To the Graduate Council:

I am submitting herewith a thesis written by Jennifer F. English entitled "Generic Transportation Model Applied to Catalytic Steam Gasification of Poultry Litter and To Rotary Kiln Incineration of Shredded Tires." I have examined the final paper copy of this thesis for form and content and recommend that it be accept in partial fulfillment of the requirements for the degree of Master of Science, with a major in Chemical Engineering.

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Dr. Atul Sheth, Major Professor

We have read this thesis and
recommend its acceptance:

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(Original Signatures are on file with official student records)

GENERIC TRANSPORTATION MODEL APPLIED TO CATALYTIC STEAM GASIFICATION OF POULTRY LITTER AND TO ROTARY KILN INCINCERATION OF SHREDDED TIRES

A Thesis
Presented for the
Master of Science
Degree
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Jennifer Fuller English

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DEDICATION

This thesis is dedicated to my family, without their continuing support I would not have had the courage to re-enter the academic world, to my husband, Greg, who has been a constant source of support and to my daughter, Abigail, who has given me the desire to achieve all that is possible so that she might someday achieve the impossible.

ACKNOWLEDGMENTS

First I must thank God who has brought me to this point in my academic career. I would like to thank Dr. Atul Sheth, Dr. Max Hailey and Dr. Roger Painter for serving as members of my thesis committee. I am eternally grateful to Dr. Sheth whose patience and understanding in the face of my relentless procrastination has been incredible. I would like to thank the University of Tennessee Space Institute for the opportunity to continue my education. I would also like to thank Andrew Jones and Anthony Turner whose theses were the basis for this work. I greatly appreciate all of the suggestions and advice offered by my classmates Bratendu Bagchi, Shenghong Qui and Todd Nichols. Finally I would like to thank Dr. David Pruitt for his weekly progress questions and advice.

ABSTRACT

Many environmental issues are related to the disposal of both poultry litter and used tires. In an effort to provide a more environmentally friendly alternative to disposal of these substances, work has been done previously at UTSI in the areas of catalytic steam gasification of poultry litter and rotary kiln incineration of shredded tires. The scope of this research is to develop a transportation model that can be used for either of these processes. The model will be used to determine their economic feasibility under changing conditions including traveling distance, feed rate, and price fluctuations in the sales price of the product gas from the gasification process and the steam generated from the incineration process.

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LIST OF NOMECLATURE

A_n	Area in a circle n miles from plant
A_{n-1}	Area in a circle n-1 miles from plant
AC	Annual Cost
AD	Average distance traveled per trip one way
AF	Annual Fuel Requirement
AL	Average time to load and unload a truck
AP	Annual Profit
AS	Average speed limit
D	Minimum Required Population Density of Poultry Farms
D_n	Sum of distances to all houses in ring
DEN	Bulk Density of Litter
F	Daily Fuel Requirement of the Gasification Plant
H	Hours truck runs per day
i	Time value of money
N	Total number of picku-up locations inside circle of radius R
NC	Construction Time
ND	Number of Days of Operation PerYear
NH	Number of Houses required to supply fuel to plant
NT	Number of truck needed to make pickups
OPDAY	Number of days of operation per year
p	population density of pick-up locations

P	Annual Litter Production Per Chicken House
R	Maximum radial distance to travel away from plant
R_n	Distance to 1 pickup location n miles from plant
TD	Sum of distances from the plant to each house in the radius R
TONS	Tons of Litter per Load
TPD	Required number of trips per day
TPEC	total purchase equipment cost
TPR	Number of trips required per year
TPT	Trips per truck each day
TT	Time to travel to a pickup location
TTPT	Total Time per Trip
VOL	Volume of dump truck

CHAPTER ONE

Introduction

Previous work carried out in the University of Tennessee Space Institute's (UTSI) chemical engineering department has included a detailed study of the catalytic steam gasification of poultry litter as well as a smaller study on the design of a rotary kiln incinerator for shredded tire fuel. These research projects were undertaken due to an interest in combating the negative environmental effects associated with the disposal of poultry litter and whole used tires.

Although poultry litter can be used as a fertilizer, there is a limit to how much litter can be applied to a specified amount of land in one years time. When excess litter is applied, groundwater pollution among other things becomes a significant problem. Previous research at UTSI has been focused on how to convert poultry litter to a useful fuel gas that can be consumed either by the farmer or by other industries in an industrial park setting. (21)

A separate study was done in 1999 for the Northeast Regional Biomass Program that included a detailed economic analysis including transportation costs, on the topic of processing poultry litter and nutrient filter biomass to produce energy for the Lower Delmarva Peninsula area. This study differed from those at UTSI in that it used existing plants, including the poultry processing facilities as possible locations for the energy production facility, whereas the focus of the UTSI studies has been the design of a completely new plant. The Delmarva area study found that the processing facilities were "not large enough to provide economically acceptable heat or power from poultry litter." (1)

Negative environmental effects associated with used tires are, fire hazards caused by tire stockpiles, and tires, which hold water for long periods of time, are excellent breeding grounds for mosquitoes and rodents. (15)

Furthermore, land filling of whole scrap tires is an undesirable alternative because they tend to float to the surface of the landfill in a short time. The previous research performed at UTSI described the design of a scrap tire incineration plant that would utilize the heating value of the tires to produce high pressure steam, which would be sold to generate income. The previous UTSI study found that the plant at a low feed rate would not be economically feasible. In this research higher feed rates will be applied to see if a larger plant would have a greater possibility of success. (15)

According to Mr. Frank Dominioni, Environmental Program Administrator of TVA's Allen Fossil Plant in Memphis Tennessee, the Allen plant uses shredded tires as an auxiliary fuel for their coal processing plant. The tires are added to the fuel on a ½ to 1 ½ weight %. The Allen plant was an existing facility that was modified to accept the shredded tire fuel. (4) However, it differs from the UTSI study in that the UTSI plant would be a new plant that would be designed to process tires as the primary fuel source.

Both of the previously discussed research projects were carried out with basic economic analyses to provide rough estimates of the feasibility of the projects. These economic analyses did not go into great detail about the costs that would be involved in transporting the materials to the plants. The purpose of this research is to use the previous works to create a transportation model that can be used for both processes to determine how transportation costs will impact the overall economic feasibility of the projects. The major variables that are considered are daily feed rate, radial distance to travel from the plant to pick up materials, and the selling price of the products produced.

The transportation model is written in the Visual Basic 6 programming language, because of its user friendly environment.

CHAPTER 2

Process Descriptions

The gasification process and the incineration process that are the basis for this study were designed in previous UTSI projects. Included here are brief descriptions of the two processes to which the transportation model is applied.

2.1 Catalytic Steam Gasification of Poultry Litter

Because an excess of poultry litter applied to the ground as fertilizer or as waste can cause adverse environmental impact, alternate uses of the litter are being explored. Work has been done at UTSI in the area of catalytic steam gasification of poultry litter, to design a hypothetical plant that would produce a product gas made up of carbon monoxide, carbon dioxide, methane and hydrogen with an average heating value of 304.7 BTU per standard cubic foot. The desirable design conditions for the gasification plant were found to be 330 days per year of operation, a base feed rate of 100 tons/day, an operating temperature of 1350 degrees F, and a pressure of 100 psig. Langbeinite would be used as an additional catalyst and would be mixed into the feed at a 10% by weight level. (21) A schematic of the gasification process is shown in Figure 2.1.

Once the poultry litter is transported to a common area it is stored in a receiving tank. From the tank, the litter is sent to a feed hopper via a conveyor. The litter leaves the hopper and enters a fixed bed gasifier. The output is carried to a cyclone separator, where the desired product gases are separated from the entrained char and sent through a

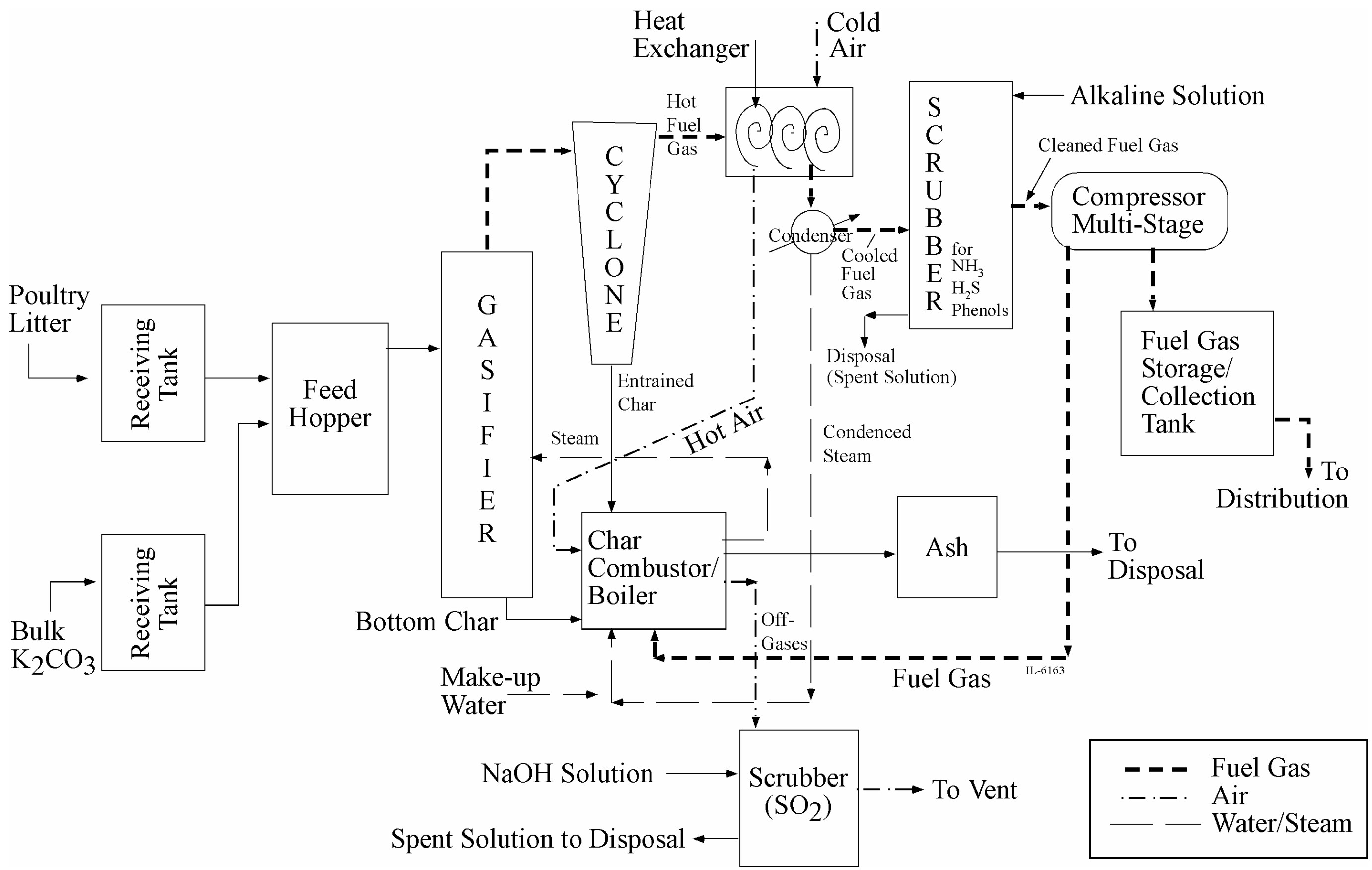


Figure 2.1 Schematic of Gasification System (21)

heat exchanger for heat extraction after which they are directed to a scrubber. The char exits the cyclone and enters an air fed combustor, which burns off the carbon from the char and sends the ash to a separate receiver. The scrubber is fed a sodium hydroxide solution to remove sulfur compounds. The scrubbed gases from the scrubber enter a compressor, part of the fuel gas is sent back to the combustor for steam generation and the remainder is collected in high pressure storage tanks. (21)

2.2 Rotary Kiln Incineration of Shredded Tire Fuel

Like poultry litter, the disposal of whole used tires contributes to environmental damage. Tires that are land filled tend to "float" to the surface of the landfill. The shape of the tires allows them to be an excellent breeding ground for mosquitoes and rodents. Tire stockpiles are also undesirable because they pose major fire hazards. (4) Work was done at UTSI to design a rotary kiln incinerator for tire fuel. The operating conditions were determined to be 300 days per year of operation with a feed rate of 2222 lb/hr. The plant would have a thermal capacity of about 7.7 MWth. (15) A schematic of the process is shown in Figure 2.2.

Truck scales are located at the main gate to account for all deliveries. Prior to the rotary kiln there is a fuel storage, handling and feeding system that includes front end loaders and a belt conveyor. The discharge from the kiln is directed to a secondary combustion chamber. The heat recovery from the secondary combustor flue gas takes place in two steps. The primary heat exchange takes place in a water tube boiler located downstream of the secondary combustor. Secondary heat recovery takes place in water preheater.

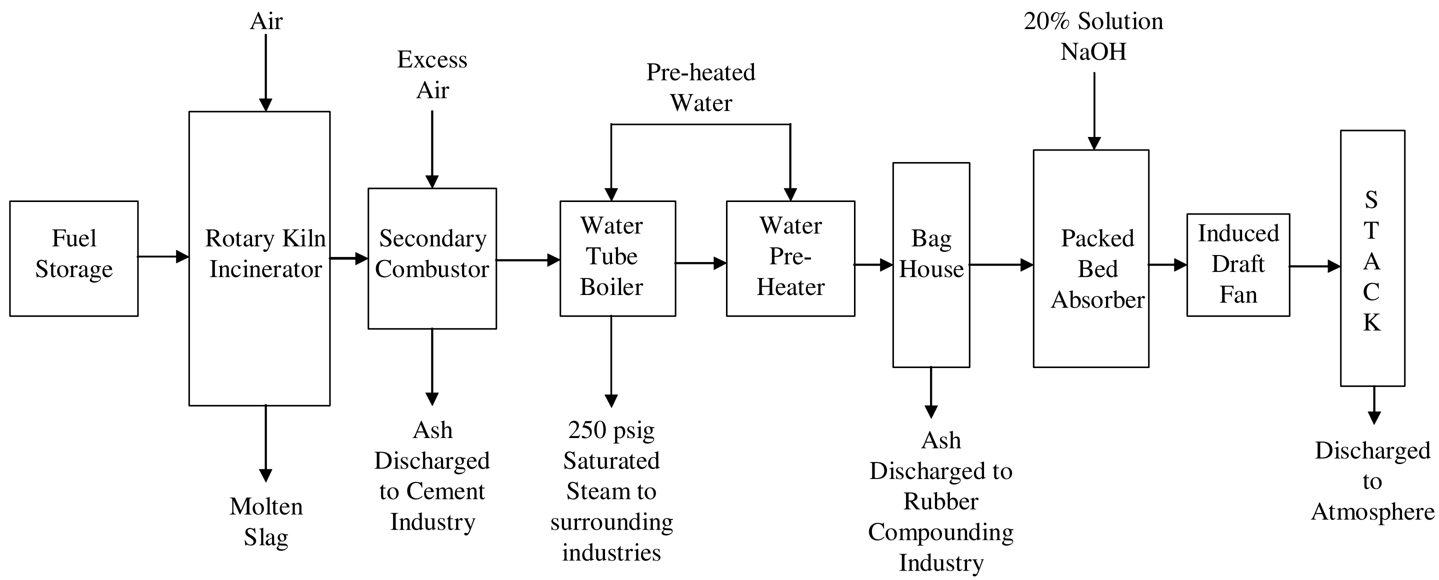


Figure 2.2 Schematic of Incineration System (15)

The flue gas from the preheater is directed to a bag house to recover the ash in dry form. Finally the exhaust gases are treated in a packed bed absorber. An induced draft fan is positioned just downstream of the scrubber and exhausts into the stack for discharge into the atmosphere. (15)

CHAPTER THREE

Program Overview

The calculations for the economic analysis in the transportation model have been carried out based on the information found in *Plant Design and Economics* for Chemical Engineers by Max S. Peters and Klaus D. Timmerhaus. (16) A copy of the program has been included in Appendix II, and copies of each of the screens in the program have been included in Appendix I

3.1 Equipment Costs

The equipment necessary to run the poultry litter gasification plant was taken from the work done previously at UTSI by Anthony Turner. The equipment for the Rotary Kiln Incineration of Shredded Tire Fuel was taken from the work done by S. Parthasarathy, X. Lu, and W.T. McMinn.(15) Their costs of the equipment were assumed to be correct as of 1999 and 1993 respectively and were brought to current economic conditions by using the Chemical Engineering Costs Indices (16)

$$Present\ Cost = Original\ Cost \left(\frac{index\ @\ present}{index\ @\ original} \right)$$

The costs indices as taken from Chemical Engineering Magazines November 2000, and May 2003 issues were for 1993 – 359.2, for 1999 – 390.6, and for 2003 – 397.2. The indices are reasonable for estimating costs within a ten year period. (16) Therefore these values should provide reasonable estimates for the equipment involved.

The cost of each piece of equipment was scaled up using the sixth tenths rule, commonly used in chemical engineering calculations. (16)

$$\textit{Cost of equipment a} = \textit{Cost of equipment b} \left(\frac{capac.equip.a}{capac.equip.b} \right)^{0.6}$$

This equation is valid to compare similar equipment with different capacities. Sometimes exponents are available to replace the 0.6 exponent that produce closer results. When the exponents were available for specific pieces of equipment they were used instead of the sixth tenths exponent. For equipment for which no literature values of exponents were available, a factor of sixth tenths was used. All exponents were taken from the text by Peters and Timmerhaus or Perry's Chemical Engineers Handbook.

The equipment list and costs for the poultry litter gasification process at a feed rate of 100 tons/day as taken from the work done by Anthony Turner are presented in Table 3.1. These costs were corrected to reflect current economic conditions and are displayed in Table 3.2. Because it is desirable to test the effect of a changing feed rate, the equipment was scaled up to 500 tons/day which is shown in Table 3.3 and 1000 tons/day in Table 3.4. The corresponding exponents used to replace the sixth tenths exponent, are included in these tables.

Equipment information regarding the rotary kiln incineration of used tire fuel for a feed rate of 2222.22 lb/hr as taken from the previously referenced work may be found in Table 3.5 and 3.6. The information for feed rates of 12,222 lb/hr and 22,222 lb/hr is shown in Tables 3.7 and 3.8 respectively along with the corresponding exponents that were used.

Table 3.1 Equipment Costs for Feed Rate of 100 tons/day as of 1999 for Poultry Litter Process (21)

Item	Purchase Cost 1999
Receiving Tanks	$80,000
Feed Hopper	$60,000
Fixed Bed Gasifier (1500 gal)	$250,000
Cyclone Separator (800 cu ft)	$60,000
Heat Exchanger (150 sq ft)	$13,000
Condenser (1500gpm)	$9,000
Combustor for steam char and ash	$130,000
Ash Container	$75,000
Gas Scrubbers	$120,000
Multi-Stage Compressor	$94,000
Building	$40,000
Fuel Gas Storage Tank	$58,000
TOTAL PURCHASED EQUIPMENT COST	$989,000

Table 3.2 Equipment Costs for Feed Rate of 100 tons/day as of 2003 for Poultry Litter Process

Item	Purchase Cost 2003
Receiving Tanks	$81,352
Feed Hopper	$61,014
Fixed Bed Gasifier (1500 gal)	$254,224
Cyclone Separator (800 cu ft)	$61,014
Heat Exchanger (150 sq ft)	$13,220
Condenser (1500gpm)	$9,152
Combustor for steam char and ash	$132,197
Ash Container	$76,267
Gas Scrubbers	$122,028
Multi-Stage Compressor	$95,588
Building	$40,676
Fuel Gas Storage Tank	$58,980
TOTAL PURCHASED EQUIPMENT COST	$1,005,711

Table 3.3 Equipment Costs for Feed rate of 500 tons/day as of 2003 for Poultry Litter Process Including Exponents

Item	exp	Purchased Cost
Receiving Tanks	0.57	$203,601
Feed Hopper	0.60	$160,255
Fixed Bed Gasifier	0.60	$667,727
Cyclone Separator	0.49	$134,253
Heat Exchanger	0.59	$34,167
Condenser	0.60	$24,038
Combustor for steam char and ash	0.60	$347,218
Ash Container	0.57	$190,876
Gas Scrubbers	0.60	$320,509
Multi-Stage Compressor	0.69	$290,198
Building	0.60	$106,836
Fuel Gas Storage Tank	0.57	$147,611
TOTAL PURCHASED EQUIPMENT COST		$2,641,528

Table 3.4 Equipment Costs for Feed Rate of 1000 tons/day as of 2003 for Poultry Litter Process Including Exponents

Item	exp	Purchased Cost
Receiving Tanks	0.57	$302,250
Feed Hopper	0.60	$242,900
Fixed Bed Gasifier	0.60	$1,012,085
Cyclone Separator	0.49	$188,551
Heat Exchanger	0.59	$51,430
Condenser	0.60	$36,435
Combustor for steam char and ash	0.60	$526,284
Ash Container	0.57	$283,360
Gas Scrubbers	0.60	$485,801
Multi-Stage Compressor	0.69	$468,171
Building	0.60	$161,934
Fuel Gas Storage Tank	0.57	$219,132
TOTAL PURCHASED EQUIPMENT COST		$3,978,334

Table 3.5 Equipment Costs for Feed Rate of 2222 tons/day as of 1993 for Used Tire Process (15)

Item	Purchase Cost 1993
Fuel Oil Tank	$37,500
Front End Loaders	$80,000
Belt Conveyor	$65,750
Rotary Kiln Incinerator with secondary combustor	$974,926
Water Tube Boiler	$131,065
Water Preheater	$50,000
Bag House	$100,000
Packed Bed Absorber	$119,381
Induced Draft Fan	$25,000
Stack	$10,000
Truck Scales	$30,000
TOTAL PURCHASED EQUIPMENT COST	$1,623,622

Table 3.6 Equipment Costs for Feed Rate of 2222 tons/day as of 2003 for Used Tire Process

Item	Purchase Cost 2003
Fuel Oil Tank	$41,467
Front End Loaders	$88,463
Belt Conveyor	$72,706
Rotary Kiln Incinerator with secondary combustor	$1,078,064
Water Tube Boiler	$144,930
Water Preheater	$55,290
Bag House	$110,579
Packed Bed Absorber	$132,010
Induced Draft Fan	$27,645
Stack	$11,058
Truck Scales	$33,174
TOTAL PURCHASED EQUIPMENT COST	$1,651,056

Table 3.7 Equipment Costs for Feed Rate of 12222 tons/day as of 2003 for Used Tire Process Including Exponents

Item	exp	Purchased Cost
Fuel Oil Tank	0.57	$109,580
Front End Loaders	0.60	$246,038
Belt Conveyor	0.50	$170,517
Rotary Kiln Incinerator with secondary combustor	0.60	$2,998,358
Water Tube Boiler	0.60	$403,087
Water Preheater	0.60	$153,774
Bag House	0.79	$425,194
Packed Bed Absorber	0.60	$367,153
Induced Draft Fan	0.44	$58,531
Stack	1.00	$60,823
Truck Scales	0.60	$92,264
TOTAL PURCHASED EQUIPMENT COST		$5,085,320

Table 3.8 Equipment Costs for Feed Rate of 22222 tons/day as of 2003 for Used Tire Process Including Exponents

Item	exp	Purchased Cost
Fuel Oil Tank	0.57	$154,073
Front End Loaders	0.60	$352,198
Belt Conveyor	0.50	$229,926
Rotary Kiln Incinerator with secondary combustor	0.60	$4,292,082
Water Tube Boiler	0.60	$577,010
Water Preheater	0.60	$220,123
Bag House	0.79	$681,873
Packed Bed Absorber	0.60	$525,571
Induced Draft Fan	0.44	$76,143
Stack	1.00	$110,589
Truck Scales	0.60	$132,074
TOTAL PURCHASED EQUIPMENT COST		$7,351,663

3.2 Associated Costs

Many of the costs associated with the construction of a plant can be estimated by assuming that they are a percentage of the total purchased equipment cost or TPEC. (16) For the purpose of this work it is assumed that this is the best way to determine these costs. All of the acceptable ranges of percentages have been taken from the text book by Peters and Timmerhaus. When they appeared reasonable, the suggested percentages were taken from the works done previously at UTSI. When the percentages used in the previous works did not agree with those recommended by the text, the average percentage given in Peters and Timmerhaus was used. Figure 3.1 is a picture of the screen from the transportation model that shows the percentages used to calculate the associated costs.

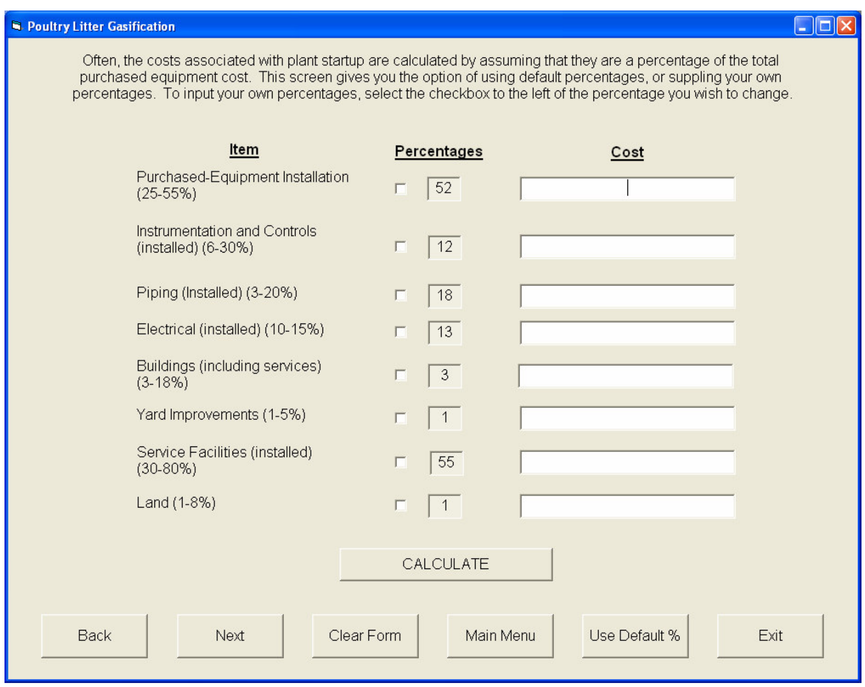


Figure 3.1 Associated Costs

3.3 Population Density of Poultry Houses for Poultry Litter Gasification

One important aspect of the poultry litter gasification plant is the need for poultry farms that are located at a reasonable distance away from the plant to pick up the poultry litter. Therefore the program calculates a minimum required population density of poultry houses, (D) using the daily fuel requirement for the gasification plant (F), the number of days of operation per year (ND), the average annual litter production per chicken house (P) and the radius that is to be traveled away from the plant to pickup the litter (R). The annual fuel requirement for the plant (AF), can be calculated using AF = F * N. The number of houses (NH), required to supply the annual requirement of litter is found from NH = AF / P. By letting A represent the area in a circle of radius R away from the plant, the area can be calculated according to $A = \pi * R^2$. Then the population density of houses required to supply the annual fuel requirement is D = NH / A.

In the above calculations a distance to be traveled away from the plant is specified and the required population density of farms is calculated based on the distance. It is also necessary to test the effect of changing population densities on the economics of the plant. For these calculations the density must be specified and the required distance to travel away from the plant will be calculated. Three different population densities are used. The current population density of broiler farms for these calculations, was estimated based on information found on the website of the Bureau of the Census, in the 1997 Census of Agriculture. The 2002 Census would have been more desirable, but is not scheduled to be released until 2004. Because the information was not available for 2003, the information for 1982 – 1997 (excluding 1992) was used to predict a value for

2003. Figure 3.2 shows the information taken from the Census. The equation used to predict the number of farms in 2003 is shown in Figure 3.3. The number of farms estimated for 2003 in Tennessee is 567. (3) To estimate the population density of those farms, the total area of Tennessee was found to be approximately 42,000 square miles. (11). Dividing the number of farms by this area gives an average population density of 0.0135 farms per square mile or 1 farm in every 74 miles. The population density will be varied by taking one half the value of the average population density and by taking double the average population density.

3.4 Population Density of Pick-up Locations for Used Tire Incineration

In order to be able to determine an average distance that might be traveled to any location within a specified radius from the tire incineration plant it is necessary to supply the program with an estimated population density of used tire collection areas that will be the pickup locations for the incineration plant. Based on Tennessee law, scrap tires should be collected at central collection facilities in each county. Approximately 45 of these collection areas would be located within a 100 mile radius of the desired location for the incineration plant.(15) Because of the fact that the county lines are unlikely to change dramatically and that it is also unlikely that there would be two such locations in any one county, the population density of the used tire pickup locations can be estimated as 45 locations per 100 square miles or 0.0014 per square mile.

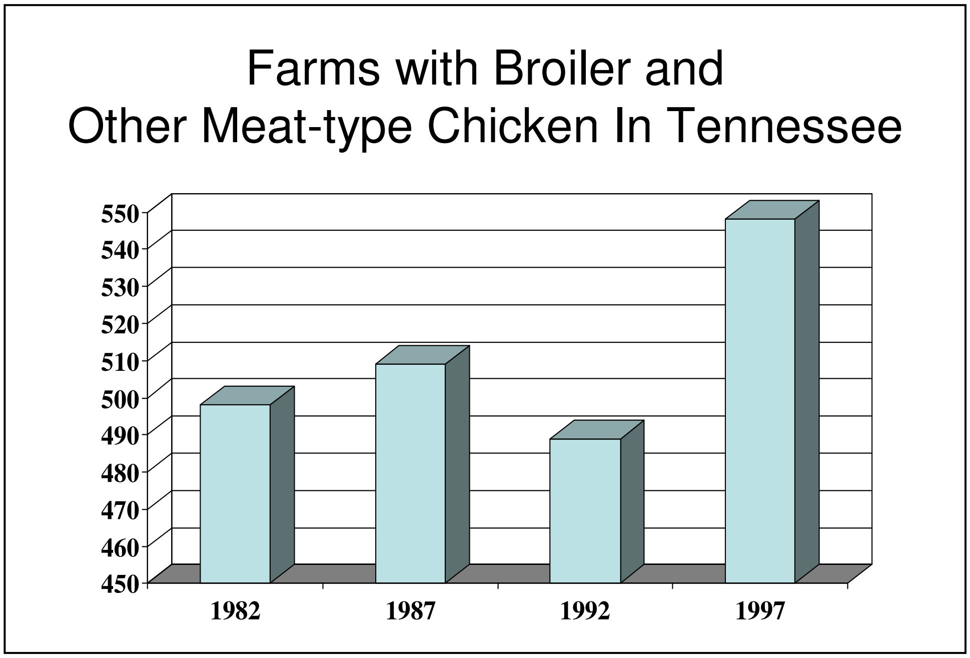


Figure 3.2 – Number of Broiler Farms in 1997 (3)

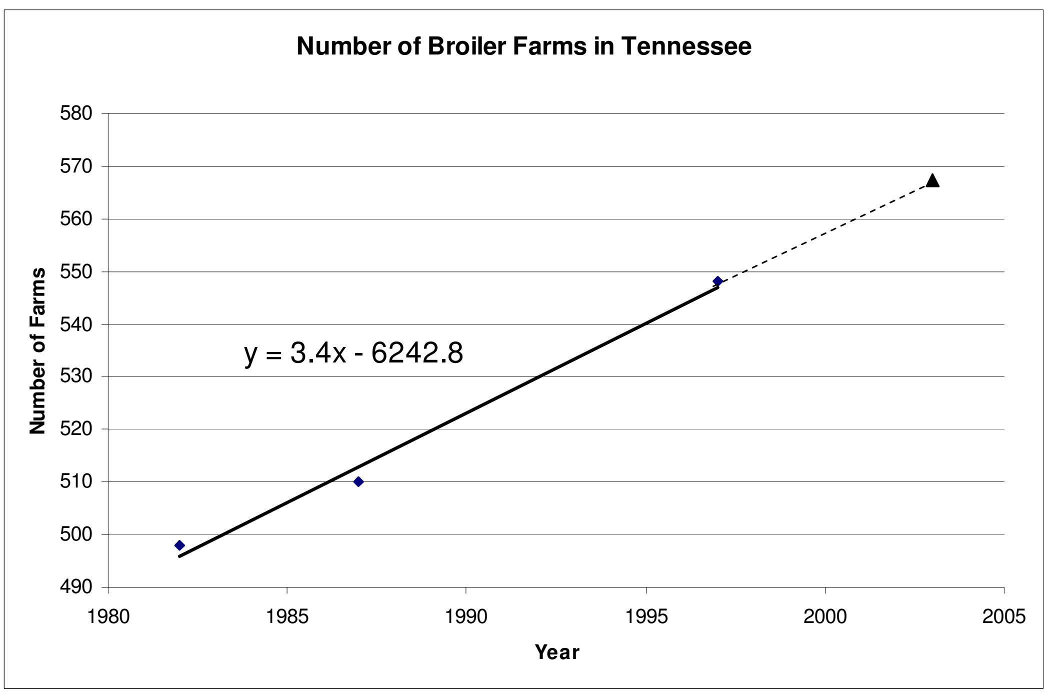


Figure 3.3 - Plot Used to Estimate Number of Farms in 2003

3.5 Used Tire Information

In order to get an idea of the number of tires disposed of in Tennessee, Mr. Allen Ball of the Division of Community Assistance in Nashville, TN was contacted. According to Mr. Ball, last year approximately 51,000 tons of tires were disposed of from June of 2001 to June of 2002 for beneficial end uses, including processes where they were used as a fuel source. In the processes that used the tires, the tire fuel was an auxiliary fuel and not the primary source of fuel. Approximately 948,000 tons of tires were shredded and land filled. These figures together lead to a total of 999,000 tons of tires that were disposed of during the last fiscal year. (2) Tennessee is divided into 9 developmental districts to handle the tire disposal . Four of these districts (50 total counties) comprise all of middle Tennessee. About 45 of these counties would be within 100 miles of the original proposed site for the plant in McMinnville, TN. (15)

The test cases for the model are based on the total number of used tires for the last fiscal year and the assumption that approximately 44% of these tires came from the area 100 miles from the plant.

The feed rates to be used in the model for the incineration plant are 2222.22 lbs/hr, 12,222lbs/hr and 22222 lbs/hr, with the 22222 lbs/hr feed rate being ten times that of the 2222.22 lb/hr feed rate and the 12,222 lb/hr being a mid-point between the two.

The distances to be used in the model calculations will be the radius of 50 miles, 100 miles and 150 miles.

Based on the numbers obtained form Mr. Ball there would be plenty of tires within a 150 to 100 mile radius from the plant to meet the feed demands.

3.6 Calculating Required Number of Trucks

The minimum number of trucks required to collect the fuel can be determined from

Volume of Dump Truck (VOL), (cubic feet)

Bulk Density of Litter (DEN), (lb/cu ft)

Tons of Litter per load (TONS), (tons)

Annual fuel requirement of plant (AF), (tons/yr)

Number of trips required per year (TPY),

Number of days of operation per year (OPDAY),

Required number of trips per day (TPD),

Hours truck runs per day (H), (hours)

Average distance traveled per trip (AD), (miles)

Average speed limit (AS), (miles/hour)

Average time to load and unload a truck (AL), (hours)

Time to travel to a pickup location (TT), (hours)

Total Time per Trip (TTPT), (hours)

Trips per truck each day (TPT)

Number of truck needed to make pickups (NT)

The total tons of fuel per load can be calculated from DEN * VOL / 2000 = TONS. The total number of trips required per year can be found using AF / TONS = TPY. Likewise, the total number of trips per day can be determined according to TPY / OPDAY = TPD. Now, the total time to travel to a pickup location can be calculated from AD * AS = TT. And the total time per trip can be found using 2*TT + AL = TTPT. Now, the number of trips that each truck must make per day can be determined by H / TTPT = TPT. And finally the number of trucks required to make the trips can be calculated using TPD / TPT = NT.

3.7 Tire Density Calculation

In order to determine how many pounds of shredded tire fuel can be transported to the incineration plant in one trip it is necessary to know the bulk density of the shredded tire fuel. The bulk density of whole car tires is 5.5 lbs/ft^3. The bulk density of whole truck tires is 15.5 lbs/ft^3. The average of these two, which is 10.5 lbs/ft^3 , will be used for the bulk density of whole tires in the calculations. The bulk density of shredded tires used in the calculations is 23.5 lbs/ft^3. Which is an average of the bulk density of shredded car tires (11.1 lbs/ft^3) and shredded truck tires (36 lbs/ft^3). (22)

3.8 Truck Selection

One major cost associated with the transportation aspect of this work is the cost to purchase the trucks. Due to limited knowledge about the trucks that could be used to haul both chicken litter and the shredded tires, two sources were contacted for information regarding trucks. One source was Ron Sewicki of Landmark International Trucks, Inc. located in Sparta Tennessee. He gave basic information about the different types of trucks on the road today and the costs associated with these trucks. His information can be found in Table 3.9. The Information provided by Landmark International Trucks was not used in the calculations.

Because our load will be lighter than the legal weight limit, it would be possible to have the dump body custom built, which would of course raise the price of the vehicle. After speaking with Mr. Sewicki, it appears that the custom built trucks would be cost prohibitive and not a very wise decision. He suggested that the dual axel vehicle would serve our needs the best. According to his reference material the expected fuel economy on a vehicle of this type is approximately 6 to 6.5 miles per gallon. (19)

Table 3.9 Truck Information Supplied by Landmark International Trucks, Inc. * (19)

Truck Type/Descrip.	Bed Characteristics	Weight (lbs)	Cost (New)
Tri-Axel This is the heaviest truck allowed on the roadway and is used mainly for extremely heavy loads	16 ft body	25,000-26,000	$80,000-$90,000
Single Axel Smaller truck. Usually used for frequent trips, Less capacity	12 ft body	Approx. 20,000	$60,000-$70,000
Dual Axel Mid line truck. Used frequently in Tennessee. Mid-sized capacity.	14-16 ft body	Approx. 22,000	$70,000's
Tractor Trailer with Dump Bed Very large body. But require more experienced and highly trained drivers.	22-30 ft body	Custom built	Custom built

** The actual dump body for any of the body lengths is typically the same with sides that are 40 inches tall.*

Another factor in the transportation of fuel from the pickup locations to the plant is the time to load and unload the trucks. As well as the number of people required to load and to unload. If the trucks were equipped with the ability to raise and empty a dumpster like container filled with the desired fuel, both the time required to load the trucks and the number of employees would be greatly reduced. This idea is like that of garbage collection. Information about trucks used in a process like this was obtained from Mr. Wayne Limbaugh, City of Tullahoma Public Works Director. The information supplied by Mr. Limbaugh can be found in Table 3.10.

According to Mr. Limbaugh it is a common practice to purchase any extended warranties on the vehicles. His estimates of maintenance and repairs reflect this practice. The purchase cost of the vehicles does not include the cost for the warranties. Once trucks have been replaced, old trucks that are still in working condition are kept to be used as backup in case any of those in regular use go down and to provide more maintenance time. Limbaugh recommended that the old trucks that are kept on sight be used on a regular basis, instead of being allowed to sit unused. This will prevent excessive maintenance and repairs due to lack of use. Mr. Limbaugh also suggested that in order to defer some costs associated with transportation, dumpsters be rented to the farmers based on capacity. The city of Tullahoma charges $2.90 per cubic yard. (10) This figure would covert to almost $8.00/ton of litter. Because many of the farmers are already financial overburdened, it was determined that this figure was too high to use in these calculations. Therefore, the base tipping fee that will be used for this research is $2.90/ton, which was chosen arbitrarily.

Table 3.10 Truck Information Supplied by City of Tullahoma Public Works Director (10)

Capacity of Truck	40 cu. yards
Number of hours of operation per day	10-12 hours
Purchase Price of trucks	$140,000 new
Average Fuel Economy	5-6 miles per gallon
Average Maintenace and Repair Costs	$5,000-$7,500 annually
Estimated Life of Vehicles	7 years
Number of People required to operate	1
Average Salary of truck operator	$27,000 annually
Buy/Lease	Buy
Salvage Value	Negligible

Because the information provided by Mr. Limbaugh is extensive and accurate, this is the information that was used in the program for this research.

3.9 Average Distance Calculation

Problem: A manufacturing plant is located at point X, the center of the circle. Raw material is brought to the plant at the expense of the plant. In order to determine the transportation costs involved in transporting the raw material, it is necessary to determine the average distance traveled to pick-up locations within a given radius and population density.

Assume: The plant is located at the center of a circle with radius R

Pick-up locations are distributed throughout the circle at distances r_i away from the plant.

Abbreviations: N – the total number of pick-up locations inside the circle

R – the maximum distance to be traveled away from the plant

r_n – the distance to one of the pickup locations n miles from the plant (this distance will be doubled in the calculations to account for the return trip.)

p – population density of farms in circle of maximum radius R.

The average distance to any pick-up location within R miles of the plant could be determined if the distance to each pickup location were known and then all the distances were summed and then divided by the total number of pickup locations N. To approximate this it is necessary to specify the density of pickup locations within the area encompassed within the circle with distance R miles from the plant. This density will be referred to as p.

Now, the number of houses inside a circle of radius r_n miles away from the plant can be calculated as:

$$N = p * (\pi * r_n^2)$$

$$N = p * A_n$$

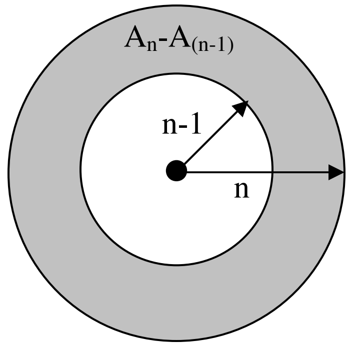


Figure 3.4 Average Distance Calculation

If n represents a distance in miles away from the plant, and (n-1) is a distance one mile less that n. Then A_n is the area in a circle n miles from the plant and $A_{(n-1)}$ is the area in a circle n-1 miles from the plant. And A_n-A_{n-1} is the Area in a ring greater than n-1 miles from the plant but less than n miles from the plant, as shown in Figure 3.4

Now, the total number of farms that are in this ring can be calculated as:

$$N_n = (A_n - A_{n-1}) * p$$

All of the farms in this ring are between n and n-1 miles from the plant. Some farms may be n miles away while others are n-1 miles away. In order to minimize the error in the calculations, the assumption will be made that the average distance to the farms inside this ring is (n-1)+ 0.5 miles.

Now, to find the sum of the distances to all of the houses in this ring, D_n, we need to multiply the total number of houses in this ring by the average distance to the houses in this ring.

i.e. $D_n = N_n * ((n-1) + 0.5) = (A_n - A_{n-1}) * p * ((n-1) + 0.5)$

so,

$D_1 = A_1 * p * 0.5 = \pi r_1^2 * p * 0.5$

$D_2 = (A_2 - A_1) * p * (n_1 + 0.5)$

$= \pi r_2^2 - \pi r_1^2 * p * (r_1 + 0.5)$

$D_3 = (A_3 - A_2) * p * (n_2 + 0.5)$

$=\pi r_3^2 - \pi r_2^2 * p * (r_2 + 0.5)$

$D_4 = (A_4 - A_3) * p * (n_3 + 0.5)$

$= \pi r_4^2 - \pi r_3^2 * p * (r_3 + 0.5)$

The Total Distance, TD, to each house in the circle of radius R is:

$TD= D_1 + D_2 + D_3 + \dots D_R$

$$TD = D_1 + \sum_{n=2}^{R} D_n$$

$$= D_1 + \sum_{n=2}^{R} \pi * p * (r_n^2 - r_{n-1}^2) * (r_{n-1} + 0.5)$$

since $r_1=1$

$$TD = 0.5*\pi*p + \pi * p \sum_{n=2}^{R} (r_n^2 - r_{n-1}^2) * (r_{n-1} + 0.5)$$

$$=\pi*p*(0.5 + \sum_{n=2}^{R} (r_n^2 - r_{n-1}^2) * (r_{n-1} + 0.5))$$

Replacing the summation by the integral sign and realizing that

$r_{n-1} = r_n - 1$

Gives

$$\text{TD}=\pi * p\left[0.5+\int_{2}^{R}\left(r_n^2-(r_n-1)^2\right)*(r_{n-1}+0.5)dr_n\right]$$

$$=\pi * p\left[0.5+\int_{2}^{R}\left(r_n^2-(r_n^2-2r_n+1)\right)*(r_n-0.5)dr_n\right]$$

$$=\pi * p\left[0.5+\int_{2}^{R}(2r_n-1)*(r_n-0.5)dr_n\right]$$

$$=\pi * p\left[0.5+\int_{2}^{R}\left(2r_n^2-2r_n+0.5\right)dr_n\right]$$

$$=\pi * p\left[0.5+\frac{2}{3}r_n^3\Big|_2^R-r_n^2\Big|_2^R+0.5r_n\Big|_2^R\right]$$

$$\text{TD}=\pi * p\left[\frac{2}{3}R^3-R^2+0.5R-\frac{11}{6}\right]$$

Now, when the maximum distance to travel away from the plant and the population density of chicken farms are specified, the sum of the distances from the plant to each house (TD) may be found.

Dividing TD by the total number of houses in the radius, N, the average distance to one house within the radius may be determined. The calculated average distance will then be doubled in all calculations involving time traveled and total miles traveled to account for the return trip to the plant.

Now in order to test this formula, a spreadsheet was created in Excel, using a population density of 1 house per square mile, and a maximum radius to travel away from the plant of 100 miles. A portion of this spreadsheet is shown In Table 3.11. Column one lists the

Table 3.11 Portion of Average Distance Test Case

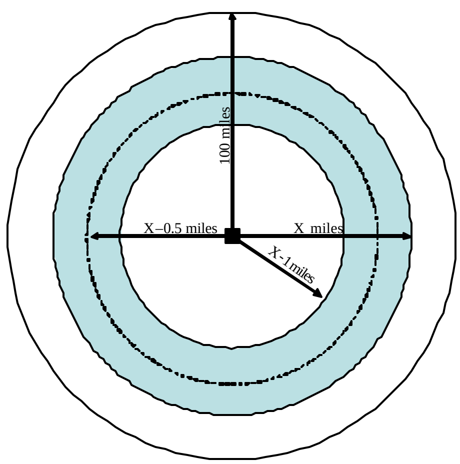
Miles from Plant (X)	Area Covered A1=πX2	Area in Ring A2=πX2-π(X-1)2	Number of houses in Ring N=A2*P	Avg. Miles to houses in this ring X-0.5 miles	Total Miles to all houses in this ring N*(X-0.5)
1	3.14	3.14	3.00	0.50	1.50
2	12.57	9.42	9.00	1.50	13.50
3	28.27	15.71	16.00	2.50	40.00
4	50.27	21.99	22.00	3.50	77.00
5	78.54	28.27	28.00	4.50	126.00
6	113.10	34.56	35.00	5.50	192.50
7	153.94	40.84	41.00	6.50	266.50
8	201.06	47.12	47.00	7.50	352.50
9	254.47	53.41	53.00	8.50	450.50
10	314.16	59.69	60.00	9.50	570.00

number of miles away from the plant,(x), that the houses might be located from 1 to 100. Column two calculates the area contained in a circle x miles away from the plant. Column three calculates the area that would be covered in a ring 1 mile wide between x and x-1 miles away from the plant. Using the population density of 1 house per square mile column four calculates the number of houses that would be contained in the ring between x and x-1 miles away from the plant. Column five lists the assumed average distance to each house in the ring, which is equal to x-0.5 miles. Column six multiples the total number of houses in each ring by the average distance to each house in the same ring, which gives the total distance that would be traveled if one, one-way trip were made to each house in the ring. These calculations are done for miles 1 to 100. The total number of houses within the 100 mile radius is then summed as well as are the distances in the one-way trips to each house within the same radius. These values are shown in Table 3.12. Figure 3.5 shows how the area for the rings was calculated.

When the total miles to each house is divided by the total number of houses the average distance to any house in the circle is calculated as 66.66 miles. When the same

Table 3.12 Continuation of Average Distance Test Case

Miles from Plant (X)	Area Covered A1=pX2	Area in Ring A2=pX2-p(X-1)2	Number of houses in Ring N=A2*P	Avg. Miles to houses in this ring X-0.5 miles	Total Miles to all houses in this ring N*(X-0.5)	
95	28352.87	593.76	594.00	94.50	56133.00	
96	28952.92	600.04	600.00	95.50	57300.00	
97	29559.25	606.33	606.00	96.50	58479.00	
98	30171.86	612.61	613.00	97.50	59767.50	
99	30790.75	618.89	619.00	98.50	60971.50	
100	31415.93	625.18	625.00	99.50	62187.50	
				Total # of miles		**Average Distance**
				traveled in one-way trips		**to houses in 100**
				to each house in the		**miles radius**
		Total # of Houses	**31416**	**100 mile radius**	**2094327**	**66.66**



Area in shaded ring = px²- p(x-1)²

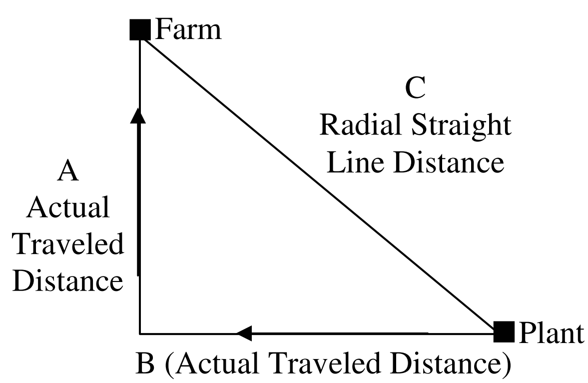
P=Population density of chicken houses

Figure 3.5 Average Distance Diagram

information concerning population density and maximum travel distance is used in the transportation model, the program returns an average distance of 65.67 miles, which is acceptably close to the actual distance of 66.66 miles. The difference between the two calculated average distances is probably caused by trying to approximate the summation by the continuous integration formula to calculate the total distances TD.

This method assumes that the distance that will be traveled away from the plant is in a straight line. A better assumption would be to assume that the actual distance traveled was the sum of two straight lines. Given a right triangle the sum of the squares of the sides is equal to the square of the hypotenuse.

Letting the hypotenuse, C, represent the straight line distance that would be traveled from the plant, the actual distance traveled could be approximated by the sum of the sides A and B. If A and B are assumed to be equal, and the distance C is known then the actual distance traveled would be equal to C*1.414. This is the method that will be used for the calculations, and is shown in Figure 3.6.



Where:

$A^2 + B^2 = C^2$

Figure 3.6 Actual Distance Calculation

3.10 Output Calculations

Originally the aim of this program was to be able to output the maximum distance that could be traveled away from the poultry litter gasification plant to collect litter. After some consideration it was determined that it would be more useful to input a possible distance and have the program output the time needed to breakeven.

This decision was made after several factors were taken into consideration.

1) Based on the fact that it will be necessary to collect and transport the litter from the poultry farms to the plant, the plant will have to be located in an area where the population density of farms is high enough to supply the fuel requirement of the plant.

2) The location of the plant is variable. But the location of most of the poultry farms will be fixed as they are already in business. For example, if the program supplied the result that the optimal distance to travel to collect the litter was 74.5 miles and 10 of the litter suppliers were located 75.2 miles away, it would be more helpful to the plant designers to see the impact that the extra 0.7 mile would make to the breakeven time for the plant.

3) The plant will have to be built on available land. So it would not be realistic to expect that the plant would be able to be built in a location predetermined by the program.

Instead, it would be more realistic to make calculations based on the location of farms that are already in existence and land that is available. Then these numbers can be used in the program to decide on an acceptable breakeven time frame.

Likewise, since the aim of the used tire collection process is to have one central collection location in each county, it is also unlikely that new ones will be sprouting up. Because the pickup locations for both plants seem to be fairly set, it appears more useful to be able to alter the distance to be traveled as a variable in the program. For example, if the program were to output that the maximum distance that could be traveled was 97.3 miles from the plant and 5 of the pickup locations needed to fuel the plant were located 100.3 miles from the plant, it would be desirable to know how visiting these further locations would affect the economics of the plant. If distance is an output, this would not be possible.

It seems that the only time having distance as a set output would be beneficial, is when the distance of the pickup locations could be changed to better suit the plants needs, which seems unlikely in examples considered here.

3.11 Calculation of Truck Operating Costs

In order to calculate the annual costs associated with the trucks that will be used to transport fuel to the plants it was assumed that the trucks were purchased at time t=0.

Therefore the cost associated with the purchase of the trucks is added into the plant construction costs brought forward to time t=0.

To obtain the annual diesel cost per year per truck several factors were considered. This includes the average distance per trip, the number of trips per truck per day, the cost of one gallon of diesel and the number of operating days per year. When these values are multiplied together the product gives the annual cost of diesel to supply one truck.
In order to get the annual cost of diesel for all of the trucks the cost per truck will have to be multiplied by the total number of trucks.

To get the annual maintenance and repair costs the monthly maintenance and repair costs were multiplied by twelve and this product was assumed to be the annual maintenance and repair cost per truck. As with the diesel, the total maintenance and repair costs for all of the trucks will be obtained by multiplying by the total number of trucks. The monthly maintenance and repair cost to be used is $520, taken from information supplied by Wayne Limbaugh. (10)

The sum of these two values gives the annual cost to operate the trucks.
The cost of diesel fuel used in the calculations was determined by contacting Stanley Pierce with the Rogers Group in Lynchburg, TN. According to Mr. Pierce, the price that the Rogers Group pays for Diesel Fuel which is purchased from A.J. Walker Oil is $1.38 per gallon. (17)

3.12 Total Capital Investment

The total Capital Investment for each process was calculated by adding the purchase price of all equipment together to obtain the Total Purchased Equipment cost or TPEC. Associated equipment and installation costs were determined by assuming that they could be calculated as percentages of the TPEC. These costs were then added to the TPEC to obtain the total direct cost. The costs of engineering and supervision, construction expenses, contractors' fees and contingency were calculated by assuming them to be a percentage of the total direct costs. These costs were then added to the total direct costs to obtain the fixed-capital investment. The working capital was assumed to be a

percentage of the fixed capital investment. When this value was added to the fixed-capital investment the total capital investment was obtained. The assumptions for all percentage estimates were taken from the text book by Peters and Timmerhaus. Costs that were assumed to be a percentage of the total direct costs are shown in Table 3.13.

Table 3.13 Costs as Percentages of Total Direct Costs

Cost	Percentage of Total Direct Costs
Engineering & Supervision	8%
Construction Expenses	10%
Contractors Fees	5%
Contingency	20%

3.13 Costs at Time t=0

Assume that the money spent for the construction of the plant is spent at the beginning of the construction phase. The working capital and the cost of the trucks is spent at time t=0.

The construction costs spent at the beginning of the construction phase will be brought to time t=0, using

$$F = P(1+i)^{N} \quad (20)$$

where,

F = Cost at time t=0

P = Cost at the beginning of the construction phase

i = Time value of money

NC = Construction time in months

After the construction costs are brought to time t=0. The total cost at t=0 will be calculated by adding together this value, the amount of working capital and the amount spent to purchase the trucks.

3.14 Calculation of Annual Operating Costs

Included in the annual cost for the two processes is the cost of labor to operate each of the plants, which was taken from the previous works and brought to current conditions. The values included in the previous works include only the plant operators' annual salaries and not the salary of the drivers to bring the raw materials to the plants.

Therefore the drivers' salaries will be estimated at $27,000 per year according to the information provided by Mr. Limbaugh. It will also be assumed that one person can operate a truck alone, so that the number of truck operators is equal to the number of trucks. (10)

The cost of supervisory and clerical labor for the plant is assumed to be 15% of the operating labor costs for the plants not including the drivers pay. The cost for annual maintenance and repairs on the processes is estimated as being 10% of the total fixed capital investment and the total cost for operating supplies is calculated as 15% of the maintenance and repair cost. (16) The cost of materials is determined by using the numbers from the previous works and correcting them to current conditions. The gasification process test runs are done using a raw material cost of zero and with a raw material cost of $10/ton. The incineration process test runs are done twice once using a raw material cost of zero and a second time with a charge of $25 per ton to take the tires. The value of depreciation, local taxes and insurance is calculated as 25% of the fixed capital investment. The cost of utilities is assumed to be roughly 10% of the total product cost. The percentages used are as recommended in the textbook by Peters and Timmerhaus. (16) The actual values used can be found in chapter four.

3.15 Calculation of Break Even Time Period

In order to calculate the time for the plant to break even, it is necessary to know the costs at time t=0 which is already known as well as the annual operating costs and the annual profits.

Assuming that the annual operating expenses are spent at the end of each year, those costs need to be brought back to time t=0 in order to be compared. The following formula is used to find the present value of a future amount:

$$P = \frac{F}{(1+i)^N} \qquad (20)$$

where P is the present value of the future amount F. N is the time in years and i is the time value of money.

In order to get the present value of all of multiple years a summation is needed. Letting AC present the annual costs, and PV present the present value.

$$PV = \sum_{1}^{N} P_N$$

where,

$$P_1 = \frac{AC}{(1+i)^1}$$

$$P_2 = \frac{AC}{(1+i)^2}$$

all the way to

$$P_N = \frac{AC}{(1+i)^N}$$

Now the sum of all of these is

$$P_N = \sum_1^N \frac{AC}{(1+i)^N}$$

This same procedure can be used to calculate the present value of the future profit amounts, where PV is the present value of the profit and AP is the annual profit.

$$PV = \sum_1^N \frac{AP}{(1+i)^N}$$

Now, we also need to account for inflation. Letting I represent inflation,

The annual cost in year 1 is AC_1 or AC_1^0

The addition of inflation gives

Annual cost in year 2 = $AC_1 * (1+I) = AC_1(1+I)^1$

Annual cost in year 3 = $AC_1(1+I)(1+I) = AC_1(1+I)^2$

Annual cost in year 4 = $AC_1(1+I)(1+I)(1+I) = AC_1(1+I)^3$

Therefore the addition of inflation to the annual cost gives

$$AC_N = AC_1(1+I)^{N-1}$$

and when applied to annual profit gives

$$AP_N = AP_1(1+I)^{N-1}$$

This changes the present value calculations for each of these as follows:

$$PV_{cost} = \sum_1^N \frac{AC_1(1+I)^{N-1}}{(1+i)^N}$$

and

$$PV_{profit} = \sum_{1}^{N} \frac{AP_1(1+I)^{N-1}}{(1+i)^N}$$

Now summing the present value of the costs and adding them to the already calculated costs and finding the first N that makes this summation less than the sum of the present value of the profits will give the time to breakeven.

The annual inflation rate to be used in the calculations was obtained online from www.inflationdata.com . Using this table, the average inflation rate over the past 3.5 years, as shown in Table 3.14, is 2.75%. This is the value that will be used in the calculations for this research.

The time value of money used for the calculations is 6%.

Table 3.14 Inflation Rate Data (8)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
2003	2.60%	2.98%	3.02%	2.22%	2.06%								
2002	1.14%	1.14%	1.48%	1.64%	1.18%	1.07%	1.46%	1.80%	1.51%	2.03%	2.20%	2.38%	1.59%
2001	3.73%	3.53%	2.92%	3.27%	3.62%	3.25%	2.72%	2.72%	2.65%	2.13%	1.90%	1.55%	2.83%
2000	2.74%	3.22%	3.76%	3.07%	3.19%	3.73%	3.66%	3.41%	3.45%	3.45%	3.45%	3.39%	3.38%

CHAPTER FOUR

Expenses and Profits

4.1 Operating Labor Calculations

To determine the annual cost of operating labor, the estimated cost of operating labor were taken from the previous works. The operating labor cost for the gasification process included nine employees, and for the incineration process included eight employees. (14), (21) The number of employees were taken from the previous work and were based on the lowest feed rates, 100 tons/day for the gasification process and 2222 lb/hr for the incineration process. The average inflation rate of 2.75% was applied to each year, to bring the operating labor costs current to 2003. The operating labor expenses were then scaled up using an exponent of 0.25 as suggested in the text book by Peters and Timmerhaus, in order to be applied to the higher feed rates. The values for the operating labor expense can be found in Table 4.1 and 4.2. Other operating expenses were assumed to be percentages of these operating labor costs as suggested in the text book by Peters and Timmerhaus.

Table 4.1 Operating Labor Expenses for Gasification Process with Nine Laborers (21)

Year	100 tons/day	Scale Up Exponent	500 tons/day	1000 tons/day
1999	$600,000	0.25	$897,209	$1,066,968
2000	$616,500	0.25	$921,883	$1,096,309
2001	$633,454	0.25	$947,234	$1,126,458
2002	$650,874	0.25	$973,283	$1,157,435
2003	$668,773	0.25	$1,000,049	$1,189,265

Table 4.2 Operating Labor Expenses for Incineration Process with Eight Laborers (15)

Year	2222 lbs/hr	Scale Up Exponent	12,222 lbs/hr	22,222 lbs/hr
1993	$241,760	0.25	$370,241	$429,927
1994	$248,408	0.25	$380,422	$441,749
1995	$255,240	0.25	$390,884	$453,898
1996	$262,259	0.25	$401,633	$466,380
1997	$269,471	0.25	$412,678	$479,205
1998	$276,881	0.25	$424,027	$492,383
1999	$284,496	0.25	$435,687	$505,924
2000	$292,319	0.25	$447,669	$519,837
2001	$300,358	0.25	$459,980	$534,132
2002	$308,618	0.25	$472,629	$548,821
2003	$317,105	0.25	$485,626	$563,914

4.2 Cost of Raw Materials

The cost of materials to be considered in the gasification process include the cost of the 10 wt% langbeinite catalyst, the cost of the poultry litter to use in the case where $10/ton will be charged by the farmers for the litter and a 10% additional cost for other materials. In order to determine the cost of the catalyst, the average inflation rate was applied to the cost in 1999.

The major costs associated with the incineration process include the cost of fuel oil for start up and auxiliary fuel equal to a full thermal load for 3 days per month, an absorber solution which is a 20% solution of NaOH, natural gas to stabilize flame and ensure complete combustion in post combustor and waste disposal of the absorber solution.

Table 4.3 lists the results of the calculations for material cost at various feed rates. Table 4.4 shows the costs for the case where the farmers charge $10/ton for litter. Other costs are presented in Tables 4.5 through 4.9 at various feed rates.

4.3 Income

In order to determine the payback period, the gross revenue must be calculated. To calculate the revenue we will assume that for every 1 ton of chicken litter fed to the plant, 14,813 scf of gas is produced. This number has been obtained from the work done previously at UTSI by Jerald Andrew Jones. (9) According to the thesis presented by Anthony Turner the average heating value of the product gas is 304.7 BTU/scf. (21) We will also assume that 10% of the litter can be recovered as residue and sold to the cement industry or as a fertilizer at a value of $29 per ton.

In order to determine an estimated sales price for the product gas Mr. Mac Hulvey, general manager of the Elk River Public Utility District was contacted. Currently the price of natural gas is $0.92/therm with 100,000 BTU's equaling one therm. This is an average price for natural gas. Mr. Hulvey also stated that an estimated high price for natural gas would be about 30-40% higher than the current average with a low price being about 20% less. Based on this information:

Current average price of natural gas - $9.20 / Million BTU

Average High Price of natural gas - $12.88 / Million BTU

Average Low Price of natural gas - $7.36 / Million BTU

Table 4.3 - Cost of Materials for Gasification Process when No Charge for Litter (21)

Feed Rate	Cost of Catalyst	Additional Material Cost (10% of Catalyst Cost)	Total Material Costs
100 tons/day	$124,740	$12,474	$137,214
500 tons/day	$623,700	$62,370	$686,070
1000 tons/day	$1,247,400	$124,740	$1,372,140

Table 4.4 – Cost of Materials for Gasification Process w/$10/ton Charge for Litter (21)

Feed Rate	Cost of Catalyst	Additional Material Cost (10% of Catalyst Cost)	Litter Cost	Total Material Costs
100 tons/day	$124,740	$12,474	$330,000	$467,214
500 tons/day	$623,700	$62,370	$1,650,000	$2,336,070
1000 tons/day	$1,247,400	$124,740	$3,300,000	$4,672,140

Table 4.5 – Cost of Fuel Oil for Incineration Process (16)

Feed Rate	Cost of Fuel Oil
2222 lbs/hr	$236,959
12222 lbs/hr	$1,303,382
22222 lbs/hr	$2,369,805

Table 4.6 – Cost of Natural Gas for Incineration Process (16)

Feed Rate	Cost of Natural Gas
2222 lbs/hr	$88,311
12222 lbs/hr	$485,751
22222 lbs/hr	$883,191

Table 4.7 – Cost of Absorber Solution for Incineration Process (16)

Feed Rate	Cost of Absorber Solution
2222 lbs/hr	$167,080
12222 lbs/hr	$918,942
22222 lbs/hr	$1,670,803

Table 4.8 – Cost to Landfill Spent Absorber Solution for Incineration Process (16)

Fuel Rate	Solution gal/min	Annual Amt (gal)	Lanfill Cost
2222	5.86	2,531,520	$398,461
12222	32.23	13,924,499	$2,191,716
22222	58.61	25,317,479	$3,984,971

Table 4.9 – Total Material and Disposal Cost for Incineration Process (16)

Feed Rate	Total Cost
2222 lbs/hr	$890,812
12222 lbs/hr	$4,899,791
22222 lbs/hr	$8,908,770

For the purpose of this work, these values will be used as the sales price of the product gas produced from the poultry litter gasification process. (7) These values lead to total profits for three different situations which can be found in Table 4.10.

The income for the tire incineration plant comes from three sources, the recycled kiln ash which can be sold to a recycling plant because of its high steel content, the recycled bag house ash, which can be sold to the rubber industry because of its zinc content and the steam produced that would be sold to surrounding industries.(21) The values for each of these were determined by using the average inflation rate to bring the previous values current. In order to vary the possible income for study, it was assumed that the steam price of $6.45 per 1000 lb is an average price with a high price being about 40% higher and a low price being about 20% lower. (14) The income associated with these sources can be found in Tables 4.10 through 4.13.

Table 4.10 – Total Income for Gasification Process

Feed Rate (tons/day)	Gross Revenue at High Price of $12.87	Gross Revenue at Average Price of $9.21	Gross Revenue at Low Price of $7.35
100	$2,012,680	$1,467,525	$1,190,479
500	$10,063,401	$7,337,625	$5,952,395
1000	$20,126,803	$14,675,250	$11,904,789

Table 4.11 – Income from Kiln Ash for Incineration Process (16)

Fuel Flow lb/hr	Income from Kiln Ash
2222	$146,929
12222	$808,177
22222	$1,469,425

Table 4.12 – Income from Bag House Ash for Incineration Process (16)

Fuel Flow lb/hr	Income from Bag House
2222	$20,990
12222	$115,454
22222	$209,918

Table 4.13 – Income from Steam Generation for Incineration Process (16)

Fuel Flow lb/hr	Income from Steam at 6.45/1000 lb	Income At High Value 40% more at at $9.03/1000 lb	Income at Low Value 20% Less at at $5.16/1000 lb
2222	$944,546	$1,300,190	$742,966
12222	$5,195,426	$7,151,630	$4,086,646
22222	$9,446,306	$13,003,070	$7,430,326

Table 4.14 – Total Income for Incineration Process (16)

Fuel Flow lb/hr	Income from Steam at 6.45/1000 lb	Income At High Value 40% more at at $9.03/1000 lb	Income at Low Value 20% Less at at $5.16/1000 lb
2222	1,112,465	1,468,109	910,885
12222	6,119,057	8,075,261	5,010,277
22222	11,125,649	14,682,413	9,109,669

CHAPTER FIVE

Test Cases

5.1 Poultry Litter Test Cases with Distance Specified

Table 5.1 lists the test cases that will be used in the transportation model. The number of houses required to supply the plant at each fuel feed rate remains constant. The runs were determined by specifying the distance to be traveled and allowing the population density of farms to change according to the number of houses required to supply the plant. For this model several assumptions were made. The assumptions include the following: the population density of pick-up locations is uniform throughout the area around the plant, a truck will travel to one location and then return full to the plant, and each location has only one poultry house.

5.2 Poultry Litter Test Cases with Population Density Specified

Table 5.2 lists the test cases that will be used in the transportation model. The number of houses required to supply the plant at each fuel feed rate remains constant. The runs were determined by specifying the population density of farms and allowing the distance to be traveled to change according to the number of houses required to supply the plant.

5.3 Used Tire Test Cases

Table 5.3 lists the test cases that will be used in the transportation model. Only the distance will be varied for the incineration process because the locations of the state collection facilities are fixed in each Tennessee county and are unlikely to change.

Table 5.1 Poultry Litter Test Cases with Distance Specified

Feed Rate tons/day	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Number of Houses Reqd	Population Density Reqd #/sq. miles	Product Gas Sales Price Range
100	50	71	229	0.029	high
	100	141	229	0.007	high
	150	212	229	0.003	high
	50	71	229	0.029	average
	100	141	229	0.007	average
	150	212	229	0.003	average
	50	71	229	0.029	low
	100	141	229	0.007	low
	150	212	229	0.003	low
500	50	71	1146	0.146	high
	100	141	1146	0.036	high
	150	212	1146	0.016	high
	50	71	1146	0.146	average
	100	141	1146	0.036	average
	150	212	1146	0.016	average
	50	71	1146	0.146	low
	100	141	1146	0.036	low
	150	212	1146	0.016	low
1000	50	71	2292	0.292	high
	100	141	2292	0.073	high
	150	212	2292	0.032	high
	50	71	2292	0.292	average
	100	141	2292	0.073	average
	150	212	2292	0.032	average
	50	71	2292	0.292	low
	100	141	2292	0.073	low
	150	212	2292	0.032	low

Table 5.2 Poultry Litter Test Cases with Density Specified

Feed Rate tons/day	Population Density Reqd #/ Sq. Mile	Number of Houses Reqd	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Product Gas Price Range
100	0.0270	229	52	73	high
	0.0135	229	73	104	high
	0.0068	229	104	146	high
	0.0270	229	52	73	average
	0.0135	229	73	104	average
	0.0068	229	104	146	average
	0.0270	229	52	73	low
	0.0135	229	73	104	low
	0.0068	229	104	146	low
500	0.0270	1146	116	164	high
	0.0135	1146	164	232	high
	0.0068	1146	232	328	high
	0.0270	1146	116	164	average
	0.0135	1146	164	232	average
	0.0068	1146	232	328	average
	0.0270	1146	116	164	low
	0.0135	1146	164	232	low
	0.0068	1146	232	328	low
1000	0.0270	2292	164	232	high
	0.0135	2292	232	329	high
	0.0068	2292	328	463	high
	0.0270	2292	164	232	average
	0.0135	2292	232	329	average
	0.0068	2292	328	463	average
	0.0270	2292	164	232	low
	0.0135	2292	232	329	low
	0.0068	2292	328	463	low

.

Table 5.3 – Used Tire Test Cases

Feed Rate lbs/hr	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Population Density #/Sq. Mile	Steam Price Range
2222	50	71	0.0014	high
	100	141	0.0014	high
	150	212	0.0014	high
	50	71	0.0014	average
	100	141	0.0014	average
	150	212	0.0014	average
	50	71	0.0014	low
	100	141	0.0014	low
	150	212	0.0014	low
12222	50	71	0.0014	high
	100	141	0.0014	high
	150	212	0.0014	high
	50	71	0.0014	average
	100	141	0.0014	average
	150	212	0.0014	average
	50	71	0.0014	low
	100	141	0.0014	low
	150	212	0.0014	low
22222	50	71	0.0014	high
	100	141	0.0014	high
	150	212	0.0014	high
	50	71	0.0014	average
	100	141	0.0014	average
	150	212	0.0014	average
	50	71	0.0014	low
	100	141	0.0014	low
	150	212	0.0014	low

CHAPTER 6

Results and Discussion

6.1 Results for Poultry Litter with Distance Specified

Table 6.1 shows the results of the test cases for the poultry litter gasification plant when the distance was specified. The first column lists the feed rate for the plant, the second the maximum radial distance that would be traveled to collect the litter, the third and forth columns show the required population density of poultry houses to meet the feed demands. The fifth column shows which sales price of the product gas was used, high price, average price or low sales price. The annual cost column lists the total annual operating costs of the plant and the profit column shows the total annual profit based on the feed rate and the sales price of the product gas. The last column lists the number of years it would take for the plant to break even. A dashed line indicates that a given test case is not economically feasible and would not break even.

The data are also displayed in chart form in Figures 6.1 to 6.3. As you can see, as the distance traveled from the plant increases so do the costs. Only the test cases where the annual cost is lower than the annual profit will be able to break even. The test cases for the average and low sales prices of the product gas for the 100 ton/day plant will not be able to break even because in each of these instances the annual costs are greater than the annual profits. In all other cases the annual profits exceed the annual cots, and therefore, are able to breakeven. The breakeven times are listed Table 6.1.

Table 6.1 – Results for Poultry Litter Test Cases with Distances Specified

Feed Rate tons/day	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Number of Houses Reqd	Population Density Reqd #/Sq. miles	Product Gas Sales Price Range	Annual Cost	Annual Income	Break Even Time(years)
100	50	71	229	0.029	high	$1,560,840	$2,012,680	3
	100	141	229	0.007	high	$1,759,847	$2,012,680	7
	150	212	229	0.003	high	$1,961,852	$2,012,680	90
	50	71	229	0.029	average	$1,560,840	$1,467,525	-
	100	141	229	0.007	average	$1,759,847	$1,467,525	-
	150	212	229	0.003	average	$1,961,852	$1,467,525	-
	50	71	229	0.029	low	$1,560,840	$1,190,479	-
	100	141	229	0.007	low	$1,759,847	$1,190,479	-
	150	212	229	0.003	low	$1,961,852	$1,190,479	-
500	50	71	1146	0.146	high	$4,032,587	$10,063,401	1
	100	141	1146	0.036	high	$4,885,760	$10,063,401	1
	150	212	1146	0.016	high	$5,723,852	$10,063,401	2
	50	71	1146	0.146	average	$4,032,587	$7,337,625	2
	100	141	1146	0.036	average	$4,885,760	$7,337,625	2
	150	212	1146	0.016	average	$5,723,852	$7,337,625	4
	50	71	1146	0.146	low	$4,032,587	$5,952,395	3
	100	141	1146	0.036	low	$4,885,760	$5,952,395	5
	150	212	1146	0.016	low	$5,723,852	$5,952,395	39
1000	50	71	2292	0.292	high	$6,491,262	$20,126,803	1
	100	141	2292	0.073	high	$8,169,034	$20,126,803	1
	150	212	2292	0.032	high	$9,987,080	$20,126,803	1
	50	71	2292	0.292	average	$6,491,262	$14,675,250	1
	100	141	2292	0.073	average	$8,169,034	$14,675,250	2
	150	212	2292	0.032	average	$9,987,080	$14,675,250	2
	50	71	2292	0.292	low	$6,491,262	$11,904,789	2
	100	141	2292	0.073	low	$8,169,034	$11,904,789	3
	150	212	2292	0.032	low	$9,987,080	$11,904,789	6

** the '-' symbol indicates that a particular test case will not break even*

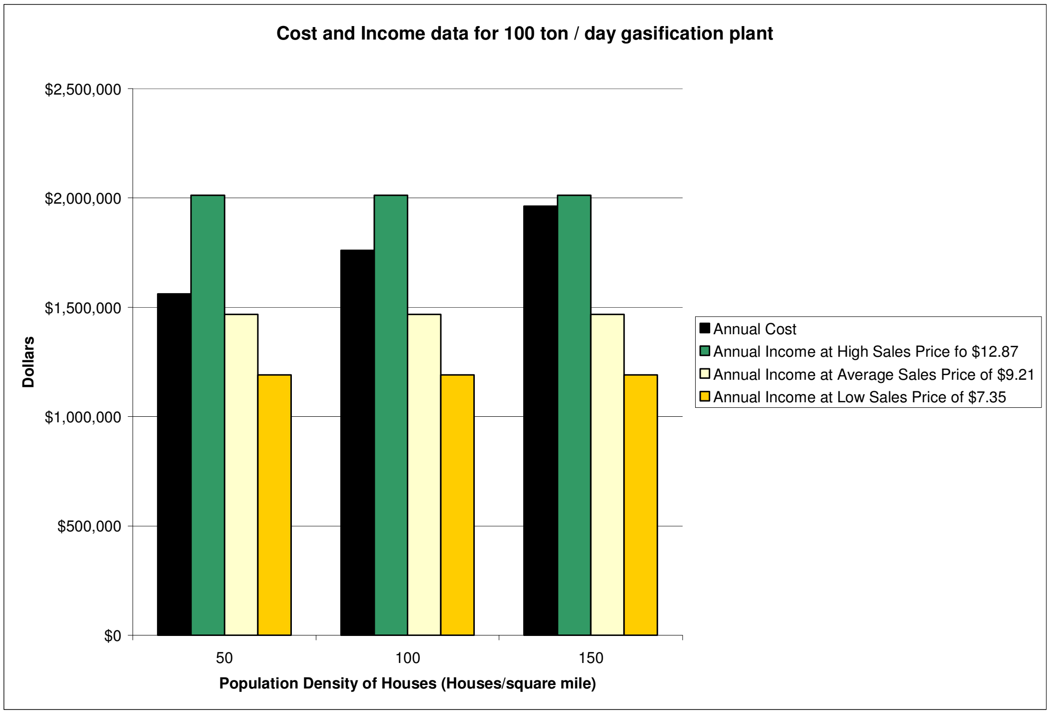


Figure 6.1 Cost and Income Data for 100 ton/day Gasification Plant

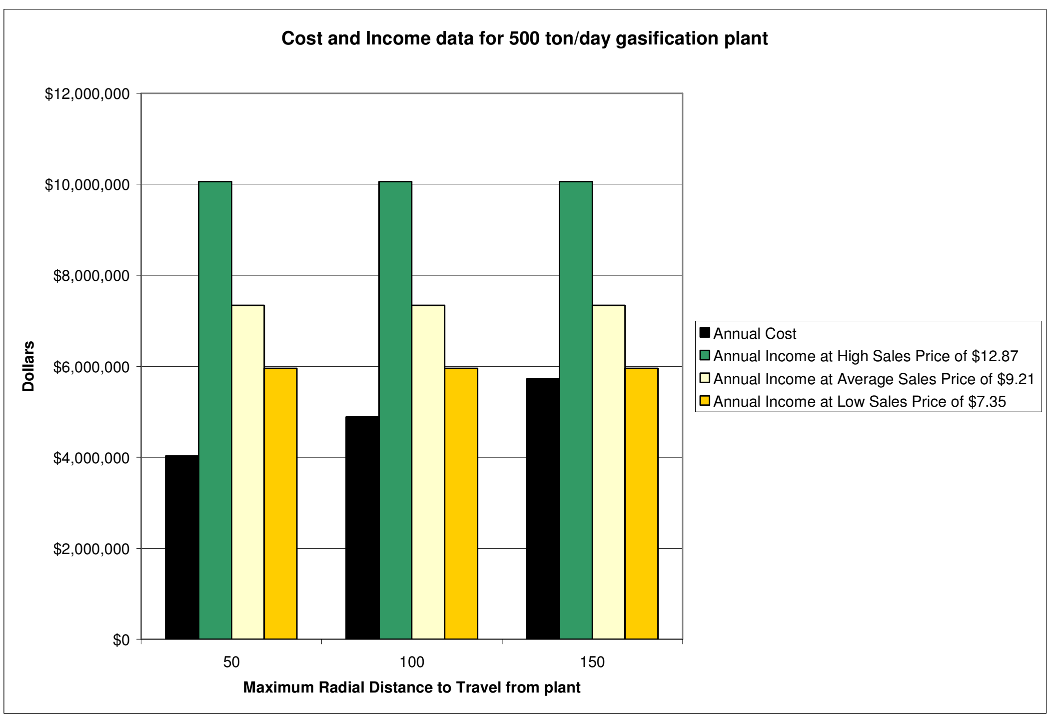


Figure 6.2 Cost and Income Data for 500 ton/day Gasification Plant

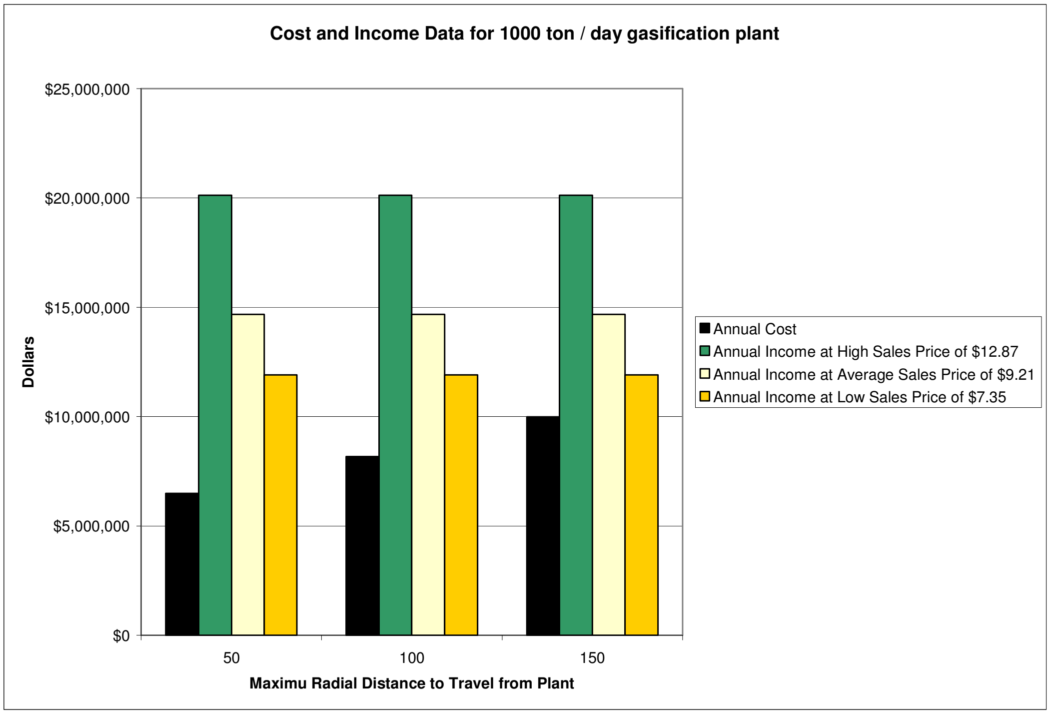


Figure 6.3 Cost and Income Data for 1000 ton/day Gasification Plant

All break even times for test cases have been included in this text for academic purposes. Breakeven times over five years are not desirable in real world industry. Both the 500 and 1000 ton/day plants are able to break even in all of the above test cases, which indicates that either of these plants would be able to withstand changing economic conditions in both the sales prices that could be charged for the product gas and the distance that would have to be traveled in order to obtain the litter, but the 100 ton per day plant is not able to break even consistently.

The greatest profits for this set of test cases are realized in the 1000 ton / day plant, which seems to indicate that this would be a better option. However, when you look at the population density of poultry houses that must exist in order to feed this plant, the location of the plant becomes very important. In this area of Tennessee, the estimated population density of poultry houses is approximately 1 house in every 74 square miles or 0.0135 houses/square mile. In Figure 6.1 you can see that the population densities of poultry houses necessary to supply the 1000 ton/day plant are as much as 0.292. Although the number of poultry farms in this area appears to be increasing it is not reasonable to expect that they would increase this much in a relatively short period of time. Therefore the 1000 ton/day plant would not be a good choice for this area.

In an effort to find a possible location for the 1000 ton/day plant, I contacted Mr. Jeff Vanemburg, Live Operations Manager of Conagra Foods in Batesville Arkansas who estimates that there are approximately 810 poultry farms in a six county area around Batesville. He estimates that there are anywhere from 1-12 poultry houses on each farm. According to Rand McNally the land area of Arkansas is 52,075 square miles and there are 75 counties in the state, which gives an average of 695 square miles per county. From these numbers it can be estimated that the six county area encompasses approximately 4200 square miles. If a conservative estimate of 3 poultry houses per poultry farm is used that places about 2430 poultry houses in this six county area which gives an estimated population density of 0.58 houses per square miles which exceeds that required by the 1000 ton/day plant. Therefore based on the information available at this time the area near Batesville Arkansas would be an ideal location for the largest poultry litter gasification plant. (22)

In an effort to find a situation in which the 100 ton/day plant might be feasible, a tipping fee was included in the annual profits. The tipping fee would be charged to the farmer to pick up the litter. Two tipping fees were tested, one being \$2.90/ ton. And the other \$5.80/ton which is the double the first tipping fee. The results of these test cases are shown in Table 6.2 and 6.3, and are shown in chart form in Figure 6.4. A study of the results for the first case shows that although the tipping fee shortens the breakeven times for the plants it still does not allow the plant to break even in every situation tested. Based on these results the \$2.90/ton tipping fee would not be enough to allow the plant to be stable in changing economic conditions. Table 6.3 lists the results of the test cases when a \$5.80/ton tipping fee was applied. The increased fee shortens the breakeven times and allows the plant to breakeven in all but the most extreme situation of the lowest sales price of the product gas and the furthest distance to travel to obtain the litter. Based on these results the 100 ton/day plant would only be desirable if you were not trying to make a profit, but just to provide an alternative end use for the litter to meet environmental constraints

Up to this point it has been assumed that the litter would be free. The next calculations add in the possibility that the farmers would charge \$10/ton for the litter. The results of these calculations can be found in Table 6.4.

As one can see from the results in Table 6.4, the addition of a \$10/ton fee for the litter increases the breakeven time for all of the cases. The 100 ton/day case is not feasible at any price. Although the 500 ton/day case is still able to breakeven, the times to

Table 6.2 Results for Poultry Litter Test Cases with $2.90/ton Tipping Fee

Feed Rate tons/day	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Number of Houses Reqd	Population Density Reqd #/Sq. miles	Product Gas Sales Price Range	Annual Cost	Annual Income	Break Even Time(years) w/$2.90 fee
100	50	71	229	0.029	high	$1,560,840	$2,012,680	2
	100	141	229	0.007	high	$1,759,847	$2,012,680	4
	150	212	229	0.003	high	$1,961,852	$2,012,680	6
	50	71	229	0.029	average	$1,560,840	$1,467,525	11
	100	141	229	0.007	average	$1,759,847	$1,467,525	-
	150	212	229	0.003	average	$1,961,852	$1,467,525	-
	50	71	229	0.029	low	$1,560,840	$1,190,479	-
	100	141	229	0.007	low	$1,759,847	$1,190,479	-
	150	212	229	0.003	low	$1,961,852	$1,190,479	-

Table 6.3 Results for Poultry Litter Test Cases with $5.80/ton Tipping Fee

Feed Rate tons/day	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Number of Houses Reqd	Population Density Reqd #/Sq. miles	Product Gas Sales Price Range	Annual Cost	Annual Income	Break Even Time(years) w/$5.80 fee
100	50	71	229	0.029	high	$1,560,840	$2,471,805	2
	100	141	229	0.007	high	$1,759,847	$2,471,805	3
	150	212	229	0.003	high	$1,961,852	$2,471,805	4
	50	71	229	0.029	average	$1,560,840	$1,926,649	4
	100	141	229	0.007	average	$1,759,847	$1,926,649	10
	150	212	229	0.003	average	$1,961,852	$1,926,649	-
	50	71	229	0.029	low	$1,560,840	$1,649,603	19
	100	141	229	0.007	low	$1,759,847	$1,649,603	-
	150	212	229	0.003	low	$1,961,852	$1,649,603	-

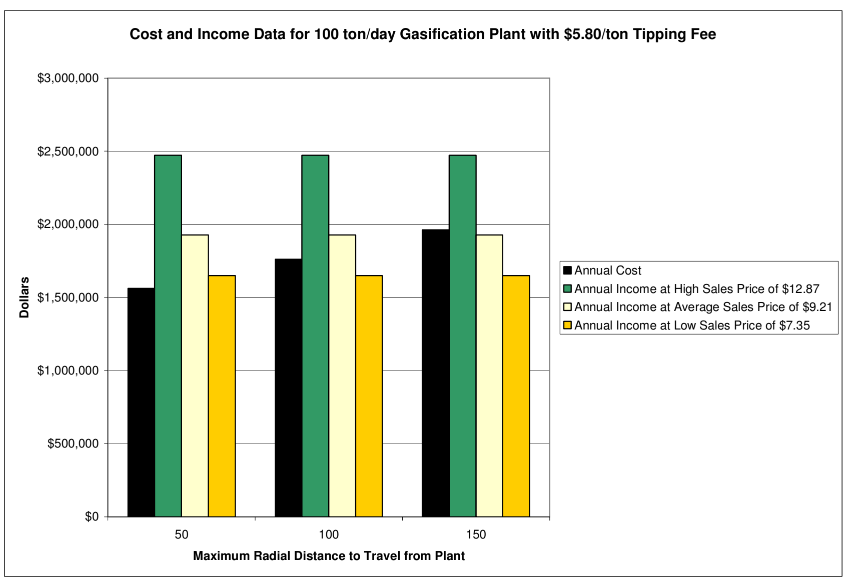


Figure 6.4 Cost and Income Data for 100 ton/day Gasification Plant with $5.80/ton

Table 6.4 - Results for Poultry Litter Test Cases with Distances Specified and $10/ton Charge for Litter

Feed Rate tons/day	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Number of Houses Reqd	Population Density Reqd #/ Sq. Mile	Product Gas Sales Price Range	Annual Cost	Annual Income	Break Even Time(years)
100	50	71	229	0.029	high	$1,927,507	$2,012,680	20
	100	141	229	0.007	high	$2,126,514	$2,012,680	-
	150	212	229	0.003	high	$2,328,519	$2,012,680	-
	50	71	229	0.029	average	$1,927,507	$1,467,525	-
	100	141	229	0.007	average	$2,126,514	$1,467,525	-
	150	212	229	0.003	average	$2,328,519	$1,467,525	-
	50	71	229	0.029	low	$1,927,507	$1,190,479	-
	100	141	229	0.007	low	$2,126,514	$1,190,479	-
	150	212	229	0.003	low	$2,328,519	$1,190,479	-
500	50	71	1146	0.146	high	$5,865,920	$10,063,401	1
	100	141	1146	0.036	high	$6,719,093	$10,063,401	2
	150	212	1146	0.016	high	$7,557,185	$10,063,401	3
	50	71	1146	0.146	average	$5,865,920	$7,337,625	3
	100	141	1146	0.036	average	$6,719,093	$7,337,625	9
	150	212	1146	0.016	average	$7,557,185	$7,337,625	-
	50	71	1146	0.146	low	$5,865,920	$5,952,395	-
	100	141	1146	0.036	low	$6,719,093	$5,952,395	-
	150	212	1146	0.016	low	$7,557,185	$5,952,395	-
1000	50	71	2292	0.292	high	$10,157,928	$20,126,803	1
	100	141	2292	0.073	high	$11,835,701	$20,126,803	1
	150	212	2292	0.032	high	$13,653,747	$20,126,803	2
	50	71	2292	0.292	average	$10,157,928	$14,675,250	2
	100	141	2292	0.073	average	$11,835,701	$14,675,250	3
	150	212	2292	0.032	average	$13,653,747	$14,675,250	11
	50	71	2292	0.292	low	$10,157,928	$11,904,789	4
	100	141	2292	0.073	low	$11,835,701	$11,904,789	-
	150	212	2292	0.032	low	$13,653,747	$11,904,789	-

** the '-' symbol indicates that the test case does not break even* breakeven are too long to be desirable at an average product gas price. If the addition of the $10/ton charge becomes necessary the only logical feed rate to use would be the 1000 ton/day plant and the sales price of the product gas would need to be set above the low price. As discussed previously the 1000 ton/day plant would need to be located outside of Tennessee in an area that has a high population density of poultry houses.

In order to provide a clear picture of how the breakeven times change for each feed rate, plots have been included in Figures 6.5 through 6.7. The test cases where the plants do not break even have not been included in these plots as they have already been discussed in the previous section. In each case shown the breakeven time is greater when the lowest sales price of the product gas is used.

As shown in Figure 6.5 the 100 ton/day facility will breakeven only when the product gas is sold at the highest price, and when the $5.80/ton tipping fee is added to the average sales price case. The most favorable break even times occur when the highest sales price is used and a tipping is added to the litter pickup.

The results for the 500 ton/day are more favorable than the 100 ton/day plant. The breakeven time of five years that occurs at the lowest sales price of the product gas and the farthest traveling distance is longer than would normally be desired, but since that is only in one case the plant would still be economically feasible.

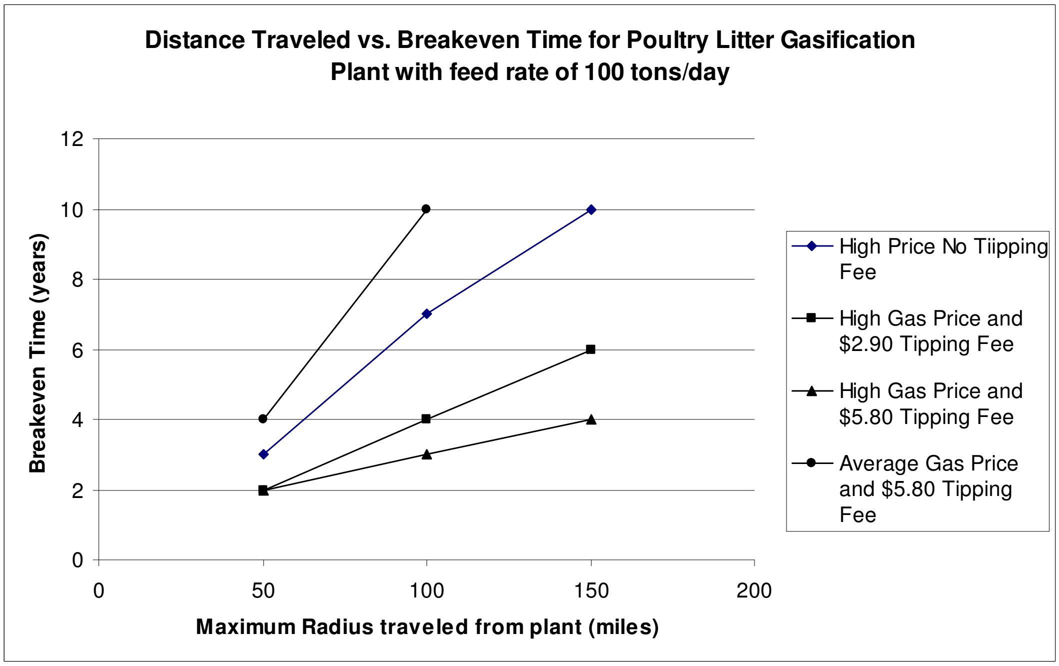


Figure 6.5 Poultry Litter Results for 100 tons/day with Distances Specified

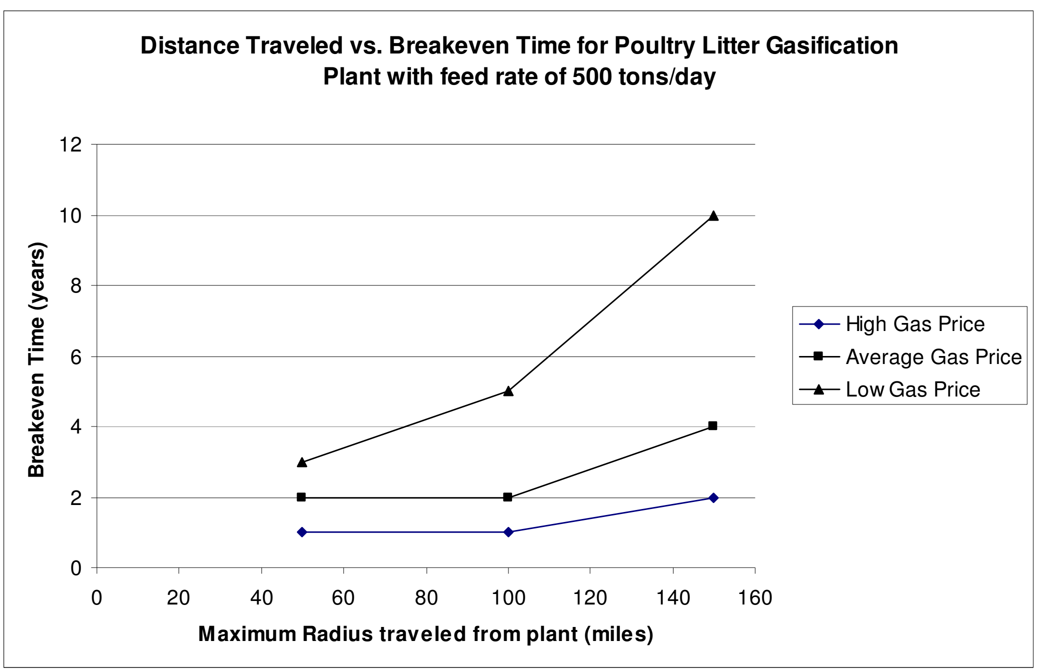


Figure 6.6 Poultry Litter Results for 500 tons/day with Distances Specified

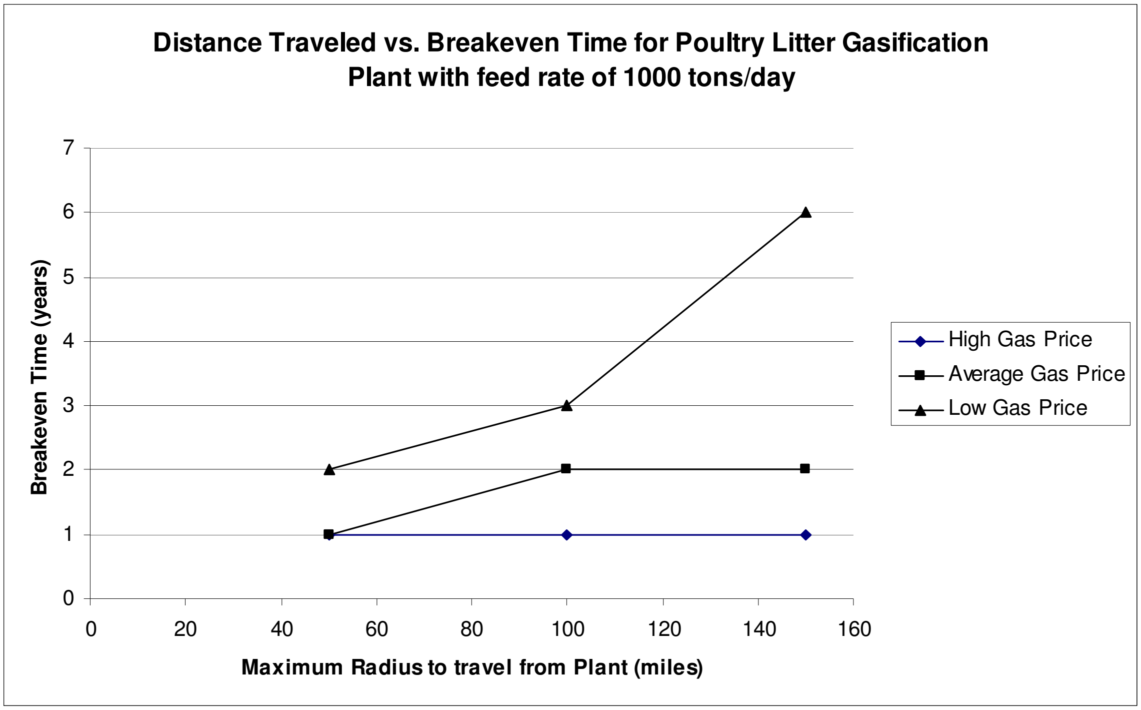


Figure 6.7 Poultry Litter Results for 1000 tons/day with Distances Specified

The results for the 1000 ton/day plant are the most favorable of the cases already presented. The plant is able to breakeven in a desirable amount of time at all sales prices and traveling distances.

6.2 Results for Poultry Litter with Population Density of Farms Specified

Test cases were also made by specifying the population density of farms in the area and changing the distances to travel. The average population density that was used was that estimated for this area . The results from these calculations are shown in Table 6.5. The first column lists the feed rate for the plant, the second the population density to be used, the third the number of poultry houses required to meet the feed demands. The maximum

Table 6.5 – Results for Poultry Litter Test Cases with Population Densities Specified

Feed Rate tons/day	Population Density Reqd #/ Sq. Mile	Number of Houses Reqd	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Product Gas Price Range	Annual Cost	Annual Income	Break Even Time (years)
100	0.0270	229	52	73	high	$1,563,194	$2,012,680	3
	0.0135	229	73	104	high	$1,722,619	$2,012,680	6
	0.0068	229	104	146	high	$1,763,947	$2,012,680	7
	0.0270	229	52	73	average	$1,563,194	$1,467,525	-
	0.0135	229	73	104	average	$1,722,619	$1,467,525	-
	0.0068	229	104	146	average	$1,763,947	$1,467,525	-
	0.0270	229	52	73	low	$1,563,194	$1,190,479	-
	0.0135	229	73	104	low	$1,722,619	$1,190,479	-
	0.0068	229	104	146	low	$1,763,947	$1,190,479	-
500	0.0270	1146	116	164	high	$5,114,996	$10,063,401	1
	0.0135	1146	164	232	high	$5,937,828	$10,063,401	2
	0.0068	1146	232	328	high	$7,155,493	$10,063,401	3
	0.0270	1146	116	164	average	$5,114,996	$7,337,625	3
	0.0135	1146	164	232	average	$5,937,828	$7,337,625	4
	0.0068	1146	232	328	average	$7,155,493	$7,337,625	-
	0.0270	1146	116	164	low	$5,114,996	$5,952,395	7
	0.0135	1146	164	232	low	$5,937,828	$5,952,395	-
	0.0068	1146	232	328	low	$7,155,493	$5,952,395	-
1000	0.0270	2292	164	232	high	$10,415,032	$20,126,803	1
	0.0135	2292	232	329	high	$12,854,470	$20,126,803	2
	0.0068	2292	328	463	high	$16,125,726	$20,126,803	4
	0.0270	2292	164	232	average	$10,415,032	$14,675,250	3
	0.0135	2292	232	329	average	$12,854,470	$14,675,250	7
	0.0068	2292	328	463	average	$16,125,726	$14,675,250	-
	0.0270	2292	164	232	low	$10,415,032	$11,904,789	7
	0.0135	2292	232	329	low	$12,854,470	$11,904,789	-
	0.0068	2292	328	463	low	$16,125,726	$11,904,789	-

** the '-' symbol indicates that a test case was not able to break even* radial distance to travel away from the plant. The fifth column shows which sales price of the product gas to use, high, average or low. The annual cost column lists the total annual operating costs of the plant and the income column shows the total annual income based on the feed rate and the sale price of the product gas. The last column lists the number of years it would take for the plant to break even.

A dashed line indicates that a given test is not economically feasible and would not break even. The data are also displayed in chart form in Figures 6.8 through 6.10. As the distance traveled from the plant increases so do the costs. Only the test cases where the annual cost is lower than the annual income will be able to break even.

For the 100 ton/day plant the only cases that will breakeven are those with the highest sales price of product gas. These results are consistent with those calculated when the traveling distance was specified.

The 500 ton/day plant shows better results with only one case not breaking even, when the lowest sales price is used and the lowest population density of houses is present, which means greater distances must be traveled to obtain the litter.

The 1000 ton/day plant shows results similar to that of the 500 ton/day plant, but the breakeven times are much greater that those for the cases where the traveling distance was specified. This is due to the fact that the population densities used for the calculations were representative of this area, and is very low. With such a high feed rate,

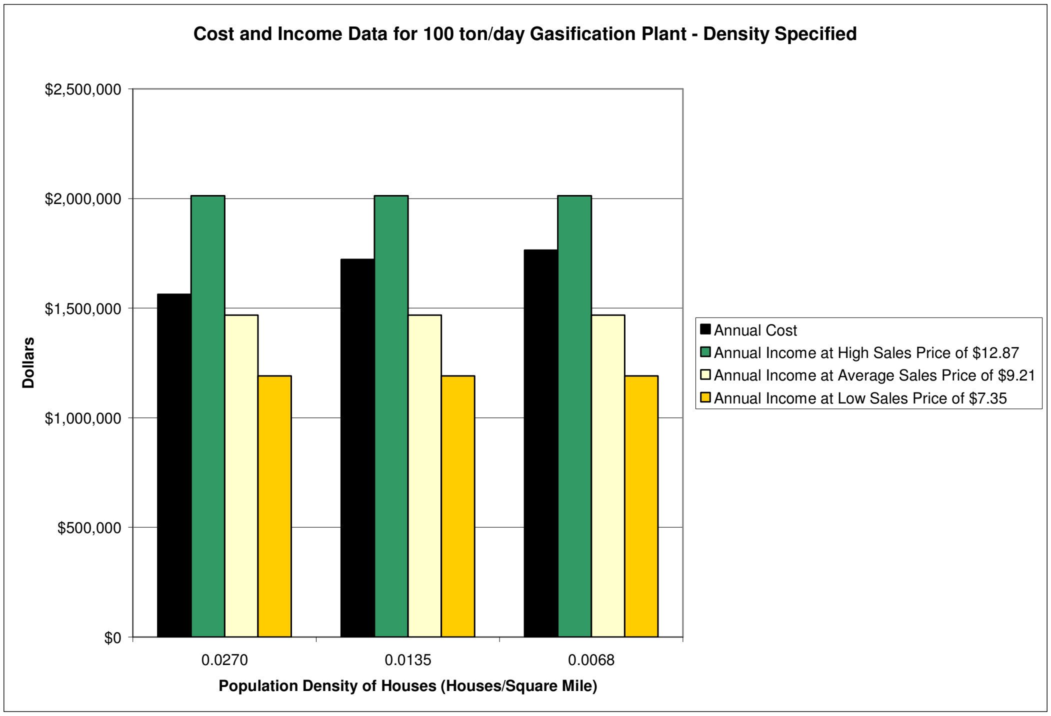


Figure 6.8 Cost and Income Data for 100 ton/day Gasification Plant with Density Specified

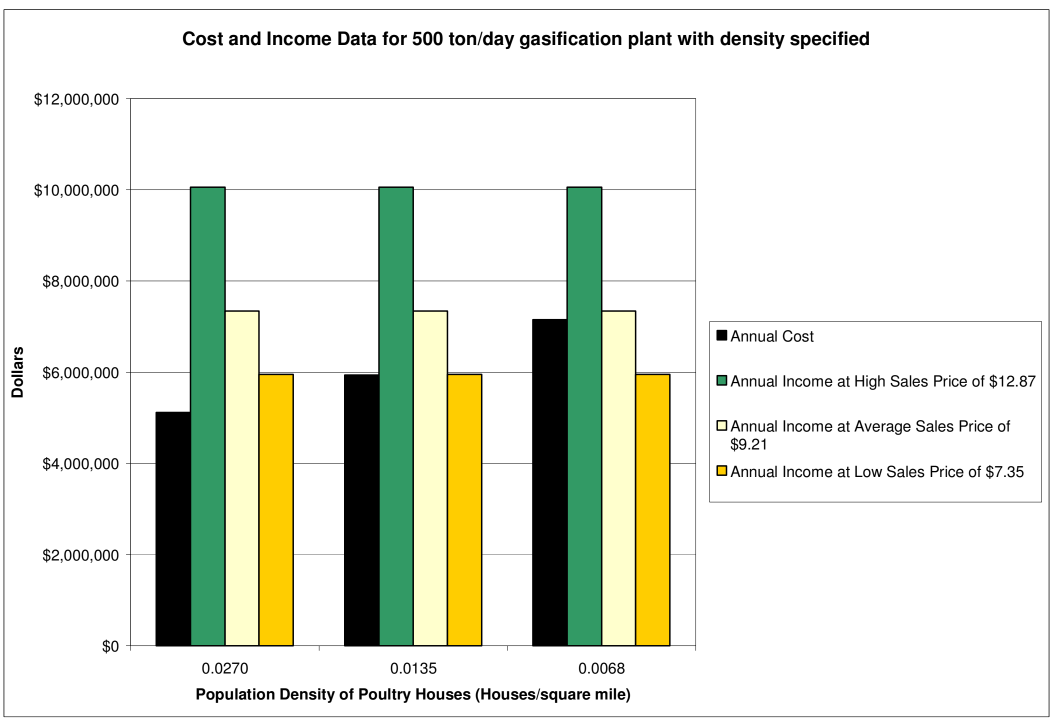


Figure 6.9 Cost and Income Data for 500 ton/day Gasification Plant with Density Specified

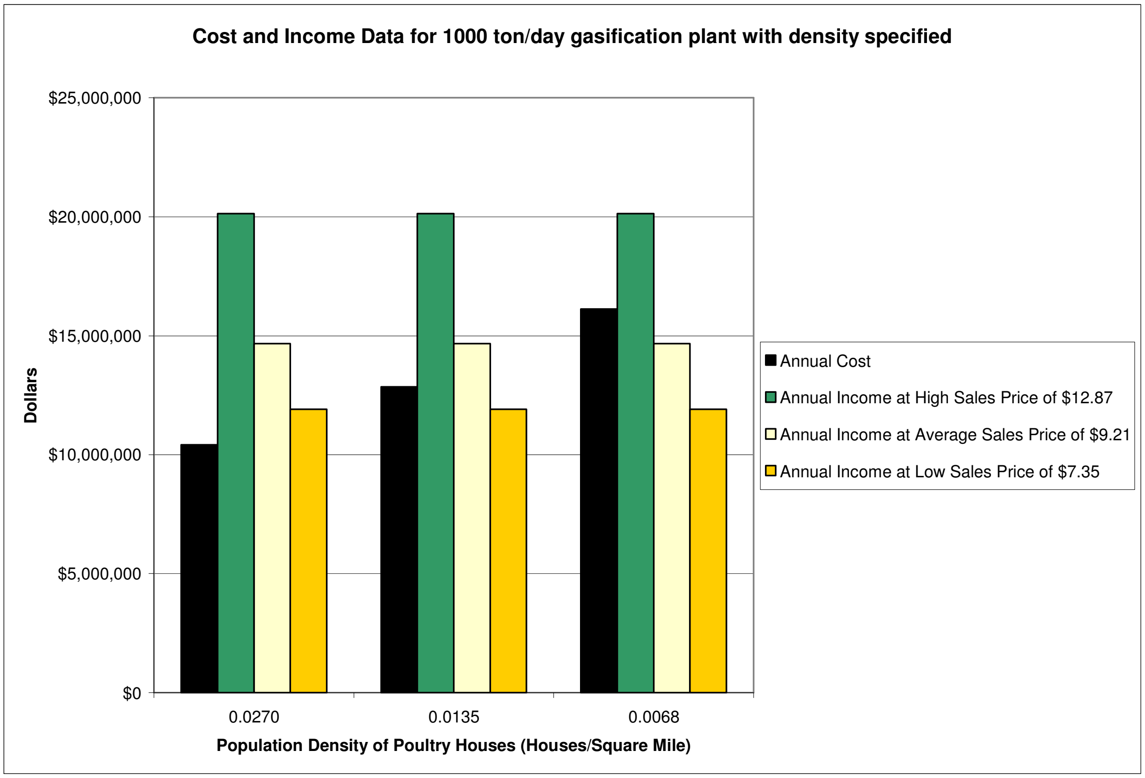


Figure 6.10 Cost and Income Data for 1000 ton/day Gasification Plant with Density Specified

great distances must be traveled to obtain the litter with the low population densities used. These results are consistent with those previously found which indicated that an area with higher population densities would be a better location for the 1000 ton/day plant.

The increased breakeven times for the 500 and 1000 ton/day plant can be observed in Figures 6.11 and 6.12.

Based on the results thus far for the density specified test cases the 500 tons/day plant is the best option at these population densities as it is consistently able to break even and

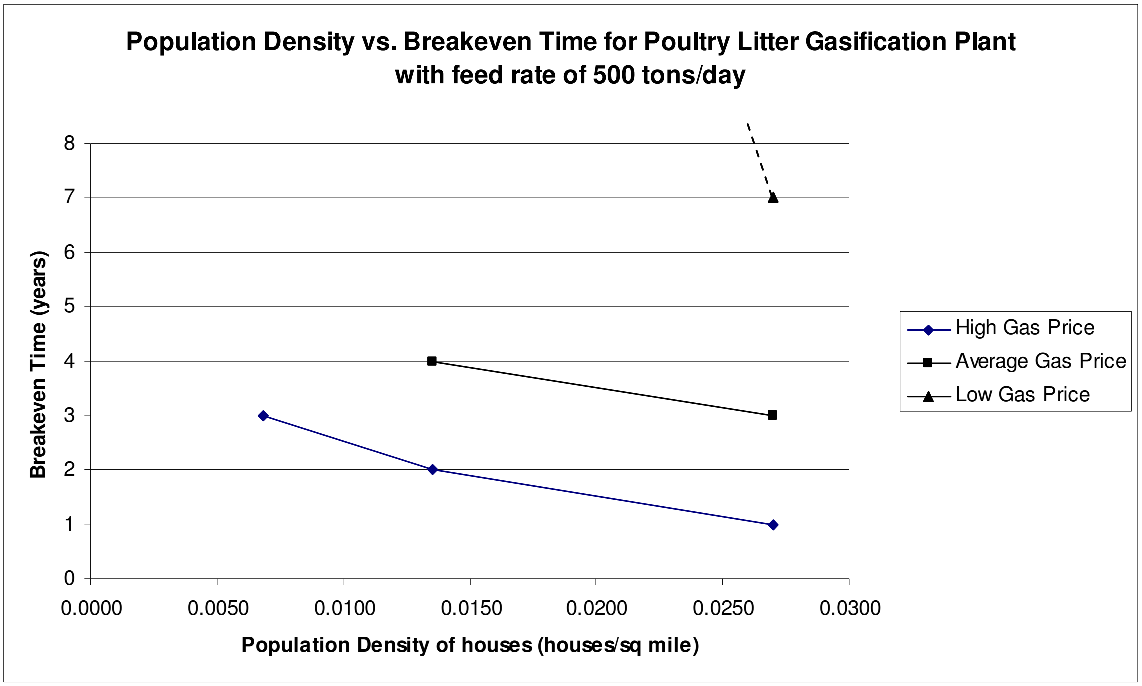


Figure 6.11 Poultry Litter Results for 500 tons/day with Population Densities Specified

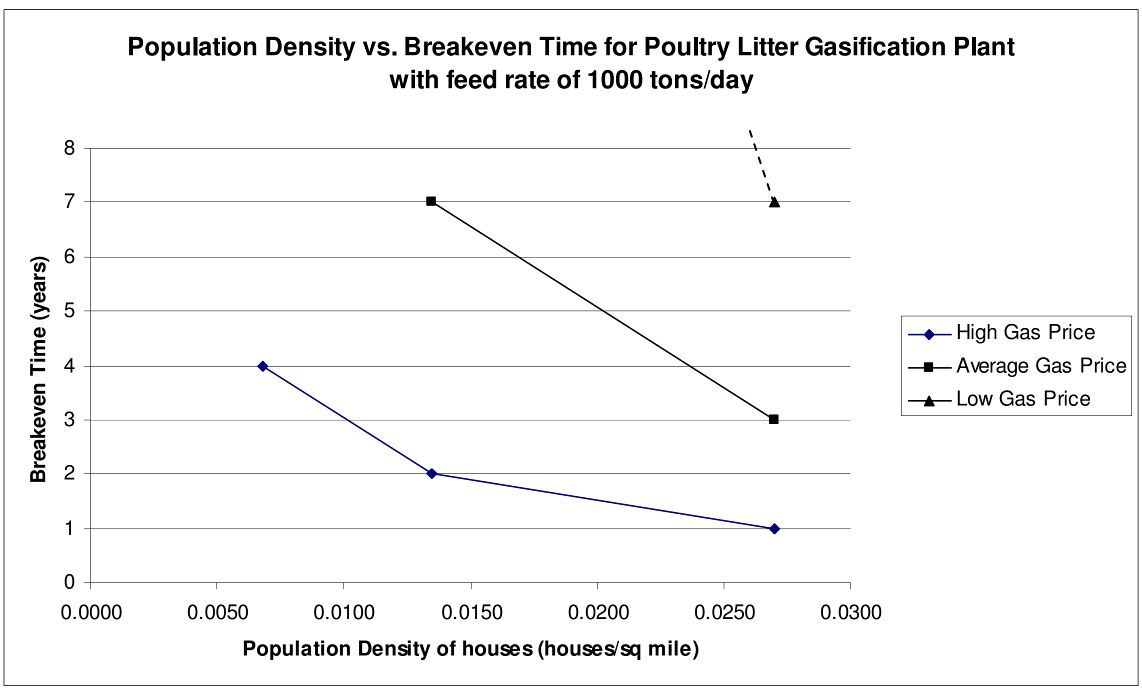


Figure 6.12 Poultry Litter Results for 1000 tons/day with Population Densities Specified

has the lowest break even times. Therefore the additional case involving a $10/ton charge by the farmer for the poultry litter will be applied only to this one case. The results of this test can be seen in Table 6.6. The only case that breaks even in a reasonable time frame is that for the high sales price of product gas. Which brings about the conclusion that the best possible scenario given all the factors considered in this study is that a 1000 ton/day plant be built in an area with population densities similar to those surrounding Batesville Arkansas. A 1000 ton/day plant would need approximately 7 poultry houses each day to meet its feed demands. This will enable the plant to weather changes in economic conditions relatively easily.

The results obtained in this study were consistent with the findings in the Delmarva Peninsula area. Both studies determined that the larger the plant the more economically feasible it becomes and that the smaller plants would not be realistic without a tipping fee applied to the farmers. In an effort to reduce the cost to the farmers the Delmarva study also suggested that the additional cost could be covered by a state or federal incentive. The study suggests that the incentive be distributed over a large number

Table 6.6 – Results for Poultry Litter Test Cases with Density Specified and $10/ton Charge for Litter

Feed Rate tons/day	Population Density Reqd #/ Sq. Mile	Number of Houses Reqd	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Product Gas Price Range	Annual Cost	Annual Profit	Break Even Time (years)
500	0.0270	1146	116	164	high	$6,948,329	$10,063,401	2
	0.0135	1146	164	232	high	$7,771,161	$10,063,401	3
	0.0068	1146	232	328	high	$8,988,827	$10,063,401	7
	0.0270	1146	116	164	average	$6,948,329	$7,337,625	16
	0.0135	1146	164	232	average	$7,771,161	$7,337,625	-
	0.0068	1146	232	328	average	$8,988,827	$7,337,625	-
	0.0270	1146	116	164	low	$6,948,329	$5,952,395	-
	0.0135	1146	164	232	low	$7,771,161	$5,952,395	-
	0.0068	1146	232	328	low	$8,988,827	$5,952,395	-

of people to decrease the cost to any one group. Examples of people who could contribute to the incentive are consumers of chicken meat and taxpayers in the vicinity of the plant.(1)

6.3 Results for Shredded Tire Process

Tables 6.7 and 6.8 show the results of the test cases for the used tire processing plant with and without a tipping fee. The 2222 lb/hr plant was not able to break even in any scenario and the 12222 lb/hr plant was able to break even at the given conditions only after the addition of a tipping fee.

The $25 per ton tipping fee was added based on the conversation with Mr. Allen Ball from the Division of Community Assistance. According to Mr. Ball, plants that utilize shredded tires as fuel must pay $25 / ton to purchase the shredded fuel. Similarly, plants that are able use whole tires are charging $25 / ton to take the tires. (2) Based on this information the assumption was made for the second set of test cases that the plant would process only whole tires and therefore be able to charge the $25 / ton fee. This additional money would be used to increase revenue, and the tires would be burned whole.

In spite of the addition of the tipping fee, the plant was able to breakeven only when the highest price was paid for the products. Because $25/ton is the going rate for tires, a higher price was not tried. Based on the results of the tests, the used tire plant does not appear to be economically feasible.

Table 6.7 Results for Used Tire Test Cases without Tipping Fee

Feed Rate lbs/hr	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Population Density #/Sq. Mile	Steam Price Range	Annual Cost	Annual Income	Break Even Time (years)
2222	50	71	0.0014	high	$2,021,168	$1,468,255	-
	100	141	0.0014	high	$2,043,169	$1,468,255	-
	150	212	0.0014	high	$2,173,903	$1,468,255	-
	50	71	0.0014	average	$2,021,168	$1,112,575	-
	100	141	0.0014	average	$2,043,169	$1,112,575	-
	150	212	0.0014	average	$2,173,903	$1,112,575	-
	50	71	0.0014	low	$2,021,168	$910,975	-
	100	141	0.0014	low	$2,043,169	$910,975	-
	150	212	0.0014	low	$2,173,903	$910,975	-
12222	50	71	0.0014	high	$8,070,138	$8,075,261	-
	100	141	0.0014	high	$8,369,696	$8,075,261	-
	150	212	0.0014	high	$8,526,825	$8,075,261	-
	50	71	0.0014	average	$8,070,138	$6,119,057	-
	100	141	0.0014	average	$8,369,696	$6,119,057	-
	150	212	0.0014	average	$8,526,825	$6,119,057	-
	50	71	0.0014	low	$8,070,138	$5,010,277	-
	100	141	0.0014	low	$8,369,696	$5,010,277	-
	150	212	0.0014	low	$8,526,825	$5,010,277	-
22222	50	71	0.0014	high	$13,703,999	$14,682,413	10
	100	141	0.0014	high	$14,091,561	$14,682,413	17
	150	212	0.0014	high	$14,571,117	$14,682,413	-
	50	71	0.0014	average	$13,703,999	$11,125,649	-
	100	141	0.0014	average	$14,091,561	$11,125,649	-
	150	212	0.0014	average	$14,571,117	$11,125,649	-
	50	71	0.0014	low	$13,703,999	$9,109,669	-
	100	141	0.0014	low	$14,091,561	$9,109,669	-
	150	212	0.0014	low	$14,571,117	$9,109,669	-

** the '-' symbol indicates that a test case does not break even*

Table 6.8 Results for Used Tire Test Cases with Tipping Fee

Feed Rate lbs/hr	Maximum Radial Distance to Travel (miles)	Actual Distance to Travel (miles)	Population Density	Price Range	Annual Cost	Annual Profit	Break Even Time (years)
2222	50	71	0.0014	high	$2,126,949	$1,668,254	-
	100	141	0.0014	high	$2,286,665	$1,668,254	-
	150	212	0.0014	high	$2,448,653	$1,668,254	-
	50	71	0.0014	average	$2,126,949	$1,312,574	-
	100	141	0.0014	average	$2,286,665	$1,312,574	-
	150	212	0.0014	average	$2,448,653	$1,312,574	-
	50	71	0.0014	low	$2,126,949	$1,110,974	-
	100	141	0.0014	low	$2,286,665	$1,110,974	-
	150	212	0.0014	low	$2,448,653	$1,110,974	-
12222	50	71	0.0014	high	$8,682,818	$9,175,241	17
	100	141	0.0014	high	$9,364,975	$9,175,241	-
	150	212	0.0014	high	$10,163,523	$9,175,241	-
	50	71	0.0014	average	$8,682,818	$7,219,036	-
	100	141	0.0014	average	$9,364,975	$7,219,036	-
	150	212	0.0014	average	$10,163,523	$7,219,036	-
	50	71	0.0014	low	$8,682,818	$6,110,256	-
	100	141	0.0014	low	$9,364,975	$6,110,256	-
	150	212	0.0014	low	$10,163,523	$6,110,256	-
22222	50	71	0.0014	high	$14,739,803	$16,682,393	6
	100	141	0.0014	high	$16,060,825	$16,682,393	26
	150	212	0.0014	high	$17,379,508	$16,682,393	-
	50	71	0.0014	average	$14,739,803	$13,125,628	-
	100	141	0.0014	average	$16,060,825	$13,125,628	-
	150	212	0.0014	average	$17,379,508	$13,125,628	-
	50	71	0.0014	low	$14,739,803	$11,109,648	-
	100	141	0.0014	low	$16,060,825	$11,109,648	-
	150	212	0.0014	low	$17,379,508	$11,109,648	-

** the '-' symbol indicates that a test case does not break even*

Only the distance to travel from the plant was specified for these calculations because the population density of pickup locations is unlikely to change.

Study of Tables 6.7 and 6.8 show that in the cases where the plant does not breakeven the annual costs are higher than the annual income. In order to break even it would be necessary to make changes to the plant that would cut the annual costs. One possible solution to the high cost issue would be to use tires only as an auxiliary fuel along with some other fuel, possibly coal.

According to Mr. Ray Richard, manager of the Coal Acquisition Department o f TVA in Nashville, Tennessee, a plant that uses approximately 2,000,000 tons per year of coal with a heating value of $12,000 BTU/lb will incur delivered coal cost of about $30/ton and energy production costs of about $20/MWh. Using this information, and a conversion factor of 1BTU=0.29307 x 10^{-6} MWh (18). The cost to produce energy from 1 ton of coal comes out to be approximately $170. The calculation for this is:

$$\frac{1\text{ ton coal}}{} \left| \frac{2000\text{ lbs}}{1\text{ ton}} \right| \frac{12{,}000\text{ BTU}}{\text{lb}} \left| \frac{0.29307 \times 10^{-6}\text{ MWh}}{1\text{ BTU}} \right. = 7.034\text{ MWh}$$

$$\frac{7.034\text{ MWh}}{} \left| \frac{\$20}{\text{MWh}} \right. = \$140 \text{ processing cost for 1 ton of coal}$$

Adding the $30/ton delivery fee gives an annual cost of approximately $170/ton of coal. The annual cost per ton to process the tires was determined by taking the previously calculated annual costs and dividing them by the total number of tons processed per year.

These costs are shown in Table 6.9

Now a rough estimate was made to predict the annual cost using a mixed fuel of both coal and whole used tires including the tipping fee of $25/ton of tires. The estimate was done using the best case scenarios of high sales price of the product steam and the shortest distance to travel away from the plant to collect the used tires. The annual profit numbers for the mixed feed case were assumed to be the same as that for the plant processing only whole tires. This assumption was made based on the fact that the TVA plant information was from a plant that produced electricity, not steam therefore any profit data from that plant would not be consistent with the steam plant and because the coal has approximately the same heating value as the tires 12,000 BTU/lb the same type of product can be expected from the mixed feed plant. The results are shown in Table 6.10

The results show that the only cases where the profits exceed the costs are for the 10, 20 and 30 percent coal usage with the 12,222 and 22,222 lb/hr feed rates. These are the same cases that were able to break even in the previous study using tires as the only source of fuel. Because the cases that were tested using the mixed fuel should be the most profitable ones, with the lowest transportation costs and highest profits, there is no reason to test any further options. The costs associated with this plant design are just too high to make it economically feasible. Also the addition of the tires as auxiliary fuel to an existing coal plant would only make the coal production more expensive and less profitable which would be undesirable.

Table 6.9 Annual Cost of Steam Production per Ton to Process Tires

Feed Rate of Tires (lbs/hr)	Maximum Distace to travel (miles)	Price Range	Annual Cost	Operation (hours/yr)	Lbs of Tires per year	Tons of Tires per year	Production Cost per ton of Tires
2,222	50	high	$2,126,949.00	7,200	15,998,400	7,999	$266
2,222		high	$2,126,949.00	7,200	15,998,400	7,999	$266
2,222		high	$2,126,949.00	7,200	15,998,400	7,999	$266
2,222		high	$2,126,949.00	7,200	15,998,400	7,999	$266
2,222		high	$2,126,949.00	7,200	15,998,400	7,999	$266
2,222		high	$2,126,949.00	7,200	15,998,400	7,999	$266
2,222		high	$2,126,949.00	7,200	15,998,400	7,999	$266
2,222		high	$2,126,949.00	7,200	15,998,400	7,999	$266
2,222		high	$2,126,949.00	7,200	15,998,400	7,999	$266
12,222	50	high	$8,682,818.00	7,200	87,998,400	43,999	$197
12,222		high	$8,682,818.00	7,200	87,998,400	43,999	$197
12,222		high	$8,682,818.00	7,200	87,998,400	43,999	$197
12,222		high	$8,682,818.00	7,200	87,998,400	43,999	$197
12,222		high	$8,682,818.00	7,200	87,998,400	43,999	$197
12,222		high	$8,682,818.00	7,200	87,998,400	43,999	$197
12,222		high	$8,682,818.00	7,200	87,998,400	43,999	$197
12,222		high	$8,682,818.00	7,200	87,998,400	43,999	$197
12,222		high	$8,682,818.00	7,200	87,998,400	43,999	$197
22,222	50	high	$14,739,803.00	7,200	159,998,400	79,999	$184
22,222		high	$14,739,803.00	7,200	159,998,400	79,999	$184
22,222		high	$14,739,803.00	7,200	159,998,400	79,999	$184
22,222		high	$14,739,803.00	7,200	159,998,400	79,999	$184
22,222		high	$14,739,803.00	7,200	159,998,400	79,999	$184
22,222		high	$14,739,803.00	7,200	159,998,400	79,999	$184
22,222		high	$14,739,803.00	7,200	159,998,400	79,999	$184
22,222		high	$14,739,803.00	7,200	159,998,400	79,999	$184
22,222		high	$14,739,803.00	7,200	159,998,400	79,999	$184

Table 6.10 Results of Mixed Fuel Case

Maximum Distace to travel (miles)	Price Range	Total Mixed Feed Rate tons/year	Percent Coal Used	Percent Tires Used	Tons of Coal Used	Tons of Tires Used	Cost of coal prod	Cost of tire prod	Total Annual Cost of Mixed Feed	Annual Income	Net Profit
50	high	7999	10	90	799.9	7199.1	$136,462.94	$1,914,206.24	$2,050,669	$1,668,254	($382,415)
	high	7999	20	80	1599.8	6399.2	$272,925.88	$1,701,516.66	$1,974,443	$1,668,254	($306,189)
	high	7999	30	70	2399.7	5599.3	$409,388.82	$1,488,827.07	$1,898,216	$1,668,254	($229,962)
	high	7999	40	60	3199.6	4799.4	$545,851.76	$1,276,137.49	$1,821,989	$1,312,574	($509,415)
	high	7999	50	50	3999.5	3999.5	$682,314.70	$1,063,447.91	$1,745,763	$1,312,574	($433,189)
	high	7999	60	40	4799.4	3199.6	$818,777.64	$850,758.33	$1,669,536	$1,312,574	($356,962)
	high	7999	70	30	5599.3	2399.7	$955,240.58	$638,068.75	$1,593,309	$1,110,974	($482,335)
	high	7999	80	20	6399.2	1599.8	$1,091,703.52	$425,379.16	$1,517,083	$1,110,974	($406,109)
	high	7999	90	10	7199.1	799.9	$1,228,166.46	$212,689.58	$1,440,856	$1,110,974	($329,882)
50	high	43999	10	90	4399.9	39599.1	$750,622.94	$7,814,500.68	$8,565,124	$9,175,241	$610,117
	high	43999	20	80	8799.8	35199.2	$1,501,245.88	$6,946,222.83	$8,447,469	$9,175,241	$727,772
	high	43999	30	70	13199.7	30799.3	$2,251,868.82	$6,077,944.97	$8,329,814	$9,175,241	$845,427
	high	43999	40	60	17599.6	26399.4	$3,002,491.76	$5,209,667.12	$8,212,159	$7,219,036	($993,123)
	high	43999	50	50	21999.5	21999.5	$3,753,114.70	$4,341,389.27	$8,094,504	$7,219,036	($875,468)
	high	43999	60	40	26399.4	17599.6	$4,503,737.64	$3,473,111.41	$7,976,849	$7,219,036	($757,813)
	high	43999	70	30	30799.3	13199.7	$5,254,360.58	$2,604,833.56	$7,859,194	$6,110,256	($1,748,938)
	high	43999	80	20	35199.2	8799.8	$6,004,983.52	$1,736,555.71	$7,741,539	$6,110,256	($1,631,283)
	high	43999	90	10	39599.1	4399.9	$6,755,606.46	$868,277.85	$7,623,884	$6,110,256	($1,513,628)
50	high	79999	10	90	7999.9	71999.1	$1,364,782.94	$13,265,789.54	$14,630,572	$16,682,393	$2,051,821
	high	79999	20	80	15999.8	63999.2	$2,729,565.88	$11,791,812.92	$14,521,379	$16,682,393	$2,161,014
	high	79999	30	70	23999.7	55999.3	$4,094,348.82	$10,317,836.31	$14,412,185	$16,682,393	$2,270,208
	high	79999	40	60	31999.6	47999.4	$5,459,131.76	$8,843,859.69	$14,302,991	$13,125,628	($1,177,363)
	high	79999	50	50	39999.5	39999.5	$6,823,914.70	$7,369,883.08	$14,193,798	$13,125,628	($1,068,170)
	high	79999	60	40	47999.4	31999.6	$8,188,697.64	$5,895,906.46	$14,084,604	$13,125,628	($958,976)
	high	79999	70	30	55999.3	23999.7	$9,553,480.58	$4,421,929.85	$13,975,410	$11,109,648	($2,865,762)
	high	79999	80	20	63999.2	15999.8	$10,918,263.52	$2,947,953.23	$13,866,217	$11,109,648	($2,756,569)
	high	79999	90	10	71999.1	7999.9	$12,283,046.46	$1,473,976.62	$13,757,023	$11,109,648	($2,647,375)

It appears that the only way the tire plant would be able to be economically feasible would be to find a way to decrease the annual costs associated with the plant. A study of the costs associated with the plant shows that much of the annual cost is incurred when the absorber solution is land filled. In addition, the cost to landfill the solution becomes excessive at the higher feed rates, and if decreased could change the outcome of this research. A study of the spent absorber solution shows that approximately 80% of the solution is water with the remaining 20% being NaOH and Na_2SO_3.(15) In an effort to lower the costs associated with the disposal of the spent absorber solution a rough estimate was made to add an evaporator to the process that would evaporate most of the water in the solution and leave only the remaining NaOH and Na_2SO_3 that would need to be land filled. Because the remaining solution would still be in liquid form the same land filling costs could be assumed as in the original work. This would reduce the land filling costs by approximately 80%. The new values of the land filling costs are shown in Table 6.11 and the total material and disposal costs for the process are shown in Table 6.12.

The cost for the evaporator was assumed to be approximately that of the Water Tube Boiler. This changes the total purchased equipment cost for the profit is shown in Table 6.13.

Because the program calculates many costs as percentages of other costs, the costs associated with the operation of the evaporator, including the utilities are included in the calculations that are performed by the program.

Table 6.11 – Cost to Landfill Spent Absorber Solution After Addition of Evaporator

Fuel Rate	Solution gal/min	Annual Amt (gal)	Lanfill Cost
2222	5.86	2,531,520	$79,692
12222	32.23	13,923,121	$438,300
22222	58.60	25,314,972	$796,915

Table 6.12 – Total Cost of Materials and Waste Disposal with Evaporator

Feed Rate	Total Cost
2222 lbs/hr	$572,043
12222 lbs/hr	$3,146,375
22222 lbs/hr	$5,720,715

Table 6.13 – Equipment Costs Including Evaporator

Feed Rate lb/hr	Purchased Equipment Cost without evaporator	Purchased Equipment Costs with evaporator
2222	$1,651,056	$1,783,253
12222	$5,085,320	$5,485,131
22222	$7,351,663	$7,923,984

The test cases for the tire incineration plant were run again using the numbers after the addition of the evaporator and the $25/ton tipping fee. The results of the runs are shown in Table 6.14.

The data are also displayed in chart form in Figures 6.13 through 6.15. These case results are slightly more promising. The removal of the large land filling charge for the spent absorber solution makes a difference in the annual cost of the process that allows the incineration plant to break even in some cases. It is also possible that the remaining solution could be sold for recovery of chemicals which will also increase the profitability of the plant.

The 2222 lb/hr test case is still not a feasible solution which was also the findings of the previous work by Parathasary. (15) However, as has been the trend throughout this research the larger plants seem to have more ability to withstand economic change. The 12222 lb/hr facility is able to break even in an acceptable time period, but only for the high sales price of the steam. However, the largest plant with the 22,222 lb/hr feed rate is able to break even at reasonable times with the highest sales price of steam and for all distances traveled. Of all of the cases tested for the tire incineration plant, the 22,222 lb/hr plant with the addition of the evaporator and the $25/ton tipping fee would obviously be the best choice for someone looking to start such a business. The results of these test cases in chart form better show the relationship between the annual cost and annual income for each of the test cases. As would be expected, the cases where the annual costs exceed the annual income are unable to break even.

Table 6.14 – Results of Test Cases with Tipping Fee and Evaporator

Feed Rate lbs/hr	Maximum Radial Distance to Travel (miles)	Actual Distance Traveled (miles)	Population Density	Price Range	Annual Cost	Annual Profit	Break Even Time (years)
2222	50	71	0.0014	high	$1,816,152	$1,668,254	-
	100	141	0.0014	high	$1,975,868	$1,668,254	-
	150	212	0.0014	high	$2,137,856	$1,668,254	-
	50	71	0.0014	average	$1,816,152	$1,312,575	-
	100	141	0.0014	average	$1,975,868	$1,312,575	-
	150	212	0.0014	average	$2,137,856	$1,312,575	-
	50	71	0.0014	low	$1,816,152	$1,110,974	-
	100	141	0.0014	low	$1,975,868	$1,110,974	-
	150	212	0.0014	low	$2,137,856	$1,110,974	-
12222	50	71	0.0014	high	$6,866,158	$9,175,241	4
	100	141	0.0014	high	$7,548,315	$9,175,241	5
	150	212	0.0014	high	$8,346,863	$9,175,241	12
	50	71	0.0014	average	$6,866,158	$7,219,036	29
	100	141	0.0014	average	$7,548,315	$7,219,036	-
	150	212	0.0014	average	$8,346,863	$7,219,036	-
	50	71	0.0014	low	$6,866,158	$6,110,256	-
	100	141	0.0014	low	$7,548,315	$6,110,256	-
	150	212	0.0014	low	$8,346,863	$6,110,256	-
22222	50	71	0.0014	high	$11,385,966	$16,682,393	2
	100	141	0.0014	high	$12,706,988	$16,682,393	3
	150	212	0.0014	high	$14,025,671	$16,682,393	6
	50	71	0.0014	average	$11,385,966	$13,125,628	7
	100	141	0.0014	average	$12,706,988	$13,125,628	60
	150	212	0.0014	average	$14,025,671	$13,125,628	-
	50	71	0.0014	low	$11,385,966	$11,109,648	-
	100	141	0.0014	low	$12,706,988	$11,109,648	-
	150	212	0.0014	low	$14,025,671	$11,109,648	-

** the '-' symbol indicates that a given test case does not break even*

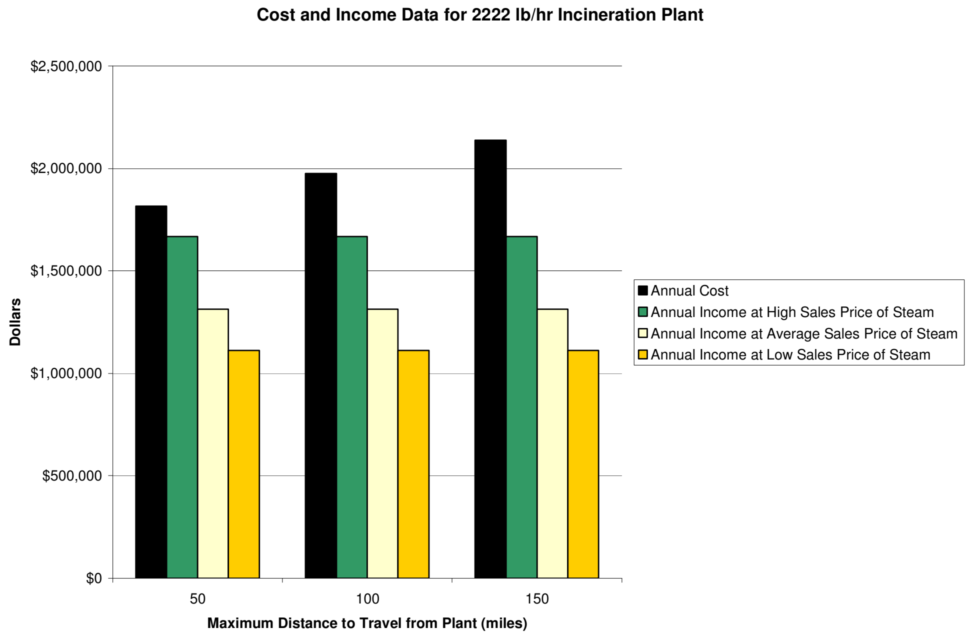


Figure 6.13 – Cost and Income Data for 2222 lb/hr Incineration Plant with the Addition of the Evaporator and the Tipping Fee

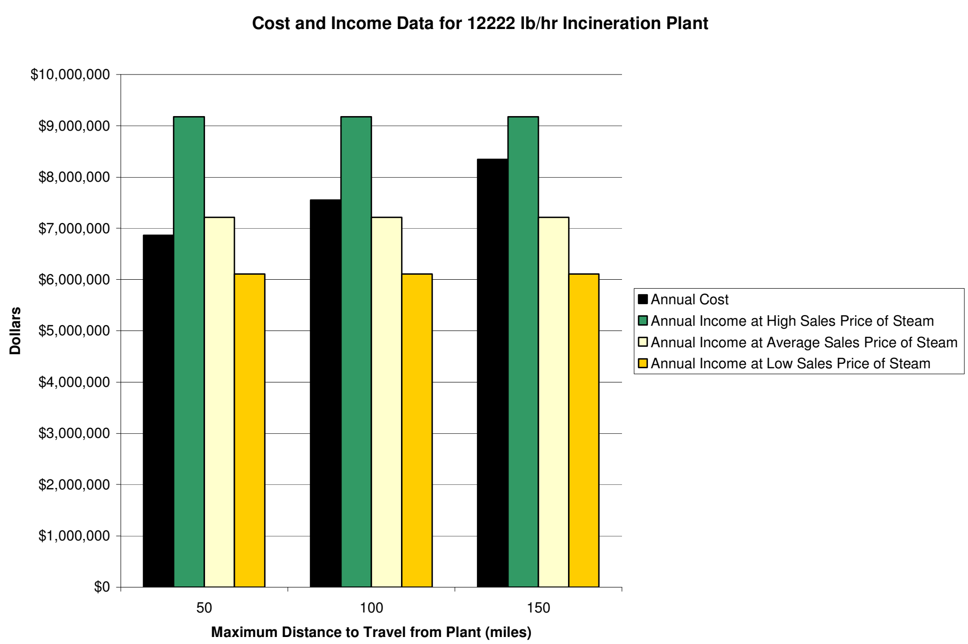


Figure 6.14 – Cost and Income Data for 12222 lb/hr Incineration Plant with the Addition of the Evaporator and the Tipping Fee

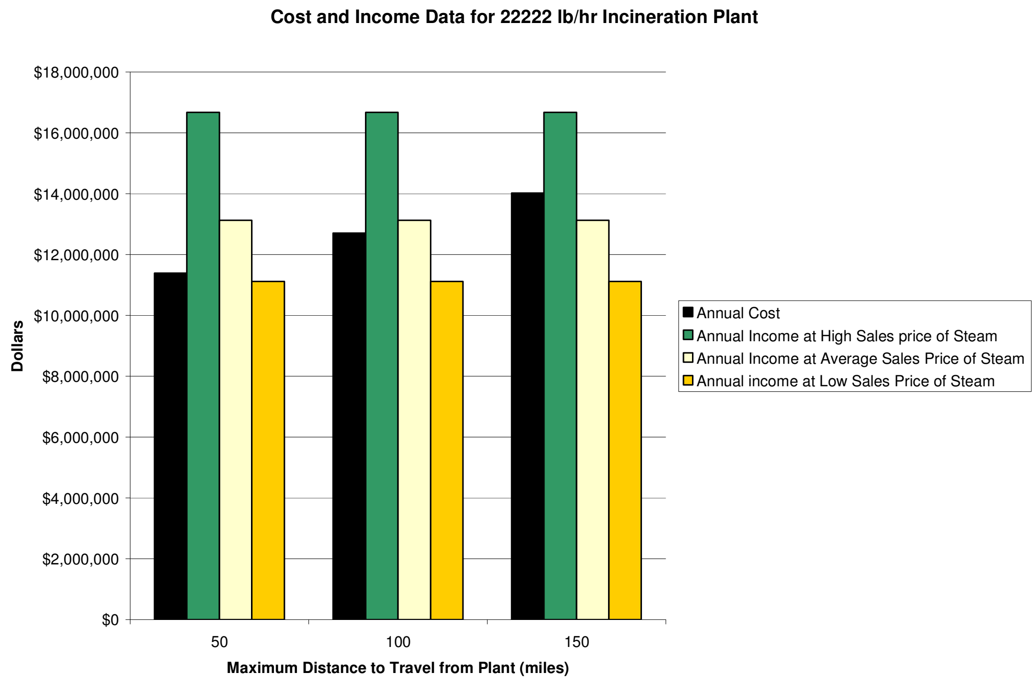


Figure 6.15 – Cost and Income Data for 22222 lb/hr Incineration Plant with the Addition of the Evaporator and the Tipping Fee

CHAPTER 7

Conclusions and Recommendations

7.1 Conclusions

- For the Poultry Litter Process, the best approximation for a specific area comes from the test cases where the population density of poultry houses is specified and the distance to travel away from the farm is dependent on the density.

- A process with a feed rate of 100 ton/day is not economically feasible. Because it cannot withstand changing economic conditions.

- The most promising poultry litter process for the Middle Tennessee area seems to be the 500 ton/day facility. It would be able to withstand some changes in economic conditions and would break even in a shorter time than the other options..

- Although the population density of poultry farms in Tennessee is increasing, it is not increasing fast enough to make the 1000 ton/day poultry farm a good choice. In order to have such a high feed rate, more farms need to be located closer to the plant location, which would be the case for the area around Batesville, Arkansas.

- The 1000 ton/day gasification plant located in Batesville Arkansas or in an area with a similar population density of poultry houses would be the most promising and most profitable of all of the poultry litter gasification plants tested in this study.

- The tire plant which uses shredded tires as its primary fuel is not economically feasible

- For a tire plant to be feasible it must use as fuel, whole used tires and charge a tipping fee of at least $25 / ton and add an evaporator to the current process.

- The current price of used tires is $25/ton. In order for the tire plant to work, without the addition of the evaporator more would need to be charged and since tires could be disposed of elsewhere for less this would not be a desirable alternative.

- The addition of coal as co-fuel to this particular incineration process design does not make it economically feasible. The coal decreases the annual cost of the plant only slightly. Not enough to make the plant feasible in more than the best possible scenarios.

7.2 Recommendations

- Work with different sizes of trucks might lower transportation costs.

- A more thorough design should be made concerning the addition of the evaporator to the tire incineration plant before any conclusions are made about the tire incineration process.

- Some research should be done to see if a buyer could be found for the solution that is left over after the addition of the evaporator in the incineration plant. If a buyer could be found to recover valuable chemicals from the spent absorber solution, it would further reduce the land filling costs and increase the profit of the plant.

- Because the population density of pick-up locations for this research was assumed to be uniform throughout a given region, developing a way to use actual locations of pick-up points in an area would give more realistic results.

- The inclusion of a loan/lease option on the trucks used for the transportation of the raw materials might make this model more comprehensive.

- Another avenue that could be studied is whether the cost of transportation might be decreased if an outside company were responsible for the transportation of the raw materials to the plant

- Research could be done to explore the possibility of mixing feed from different types of animal manure to make smaller plants feasible.

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REFERENCES

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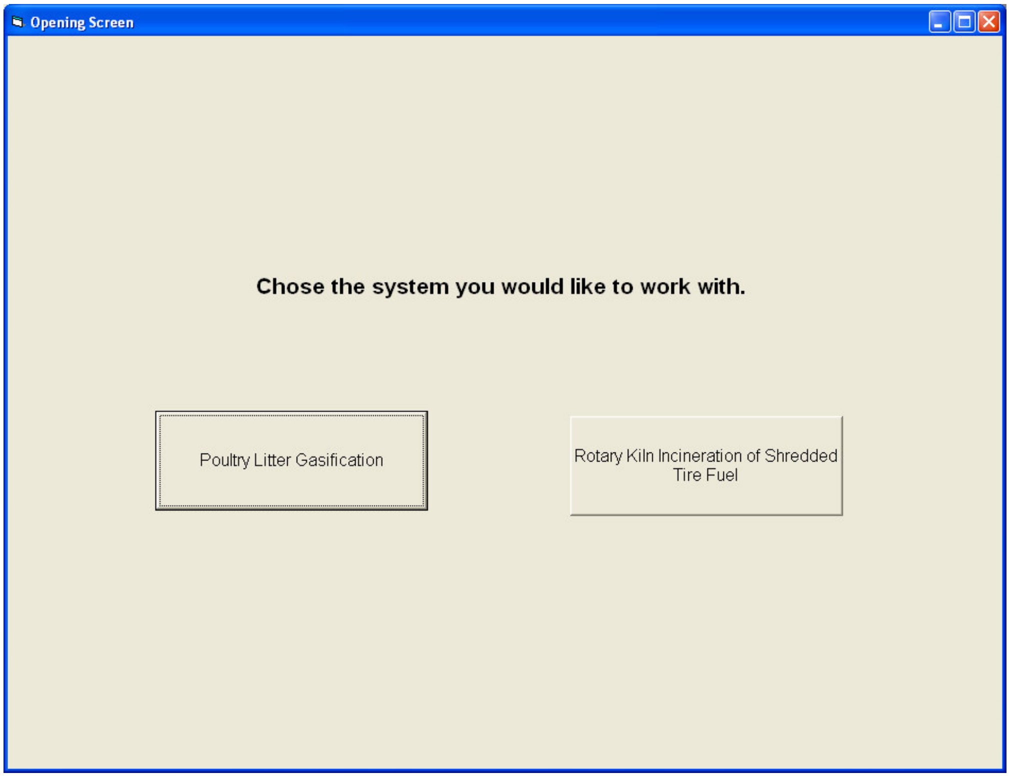
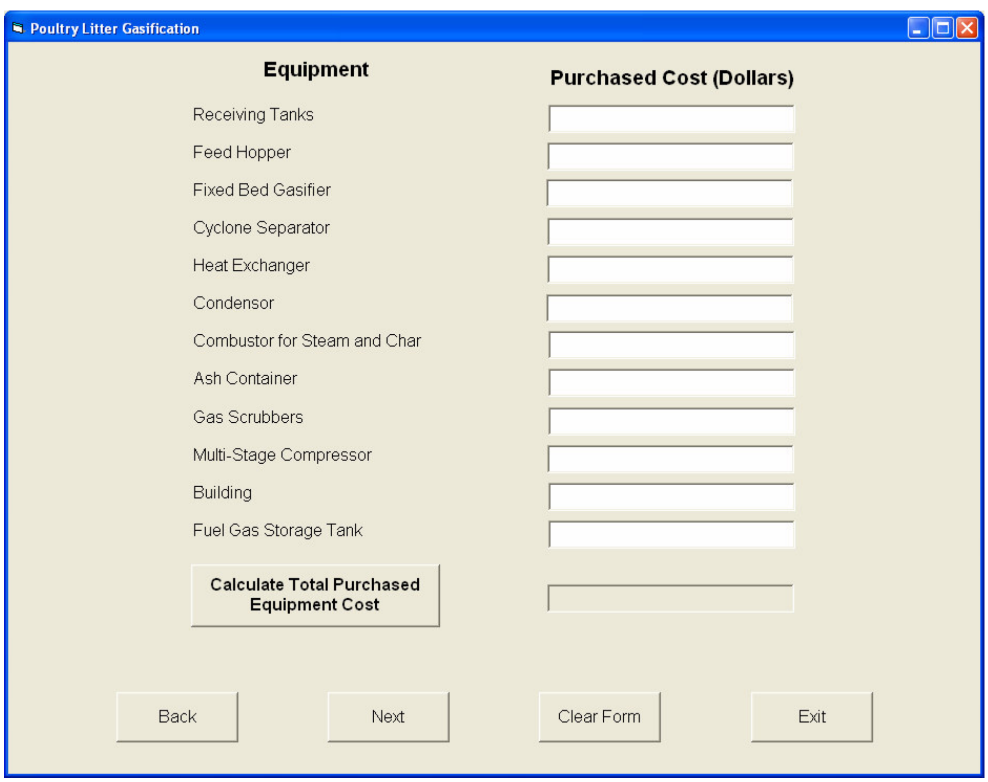
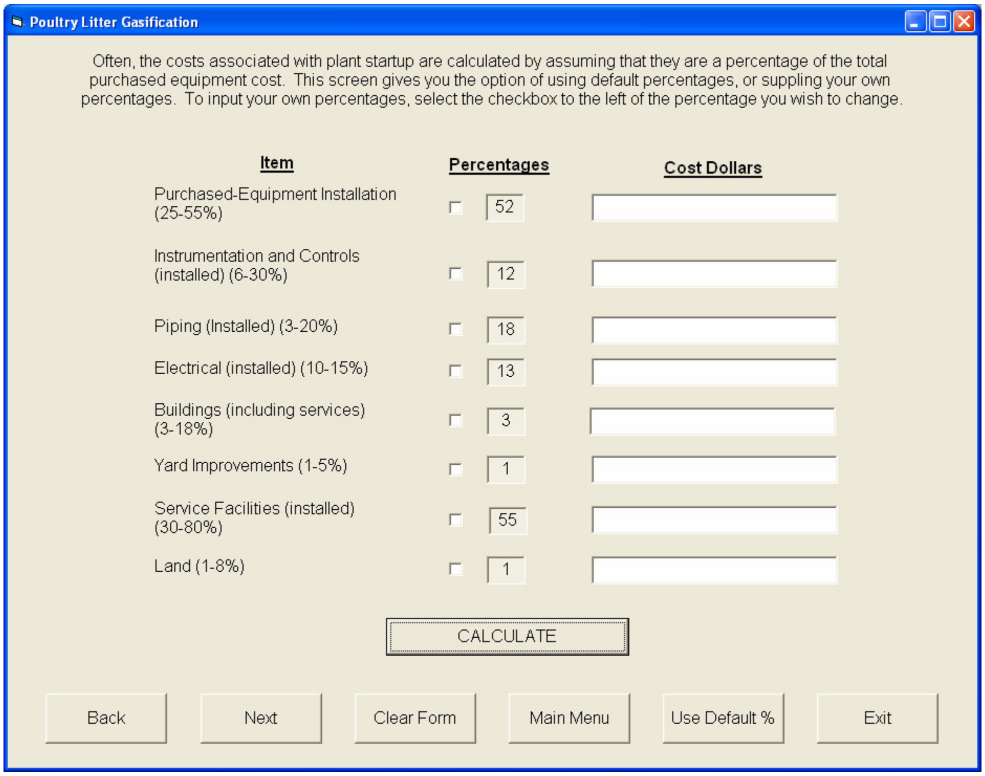
APPENDICES

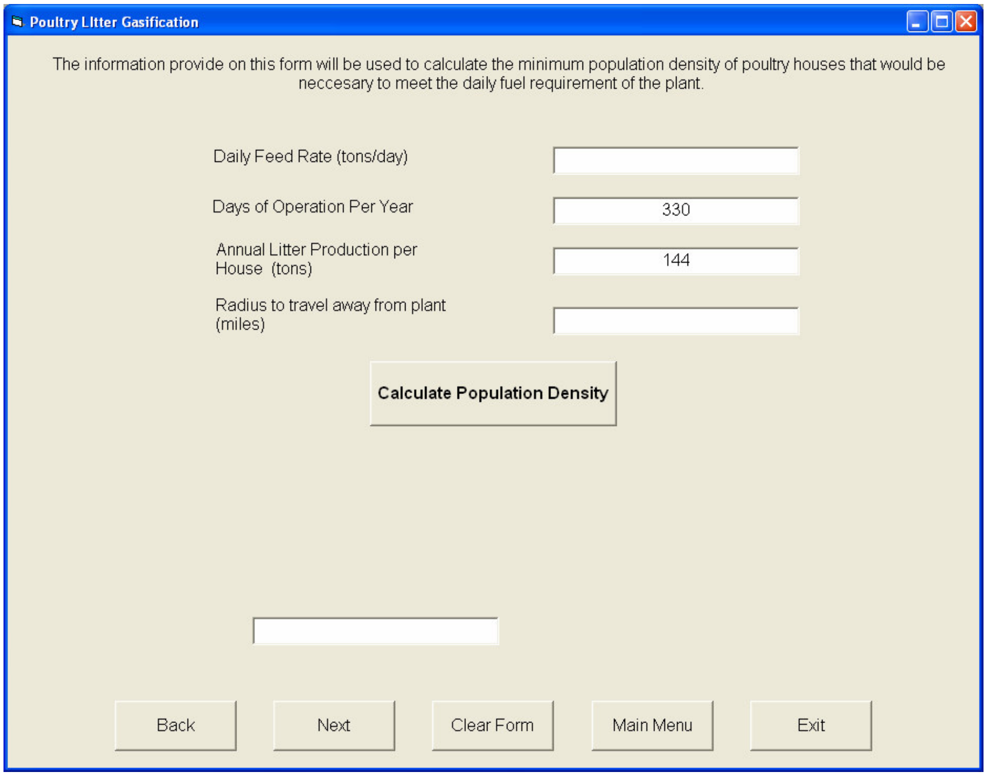
APPENDIX I

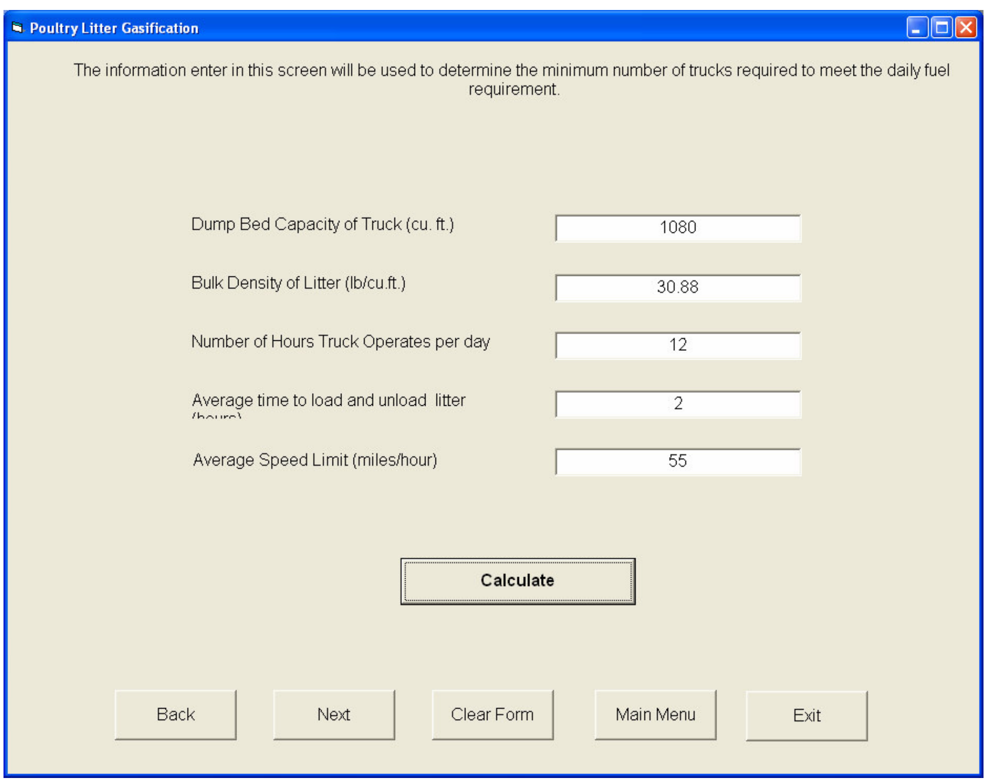
Program Screens

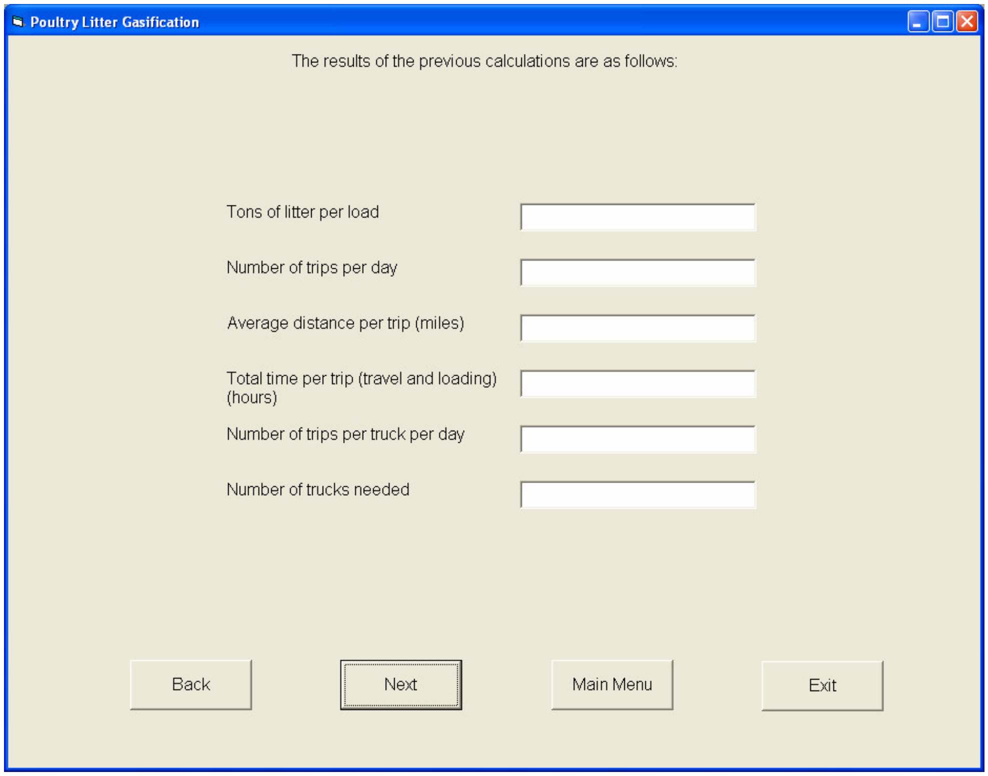

Opening Screen
Chose the system you would like to work with.
Poultry Litter Gasification
Rotary Kiln Incineration of Shredded Tire Fuel

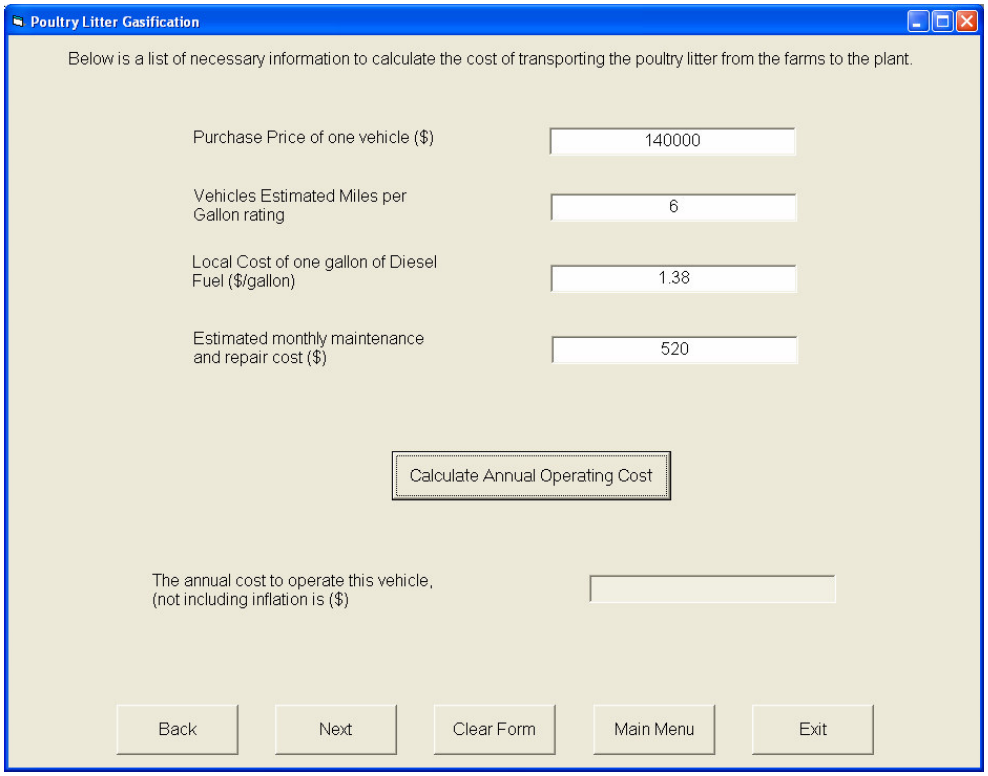

Poultry Litter Gasification
Equipment
Purchased Cost (Dollars)
Receiving Tanks
Feed Hopper
Fixed Bed Gasifier
Cyclone Separator
Heat Exchanger
Condensor
Combustor for Steam and Char
Ash Container
Gas Scrubbers
Multi-Stage Compressor
Building
Fuel Gas Storage Tank
Calculate Total Purchased Equipment Cost
Back
Next
Clear Form
Exit

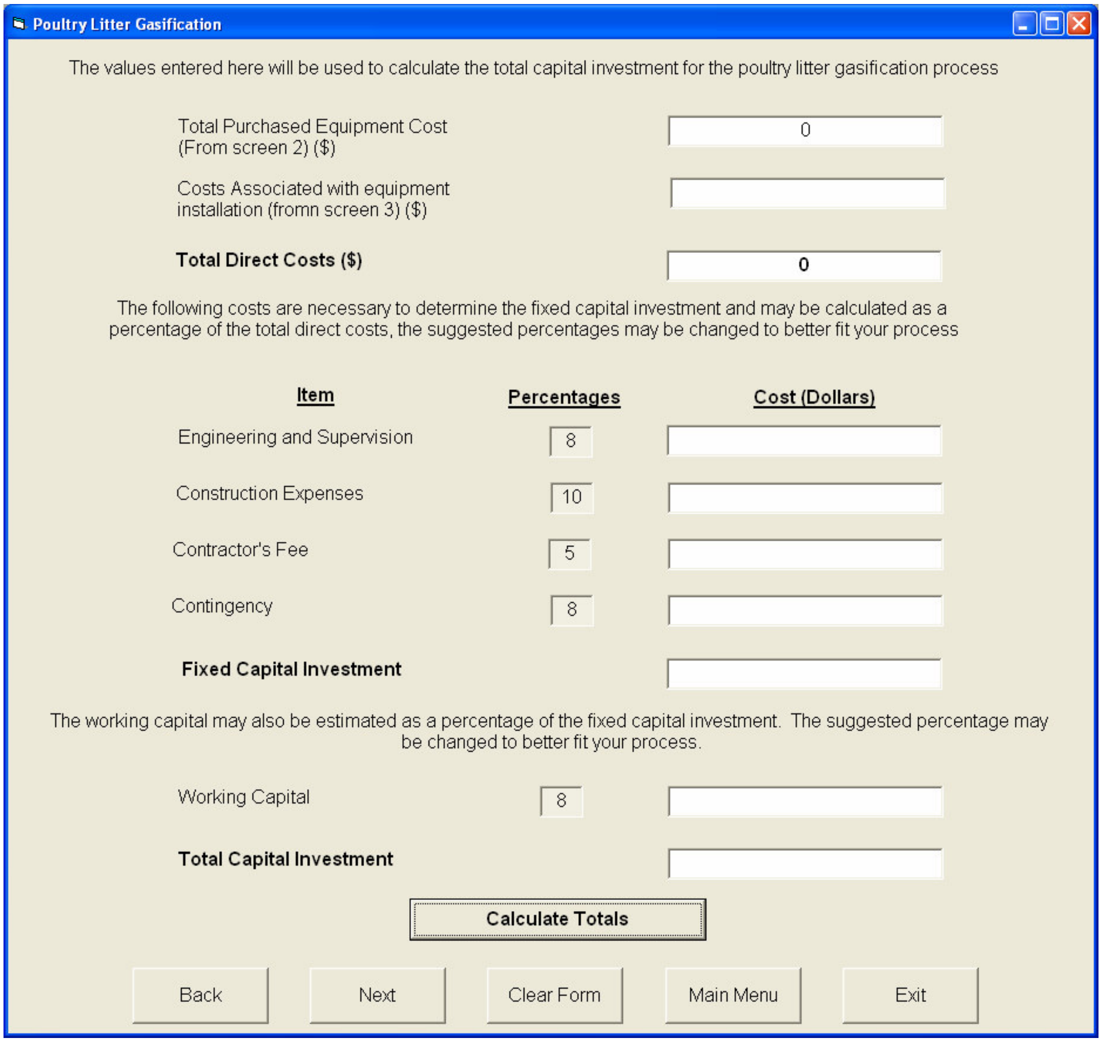

Poultry Litter Gasification
Often, the costs associated with plant startup are calculated by assuming that they are a percentage of the total purchased equipment cost. This screen gives you the option of using default percentages, or suppling your own percentages. To input your own percentages, select the checkbox to the left of the percentage you wish to change.
Item
Percentages
Cost Dollars
Purchased-Equipment Installation (25-55%)
52
Instrumentation and Controls (installed) (6-30%)
12
Piping (Installed) (3-20%)
18
Electrical (installed) (10-15%)
13
Buildings (including services) (3-18%)
3
Yard Improvements (1-5%)
1
Service Facilities (installed) (30-80%)
55
Land (1-8%)
1
CALCULATE
Back
Next
Clear Form
Main Menu
Use Default %
Exit

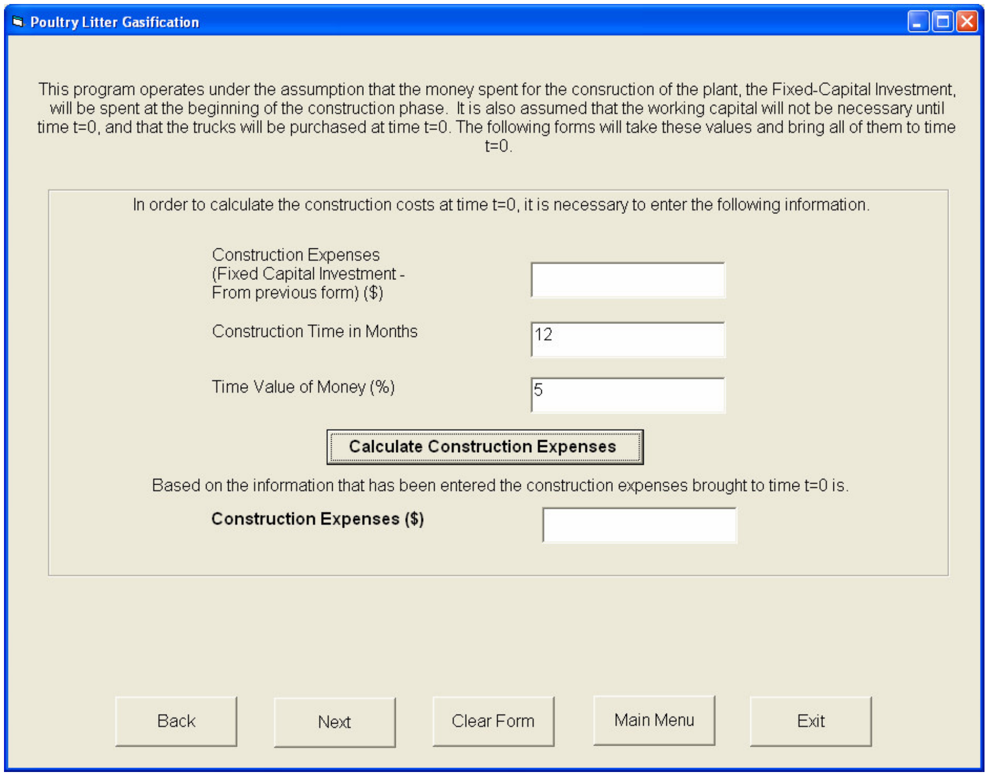

Poultry LItter Gasification
The information provide on this form will be used to calculate the minimum population density of poultry houses that would be neccesary to meet the daily fuel requirement of the plant.
Daily Feed Rate (tons/day)
Days of Operation Per Year
330
Annual Litter Production per House (tons)
144
Radius to travel away from plant (miles)
Calculate Population Density
Back
Next
Clear Form
Main Menu
Exit

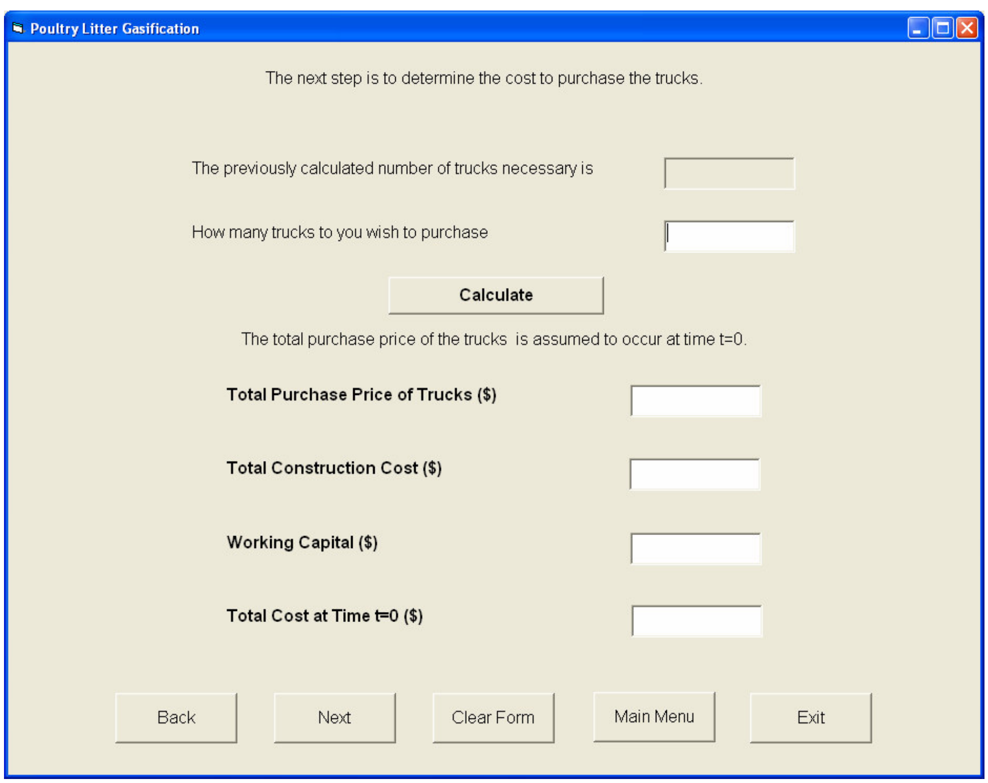

Poultry Litter Gasification
The information enter in this screen will be used to determine the minimum number of trucks required to meet the daily fuel requirement.
Dump Bed Capacity of Truck (cu. ft.)
1080
Bulk Density of Litter (lb/cu.ft.)
30.88
Number of Hours Truck Operates per day
12
Average time to load and unload litter
2
Average Speed Limit (miles/hour)
55
Calculate
Back
Next
Clear Form
Main Menu
Exit

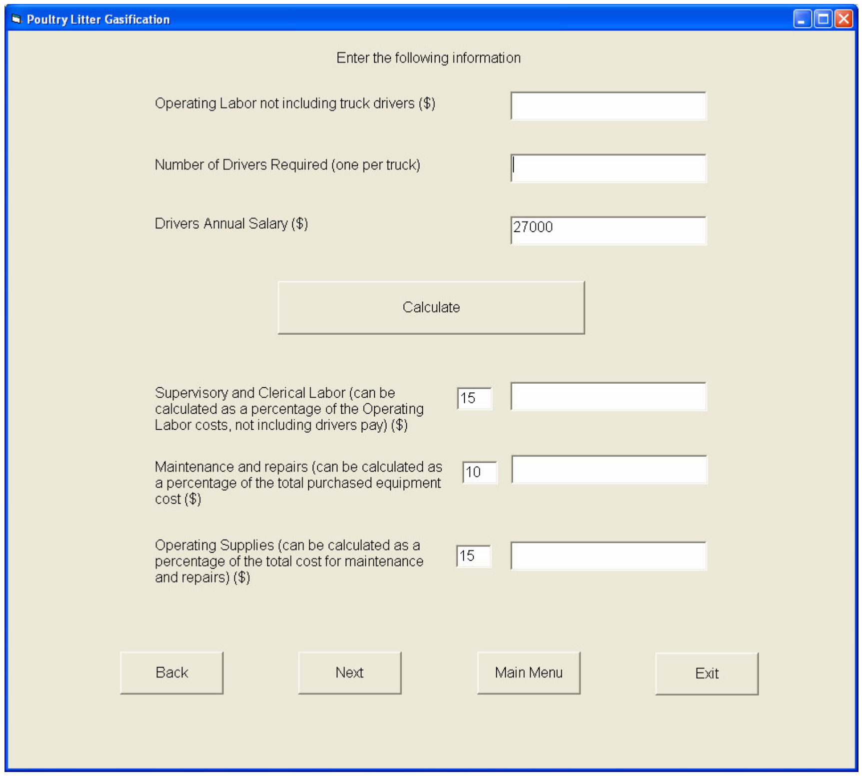

Poultry Litter Gasification
The results of the previous calculations are as follows:
Tons of litter per load
Number of trips per day
Average distance per trip (miles)
Total time per trip (travel and loading) (hours)
Number of trips per truck per day
Number of trucks needed
Back
Next
Main Menu
Exit

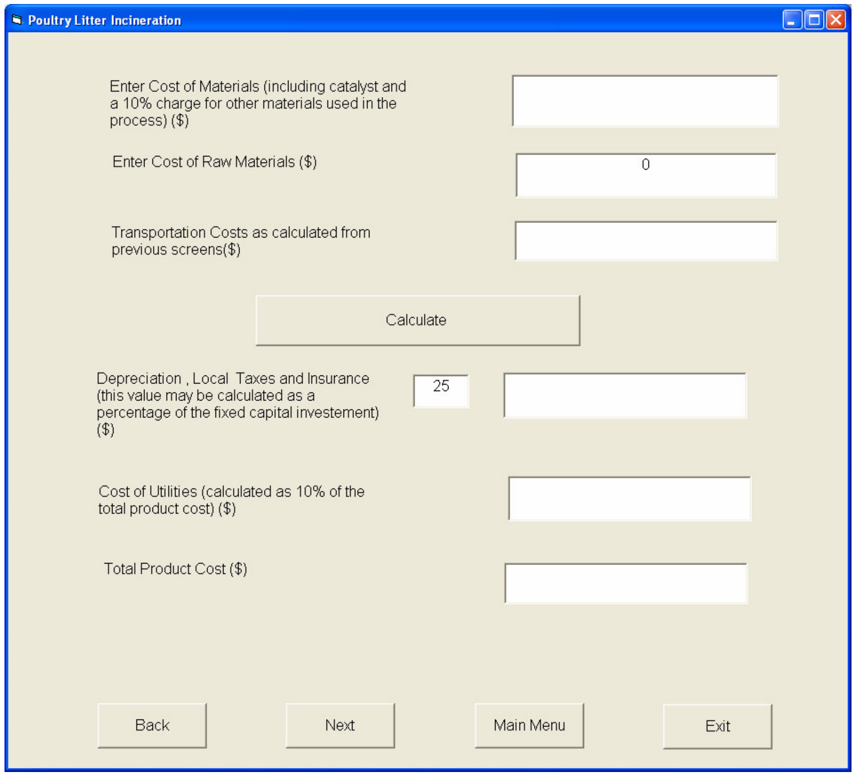

Poultry Litter Gasification
Below is a list of necessary information to calculate the cost of transporting the poultry litter from the farms to the plant.
Purchase Price of one vehicle ($)
140000
Vehicles Estimated Miles per Gallon rating
6
Local Cost of one gallon of Diesel Fuel ($/gallon)
1.38
Estimated monthly maintenance and repair cost ($)
520
Calculate Annual Operating Cost
The annual cost to operate this vehicle, (not including inflation is ($)
Back
Next
Clear Form
Main Menu
Exit

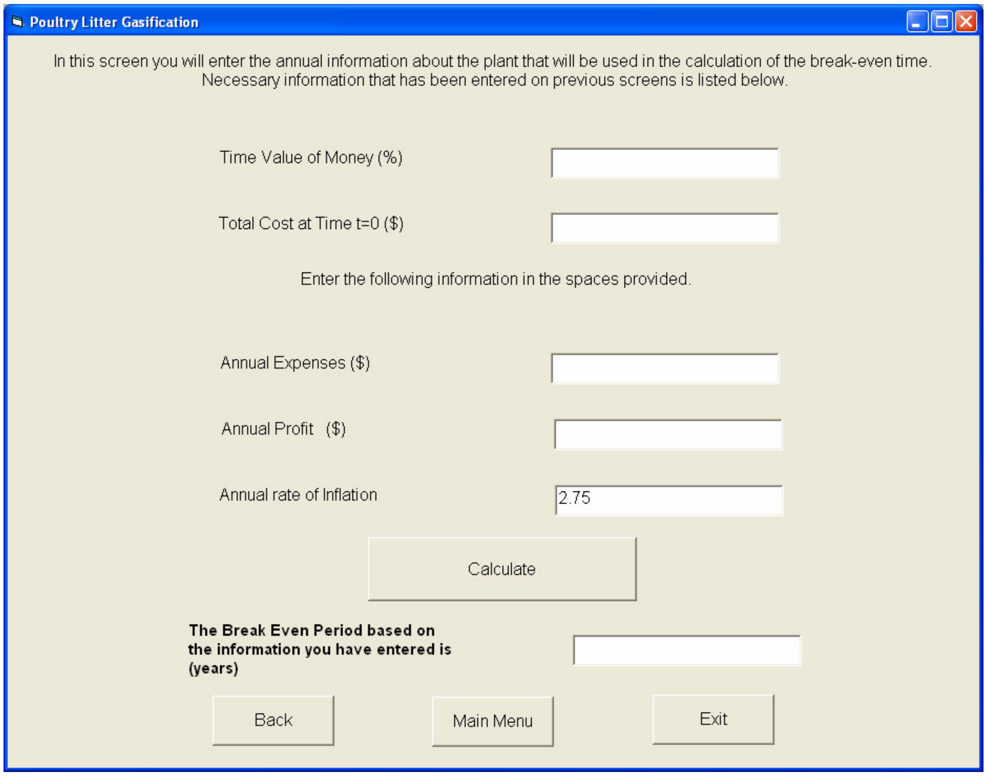

Poultry Litter Gasification
The values entered here will be used to calculate the total capital investment for the poultry litter gasification process
Total Purchased Equipment Cost (From screen 2) ($)
0
Costs Associated with equipment installation (fromn screen 3) ($)
Total Direct Costs ($)
0
The following costs are necessary to determine the fixed capital investment and may be calculated as a percentage of the total direct costs, the suggested percentages may be changed to better fit your process
Item
Percentages
Cost (Dollars)
Engineering and Supervision
8
Construction Expenses
10
Contractor's Fee
5
Contingency
8
Fixed Capital Investment
The working capital may also be estimated as a percentage of the fixed capital investment. The suggested percentage may be changed to better fit your process.
Working Capital
8
Total Capital Investment
Calculate Totals
Back
Next
Clear Form
Main Menu
Exit

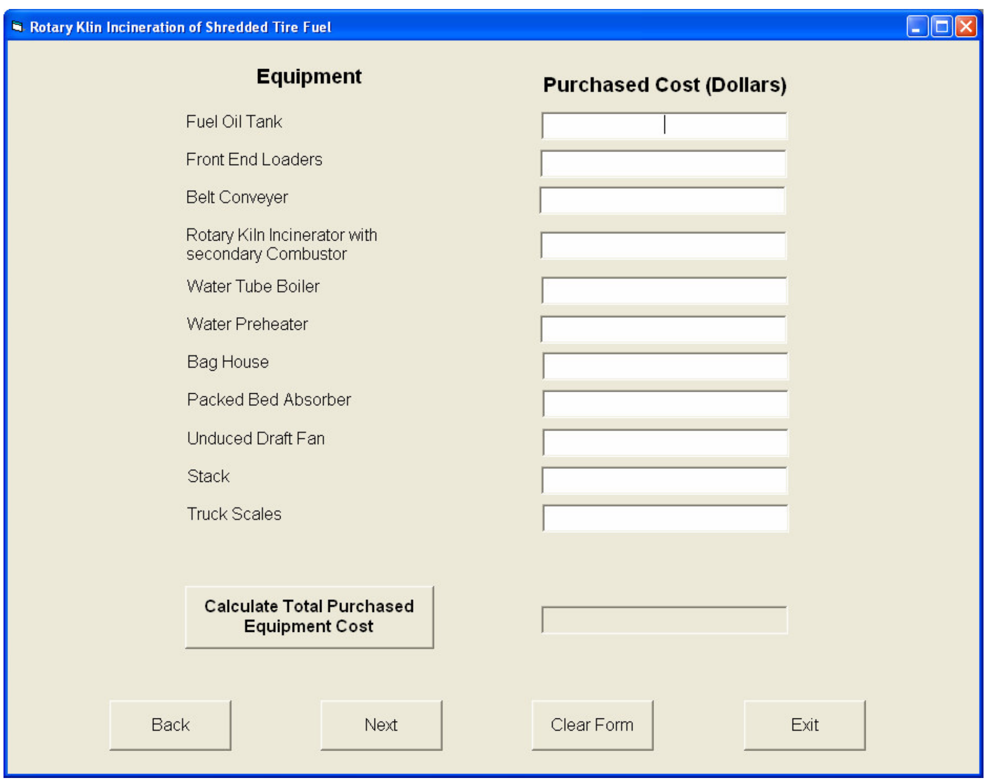

Poultry Litter Gasification
This program operates under the assumption that the money spent for the consruction of the plant, the Fixed-Capital Investment, will be spent at the beginning of the construction phase. It is also assumed that the working capital will not be necessary until time t=0, and that the trucks will be purchased at time t=0. The following forms will take these values and bring all of them to time t=0.
In order to calculate the construction costs at time t=0, it is necessary to enter the following information.
Construction Expenses (Fixed Capital Investment - From previous form) ($)
Construction Time in Months
12
Time Value of Money (%)
5
Calculate Construction Expenses
Based on the information that has been entered the construction expenses brought to time t=0 is.
Construction Expenses ($)
Back
Next
Clear Form
Main Menu
Exit

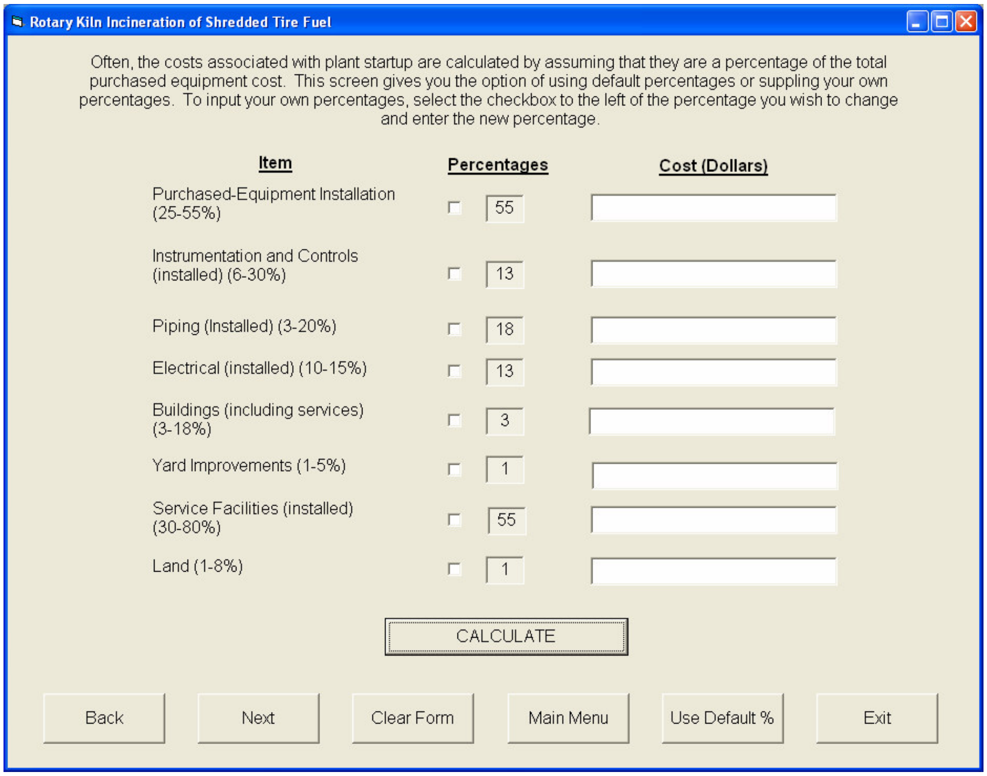

Poultry Litter Gasification
The next step is to determine the cost to purchase the trucks.
The previously calculated number of trucks necessary is
How many trucks to you wish to purchase
Calculate
The total purchase price of the trucks is assumed to occur at time t=0.
Total Purchase Price of Trucks ($)
Total Construction Cost ($)
Working Capital ($)
Total Cost at Time t=0 ($)
Back
Next
Clear Form
Main Menu
Exit

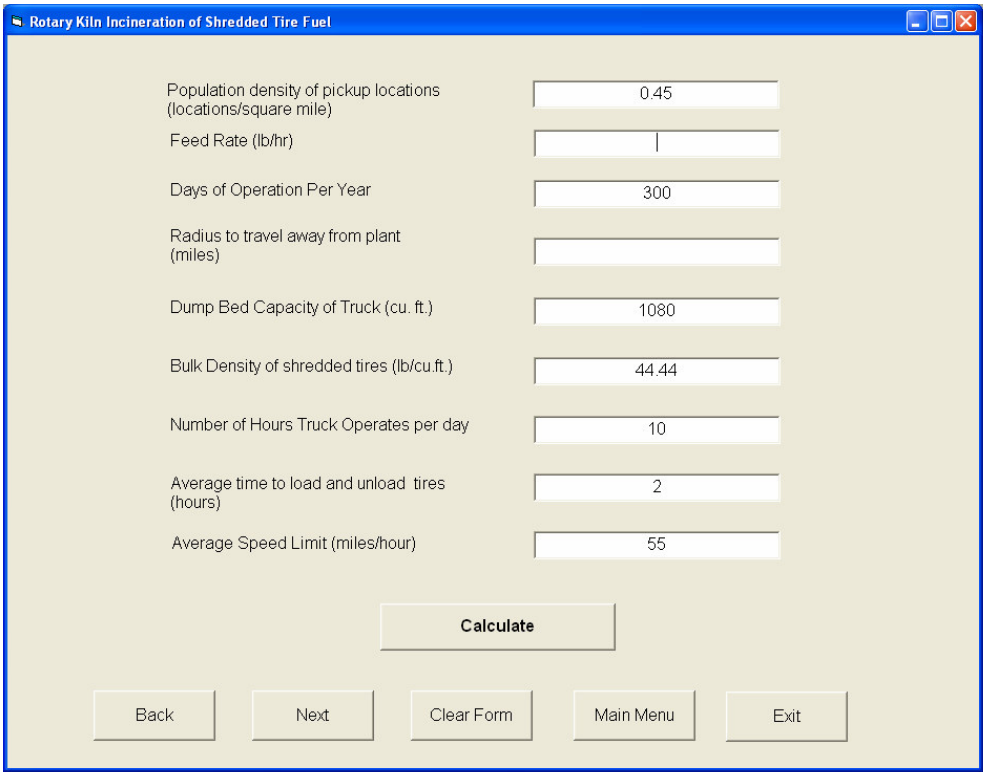

Poultry Litter Gasification
Enter the following information
Operating Labor not including truck drivers ($)
Number of Drivers Required (one per truck)
Drivers Annual Salary ($)
27000
Calculate
Supervisory and Clerical Labor (can be calculated as a percentage of the Operating Labor costs, not including drivers pay) ($)
15
Maintenance and repairs (can be calculated as a percentage of the total purchased equipment cost ($)
10
Operating Supplies (can be calculated as a percentage of the total cost for maintenance and repairs) ($)
15
Back
Next
Main Menu
Exit

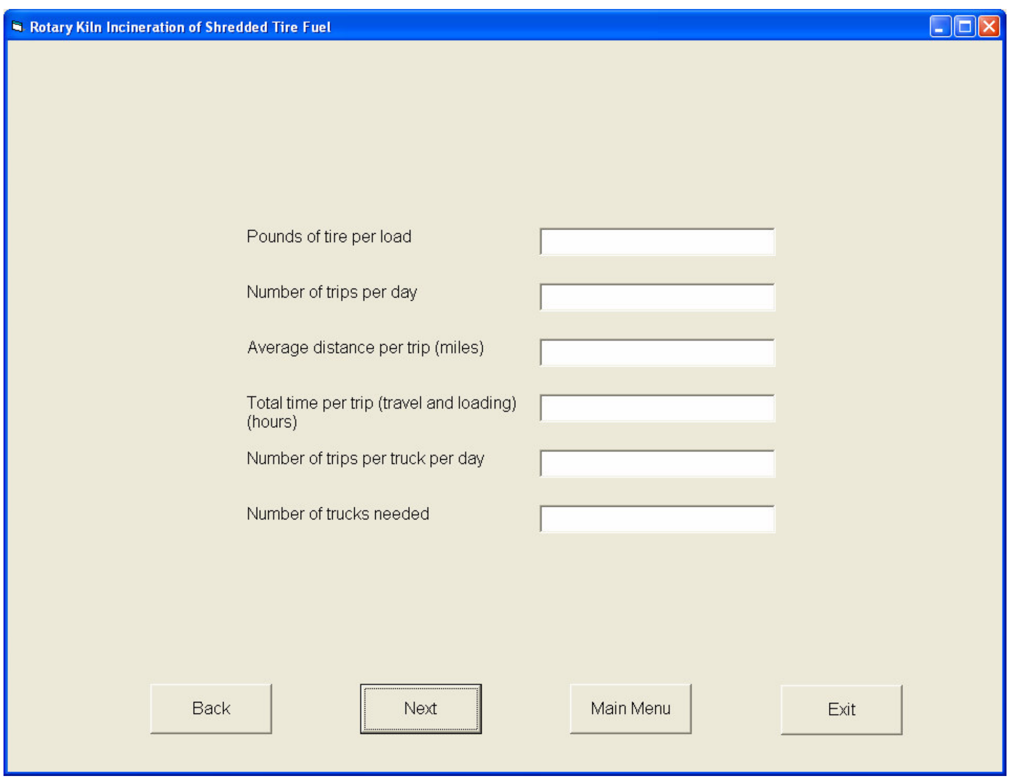

Poultry Litter Incineration
Enter Cost of Materials (including catalyst and a 10% charge for other materials used in the process) ($)
Enter Cost of Raw Materials ($)
0
Transportation Costs as calculated from previous screens($)
Calculate
Depreciation , Local Taxes and Insurance (this value may be calculated as a percentage of the fixed capital investement) ($)
25
Cost of Utilities (calculated as 10% of the total product cost) ($)
Total Product Cost ($)
Back
Next
Main Menu
Exit

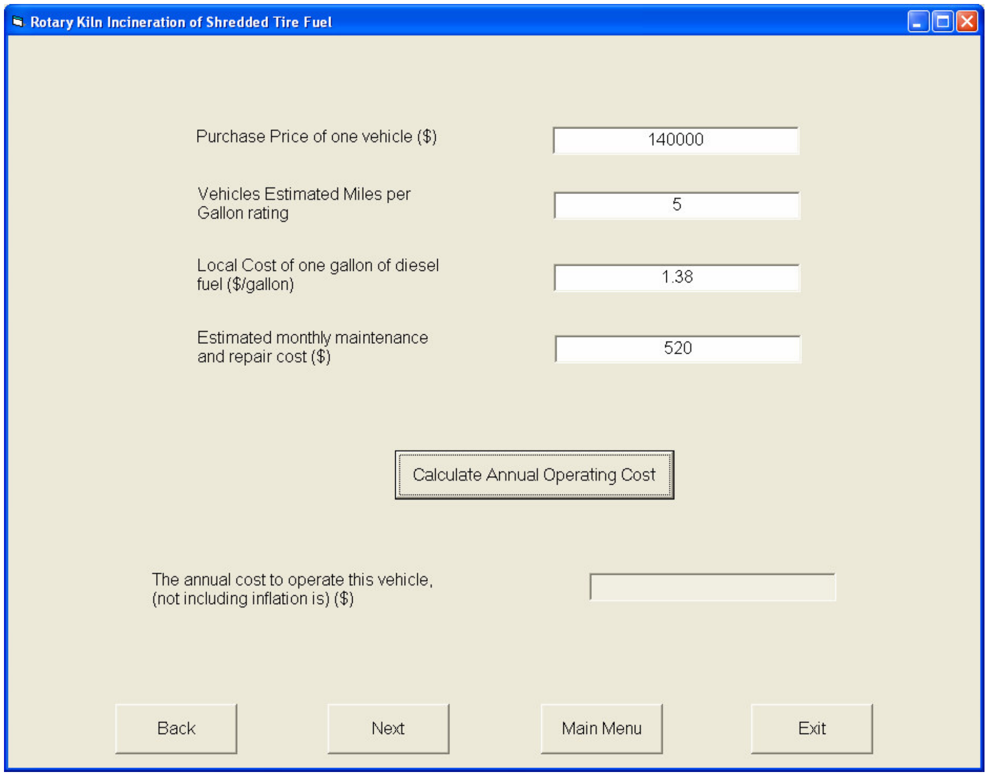

Poultry Litter Gasification
In this screen you will enter the annual information about the plant that will be used in the calculation of the break-even time. Necessary information that has been entered on previous screens is listed below.
Time Value of Money (%)
Total Cost at Time t=0 ($)
Enter the following information in the spaces provided.
Annual Expenses ($)
Annual Profit ($)
Annual rate of Inflation
2.75
Calculate
The Break Even Period based on the information you have entered is (years)
Back
Main Menu
Exit

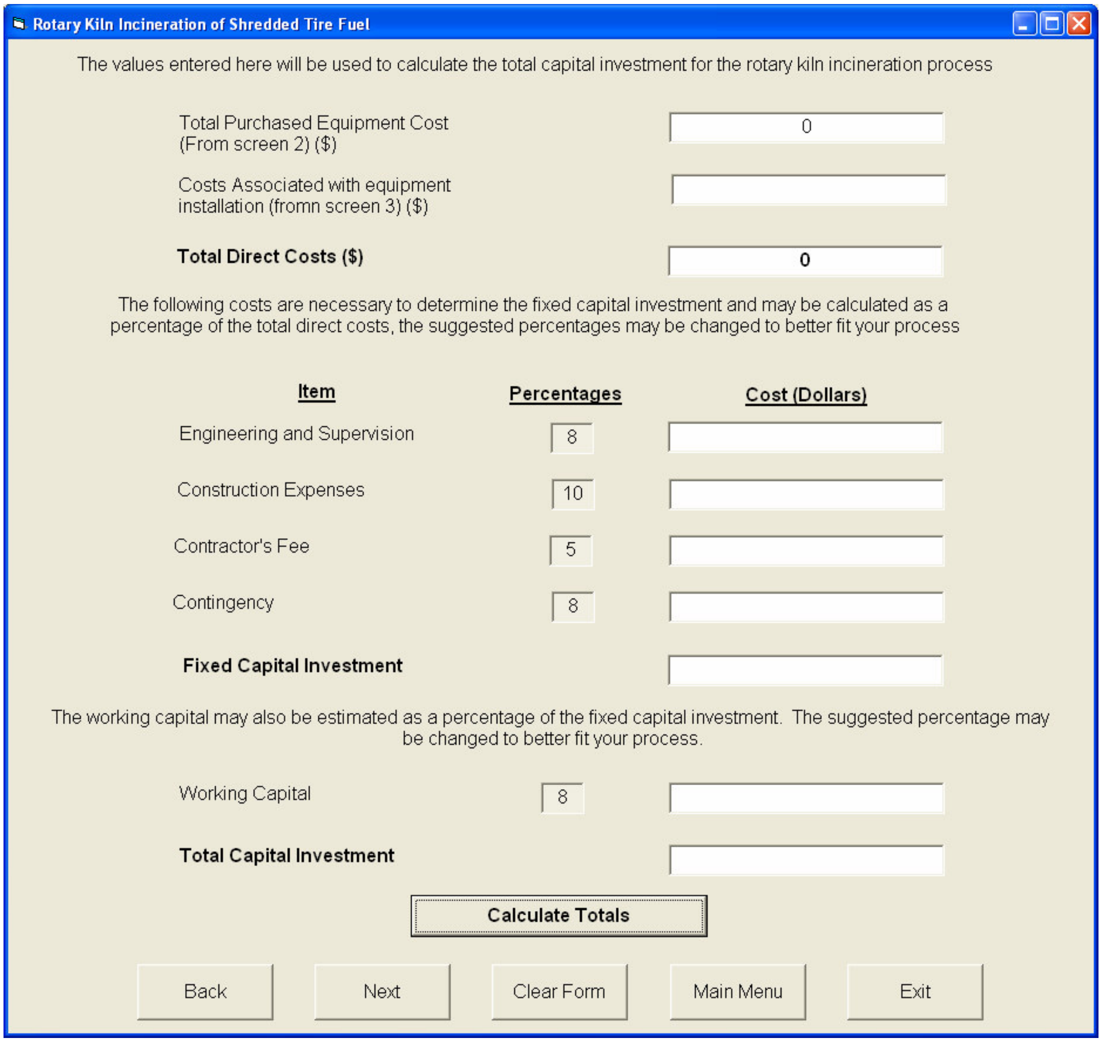

Rotary Klin Incineration of Shredded Tire Fuel
Equipment
Purchased Cost (Dollars)
Fuel Oil Tank
Front End Loaders
Belt Conveyer
Rotary Kiln Incinerator with secondary Combustor
Water Tube Boiler
Water Preheater
Bag House
Packed Bed Absorber
Unduced Draft Fan
Stack
Truck Scales
Calculate Total Purchased Equipment Cost
Back
Next
Clear Form
Exit

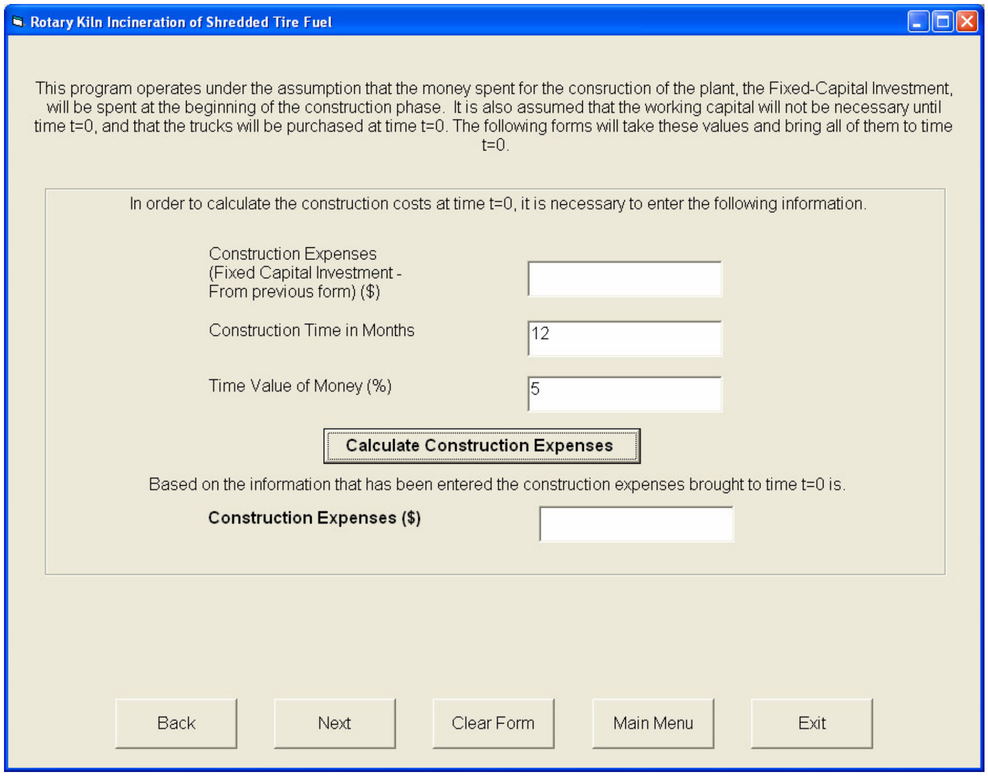

Rotary Kiln Incineration of Shredded Tire Fuel
Often, the costs associated with plant startup are calculated by assuming that they are a percentage of the total purchased equipment cost. This screen gives you the option of using default percentages or suppling your own percentages. To input your own percentages, select the checkbox to the left of the percentage you wish to change and enter the new percentage.
Item
Percentages
Cost (Dollars)
Purchased-Equipment Installation (25-55%)
55
Instrumentation and Controls (installed) (6-30%)
13
Piping (Installed) (3-20%)
18
Electrical (installed) (10-15%)
13
Buildings (including services) (3-18%)
3
Yard Improvements (1-5%)
1
Service Facilities (installed) (30-80%)
55
Land (1-8%)
1
CALCULATE
Back
Next
Clear Form
Main Menu
Use Default %
Exit

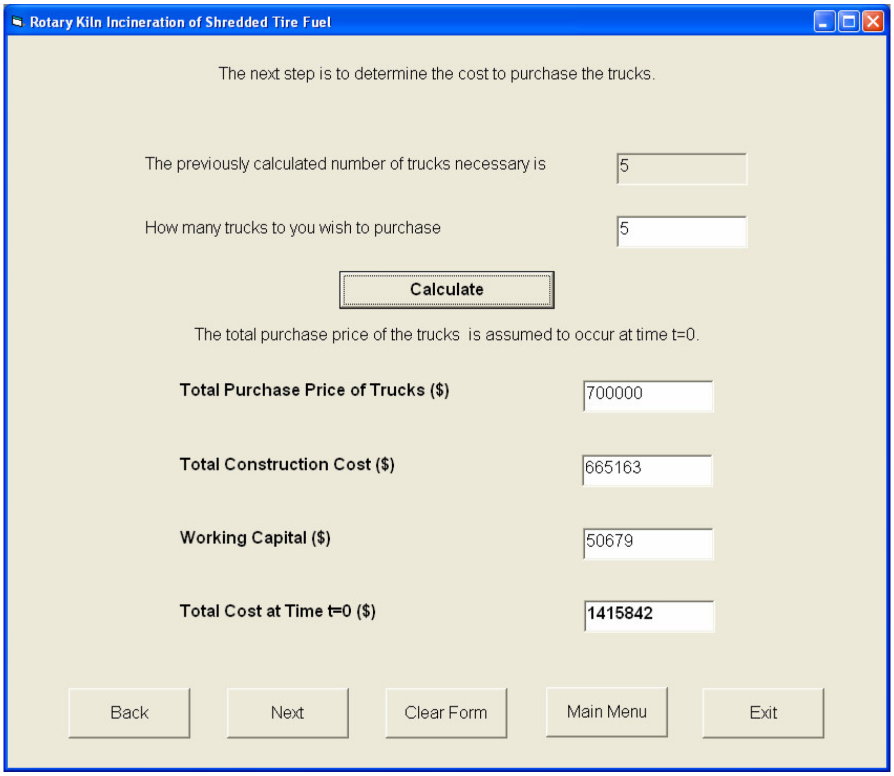

Rotary Kiln Incineration of Shredded Tire Fuel
Population density of pickup locations (locations/square mile)
0.45
Feed Rate (lb/hr)
Days of Operation Per Year
300
Radius to travel away from plant (miles)
Dump Bed Capacity of Truck (cu. ft.)
1080
Bulk Density of shredded tires (lb/cu.ft.)
44.44
Number of Hours Truck Operates per day
10
Average time to load and unload tires (hours)
2
Average Speed Limit (miles/hour)
55
Calculate
Back
Next
Clear Form
Main Menu
Exit

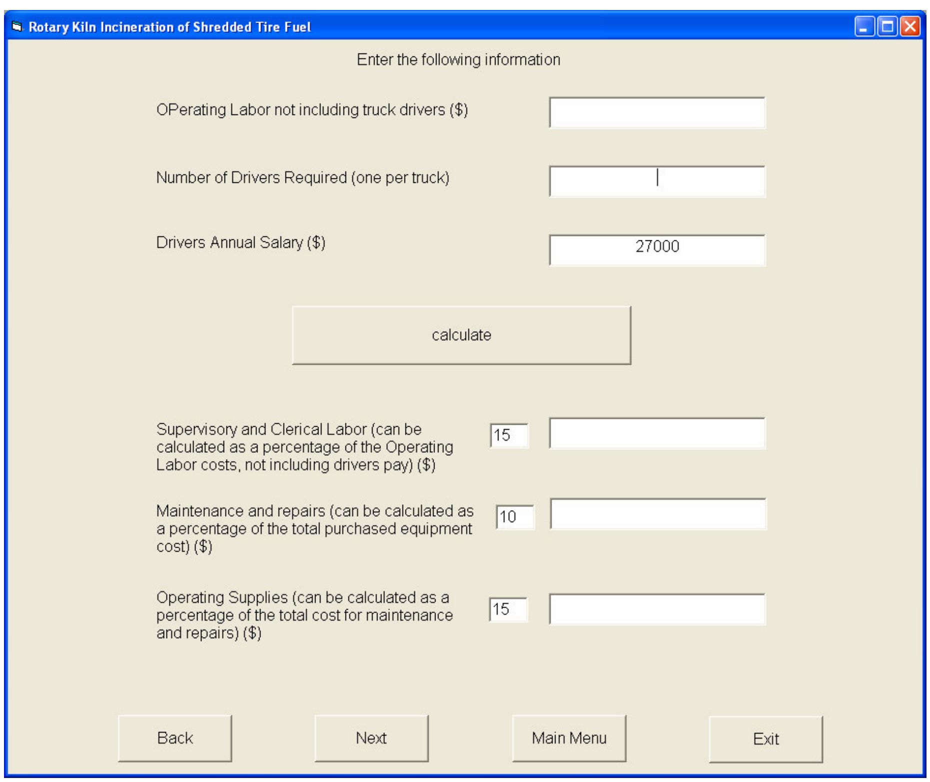

Rotary Kiln Incineration of Shredded Tire Fuel
Pounds of tire per load
Number of trips per day
Average distance per trip (miles)
Total time per trip (travel and loading) (hours)
Number of trips per truck per day
Number of trucks needed
Back
Next
Main Menu
Exit

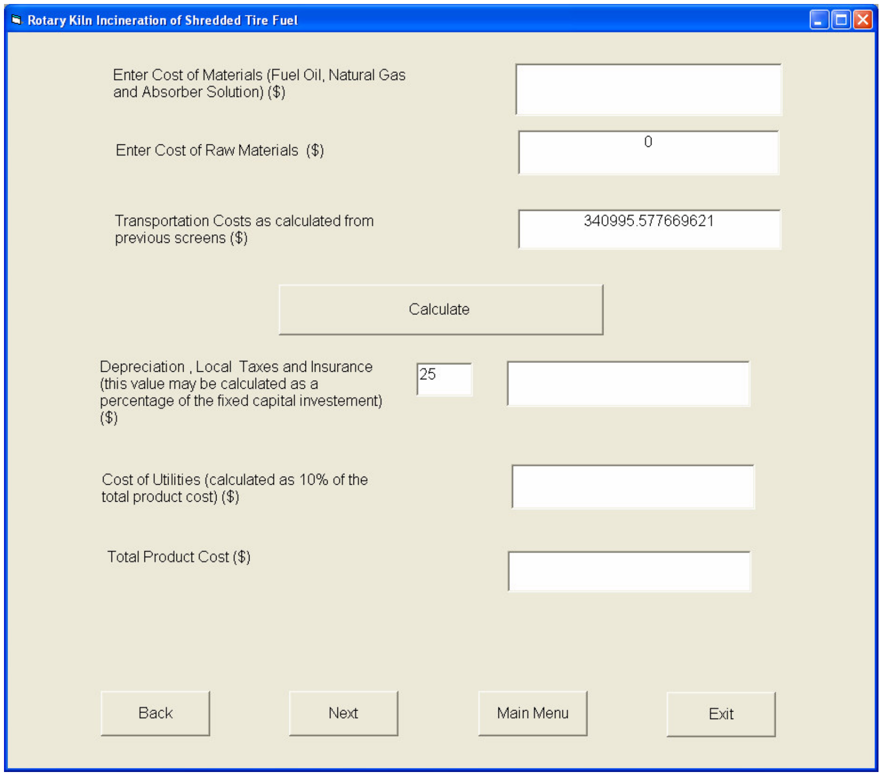

Rotary Kiln Incineration of Shredded Tire Fuel
Purchase Price of one vehicle ($)
140000
Vehicles Estimated Miles per Gallon rating
5
Local Cost of one gallon of diesel fuel ($/gallon)
1.38
Estimated monthly maintenance and repair cost ($)
520
Calculate Annual Operating Cost
The annual cost to operate this vehicle, (not including inflation is) ($)
Back
Next
Main Menu
Exit

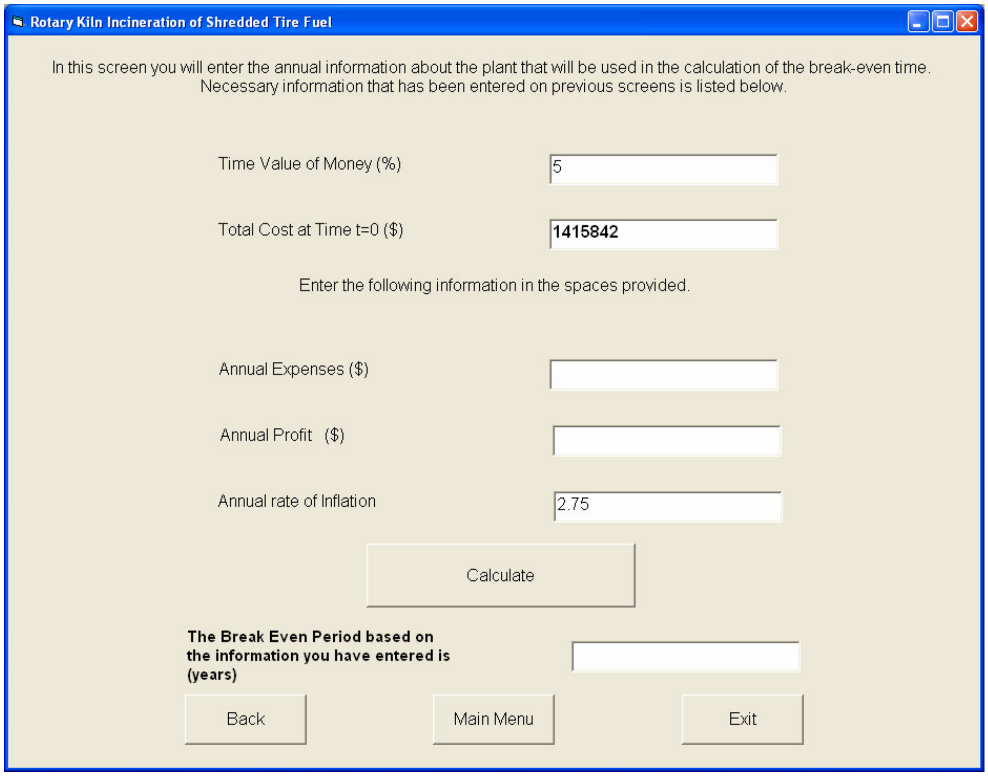

Rotary Kiln Incineration of Shredded Tire Fuel
The values entered here will be used to calculate the total capital investment for the rotary kiln incineration process
Total Purchased Equipment Cost (From screen 2) ($)
0
Costs Associated with equipment installation (fromn screen 3) ($)
Total Direct Costs ($)
0
The following costs are necessary to determine the fixed capital investment and may be calculated as a percentage of the total direct costs, the suggested percentages may be changed to better fit your process
Item
Percentages
Cost (Dollars)
Engineering and Supervision
8
Construction Expenses
10
Contractor's Fee
5
Contingency
8
Fixed Capital Investment
The working capital may also be estimated as a percentage of the fixed capital investment. The suggested percentage may be changed to better fit your process.
Working Capital
8
Total Capital Investment
Calculate Totals
Back
Next
Clear Form
Main Menu
Exit


Rotary Kiln Incineration of Shredded Tire Fuel
This program operates under the assumption that the money spent for the consruction of the plant, the Fixed-Capital Investment, will be spent at the beginning of the construction phase. It is also assumed that the working capital will not be necessary until time t=0, and that the trucks will be purchased at time t=0. The following forms will take these values and bring all of them to time t=0.
In order to calculate the construction costs at time t=0, it is necessary to enter the following information.
Construction Expenses (Fixed Capital Investment - From previous form) ($)
Construction Time in Months
12
Time Value of Money (%)
5
Calculate Construction Expenses
Based on the information that has been entered the construction expenses brought to time t=0 is.
Construction Expenses ($)
Back
Next
Clear Form
Main Menu
Exit


Rotary Kiln Incineration of Shredded Tire Fuel
The next step is to determine the cost to purchase the trucks.
The previously calculated number of trucks necessary is
5
How many trucks to you wish to purchase
5
Calculate
The total purchase price of the trucks is assumed to occur at time t=0.
Total Purchase Price of Trucks ($)
700000
Total Construction Cost ($)
665163
Working Capital ($)
50679
Total Cost at Time t=0 ($)
1415842
Back
Next
Clear Form
Main Menu
Exit


Rotary Kiln Incineration of Shredded Tire Fuel
Enter the following information
OPerating Labor not including truck drivers ($)
Number of Drivers Required (one per truck)
Drivers Annual Salary ($)
27000
calculate
Supervisory and Clerical Labor (can be calculated as a percentage of the Operating Labor costs, not including drivers pay) ($)
15
Maintenance and repairs (can be calculated as a percentage of the total purchased equipment cost) ($)
10
Operating Supplies (can be calculated as a percentage of the total cost for maintenance and repairs) ($)
15
Back
Next
Main Menu
Exit


Rotary Kiln Incineration of Shredded Tire Fuel
Enter Cost of Materials (Fuel Oil, Natural Gas and Absorber Solution) ($)
Enter Cost of Raw Materials ($)
0
Transportation Costs as calculated from previous screens ($)
340995.577669621
Calculate
Depreciation , Local Taxes and Insurance (this value may be calculated as a percentage of the fixed capital investement) ($)
25
Cost of Utilities (calculated as 10% of the total product cost) ($)
Total Product Cost ($)
Back
Next
Main Menu
Exit


Rotary Kiln Incineration of Shredded Tire Fuel
In this screen you will enter the annual information about the plant that will be used in the calculation of the break-even time.
Necessary information that has been entered on previous screens is listed below.
Time Value of Money (%)
5
Total Cost at Time t=0 ($)
1415842
Enter the following information in the spaces provided.
Annual Expenses ($)
Annual Profit ($)
Annual rate of Inflation
2.75
Calculate
The Break Even Period based on the information you have entered is (years)
Back
Main Menu
Exit

APPENDIX II

Program Code

```
'frm2clequip Variables
Public clTPEC As Currency

'frm3clequip2 variables
Public classocosts

'frm5opden variables
Public clfeed, cldays, clradius, clanprod
Public clanreq, clminden As Single, clminden2 As Integer, clarea
Public PI, clhouses, clpopden

'frm7transinfo variables
Public clbedcap, cldens, clophrs, clload, clspeed, cltons, cltripsyr, cltripsday
Public clavgdist, cltraveltime, cltriptime, clnumtrips, clnumtrucks

'frm8vehicleinfo variables
Public cltruckcost, clsalestax, clmpg, clgalgas, clmonthmaint, clvehiclelife,
clvehicleanopcost
Public clyrlygascost, clyrlymaintcost

'frm9totcapinv variables
Public cltotdircost, clfixedcapinv, cltotcapinv, clworkcap

'frm9astartcost variables
Public clconstructtime, clrate, clconstructcost

'frm9astartcosts2 variables
Public cltotcost, clAC, clAP, clinflation, cltrucknumber

'frm9a1opcosts variables
Public clopcosts, clsupcost, clmaintcost, clopsupcost, cldriverspay, clmatlcost,
clrawmatlcost, cldeprecost, clutilcost, clprodcost
Public clantranscost



'frmtire1equip variables
Public tTPEC As Currency

'frmtire2equip variables
Public tassocosts

'frmtire4geninfo variables
Public tpopden, tfeed, tdaysop, tradius, tbedcap, tdens, ttruckhrs, tload, tspeed
```

```
'frmtire5transresult variables
Public tlbsload, ttripsyr, ttripsday, tavgdist, ttraveltime, ttriptime, tnumtrips, tnumtrucks

'frmtire6vehicleinfo variables
Public ttruckcost, tsalestax, tmpg, tgalgas, tmonthmaint, tvehiclelife, tvehicleanopcost
Public tyrlygascost, tyrlymaintcost

'frmtire7totcapinv variables
Public ttotcapinv, tfixedcapinv, tworkcap, ttotdircost

'frmtire8startcosts variables
Public tconstructtime, trate, tconstructcost

'frmtire9annualinfo variables
Public ttotcost, tAC, tAP, tinflation, ttrucknumber

'frmtire8x1opcosts variables
Public topcosts, tsupcost, tmaintcost, topsupcost, tdriverspay, tmatlcost, trawmatlcost,
tdeprecost, tutilcost, tprodcost
Public tantranscost



Private Sub cmdplopen_Click()
frm2clequip.Show
frm1Open.Hide
End Sub

Private Sub cmdtireopen_Click()
frm1Open.Hide
frmtire1equip.Show
End Sub

Private Sub Form_Load()
PI = 3.141592654
End Sub




Option Explicit
Dim Receiving As Currency, Hopper As Currency, Gasifier As Currency, Separator As
Currency
Dim Exchanger As Currency, Condensor As Currency, Combustor As Currency,
Container As Currency
```

```
Dim Scrubber As Currency, Compressor As Currency, Building As Currency, Storage As
Currency


Private Sub Command1_Click()
frm1Open.Show
End Sub

Private Sub Command2_Click()
frm3clequip2.Show
frm2clequip.Hide
End Sub

Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""
Text3.Text = ""
Text4.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""
Text8.Text = ""
Text9.Text = ""
Text10.Text = ""
Text11.Text = ""
Text12.Text = ""
lblclTPEC.Caption = ""
End Sub

Private Sub Command4_Click()
Receiving = Val(Text1.Text)
Hopper = Val(Text2.Text)
Gasifier = Val(Text3.Text)
Separator = Val(Text4.Text)
Exchanger = Val(Text5.Text)
Condensor = Val(Text6.Text)
Combustor = Val(Text7.Text)
Container = Val(Text8.Text)
Scrubber = Val(Text9.Text)
Compressor = Val(Text10.Text)
Building = Val(Text11.Text)
Storage = Val(Text12.Text)
clTPEC = Receiving + Hopper + Gasifier + Separator + Exchanger + Condensor +
Combustor + Container + Scrubber _
+ Compressor + Building + Storage
```

```
lblclTPEC.Caption = clTPEC
End Sub

Private Sub Command5_Click()
End
End Sub



Private Sub Form_Load()

End Sub



Private Sub Check1_Click()
Text9.Text = ""
Text9.BackColor = vbWhite
Text9.SetFocus
End Sub

Private Sub Check2_Click()
Text10.Text = ""
Text10.BackColor = vbWhite
Text10.SetFocus
End Sub

Private Sub Check3_Click()
Text11.Text = ""
Text11.BackColor = vbWhite
Text11.SetFocus
End Sub

Private Sub Check4_Click()
Text12.Text = ""
Text12.BackColor = vbWhite
Text12.SetFocus
End Sub

Private Sub Check5_Click()
Text13.Text = ""
Text13.BackColor = vbWhite
Text13.SetFocus
End Sub
```

```
Private Sub Check6_Click()
Text14.Text = ""
Text14.BackColor = vbWhite
Text14.SetFocus
End Sub

Private Sub Check7_Click()
Text15.Text = ""
Text15.BackColor = vbWhite
Text15.SetFocus
End Sub

Private Sub Check8_Click()
Text16.Text = ""
Text16.BackColor = vbWhite
Text16.SetFocus
End Sub

Private Sub Command1_Click()
frm2clequip.Show
End Sub

Private Sub Command2_Click()
frm5popden.Show
frm3clequip2.Hide
End Sub

Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""
Text3.Text = ""
Text4.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""
Text8.Text = ""
End Sub

Private Sub Command4_Click()
frm1Open.Show
frm3clequip2.Hide
End Sub

Private Sub Command5_Click()
```

```
End
End Sub

Private Sub Command6_Click()
Check1.Value = 0
Text9.Text = 9
Check2.Value = 0
Text10.Text = 7
Check3.Value = 0
Text11.Text = 8
Check4.Value = 0
Text12.Text = 5
Check5.Value = 0
Text13.Text = 10
Check6.Value = 0
Text14.Text = 2
Check7.Value = 0
Text15.Text = 15
Check8.Value = 0
Text16.Text = 1
End Sub

Private Sub Command7_Click()
Text1.Text = clTPEC * (Val(Text9.Text) / 100)
Text2.Text = clTPEC * (Val(Text10.Text) / 100)
Text3.Text = clTPEC * (Val(Text11.Text) / 100)
Text4.Text = clTPEC * (Val(Text12.Text) / 100)
Text5.Text = clTPEC * (Val(Text13.Text) / 100)
Text6.Text = clTPEC * (Val(Text14.Text) / 100)
Text7.Text = clTPEC * (Val(Text15.Text) / 100)
Text8.Text = clTPEC * (Val(Text16.Text) / 100)
classocosts = Val(Text1.Text) + Val(Text2.Text) + Val(Text3.Text) + Val(Text4.Text) +
Val(Text5.Text) + Val(Text6.Text) + Val(Text7.Text) + Val(Text8.Text)
End Sub

Private Sub Form_Load()
Label1.Caption = "Often, the costs associated with plant startup are calculated by
assuming that they are a percentage of the total purchased equipment cost.  This screen
gives you the option of using default percentages, or suppling your own percentages.  To
input your own percentages, select the checkbox to the left of the percentage you wish to
change."
End Sub
```

```
Option Explicit


Private Sub Command1_Click()
frm3clequip2.Show
frm5popden.Hide
End Sub

Private Sub Command2_Click()
frm6transinfo.Show
frm5popden.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
clfeed = Val(Text1.Text)
cldays = Val(Text2.Text)
clanprod = Val(Text3.Text)
clradius = Val(Text4.Text)
clanreq = clfeed * cldays
clhouses = clanreq / clanprod
clarea = PI * clradius ^ 2
clminden = clhouses / clarea
clminden2 = 1 / clminden
Label6.Caption = Format(clminden, "#.####")
Label8.Caption = clminden2
Label7.Caption = "The minimum population density required is "
Label10.Caption = " house per square mile"
Label9.Caption = " or 1 house in every "
Label11.Caption = " square miles"
Label12.Caption = " Enter the population density of houses that you wish to use in the
remaining calculations below."
Label13.Caption = " House per square mile "
End Sub

Private Sub Form_Load()
Label1.Caption = "The information provide on this form will be used to calculate the
minimum population density of poultry houses that would be neccesary to meet the daily
fuel requirement of the plant."
End Sub

Private Sub Text5_Change()
```

```
clpopden = Val(Text5.Text)
End Sub



Option Explicit


Private Sub Command1_Click()
frm5popden.Show
frm6transinfo.Hide
End Sub

Private Sub Command2_Click()
frm7transresult.Show
frm6transinfo.Hide

End Sub

Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""
Text3.Text = ""
Text4.Text = ""

End Sub

Private Sub Command4_Click()
frm1Open.Show
frm7transinfo.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
clbedcap = Val(Text1.Text)
cldens = Val(Text2.Text)
clophrs = Val(Text3.Text)
clload = Val(Text4.Text)
clspeed = Val(Text5.Text)
cltons = cldens * clbedcap / 2000
cltripsyr = clanreq / cltons
cltripsday = cltripsyr / cldays
```

```
clavgdist = (2 / 3 * clradius ^ 3 - clradius ^ 2 + 0.5 * clradius - 5.5 / 3) / (clradius ^ 2)
'clavgdist = (clradius ^ 3 / 3 - (0.5 * clradius ^ 2) / 2 + 0.0625 * clradius + 1 / 6) /
(clradius ^ 2)
cltraveltime = 2 * clavgdist / clspeed
cltriptime = cltraveltime + clload
clnumtrips = clophrs / cltriptime
clnumtrucks = cltripsday / clnumtrips
frm7transresult.Show
End Sub

Private Sub Form_Load()
Label5.Caption = "The information enter in this screen will be used to determine the
minimum number of trucks required to meet the daily fuel requirement."
End Sub



Private Sub Command1_Click()
frm6transinfo.Show
frm7transresult.Hide
End Sub

Private Sub Command2_Click()
frm8vehicleinfo.Show
frm7transresult.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Form_Load()
Label1.Caption = "The results of the previous calculations are as follows:"
Text1.Text = Format(cltons, "##.##")
Text2.Text = Format(cltripsday, "##")
Text3.Text = Format(clavgdist, "###.##")
Text4.Text = Format(cltriptime, "##.#")
Text5.Text = Format(clnumtrips, "##")
Text6.Text = Format(clnumtrucks, "##.#")
End Sub



Option Explicit
```

```
Private Sub Command1_Click()
frm7transresult.Show
frm8vehicleinfo.Hide
End Sub

Private Sub Command2_Click()
frm9totcapinv.Show
frm8vehicleinfo.Hide
End Sub

Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""
Text8.Text = ""
Text9.Text = ""

End Sub

Private Sub Command4_Click()
frm1Open.Show
frm8vehicleinfo.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
cltruckcost = Val(Text1.Text)

clmpg = Val(Text5.Text)
clgalgas = Val(Text6.Text)
clmonthmaint = Val(Text7.Text)

clyrlygascost = clavgdist * clnumtrips * clgalgas * cldays
clyrlymaintcost = clmonthmaint * 12
clvehicleanopcost = clyrlygascost + clyrlymaintcost
Text9.Text = Format(clvehicleanopcost, "#")



End Sub
```

```
Private Sub Form_Load()
Label1.Caption = "Below is a list of necessary information to calculate the cost of
transporting the poultry litter from the farms to the plant."
End Sub



Option Explicit

Private Sub Command1_Click()
clopcosts = Format(Val(Text1.Text), "#")
cldriverspay = Val(Text2.Text) * Val(Text3.Text)

clsupcost = Val(Text1.Text) * Val(Text4.Text) / 100
Text5.Text = Format(clsupcost, "#")
clmaintcost = clTPEC * Val(Text6.Text) / 100
Text7.Text = Format(clmaintcost, "#")
clopsupcost = Val(Text7.Text) * Val(Text8.Text) / 100
Text9.Text = Format(clopsupcost, "#")

End Sub

Private Sub Command2_Click()
frm9astartcosts2.Show
frm9a1opcosts.Hide
End Sub

Private Sub Command3_Click()
frm9a2opcosts.Show
frm9a1opcosts.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Form_Load()

End Sub



Option Explicit
```

```
Private Sub Command1_Click()
clmatlcost = Val(Text3.Text)
clrawmatlcost = Val(Text4.Text)
cldeprecost = clfixedcapinv * Val(Text1.Text) / 100
Text2.Text = Format(cldeprecost, "#")
clprodcost = (clantranscost + clopcosts + cldriverspay + clsupcost + clmaintcost +
clopsupcost + clmatlcost + clrawmatlcost) / 0.9
Text7.Text = Format(clprodcost, "#")
clutilcost = 0.1 * clprodcost
Text6.Text = Format(clutilcost, "#")


End Sub

Private Sub Command2_Click()
frm9a1opcosts.Show
frm9a2opcosts.Hide
End Sub

Private Sub Command3_Click()
frm9bannualinfo.Show
frm9a2opcosts.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Form_Load()
clantranscost = clvehicleanopcost * cltrucknumber
Text5.Text = Format(clantranscost, "#")
End Sub

Private Sub Command2_Click()



Option Explicit
Dim cost

Private Sub Command1_Click()
cltrucknumber = Val(Text2.Text)
cost = cltrucknumber * cltruckcost
Text3.Text = cost
Text4.Text = Format(clconstructcost, "#")
```

```
Text5.Text = Format(clworkcap, "#")
cltotcost = Val(Text3.Text) + Val(Text4.Text) + Val(Text5.Text)
Text6.Text = Format(cltotcost, "#")
End Sub

Private Sub Command2_Click()
frm9a1opcosts.Show
'frm9bannualinfo.Show
frm9astartcosts2.Hide
End Sub

Private Sub Command4_Click()
frm1Open.Show
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
frm9astartcosts.Show
frm9astartcosts2.Hide
End Sub

Private Sub Form_Load()
Label1.Caption = "The next step is to determine the cost to purchase the trucks."
Text1.Text = Format(clnumtrucks, "#.#")
End Sub



Option Explicit
Dim sumprofit, sumcost, leftside, rightside, cost, n, ancost, anprofit

Private Sub Command1_Click()

clAC = Val(Text1.Text)
clAP = Val(Text2.Text)
clinflation = Val(Text3.Text)
sumprofit = 0
sumcost = 0
leftside = 1
rightside = 0
cost = cltotcost
n = 1
```

```
Do While leftside >= rightside
Text4.Text = " "
ancost = (clAC * (1 + clinflation / 100) ^ (n - 1)) / (1 + clrate / 100) ^ n
sumcost = sumcost + ancost
leftside = cost + sumcost
anprofit = (clAP * (1 + clinflation / 100) ^ (n - 1)) / (1 + clrate / 100) ^ n
sumprofit = sumprofit + anprofit
rightside = sumprofit
n = n + 1
'Print ancost, anprofit, leftside, rightside

Text4.Text = n - 1
Loop
End Sub

Private Sub Command4_Click()
frm1Open.Show
frm9bannualinfo.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
frm9astartcosts2.Show
frm9bannualinfo.Hide
End Sub

Private Sub Form_Load()
Text1.Text = Format(clprodcost + cldeprecost, "#")
Text5.Text = clrate
Text6.Text = Format(cltotcost, "#")
Label1.Caption = "In this screen you will enter the annual information about the plant
that will be used in the calculation of the break-even time. Necessary information that has
been entered on previous screens is listed below."
Label7.Caption = "Enter the following information in the spaces provided."
End Sub



Option Explicit

Private Sub Command1_Click()
frm8vehicleinfo.Show
```

```
frm9totcapinv.Hide
End Sub

Private Sub Command2_Click()
frm9astartcosts.Show
frm9totcapinv.Hide
End Sub

Private Sub Command4_Click()
frm1Open.Show
frm9totcapinv.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
Text3.Text = Format(Val(Text7.Text) * Val(Text9.Text) / 100, "#")
Text4.Text = Format(Val(Text7.Text) * Val(Text10.Text) / 100, "#")
Text5.Text = Format(Val(Text7.Text) * Val(Text11.Text) / 100, "#")
Text6.Text = Format(Val(Text7.Text) * Val(Text12.Text) / 100, "#")
clfixedcapinv = Val(Text3.Text) + Val(Text4.Text) + Val(Text5.Text) + Val(Text6.Text)
Text8.Text = Format(clfixedcapinv, "#")
Text13.Text = Format(Val(Text8.Text) * Val(Text15.Text) / 100, "#")
clworkcap = Val(Text13.Text)
cltotcapinv = Val(Text7.Text) + Val(Text8.Text) + Val(Text13.Text)
Text14.Text = Format(cltotcapinv, "#")

End Sub

Private Sub Form_Load()
Text1.Text = clTPEC
Text2.Text = classocosts
cltotdircost = clTPEC + classocosts
Text7.Text = cltotdircost
Label2.Caption = "The values entered here will be used to calculate the total capital
investment for the poultry litter gasification process"
Label4.Caption = "The following costs are necessary to determine the fixed capital
investment and may be calculated as a percentage of the total direct costs, the suggested
percentages may be changed to better fit your process"
Label14.Caption = "The working capital may also be estimated as a percentage of the
fixed capital investment.  The suggested percentage may be changed to better fit your
process."
End Sub
```

```
Private Sub Command1_Click()
frm8vehicleinfo.Show
frm9output1.Hide
End Sub

Private Sub Command4_Click()
frm1Open.Show
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Form_Load()
Label1.Caption = "Based on the information you have entered, the follow have been
calculated"
End Sub



Option Explicit

Private Sub Command1_Click()
frm1Open.Show
frmtire1equip.Hide
End Sub

Private Sub Command2_Click()
frmtire2equip.Show
frmtire1equip.Hide
End Sub

Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""
Text3.Text = ""
Text4.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""
Text8.Text = ""
Text9.Text = ""
```

```
Text10.Text = ""
Text11.Text = ""

lbltTPEC = ""
End Sub

Private Sub Command4_Click()
tTPEC = Val(Text1.Text) + Val(Text2.Text) + Val(Text3.Text) + Val(Text4.Text) +
Val(Text5.Text) + Val(Text6.Text) + Val(Text7.Text) + Val(Text8.Text) +
Val(Text9.Text) + Val(Text10.Text) + Val(Text11.Text)
lbltTPEC.Caption = tTPEC

End Sub

Private Sub xt_Click()

End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Form_Load()

End Sub



Private Sub Check1_Click()
Text9.Text = ""
Text9.BackColor = vbWhite
Text9.SetFocus
End Sub

Private Sub Check2_Click()
Text10.Text = ""
Text10.BackColor = vbWhite
Text10.SetFocus
End Sub

Private Sub Check3_Click()
Text11.Text = ""
Text11.BackColor = vbWhite
Text11.SetFocus
End Sub
```

```
Private Sub Check4_Click()
Text12.Text = ""
Text12.BackColor = vbWhite
Text12.SetFocus
End Sub

Private Sub Check5_Click()
Text13.Text = ""
Text13.BackColor = vbWhite
Text13.SetFocus
End Sub

Private Sub Check6_Click()
Text14.Text = ""
Text14.BackColor = vbWhite
Text14.SetFocus

End Sub

Private Sub Check7_Click()
Text15.Text = ""
Text15.BackColor = vbWhite
Text15.SetFocus
End Sub

Private Sub Check8_Click()
Text16.Text = ""
Text16.BackColor = vbWhite
Text16.SetFocus

End Sub

Private Sub Command1_Click()
frmtire1equip.Show
frmtire2equip.Hide
End Sub

Private Sub Command2_Click()
frmtire4geninfo.Show
frmtire2equip.Hide
End Sub

Private Sub Command3_Click()
Text1.Text = ""
```

```
Text2.Text = ""
Text3.Text = ""
Text4.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""
Text8.Text = ""
Check1.Value = 0
Check2.Value = 0
Check3.Value = 0
Check4.Value = 0
Check5.Value = 0
Check6.Value = 0
Check7.Value = 0
Check8.Value = 0

End Sub

Private Sub Command4_Click()
frm1Open.Show
frmtire2equip.Hide

End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
Text9.Text = "9"
Text10.Text = "7"
Text11.Text = "8"
Text12.Text = "5"
Text13.Text = "10"
Text14.Text = "2"
Text15.Text = "15"
Text16.Text = "1"

End Sub

Private Sub Command7_Click()
Text1.Text = tTPEC * (Val(Text9.Text) / 100)
Text2.Text = tTPEC * (Val(Text10.Text) / 100)
Text3.Text = tTPEC * (Val(Text11.Text) / 100)
Text4.Text = tTPEC * (Val(Text12.Text) / 100)
```

```
Text5.Text = tTPEC * (Val(Text13.Text) / 100)
Text6.Text = tTPEC * (Val(Text14.Text) / 100)
Text7.Text = tTPEC * (Val(Text15.Text) / 100)
Text8.Text = tTPEC * (Val(Text16.Text) / 100)
tassocosts = Val(Text1.Text) + Val(Text2.Text) + Val(Text3.Text) + Val(Text4.Text) +
Val(Text5.Text) + Val(Text6.Text) + Val(Text7.Text) + Val(Text8.Text)

End Sub

Private Sub Form_Load()
Label1.Caption = "Often, the costs associated with plant startup are calculated by
assuming that they are a percentage of the total purchased equipment cost.  This screen
gives you the option of using default percentages or suppling your own percentages.  To
input your own percentages, select the checkbox to the left of the percentage you wish to
change and enter the new percentage."
End Sub



Private Sub Command1_Click()
frmtire2equip.Show
frmtire4geninfo.Hide
End Sub

Private Sub Command2_Click()
frmtire5transresult.Show
frmtire4geninfo.Hide
End Sub

Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""
Text3.Text = ""
Text4.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""
Text8.Text = ""
Text9.Text = ""

End Sub

Private Sub Command4_Click()
frm1Open.Show
frmtire4geninfo.Hide
```

```
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
tpopden = Val(Text6.Text)
tfeed = Val(Text9.Text)
tdaysop = Val(Text8.Text)
tradius = Val(Text7.Text)
tbedcap = Val(Text1.Text)
tdens = Val(Text2.Text)
ttruckhrs = Val(Text3.Text)
tload = Val(Text4.Text)
tspeed = Val(Text5.Text)
tlbsload = tdens * tbedcap
ttripsyr = (tfeed * 24 * tdaysop) / tlbsload
ttripsday = ttripsyr / tdaysop
tavgdist = (2 / 3 * tradius ^ 3 - tradius ^ 2 + 0.5 * tradius - 5.5 / 3) / (tradius ^ 2)
ttraveltime = 2 * tavgdist / tspeed
ttriptime = ttraveltime + tload
tnumtrips = ttruckhrs / ttriptime
tnumtrucks = ttripsday / tnumtrips
frmtire5transresult.Show
frmtire4geninfo.Hide

End Sub

Private Sub Form_Load()

End Sub



Private Sub Command1_Click()
frmtire4geninfo.Show
frmtire5transresult.Hide
End Sub

Private Sub Command2_Click()
frmtire6vehicleinfo.Show
frmtire5transresult.Hide
End Sub
```

```
Private Sub Command4_Click()
frm1Open.Show
frmtire5transresult.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Form_Load()
Text1.Text = Format(tlbsload, "#.##")
Text2.Text = Format(ttripsday, "#.#")
Text3.Text = Format(tavgdist, "##.##")
Text4.Text = Format(ttriptime, "#.##")
Text5.Text = Format(tnumtrips, "#.#")
Text6.Text = Format(tnumtrucks, "#.#")

End Sub



Option Explicit

Private Sub Command1_Click()
frmtire5transresult.Show
frmtire6vehicleinfo.Hide
End Sub

Private Sub Command2_Click()
frmtire7totcapinv.Show
frmtire6vehicleinfo.Hide
End Sub

Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""
Text8.Text = ""
Text9.Text = ""

End Sub

Private Sub Command4_Click()
```

```
frm1Open.Show
frmtire6vehicleinfo.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
ttruckcost = Val(Text1.Text)

tmpg = Val(Text5.Text)
tgalgas = Val(Text6.Text)
tmonthmaint = Val(Text7.Text)

tyrlygascost = tavgdist * tnumtrips * tgalgas * tdaysop
tyrlymaintcost = tmonthmaint * 12
tvehicleanopcost = tyrlygascost + tyrlymaintcost
Text9.Text = Format(tvehicleanopcost, "#")

End Sub

Private Sub Form_Load()

End Sub



Option Explicit

Private Sub Command1_Click()
frmtire6vehicleinfo.Show
frmtire7totcapinv.Hide
End Sub

Private Sub Command2_Click()
frmtire8startcosts.Show
frmtire7totcapinv.Hide
End Sub

Private Sub Command4_Click()
frm1Open.Show
frmtire7totcapinv.Hide
End Sub
```

```
Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
Text3.Text = Format(Val(Text7.Text) * Val(Text9.Text) / 100, "#")
Text4.Text = Format(Val(Text7.Text) * Val(Text10.Text) / 100, "#")
Text5.Text = Format(Val(Text7.Text) * Val(Text11.Text) / 100, "#")
Text6.Text = Format(Val(Text7.Text) * Val(Text12.Text) / 100, "#")
tfixedcapinv = Val(Text3.Text) + Val(Text4.Text) + Val(Text5.Text) + Val(Text6.Text)
Text8.Text = Format(tfixedcapinv, "#")
Text13.Text = Format(Val(Text8.Text) * Val(Text15.Text) / 100, "#")
tworkcap = Val(Text13.Text)
ttotcapinv = Val(Text7.Text) + Val(Text8.Text) + Val(Text13.Text)
Text14.Text = Format(ttotcapinv, "#")
End Sub

Private Sub Form_Load()
Text1.Text = tTPEC
Text2.Text = tassocosts
Text7.Text = tTPEC + tassocosts
Label2.Caption = "The values entered here will be used to calculate the total capital
investment for the rotary kiln incineration process"
Label4.Caption = "The following costs are necessary to determine the fixed capital
investment and may be calculated as a percentage of the total direct costs, the suggested
percentages may be changed to better fit your process"
Label14.Caption = "The working capital may also be estimated as a percentage of the
fixed capital investment.  The suggested percentage may be changed to better fit your
process."
End Sub



Option Explicit
Dim rate, time

Private Sub Command1_Click()
frmtire7totcapinv.Show
frmtire8startcosts.Hide
End Sub

Private Sub Command2_Click()
frmtire8startcosts2.Show
frmtire8startcosts.Hide
End Sub
```

```
Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
tconstructtime = Val(Text2.Text)
trate = Val(Text3.Text)
rate = trate / 100
time = tconstructtime / 12
tconstructcost = tfixedcapinv * (1 + rate) ^ time
Text4.Text = Format(tconstructcost, "#")
End Sub

Private Sub Form_Load()
Text1.Text = tfixedcapinv
Label1.Caption = "This program operates under the assumption that the money spent for the consruction of the plant, the Fixed-Capital Investment, will be spent at the beginning of the construction phase.  It is also assumed that the working capital will not be necessary until time t=0, and that the trucks will be purchased at time t=0. The following forms will take these values and bring all of them to time t=0."
Label2.Caption = "In order to calculate the construction costs at time t=0, it is necessary to enter the following information."
Label6.Caption = "Based on the information that has been entered the construction expenses brought to time t=0 is."

End Sub



Option Explicit
Dim cost

Private Sub Command1_Click()
ttrucknumber = Val(Text2.Text)
cost = ttrucknumber * ttruckcost
Text3.Text = Format(cost, "#")
Text4.Text = Format(tconstructcost, "#")
Text5.Text = Format(tworkcap, "#")
ttotcost = Val(Text3.Text) + Val(Text4.Text) + Val(Text5.Text)
Text6.Text = Format(ttotcost, "#")
End Sub

Private Sub Command2_Click()
frmtire8z1opcosts.Show
```

```
'frmtire9annualinfo.Show
frmtire8startcosts2.Hide
End Sub

Private Sub Command4_Click()
frm1Open.Show
frmtire8startcosts2.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
frmtire8startcosts.Show
frmtire8startcosts2.Hide
End Sub

Private Sub Form_Load()
Label1.Caption = "The next step is to determine the cost to purchase the trucks."
Text1.Text = tnumtrucks
End Sub



Option Explicit

Private Sub Command1_Click()
topcosts = Val(Text1.Text)
tdriverspay = Val(Text2.Text) * Val(Text3.Text)

tsupcost = Val(Text1.Text) * Val(Text4.Text) / 100
Text5.Text = Format(tsupcost, "#")
tmaintcost = tTPEC * Val(Text6.Text) / 100
Text7.Text = Format(tmaintcost, "#")
topsupcost = Val(Text7.Text) * Val(Text8.Text) / 100
Text9.Text = Format(topsupcost, "#")
End Sub

Private Sub Command2_Click()
frmtire8startcosts2.Show
frmtire8z1opcosts.Hide
End Sub

Private Sub Command3_Click()
```

```
frmtire8z2opcosts.Show
frmtire8z1opcosts.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Form_Load()

End Sub



Option Explicit

Private Sub Command1_Click()
tmatlcost = Val(Text3.Text)
trawmatlcost = Val(Text4.Text)
tdeprecost = tfixedcapinv * Val(Text1.Text) / 100
Text2.Text = Format(tdeprecost, "#")
tprodcost = (tantranscost + topcosts + tdriverspay + tsupcost + tmaintcost + topsupcost +
tmatlcost + trawmatlcost) / 0.9
Text7.Text = Format(tprodcost, "#")
tutilcost = 0.1 * tprodcost
Text6.Text = Format(tutilcost, "#")

End Sub

Private Sub Command2_Click()
frmtire8z1opcosts.Show
frmtire8z2opcosts.Hide
End Sub

Private Sub Command3_Click()
frmtire9annualinfo.Show
frmtire8z2opcosts.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Form_Load()
tantranscost = tvehicleanopcost * ttrucknumber
```

```
Text5.Text = tantranscost
End Sub



Option Explicit
Dim sumprofit, sumcost, leftside, rightside, cost, n, ancost, anprofit

Private Sub Command1_Click()
tAC = Val(Text1.Text)
tAP = Val(Text2.Text)
tinflation = Val(Text3.Text)
sumprofit = 0
sumcost = 0
leftside = 1
rightside = 0
cost = ttotcost
n = 1
Do While leftside >= rightside
ancost = (tAC * (1 + tinflation / 100) ^ (n - 1)) / (1 + trate / 100) ^ n
sumcost = sumcost + ancost
leftside = cost + sumcost
anprofit = (tAP * (1 + tinflation / 100) ^ (n - 1)) / (1 + trate / 100) ^ n
sumprofit = sumprofit + anprofit
rightside = sumprofit
n = n + 1
'Print ancost, anprofit, leftside, rightside
Loop
Text4.Text = n - 1
End Sub

Private Sub Command4_Click()
frm1Open.Show
frmtire9annualinfo.Hide
End Sub

Private Sub Command5_Click()
End
End Sub

Private Sub Command6_Click()
frmtire8startcosts2.Show
frmtire9annualinfo.Hide
End Sub
```

```
Private Sub Form_Load()
Text1.Text = Format(tprodcost + tdeprecost, "#")
Text5.Text = trate
Text6.Text = Format(ttotcost, "#")
Label1.Caption = "In this screen you will enter the annual information about the plant
that will be used in the calculation of the break-even time. Necessary information that has
been entered on previous screens is listed below."
Label7.Caption = "Enter the following information in the spaces provided."
End Sub
```

VITA

Jennifer Fuller English was born in Tullahoma, Tennessee on January 24, 1975. She attended schools in the Tullahoma City School System, where she graduated from Tullahoma High School in 1993. She entered the Tennessee Technological University in August of 1993. In May of 1998, she received a Bachelor of Science degree in Chemical Engineering. She worked as a loan officer for Traders National Bank in Tullahoma Tennessee prior to enrolling in the University of Tennessee Space Institute's Master of Science in Chemical Engineering Program in the fall of 2001. She was employed as a graduate research assistance while working on her degree. She officially received her Master of Science degree in December of 2003.