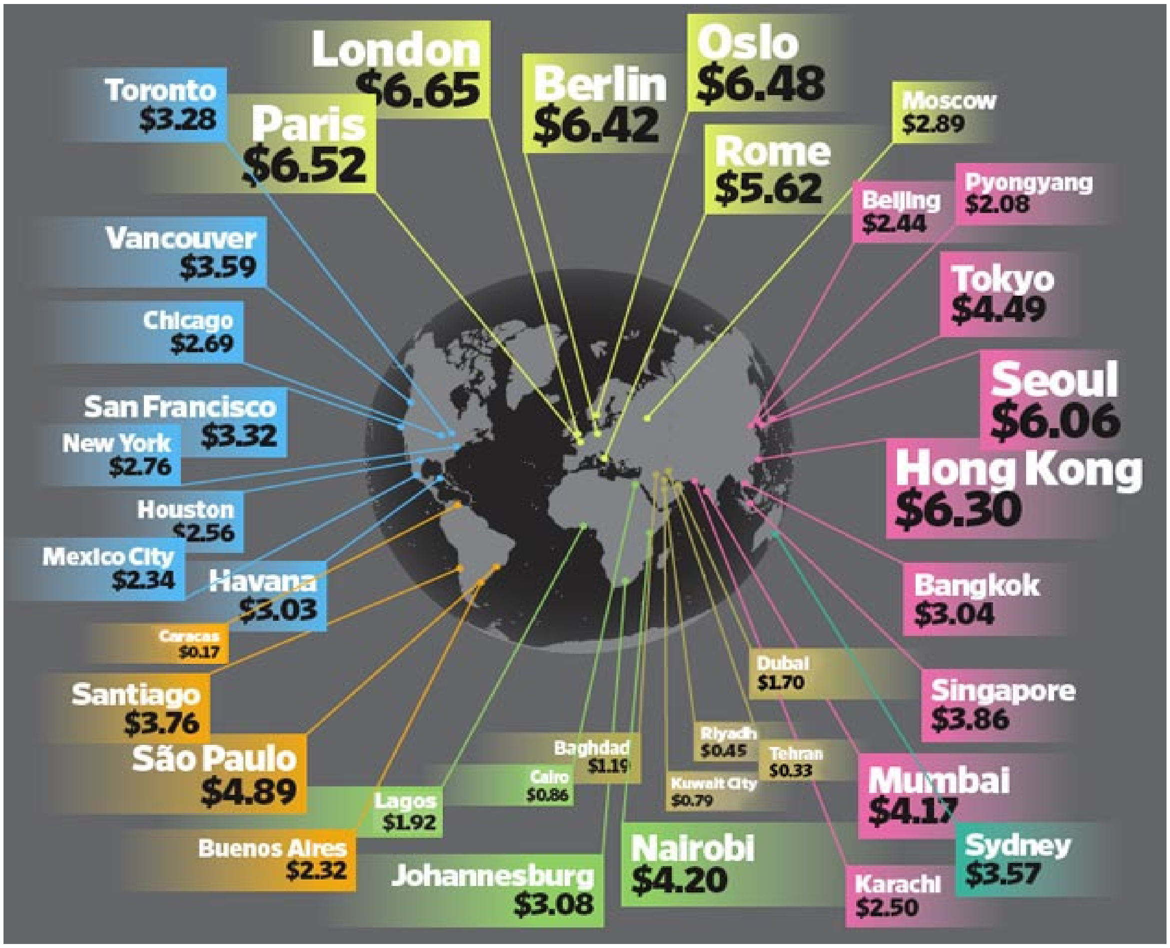


Figure 1: World Gasoline Prices

Because gasoline prices have risen people have taken action in several ways;

- They drive less
- Car pools have formed
- Consumers are buying higher mileage cars
- Consumers are selling big SUV and Hummers
- People are buying diesel fueled cars
- And some folks are looking at alternative fuels

A great historical story and some very old pictures of wood burning cars and trucks can be found at Low-Tech magazine with the following internet link:
http://www.lowtechmagazine.com/2010/01/wood-gas-cars.html
There are hundreds of vehicles spanning over 50 years, which makes for great reading and viewing. YouTube also has a large collection of mini movies of these vehicles being started and operated.

Consider the following wood burning trucks:

Figure 2: Old Wood Burning Truck in Garage

Figure 3: Wood Burning Truck on Water Front

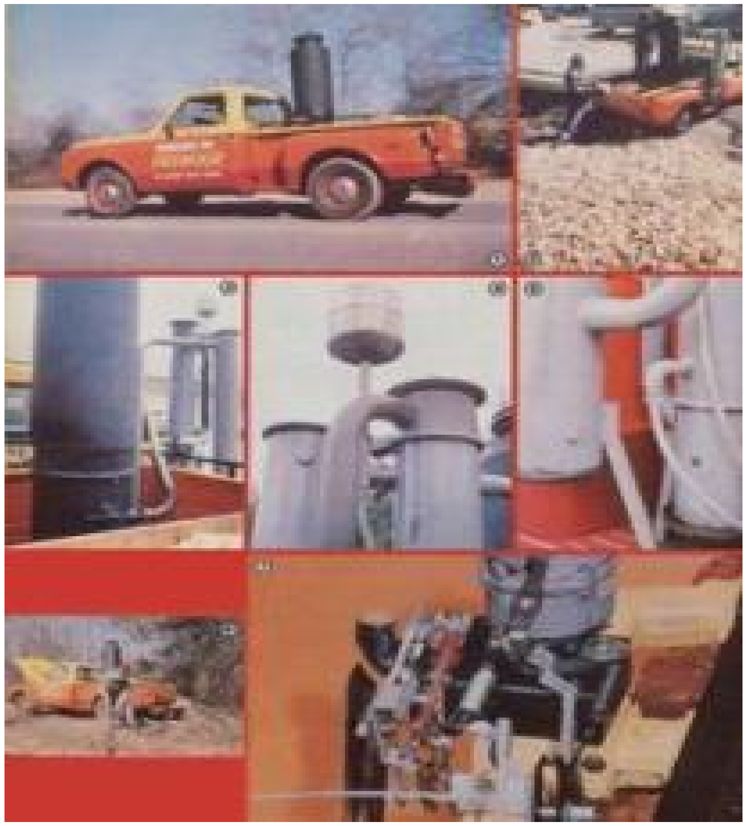


Figure 4: Wood Burning Truck Collage Detail

Figure 5: California Wood Burning Truck

Figure 6: Vending Wood Burning Tuck

Figure 7: Wood Burning Cars in Corn Field

Consider for a moment why these individuals would invest their precious time and limited money in designing and constructing these unique wood burning trucks. They were first motivated by the high cost of gasoline and they obliviously have a passion for their craft. They are pursuing an alternative energy source for their vehicles where no commercial available option exists. Furthermore, they consider the ongoing cost and price increase of gasoline to be worth the capital investment.

The average American drives 12,000 miles per year and assuming the typical automobile gets 25 miles per gallon, the annual budget for gasoline is as follows for various prices at the pump. These are prices that we have seen over the past 25 years and prices we expect in the future. Notice the budget impact for rising prices.

Dollar per Gallon	Annual Gasoline Budget
$1.00	$480
$2.00	$960
$3.00	$1,440
$4.00	$1,900
$5.00	$2,400

Table 4: Gasoline Budget

The gasoline budget is clearly going up, but this is only part of the total life cycle ownership story. Assume that the typical automobile costs $20,000 and that it is kept for five years with zero salvage value. Further assume that typical oil, tires and other maintenance items amount to $800 dollars per year. Automobile insurance is assumed to be $1,500 per year. Given these conditions and the above driving habits, the annual cost of automobile operation will increase with each additional gasoline pump price increase. The percent of budget (due to fuel) will increase from 7% to 28% and the cost per mile will go up as shown in the five tables on the next page.

Before viewing those tables, let's consider ownership cost, life cycle cost, case cost (for factory goods) or sales price per ton of a product. All of these measures inform the owner of his profit or loss in running an enterprise. As you will see in the five tables, the cost is increasing and the major cost driver can be traced back to fuel.

Owners of cars, homes, buildings, factories and process plants have seen the fuel dollars increase and have calculated a percent increase. However, have they taken the time to calculate the increasing percent of the annual operation role that gasoline plays? If they did, they might also have considered not only alternative fuels but also capital improvements that seek to reduce fuel use.

In the case of automobile owners, they have made a decision to trade in (read capital improvement) their gas guzzling SUV's, large trucks and other fuel inefficient vehicles for economical high mileage cars. By doing so, they enjoy a lower operational cost per mile for transportation. The same reduction concept can be applied to process plants. Now let’s look at those tables.

Item	Annual Cost	% of Total	$/Mile
Annual Capital	$4,000	59%	$0.33
Annual Maintenance	$800	12%	$0.07
Annual Gas at **$1.00** per Gal	$480	**7%**	**$0.04**
Insurance	$1,500	22%	$0.13
Total Annual Automobile Cost	$6,780	100%	$0.57

Table 5 Gasoline at $1.00 per Gallon

Item	Annual Cost	% of Total	$/Mile
Annual Capital	$4,000	55%	$0.33
Annual Maintenance	$800	11%	$0.07
Annual Gas at **$2.00** per Gal	$960	**13%**	**$0.08**
Insurance	$1,500	21%	$0.13
Total Annual Automobile Cost	$7,260	100%	$0.61

Table 6 Gasoline at $2.00 per Gallon

Item	Annual Cost	% of Total	$/Mile
Annual Capital	$4,000	52%	$0.33
Annual Maintenance	$800	10%	$0.07
Annual Gas at **$3.00** per Gal	$1,440	**19%**	**$0.12**
Insurance	$1,500	19%	$0.13
Total Annual Automobile Cost	$7,740	100%	$0.65

Table 7 Gasoline at $3.00 per Gallon

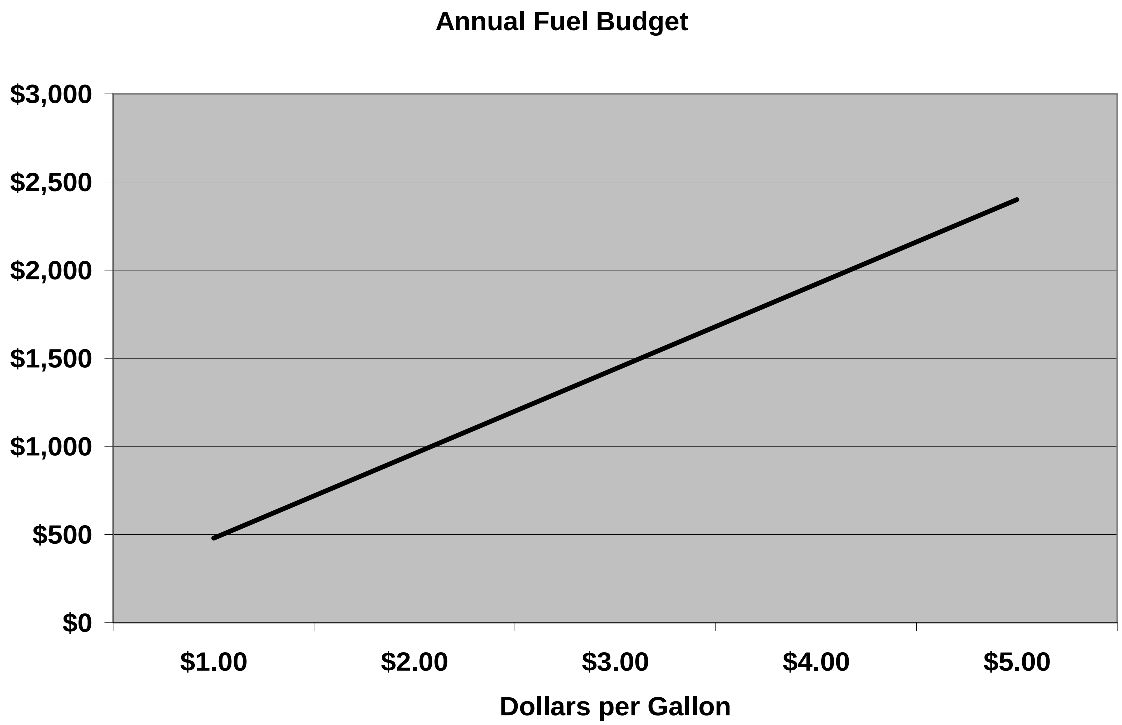
Item	Annual Cost	% of Total	$/Mile
Annual Capital	$4,000	49%	$0.33
Annual Maintenance	$800	10%	$0.07
Annual Gas at **$4.00** per Gal	$1,920	**23%**	**$0.16**
Insurance	$1,500	18%	$0.13
Total Annual Automobile Cost	$8,220	100%	$0.69

Table 8 Gasoline at $4.00 per Gallon

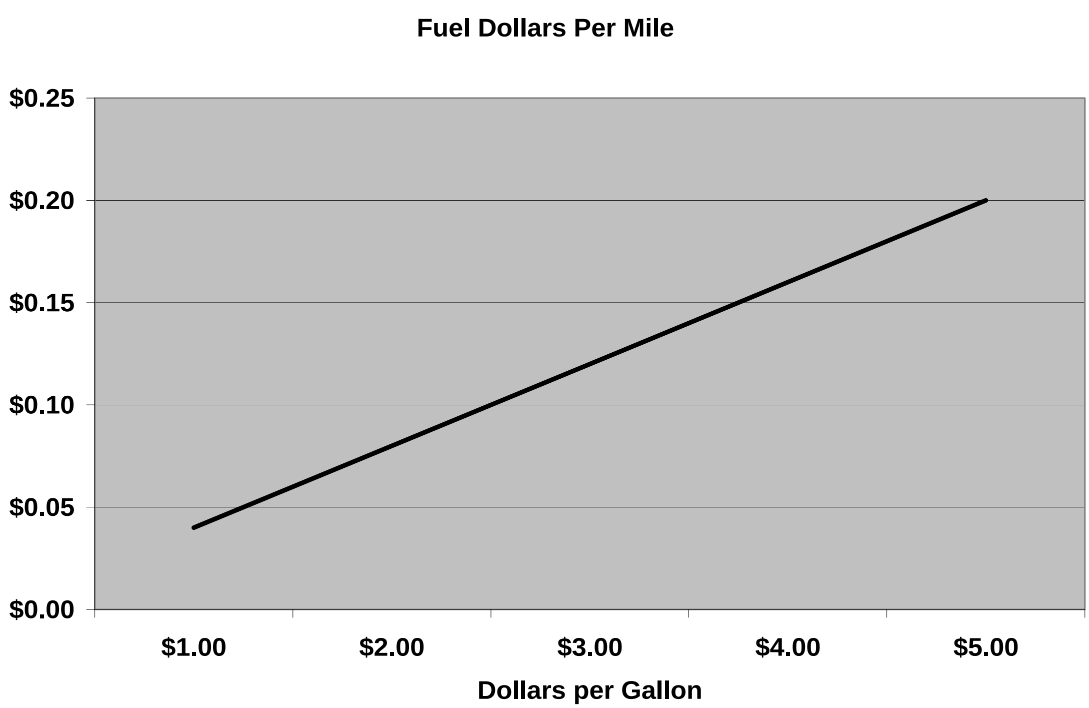
Item	Annual Cost	% of Total	$/Mile
Annual Capital	$4,000	46%	$0.33
Annual Maintenance	$800	9%	$0.07
Annual Gas at **$5.00** per Gal	$2,400	**28%**	**$0.20**
Insurance	$1,500	17%	$0.13
Total Annual Automobile Cost	$8,700	100%	$0.73

Table 9 Gasoline at $5.00 per Gallon

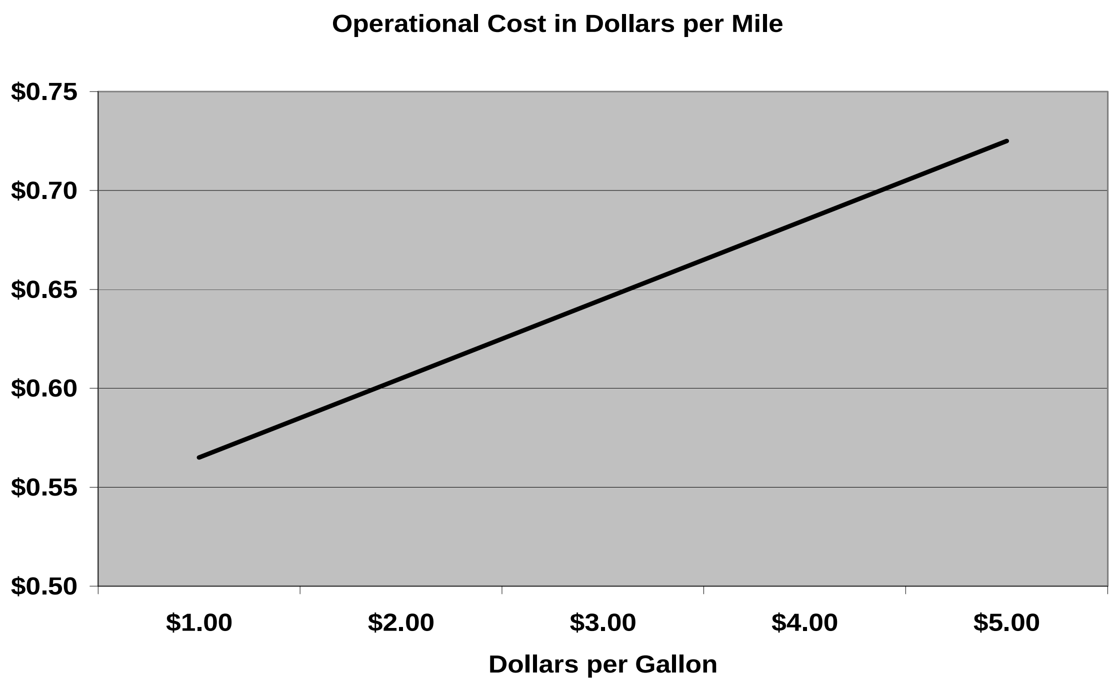
Key data from these tables can now be plotted as follows in the next four graphs.



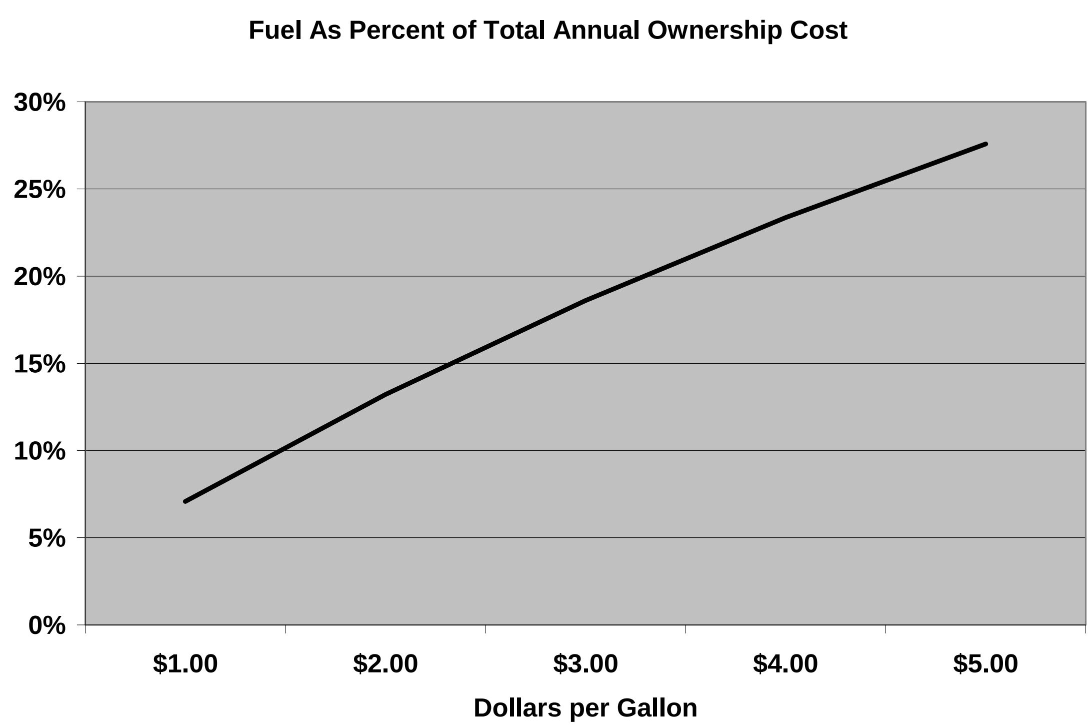
Graph 4: Annual Fuel Budget



Graph 5: Fuel Dollars per Mile



Graph 6: Operational Cost in Dollars per Mile



Graph 7: Fuel as Percent of Total Annual Ownership Cost

The last curve (Fuel As Percent of Total Annual Ownership Cost) best illustrates the large role that fuel plays in ownership. Note again the increase from 7% to 28% of life cycle cost. Fuel started as a minor expense and now makes up over a quarter of the ownership cost. Today we have fuel surcharges on shipping and airline tickets. This gives new meaning to that old phrase "let me give you some gas money." for driving me to the airport.

Lets conclude this chapter on cars with another alternative fuel. Recall that Otto originally ran his diesel engine on peanut oil. Also note that in the past restaurants had to pay to have waste management companies remove their spent deep fat frying oil and empty the waste water grease traps. As diesel fuel prices increased some enterprising car owners approached the restaurant owners and obtained the spent oil and grease for free. It is a rather simple shade tree process that can convert, filter and stabilize the oil and grease into bio-fuel.

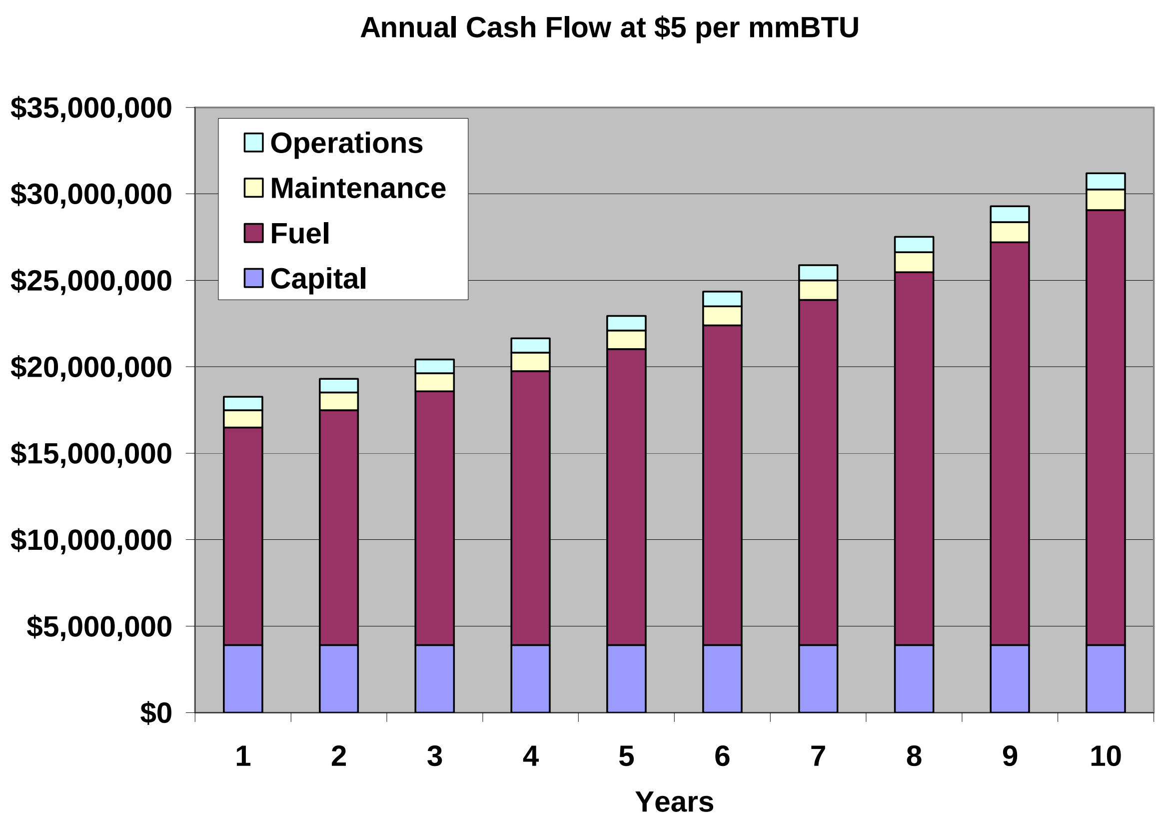
As the cost of diesel fuel has increased and word of free fuel spread, the shade tree industry grew to the point that restaurant owners began selling the spent oil and grease and now charge 75% of the pump price for what a few years ago was a "waste" material. The capitalist free market has a quick way of adapting to economic forces.

Boiler Operation

Boiler steam production and/or electrical generation is much more fuel intensive than the automobile example given earlier. In fact, as you will soon see, fuel dominates the ownership and operation of steam boilers. A typical 600 psig steam boiler producing 200,000 pounds per hour of 740 °F superheated steam may have the following cost[1] structure.

Construction capital.............$25,000,000
Annual Fuel cost[2] $12,590,000
Annual Maintenance..............$1,000,000
Annual Operations....................$776,000

If we assume that the construction cost is financed over 10 years at 9% interest, the annual cost of ownership (assuming some inflation) would look as follows:

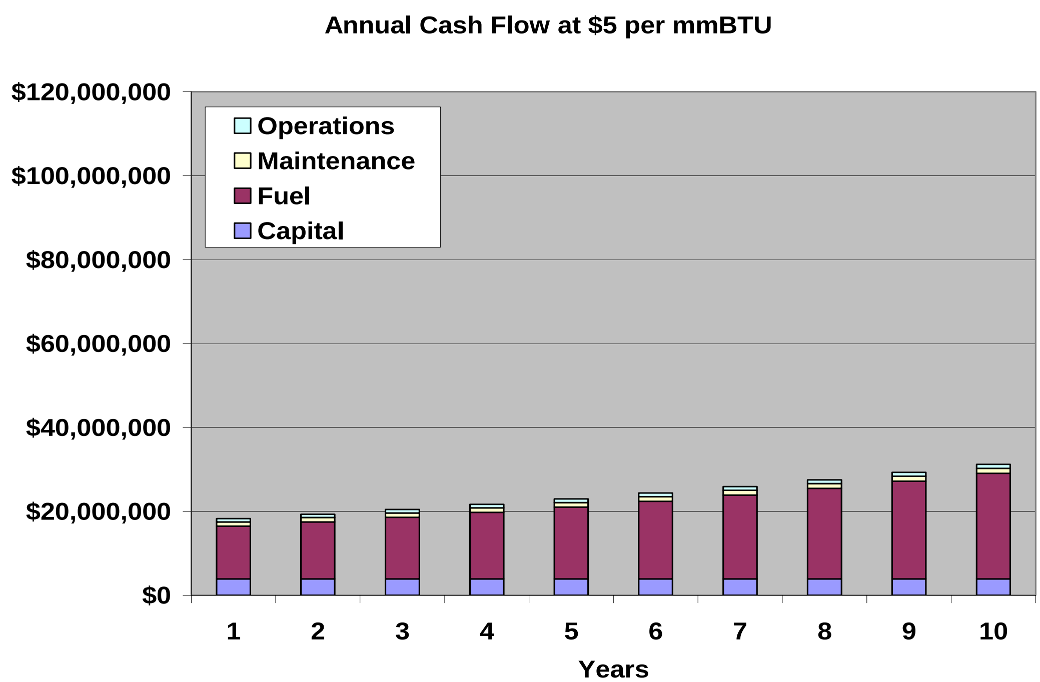


Graph 8: Annual Cash Flow at $5 per mmBTU

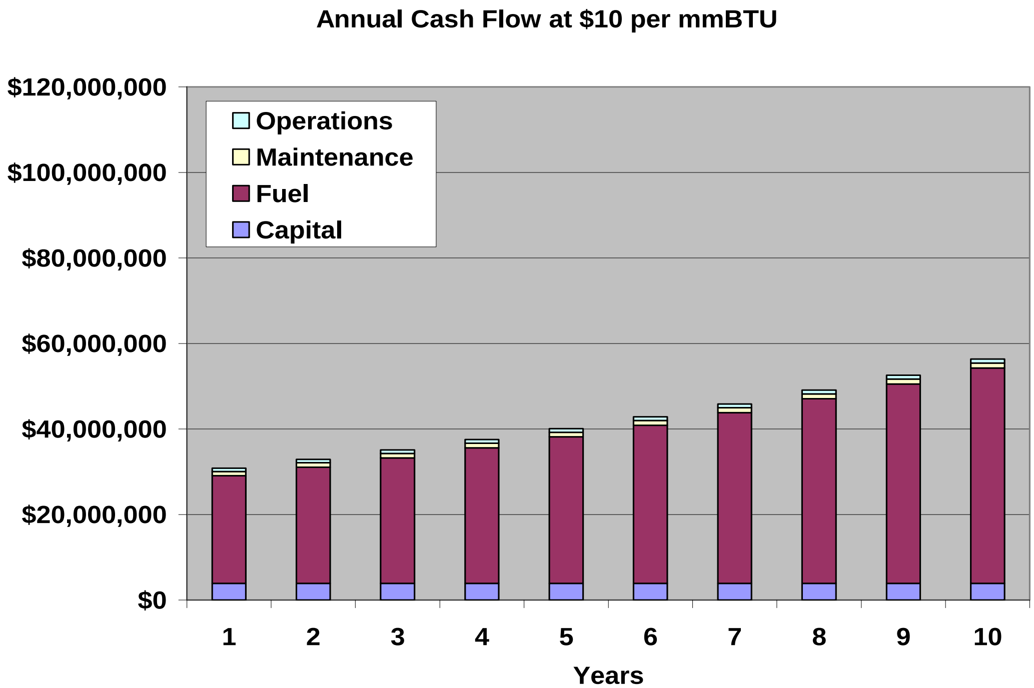
[1] The assumptions for this cost structure are given in the appendix

[2] This initial cost is based on purchased fuel of $5.00 per mmBTU

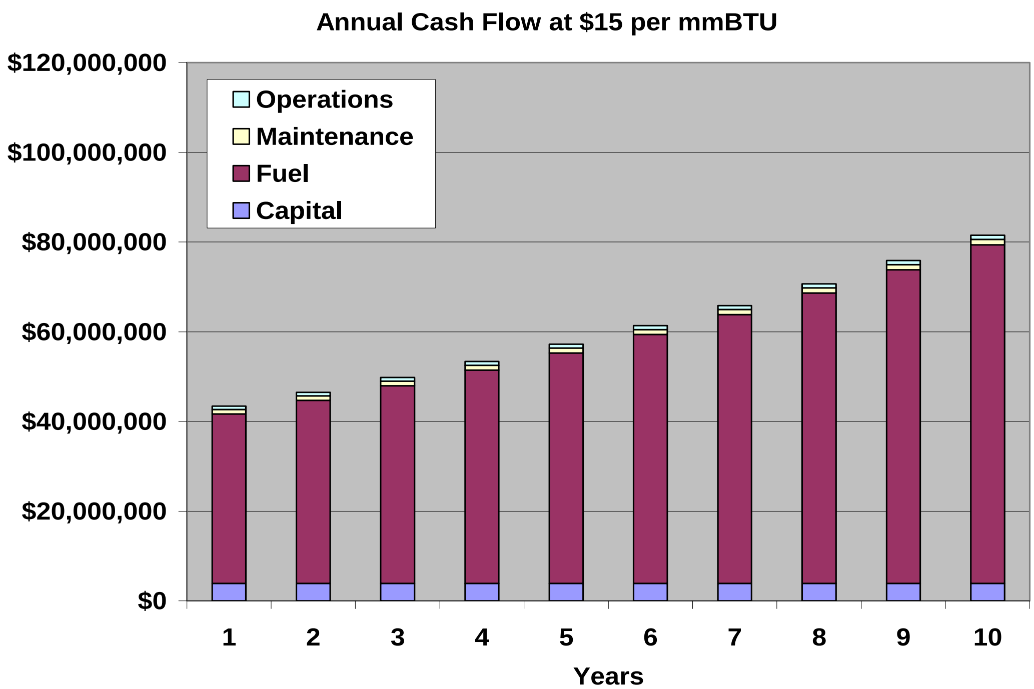
As you can see, the brown portion (representing fuel) of the column graph makes up the majority of the annual ownership cost. The millions of dollars spent on construction in year one are now very small in the big ten-year ownership picture. This is because we have levelized the capital construction cost over a ten-year loan repayment period. If we now change the dollar scale from zero $0.00 to $35 million on the vertical axis, select a $0.00 to $120,000,000 scale, then walk thru four fuel prices of $5, $10, $15 and $20 per mmBTU, we can see the heavy burden of the increasing fuel budget.



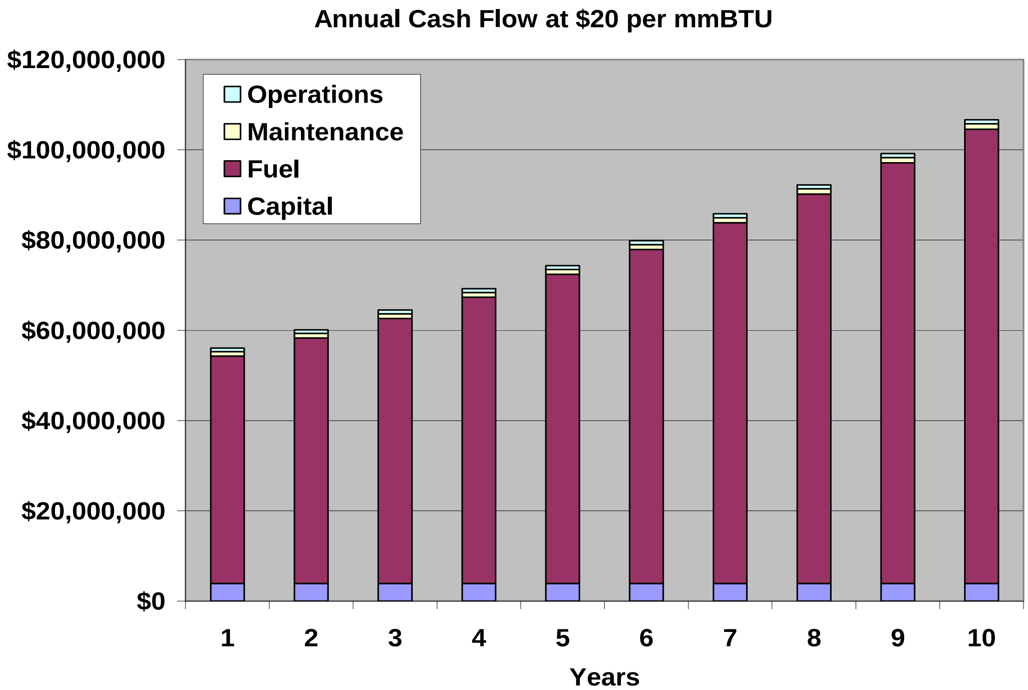
Graph 9: Annual Cash Flow at $5 per mmBTU



Graph 10: Annual Cash Flow at $10 per mmBTU

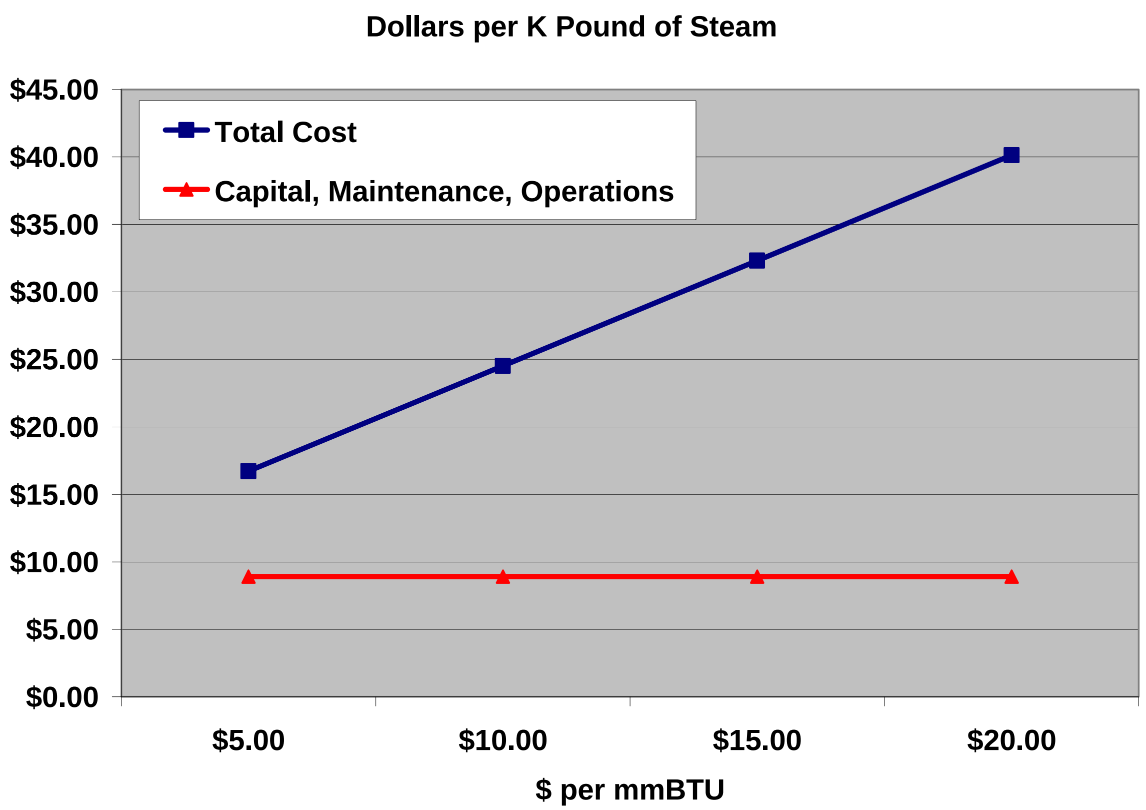


Graph 11: Annual Cash Flow at $15 per mmBTU



Graph 12: Annual Cash Flow at $20 per mmBTU

The boiler or utility area may be a cost center within the plant that charges users for their product so as to allocate the costs across various production departments. Using the numbers developed above, the cost of a K pound of steam sold would look as follows:



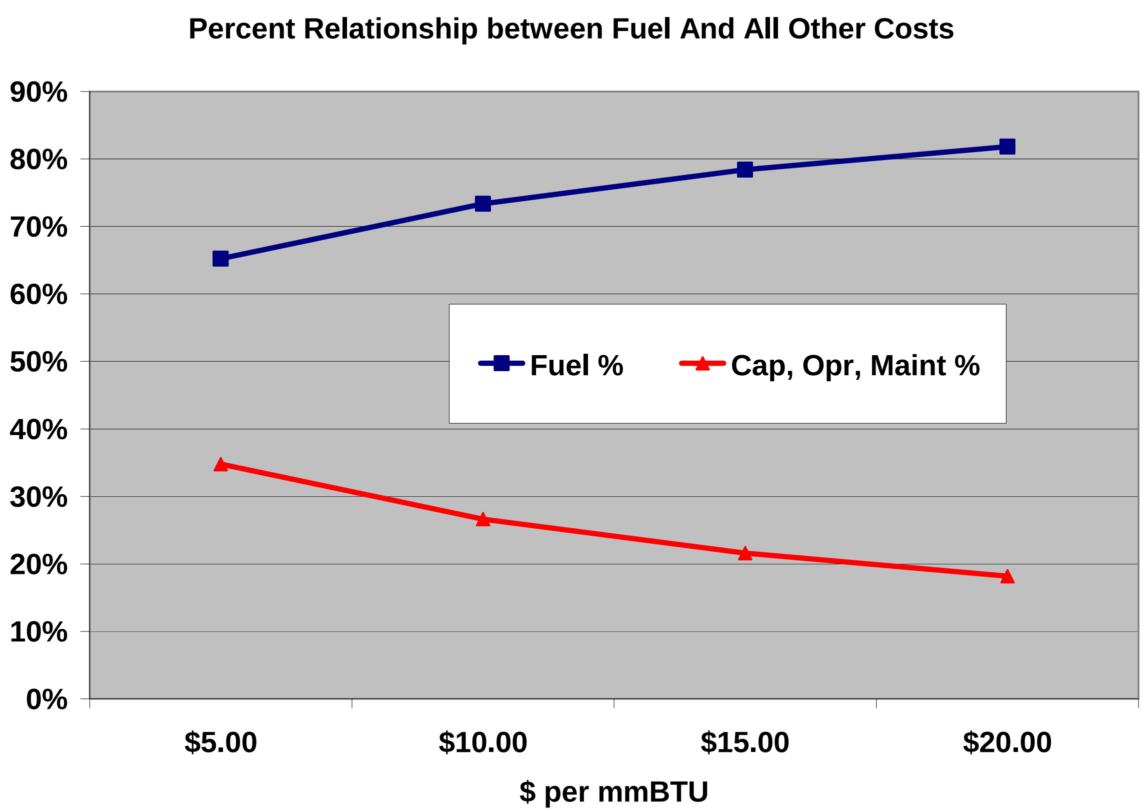
Graph 13: Dollars per K Pound of Steam

Notice that the red line (representing the annualized construction cost, annual maintenance and annual operations cost) remains constant and flat. The blue line (called "Total Cost") is the red line plus the fuel cost at the listed price per mmBTU and dominates the price structure for the sale of this plant utility called steam. If one desires to reduce the price of a K pound of steam, it would make more sense to switch to another fuel or look into equipment efficiency than to have management lay off one of the shift workers.

The following graph shows the percentage relationship between the cost of fuel and all others costs incurred in the production of steam. These other costs include:

1. Capital
2. Financing
3. Maintenance
4. Personal
5. Insurance
6. Water
7. Disposal
8. Chemicals
9. Etc.

This single graph should provide adequate incentive to research alternative fuels.



Graph 14: Percent Relationship between Fuel and All Other Costs

The Various Viewpoints of Alternative Fuels

Recall that this paper is to explore several aspects or viewpoints of alternative fuels. Moreover, engineers are very familiar with the pros and cons (also known as tradeoffs) of various options. We also heard from Georgia Tech professor Sam Shelton who said that "There is no single silver bullet for our energy situation, however, there are 100 brass bullets and we just need to find the right match." As we will now see, alternative fuels have many tradeoffs between price, carbon footprint, bottom ash, etc.

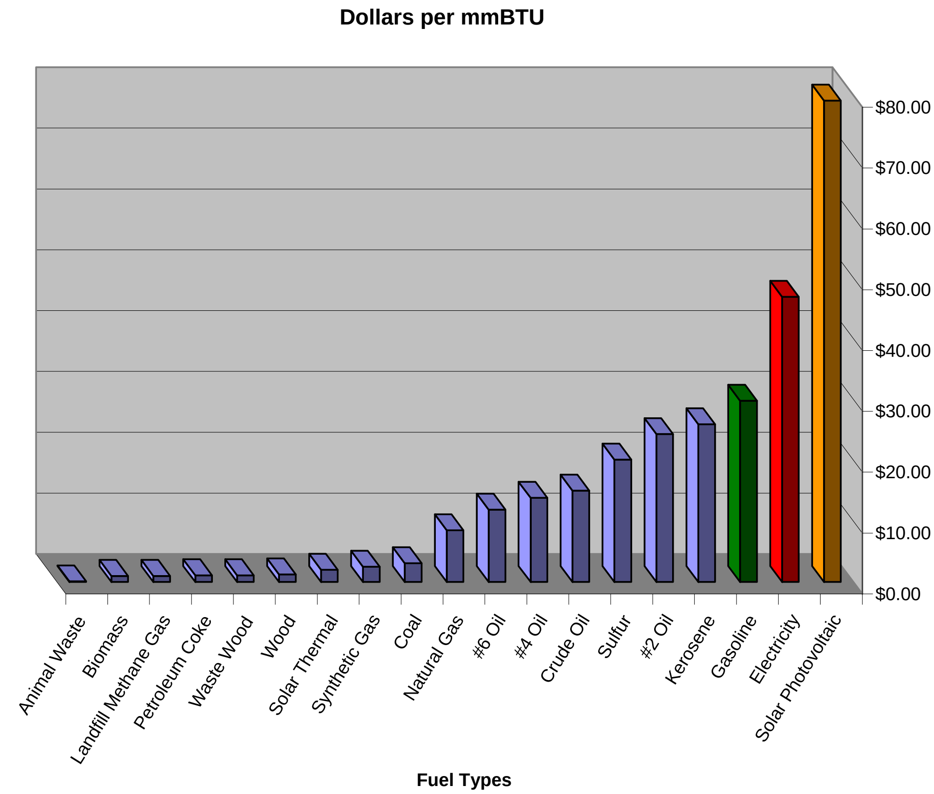
The first viewpoint is fuel cost. This is the overall motivation for making a fuel switch or fuel change. Recall that fuels are sold based on their own particular volume or weight units and that a proper comparison requires a "common denominator". In our case we choose to use dollars per million BTUs or $/mmBTU. The following table provides a comparison overview of "Dollars per mmBTU.

Fuel	Commonly Quoted Price	Commonly Used Units of Sale	Dollars per mmBTU
Animal Waste	$1.00	$ per Ton	$0.11
Biomass	$8.00	$ per Ton	$1.00
Landfill Methane Gas	$0.10	$ per Therm	$1.00
Petroleum Coke	$1.10	$ per mmBTU	$1.10
Waste Wood	$10.00	$ per Ton	$1.11
Wood	$12.50	$ per Ton	$1.25
Solar Thermal	$2.00	$ per mmBTU	$2.00
Synthetic Gas	$0.25	$ per Therm	$2.50
Coal	$80.00	$ per Ton	$3.08
Natural Gas	$0.85	$ per Therm	$8.50
#6 Oil	$1.75	$ per Gallon	$11.88
#4 Oil	$2.00	$ per Gallon	$13.84
Crude Oil	$100.00	$ per Barrel	$15.03
Sulfur	$160.00	$ per Ton	$20.10
#2 Oil	$3.20	$ per Gallon	$24.31
Kerosene	$3.50	$ per Gallon	$25.93
Gasoline	$4.00	$ per Gallon	$29.79
Electricity	$0.16	$ per kWh	$46.88
Solar Photovoltaic	$0.27	$ per kWh	$79.11

Table 10: Fuel Prices

On first glance all of us choose to utilize a fuel that is first on the list due to its low cost. Notice that oil of various grades occupies the higher priced spots on the list. Some of these fuel choices have the power to break an OPEC oil cartel and wean the United States from expensive oil, gasoline and electricity. Also notice the three highlighted fuels that occupy the most expensive slots.

The following graph presents the same data in the table above and clearly shows why alternative energy and fuel sources are gaining in popularity. Notice where gasoline (green bar), electricity (red bar) and solar Photovoltaic electricity (orange bar) are on the graph. Notice that 16 other (brass bullets) have a lower cost.



Graph 15: Fuel Prices

Let us turn our attention to carbon footprint. Do alternative fuels offer a better carbon footprint than traditional fuels? Recall that carbon footprint is pounds of CO2 emitted into the atmosphere per kWh, home, person, pound of fuel purchased or burned, or in our case per mmBTU. The following table is a stack up of the fuels.

Fuel	Carbon Footprint Pounds of CO2 per mmBTU
Sulfur	0
Solar Thermal	0
Solar Photovoltaic	0
Synthetic Gas	62
Landfill Methane Gas	87
Animal Waste	102
Natural Gas	118
Gasoline	143
Kerosene	157
#2 Oil	160
#4 Oil	168
#6 Oil	172
Crude Oil	177
Waste Wood	198
Coal	211
Petroleum Coke	212
Wood	221
Electricity	395
Biomass	410

Table 11: Carbon Footprint

From this stack up we can clearly see why, despite the high cost, Solar Thermal and Solar Photovoltaic are popular with the press and environmentalist. Notice that electricity is high on the list. This is due to the heavy reliance on oil and coal combustion. Both oil and coal are high in carbon content. Also consider for a moment the disconnect between the non-polluting electric car and the electric source that charges those electric car batteries. The press and politicians have only drawn an energy emission bounty around the car and have failed to take into consideration the actual source impacts that come from plugging that car into an electrical outlet.

Bottom ash is a solid waste product that results from combustion of fuels in boilers. The ash is primarily sand or silica and drops out of the combustion zone to the bottom of the boiler and also rises though the boiler and tends to plate out on boiler tubes. The following chart shows the pounds of bottom ash produced from each mmBTU.

Fuel	**Bottom Ash Pounds of Ash per mm BTU**
Natural Gas	0.00
Kerosene	0.00
Gasoline	0.00
#2 Oil	0.00
Landfill Methane Gas	0.00
Sulfur	0.00
Synthetic Gas	0.00
Solar Thermal	0.00
Solar Photovoltaic	0.00
Electricity	0.00
#4 Oil	0.05
Crude Oil	0.08
#6 Oil	0.13
Petroleum Coke	0.35
Wood	4.81
Coal	5.38
Biomass	6.37
Waste Wood	10.00
Animal Waste	52.00

Table 12: Bottom Ash

Notice the double highlight. Electricity used in your home or business has zero bottom ash. However, electricity produced from the combustion of coal creates bottom ash.

Air emissions are a very complex subject owing to several factors such as;

- The county you are operating in
- The air emissions standards of that county
- The detailed source and analysis of your specific fuel. For instance, here in the US we have many different types of coal including Anthracitic, Bituminous, Subbituminous, and Lignitic and each has its own sulfur content. In fact we refer to Appalachian coal as high sulfur and western coal from the Power River Basin as low sulfur. Natural gas, and crude oil also have site specific characteristics.
- The type of combustion such as turbine, boiler or furnace
- The size and operating temperature of your combustion zone
- The presence of exhaust gas treatment, such as dry or wet scrubber, electro static precipitator or selective catalytic reduction

With the previous fuel source and combustion considerations as a back drop, some of the major and/or common air emission products that require attention include;

- Carbon Monoxide
- Carbon Dioxide
- Nitrogen
- Nitrous oxides
- Sulfur dioxide
- Fly ash
- Water vapor – think unsightly plume and plume burners
- Mercury
- Chromium
- Iron
- Copper
- Cobalt
- Vanadium

Biogas and Landfill Methane Gas:

Landfill gas is one of three major types of Biogas that are available as a fuel. Here in the United States, as in most of the world, society has to deal with animal and agricultural waste, municipal solid waste, as well as sewage and wastewater. Previous methods of handling animal and agricultural waste have involved wash downs into streams and rivers or spreading onto fields. Municipal solid waste has been land filled or incinerated. Sewage treatment technology has evolved from river entry to primary, secondary and tertiary waste treatment plants. The last 20-years have seen the chlorination and distribution of the sewer plant tertiary outfall back to the community as reclaimed water which is used for lawn irrigation.

In recent years these three waste streams have been tapped for their Biogas production. The gas is of sufficient quality and quantity to power 100kW to 500kW or larger diesel engines that have carburetor/fuel system modified to burn the 50% methane / 50% carbon dioxide (CO_2) mixture. These engines either provide shaft horsepower for process pumps or electric generators for either in-plant or utility sales. The break down of the major Biogas sources here in the US is a follows:

Source	**Percentage**
Animal & Agricultural	75%
Municipal Solid Waste	17%
Sewage and Wastewater	8%

Table 13: Biogas Sources

Farms are now installing tented lagoons or enclosed tanks and allowing the heat of the sunlight to speed the production of methane.

Figure 8: Enclosed Bio Gas Tanks

Figure 9: Bio Gas Pond with Tent Collection

Cow Power

The following story and pictures come from the December 15, 2007 issue of Power Magazine. Dr. Robert Peltier, PE, senior editer of Power magazine, and his staff voted this Central Vermont Public Service, Cow Power Program as the “Power Plant” of the year award. It was both a front cover picture and feature story.

December 15, 2007

Central Vermont Public Service, Cow Power Program

Dr. Robert Peltier, PE

Renewable energy projects often reflect the character of the local economy and locally available natural resources. Solar energy power generation systems are a natural for the Southwest but are less applicable in the more-cloudy and congested Northeast. The southeastern U.S. lacks the wind velocity profiles to justify installation of wind turbines, the flowing rivers required by hydroelectric projects, and the geysers essential to geothermal power. Mother Nature didn't consider state boundaries when distributing her natural resources. Nevertheless, many regions are getting creative about developing renewable energy generation projects that support the local economy and make the most of available resources.

Take Vermont, for example. Think of Vermont's bucolic landscape and you may visualize dairy farms. But what you may not envision—because only 2% of the U.S. population is now involved in farming of any type—are the economic challenges that dairy farmers face, including issues of manure disposal, rapidly increasing costs of bedding material, and the rising cost of electricity to operate the business. Dairy farming is capital cost intensive, and limited land availability makes expanding many of Vermont's family farms impossible or cost prohibitive. Diversification of the product line and more efficient internal operations are the keys to continued dairy farm profitability.

And that's where a new program at Central Vermont Public Service (CVPS) fits into the picture. CVPS Cow Power, as the program is called, promotes development of and reliance on renewable energy in Vermont by creating a market for energy generated from a renewable biogas fuel derived from cow manure.

Reliably renewable

Central Vermont Public Service is a small utility serving about 158,000 customers in Vermont principally through long-term contracts with Vermont Yankee and Hydro Quebec (54% nuclear and 38% hydro). Another 6.5% of its customers' power needs are served by 20 small hydro stations owned by CVPS. Most of the remainder is delivered by independent power producer contracts, most involving renewable sources. A new addition to the CVPS renewable portfolio is power generated by biogas that's derived from digested cow manure at several large dairy farms (Figure 1).

1. Tanks for the manure. Steve Dvorak (far left), who designed the digester at Blue Spruce Farm, Dave Dunn, Earl Audet (with Sierra at his feet), and Melissa Dvorak discuss the separation process, which divides liquids from solids after the manure spends 21 days in the digester. Courtesy: CVPS

The gaseous engine fuel comes from manure and other farm waste held in a sealed concrete tank at the same temperature as a cow's stomach (approximately 101F) for about 21 days. Bacteria digest the volatile components, creating methane while killing pathogens and weed seeds. The methane is then piped to a modified, naturally aspirated engine-generator (Figure 2).

. Low-Btu gas. David Dunn, CVPS Cow Power coordinator (left), and Ernie Audet discuss generator operation at the Blue Spruce Farm in Bridport, Vt. Audet and his brothers own the farm, the first to begin producing CVPS Cow Power. Four farms are now part of the program. Courtesy: CVPS

Several dozen farms across the United States are now generating electricity in this way, but CVPS Cow Power was the first program designed to support this effort by linking local customers and producers in an entirely new farm-to-market model and by providing cash grants to defray the costs of interconnection to the rural grid.

By enrolling in CVPS Cow Power, retail customers help support Vermont dairy farms develop biogas-fueled generators, renewable generation in the region, and incentives to farmers for getting into the business. These farms are significant customers for CVPS, so helping them improve their financial strength is good for the local economy as well as the utility.

The program has garnered strong public support: More than 4,570, or 2.8%, of the company's customers participate. CVPS expects to have 5% of its customers enrolled by year-end 2010. "Our goal has been to make CVPS Cow Power one of the top 10 programs in the country by year-end 2010, and we are well on our way toward meeting that goal," CVPS President Bob Young said. "Customers continue to enroll by the dozens each week, voting with their energy choice for Vermont farming, an improved environment, and renewable energy production."

Green Mountain College, known for its emphasis on the environment and energy sustainability, has committed to purchase 50% of its main campus's electricity as Cow Power and 100% on all its other accounts, which include the president's house, the college farm, the college inn and alumni house, and an off-campus residence hall in Killington, Vt. The college's total Cow Power purchases will eventually rise to approximately 1.2 million kilowatt-hours annually.

"This is a great step for us toward a sustainably powered campus," said Provost Bill Throop. "We are very happy to be supporting not just renewable energy but also the regional economy and the family farms that are so important to the Vermont way of life. It is a good fit with our mission, and departments across campus are supporting the project from their own budgets because they feel it's a priority."

Enrollment options

Customers may choose to enroll 25%, 50%, or all of their electricity purchases in the Cow Power program, which adds a 4-cent premium per kWh. Customers using 500 kWh per month who buy 25% of their electricity under the rider pay only an additional $5 a month. At 50% Cow Power, those customers would pay an additional $10. Farmers receive 95% of the hourly market price for the energy they generate, plus the 4-cent premium paid by tariff customers for the value-added attributes of Cow Power.

Customers enroll for a variety of reasons. Some want to reduce their reliance on nonrenewable energy, so providing them with a renewable energy choice is important. Others want to support Vermont agriculture or reduce environmental impacts.

Diversified benefits

Regardless of the reasons customers enroll, Cow Power provides several benefits to participating farmer-generators. Chief among them is a new, steady income stream that offsets fluctuations in milk prices. Farmers also benefit by using excess heat from the engine-generator to heat water and provide space heating, thereby saving $10,000 to $15,000 annually in offset fuel purchases.

Anaerobic digesters also solve another problem: manure management. Manure can be processed through a mechanical separator, and then the solids can be dried and used to replace sawdust or sand as bedding for the animals, because pathogens are killed during digestion. That use alone saves $80,000 to $150,000 annually for participating farms. Any solids not used for bedding may be further processed and sold to the public or garden centers as a soil amendment or garden compost, providing an additional revenue stream. Taken together, these are enormous benefits in a state with a major farm economy (Figure 3).

3. Recycling solids. Earl Audet (left) and David Dunn examine some of the dry solids left over from the manure digestion process at Blue Spruce Farm. The solids, which resemble peat moss, are used as bedding for the cows, saving over $100,000 annually on sawdust. Courtesy: CVPS

Cow Power even improves air quality. The digestion process removes the odor normally associated with spreading the liquid portion of manure on crop fields as fertilizer. That reduces the impact on aquatic organisms should an accidental manure spill or unintended runoff into a body of water occur. Neighbors within smelling distance appreciate the use of the naturally odorless liquid manure.

David Dunn, of Central Vermont Public Service, and I spoke by phone and exchanged some emails regarding the capital cost and payback of the cow power program. Here is the raw data that he provided along with my 20-year cash flow projection, the project payback and rate of return. I think that we would all agree that even the raw un-subsidized project at 14% rate of return would be attractive to an investor.

Item / Description	(Cost) or Revenue
Cost of Project	($1,300,000)
Grant Funding	$550,000
Annual Maintenance Cost	($30,000)
Energy Sales	$84,500
Attributes Sales	$52,000
Bedding Offset	$72,000
Hot Water Savings	$14,000

Cash Flow for both Raw and Subsidized Cost		
Year	Raw Cost	**Subsidized Cost**
0	($1,300,000)	($750,000)
1	$192,500	$192,500
2	$192,500	$192,500
3	$192,500	$192,500
4	$192,500	$192,500
5	$192,500	$192,500
6	$192,500	$192,500
7	$192,500	$192,500
8	$192,500	$192,500
9	$192,500	$192,500
10	$192,500	$192,500
11	$192,500	$192,500
12	$192,500	$192,500
13	$192,500	$192,500
14	$192,500	$192,500
15	$192,500	$192,500
16	$192,500	$192,500
17	$192,500	$192,500
18	$192,500	$192,500
19	$192,500	$192,500
20	$192,500	$192,500

Payback in Years	**6.75**	**3.90**
Rate of Return	**14%**	**25%**

Table 14: Cow Power ROI

Summary

As we have seen, fuel prices are rising and many of us are switching to high mileage cars. Business and industry can also reduce the budget impact of rising fuel prices by investing in new equipment and switching to alternative fuels. The following is a simple calculator that can be used for quick "back of the envelope" calculations. This particular example is based on the 200,000 pounds per hour 600 psig boiler we reviewed earlier. The existing fuel is oil and the new fuel is coal.

Description	**Value**	**Units**
Existing Fuel	$24.00	$/mmBTU
New Fuel	$3.00	$/mmBTU
Savings	$21.00	$/mmBTU
BTU per hour	265,400,000	BTU/Hour
Savings	$21.00	$/mmBTU
Dollars per Hour	$5,573.40	$/Hour
Hours per Year	8,400	Hours
Dollars per Year	$46,816,560.00	$/Year
Capital	$200,000,000.00	Dollars
Simply Payback	4.27	Years

Table 15: Payback Calculator

A four year payback would provide approximately a 25% rate of return, which is very good even by current New York City stock market standards.

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Gasoline price table is a composite of Road & Track magazine December 2009 page 100, and the Wall Street Journal, story Drivers Seat Blog "Gas Prices Around the World" story dated March 7, 2011,

Picture of Earth with gasoline prices on page 12 is complements of Jean's Blog - a part of the "The Huffington Post" originally published on July, 22, 2010

The old wood burning truck in the garage on page 13 is from The Wood Truck Company

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The collage of pictures of the wood burning truck on the top of page 14 is from the May/June issue of Mother Earth News.

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The enclosed Bio Gas tanks on page 31 are from Image Cat

The Bio Gas pond with tent collection on page 32 are from Argentina Bio Energy

The pictures of the manure tanks on page 35, the engine generator on page 36, and the recycling solids on page 38 are all from the December 15, 2007 Power Magazine story and were taken by Central Vermont Public Service. See small note at the bottom of each of these three pictures.

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Eric Coffin, P.E. graduated from the University of South Florida in 1978 with a BS in Mechanical Engineering. He specialized in thermodynamics, fluids, and process control. Having experience in Electric Utility, Large Industrial and Heavy Commercial markets, he is well versed in energy audits, process control, option development, financial studies, and Green Energy Solutions (solutions that can reduce the amount and cost of purchased energy).

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Certified Energy Manager – Worldwide
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Department of Business & Professional Regulation, Continuing Education Provider for Certified Public Accountants – Florida
Department of Business & Professional Regulation, Continuing Education Provider for Construction Industry Licensing Board - Florida
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Eric is also approved to teach PE continuing education in an additional 38 states and two U.S. territories.

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