

Techno-Economic Evaluation of Thermal and Catalytic Pyrolysis Plants for the Conversion of Heterogeneous Waste Plastics to Liquid Fuels in Nigeria

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Abstract

Techno-economic potentials of thermal and catalytic pyrolysis plants for the conversion of waste plastics to liquid fuels have been widely studied, but it is not obvious which of the two plants is more profitable, as the existing studies used different assumptions and cost bases in their analyses, thereby making it difficult to compare the economic potentials of the two plants. In this study, industrial-scale thermal and catalytic waste plastics pyrolysis plants were designed and economically analyzed using ASPEN PLUS. Amorphous silica-alumina was considered the optimum catalyst, with 3:1 feed to catalyst ratio. Based on 20,000 tons/year of feed and 20% interest rate, the catalytic plant, having a net present value (NPV) of ₦2208 million, was found to be economically less attractive than the thermal plant, having the NPV of ₦2426.4 million. On the contrary, sensitivity analyses of the two plants at a feed rate of 50,000 tons/year gave rise to a slightly higher NPV for the catalytic plant (₦9861 million) than the thermal plant having NPV of ₦9838 million, thereby making the former more economically attractive for processing large amounts of waste plastics into liquid fuels. Consequently, as the catalytic plant showed a better scale economy and would produce higher quality liquid fuels than the thermal plant, it is recommended for commercialization in Nigeria.

Keywords

Waste Plastics, Heterogeneous, Liquid Fuels, Thermal Pyrolysis, Catalytic Pyrolysis

1. Introduction

The plastics industry obtains its energy and feedstock requirements mainly from

petroleum and natural gas. According to Bhatti, the production of plastics consumes about 8% of the world's annual oil production—4% as feedstock and another 4% in the form of energy used during manufacture, and annual plastics production consumes about 400 million tons of oil and gas globally [1]. It was reported that about 129 million tons of waste plastics are produced annually in the world, out of which about 77 million tons (60%) are produced from petroleum [2]. According to Thorat and Co-workers, over 100 million tons of plastics are produced yearly on a global basis, out of which about 25 million tons are dumped as waste [3]. In the References [4] [5], it was reported that over 8300 million tons of plastics are produced in the world annually, out of which over 78% are dumped as waste. In Nigeria, over 100,000 tons of plastics are produced per year, but more than 80% of plastic waste generated goes to landfills and dump sites [6] [7]. Since 1950s, when plastics were first manufactured on a large scale, more than 1 billion tons of waste plastics have been dumped, and the dumping of waste plastics will continue as long as the traditional practice of land-filling continues [8]. Excessive generation and dumping of waste plastics deplete the limited reserves of the non-renewable, highly consumed petroleum and natural gas.

Worldwide, energy demand has been increasing steadily, while petroleum resources decrease on daily basis. This raises concerns about the depletion of petroleum. In a study by Sarker and Co-workers [2], it was observed that global crude oil production of about 26.28 billion barrels per year is lower than its consumption of over 28.57 billion barrels per year, the deficient amount being supplemented with alternative energy sources such as solar, wind and hydrogen. Based on International Energy Outlook 2010 report, it was asserted that global consumption of liquid petroleum products would grow from 86.1 million barrels per day in 2007 to 92.1 million barrels per day in 2020, 103.9 million barrels per day in 2030, and 110.6 million barrels per day in 2035 and natural gas consumption would increase from 108 trillion cubic feet in 2007 to 156 trillion cubic feet in 2035 [9]. Based on these trends, the oil and gas reserves available can meet only 43 and 167 years further, respectively. With the constantly growing energy demand, dumping hefty amounts of highly calorific materials as waste plastics is a sheer waste of lots of non-renewable, fossil-based material and energy resources in the form of crude oil and natural gas, which are used to make plastics and a symptom of lack of rational management of waste plastics. This is not sustainable since none of the material resources used to produce the plastics is recovered—the material flow is linear rather than cyclic [10] [11].

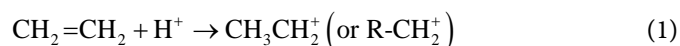
A survey of alternative fuels shows that waste plastics, due to their high calorific values (36 - 46 MJ/kg) and abundance in local communities, are among the most promising resources for energy production [12]. Both plastics and petroleum products are mostly composed of hydrocarbons, although molecules in plastics have longer carbon chains than those in petroleum products. Interestingly, plastics have calorific values in a similar range as fossil fuels [10]. Studies on the performance, emission and combustion characteristics of waste plas-

tics-derived fuel in diesel engines show that waste plastic pyrolysis oil represents a good alternative to diesel [13] [14] [15] [16]. It has been observed that liquid fuels obtained from waste plastics pyrolysis are not only similar to regular gasoline in properties but also give better mileage [11] [12].

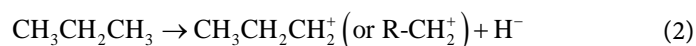
Consequently, converting waste plastics into liquid fuels can provide a huge amount of energy which can, in turn, reduce dependence on natural reserves of fossil fuels and minimize environmental pollution. One of the best techniques for conserving petroleum and protecting the environment by decreasing the volume of waste plastics is pyrolysis because of its high rate of conversion of plastics into oil which can be upgraded for use as fuel in engines. In the process, the polymer chains of the plastics are decomposed at high temperatures into a variety of useful smaller molecular-weight hydrocarbon molecules. It produces solid residues and a volatile fraction, part of which can be condensed to a liquid composed of paraffins, olefins, naphthenes and aromatics (PONA), being the main product while the remaining is a non-condensable high-calorific value gas [17].

Pyrolysis can proceed with or without the use of a catalyst. Pyrolysis of plastics without the aid of a catalyst is known as thermal pyrolysis, and usually requires high temperatures. In catalytic pyrolysis, decomposition of plastics is performed in the presence of a catalyst, and requires a relatively lower temperature. Catalytic pyrolysis of plastics occurs mostly through carbocations, although free radicals also play a role. This is unlike thermal cracking of plastics which occurs by a mechanism of free radical intermediates only, with the initiating radicals formed by the effect of heat [18]. Carbocations live longer and are more selective than free radicals. Unlike free radicals, primary and secondary carbocations can rearrange themselves to form a tertiary carbocation, having a carbon atom with three other carbon bonds attached to it. This isomerisation reaction of straight-chain hydrocarbons into their corresponding branched-chain isomers increases their stability due to a higher degree of branching and produces gasoline with higher octane numbers and diesel fuel with a lower cloud point. This is not typical for free radicals, which usually form straight-chain hydrocarbons. Also, a carbocation can add to an alkene to form a larger carbocation. This dimerization is of great importance in the formation of stable branched-chain isomers, which have higher octane numbers in gasoline. Isomerisation of straight-chain carbocations into their corresponding branched-chain isomers and their dimerization reactions with alkenes explain why catalytic pyrolysis yields better motor fuels than thermal pyrolysis [18].

Although both carbenium ($R-CH_2^+$) and carbonium (CH_5^+) ions are carbocations, the charge of a carbonium ion is not stable, and the sites of most acid catalysts are not strong enough to form many carbonium ions. Thus, catalytic cracking generally occurs by carbenium ions, produced in the initial reaction step [18]. Carbenium ions are generated when the Bronsted site of the acid catalyst acts as Bronsted acid, donating a proton (H^+) to an olefin molecule as shown in Equation (1):



They are also formed when the Lewis site of the catalyst acts as a Lewis acid, abstracting a hydride ion (H^-) from a paraffin molecule in Equation (2):



The carbenium ions formed from either of the two reactions can rearrange through a methide-hydride shift which is the migration of hydrogen with a pair of electrons. This isomerisation reaction contributes to a high proportion of branched isomers in the products of catalytic pyrolysis. The formation of carbenium ions and their reaction behavior play a vital role in the overall catalytic pyrolysis reaction as the carbenium ions are products of several further reactions, the important ones being cracking of a C-C bond, isomerisation and hydrogen transfer [18].

In some studies [2] [10] [12] [18], it was observed that catalytic pyrolysis requires lower heating time and temperature, has a higher reaction rate and produces higher quality fuels, with higher liquid yield and narrow products distribution, compared to thermal pyrolysis, but involves long material resistance time between molecules of plastics or primary pyrolysis products and catalysts, undesired contact between pyrolysis products and catalysts, difficulties in recovering catalysts for reuse, and requires high heat transfer rates.

Thermal and catalytic pyrolysis plants have been widely studied because of their promise and near-term technical viability in converting waste plastics to liquid fuels; however, it is not obvious which of the plants is more promising. Previous techno-economic studies on pyrolysis of heterogeneous waste plastics were based on a single plant or process. Also, they used different assumptions and cost bases, thereby making it difficult to compare the profitability of thermal and catalytic pyrolysis plants. Kpere-Daibo asserted that since catalytic pyrolysis requires a lower cracking temperature (due to lower activation energy), and a shorter cracking time, yields fuels with narrow products distribution, and has a higher selectivity to liquid products, the energy costs, on the one hand, and the costs of subsequent upgrading procedures for the products, on the other hand, should be lower. Hence, catalytic pyrolysis should be cheaper than thermal pyrolysis [18]. This assertion was, however, not backed up with detailed economic costing and evaluation that can guide investment in waste plastics pyrolysis. Therefore, the profitability of the catalytic plant should be compared with that of the thermal plant for waste plastics pyrolysis.

The aim of this study is, therefore, to identify the more promising plant of the two heterogeneous waste plastics pyrolysis plants—thermal and catalytic pyrolysis plants.

2. Methodology

2.1. Modeling and Simulation of the Pyrolysis Plants

ASPEN PLUS Software [19] was used to model and simulate the pyrolysis plants

since its library includes a physical property database for the various components needed in the simulation, and it has been previously used in modeling the thermal decomposition of plastics [8] [20]. Simulating complete plastics pyrolysis plant allows investigation of the technological feasibility and limitations of the plant before its economic aspects are examined, and generates accurate material and energy balances for detailed and accurate estimation of the costs of utility and other materials required for its economic analysis. Also, the effects of process parameters, such as temperature and pressure, can be studied and optimized.

Material and energy balances were arbitrarily based on 20,000 ton/yr waste plastics. Waste plastics were composed of 9.57% polypropylene (PP), 17.29% low-density polyethylene (LDPE), 17.29% linear low-density polyethylene (LLDPE), 34.57% high-density polyethylene (HDPE), 9.57% polystyrene (PS), 1.07% poly(vinyl chloride) (PVC) and 10.64% poly(ethylene terephthalate) (PET), representing common plastics in a municipal solid waste stream. Developing conceptual flow sheets for the plants was the first step in developing their models. Chemical components and related thermodynamic models, together with unit operations and their operating and input conditions, were selected and specified. Then, the various units of the two plants were simulated in the sequences of their flow sheets, with the output of a unit serving as an input to the succeeding unit, until synthesis and test-running of the complex plants were achieved.

Figure 1 and **Figure 2** present the various stages in the thermal plant, while the various stages in the catalytic plant are presented in **Figure 1** and **Figure 3**. The processes depicted in **Figure 1** are common to both the thermal and catalytic pyrolysis plants. In the feed preparation stage, waste plastics were washed in a washer tank using a 1:1 plastic to water ratio by mass to reduce the level of contaminants. The cleaned waste plastics were shredded into small spherical pieces of 3.0 mm mean diameter before being purged and dried to 0.0% water content by N_2 at 176.7°C. The dried plastics were sent into a dehydrochlorination reactor where low-temperature (300°C) pyrolysis was used to remove HCl.

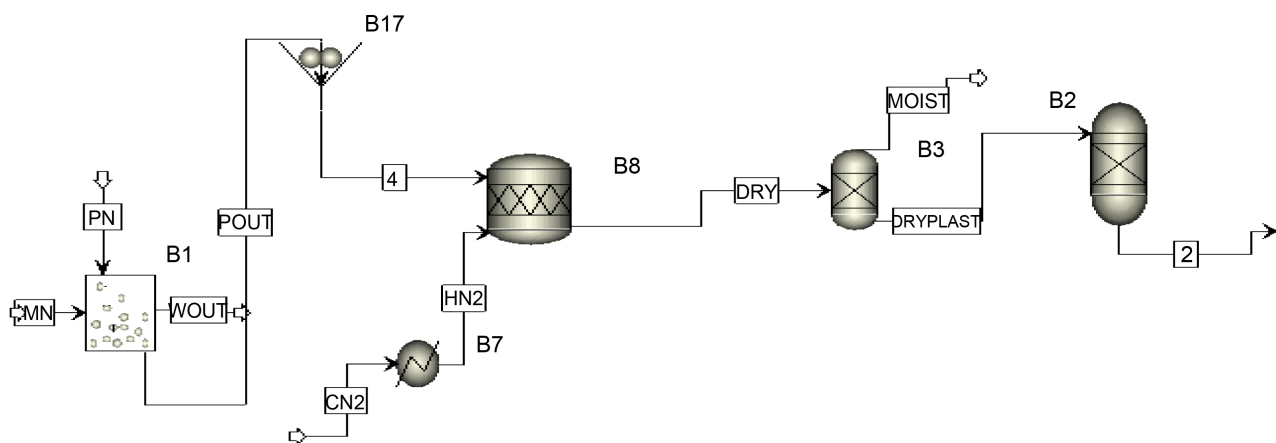


Figure 1. PFD for washing, crushing, drying and dechlorination in both the thermal and catalytic plants.

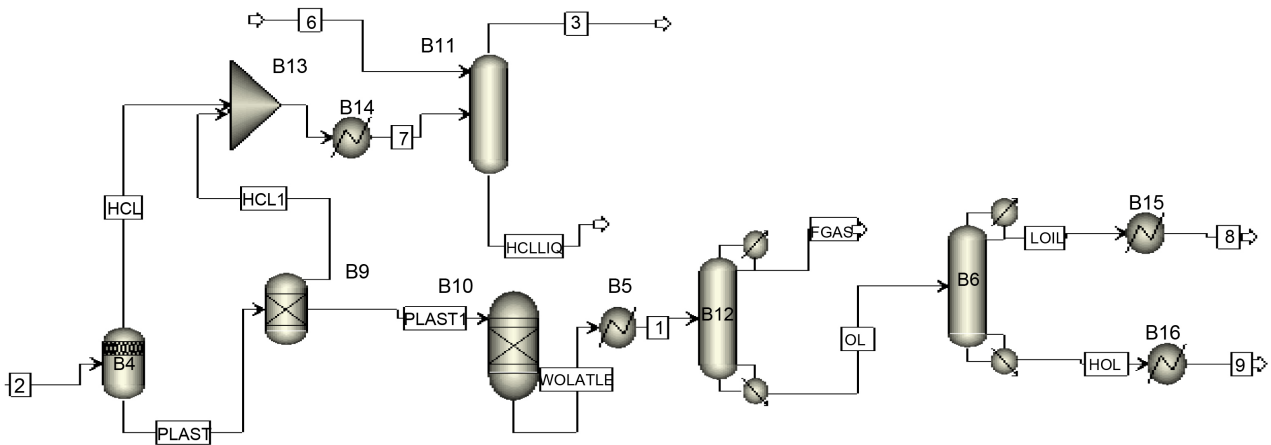


Figure 2. PFD for HCl absorption, plastics pyrolysis and products separation in the thermal plant.

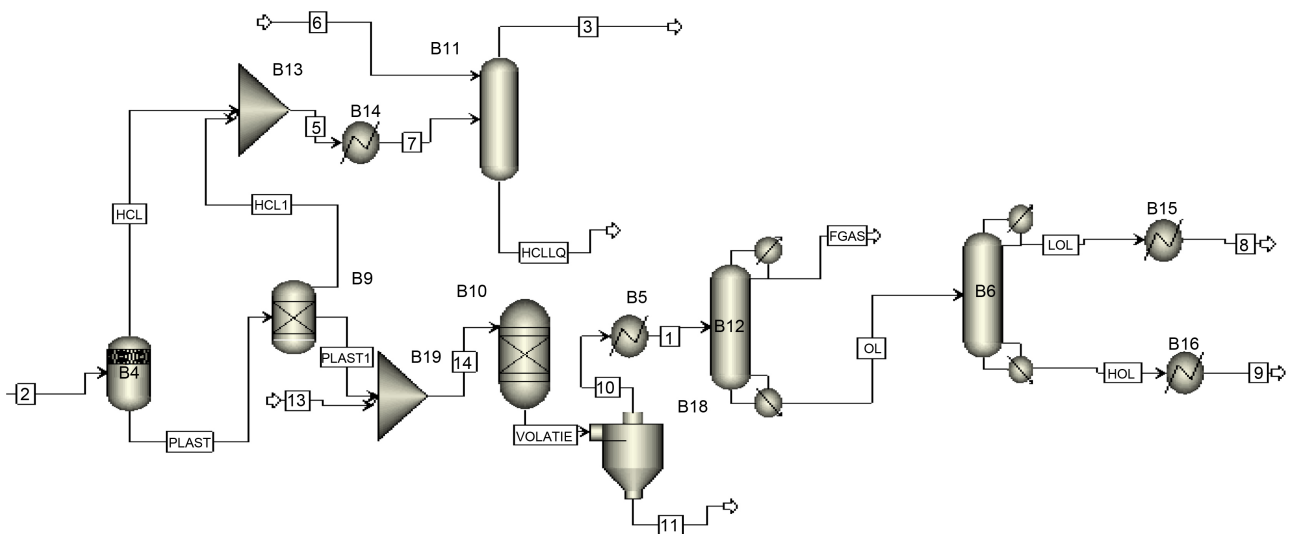


Figure 3. PFD for HCl absorption, plastics pyrolysis and products separation in the catalytic plant.

The HCl gas was cooled to 43°C and dissolved in water to form aqueous HCl, while the plastic melt was sent into the main pyrolysis reactor for thermal or catalytic pyrolysis. The volatile stream leaving the pyrolysis reactor was cooled to 300°C and fed into the first distillation column which split it into fuel gas collected at the top of the column, and fuel oil separated into light fuel oil (LOIL) and heavy fuel oil (HOIL) fractions in the second distillation column. The LOIL, which is composed of gasoline-range hydrocarbons, was heated up to room temperature while the HOIL, which contains diesel-range hydrocarbons, was cooled down to the same temperature as that of LOIL to avoid wax deposition in pipelines during transportation. LOIL and HOIL were the main products of the pyrolysis, while HCl and hydrocarbon fuel gas were the by-products.

2.2. Economic Evaluation

Estimation of the capital cost of each of the plants was performed by mapping modeling results from ASPEN PLUS into Icarus Process Evaluator (IPE) and re-

lating each unit in the simulation model to a specific type of process equipment. Working capital was set at 15% of fixed capital cost. Mapping simulation results in IPE enhancing effective sizing and costing of equipment to generate an accurate estimate of the capital cost of a plant. IPE is a model-based estimator which uses a sophisticated “volumetric model” rather than a factor-based model of costs to prepare detailed lists of costs of process equipment and bulk materials [21]. Obtaining the actual model or data used to come up with the model used in IPE is difficult, as ASPEN PLUS is proprietary Software [22].

Total manufacturing cost was estimated from heat and mass balances, prices of raw materials, chemicals, and utilities, as well as operating labor cost and fixed capital cost. Depreciation was calculated using a straight-line method over 10 years, with a salvage value of 10%, while the tax rate was set to 45%. All other items of manufacturing cost were estimated by the method presented in the book written by Turton and his Co-workers [23]). The method was based on fixed capital, utility and labor costs. Labor cost was estimated from the published work by Ringer and Co-workers [24]. **Table 1** presents details of estimated operating expenses for the two pyrolysis plants.

To gain economic insights into the plants, discounted payback period (DPP), net present value (NPV), internal rate of return (IRR) and present value ratio (PVR) were calculated to assess the profitability of each of the plants. Their values are presented in **Table 2**. For the calculations, constant full-scale plant operation and 100% market for the liquid fuels and by-products were assumed. The selling prices of LOIL and HOIL used for the economic assessment were ₦155.00 and ₦190.00/L, respectively. Current retail petroleum gasoline and diesel pump prices in Nigeria are ₦165.00/L and ₦350.00/L, respectively.

Discounted profitability evaluation measures were used because they allow each of the yearly cash flows to be discounted back to time zero, thus accounting for the time value of money. Sums of money arising at different times do not have the same value, and cannot be compared directly. They must be reduced to equivalent values at some common date, such as the present time. Besides making due allowance for the time value of money, most discounted techniques are based on estimates of cash flows throughout the life of an investment, unlike non-discounted cash flow techniques, some of which are based on accounting profits or accounting flows. For investment evaluation purposes, a project-oriented approach using cash flows is preferred to a period-oriented approach using accounting profits because the use of cash flow is more objective based [23].

DPP, a variation of the payback period (PBP), was calculated using Equation (3) after discounting cash flows. It is the time needed, after start-up, to recover the fixed capital investment required for a project, with all cash flows discounted back to time zero. It is not only simple to apprehend and compute but also objectively based since it uses project cash flows rather than accounting profits. When comparing mutually exclusive projects, the one with the shortest DPP is the most desirable. This, however, may lead to an economically incorrect decision, as the project with the shortest DPP may not produce the highest return at

Table 1. Estimated operating expenses of the plants at 20,000 ton/yr of waste plastics.

Element	Yearly Cost (₦/Year)	
	Thermal Pyrolysis Plant	Catalytic Pyrolysis Plant
Total capital investment:		
Raw material:	6,705,810,000	9,435,155,000
Gross material expenses	5,076,708,112	6,084,708,112
By-product credit	4063637.44	3822498.72
Net material expenses	5,072,644,476	6,080,885,612
Direct expenses:		
Total utility cost	274306052.4	284567986.4
Total labor cost, C_{OL}	468,368,000	468,368,000
Supervision and clerical, $0.14C_{OL}$	65,571,520	65,571,520
Miscellaneous:		
Laboratory charges, $0.15C_{OL}$	70,255,200	70,255,200
Maintenance and repairs, $0.05C_{FC}$	134,566,200	178,731,000
Operating supplies, $0.15C_{\text{maint. and repairs}}$	20,184,930	26,809,650
Subtotal	758,945,852	809,735,370
Total direct expense	1,033,251,904	1,094,303,356
Total direct + net material costs	6,105,896,380	7,175,188,968
Indirect expenses:		
Depreciation, $0.1C_{FC}$	283,308	376,180
Local taxes and insurance, $0.015C_{FC}$	42496.2	56,427
Plant overhead, $0.5(C_{OL} + C_{\text{super. and clerical}} + C_{\text{maint.}})$	334,252,860	356335.260
Total indirect expenses	334578664.2	356,767,867
Total manufacturing expenses (cost of raw material + direct expenses + indirect expenses)	6,440,475,044	7,531,956,836
General expenses:		
Admins cost, $0.15(C_{OL} + \text{sup. and clerical} + \text{maint. and repairs})$	100,275,858	106,900,578
Distribution and selling cost, $0.05(\text{Tot. Manu. Expenses})$	322023752.2	376597841.8
Research and Development, $0.05(\text{Tot. Manu. Expenses})$	322023752.2	376597841.8
Total General Expenses	744323362.4	860096261.6
Total Operation Expenses:	7,184,798,408	8,392,053,096

Table 2. Profitability measures of the two pyrolysis plants.

Profitability Measure	Thermal Pyrolysis	Catalytic Pyrolysis
DPP – time criterion(years)	2.52	3.14
NPV – cash criterion (₦ millions)	2426.4	2060.8
DCFRR –interest rate criterion (%)	42.01	34.88
PVR – cash flow criterion	2.099	1.703

the end of the project's life [23] [25]). Hence, DPP is not used as a stand-alone financial performance measure, but only for initial screening of investment and in conjunction with NPV or DCFRR to give supplementary information and provide assistance in assessing time-related risks associated with a project since choosing projects which payout quickest will tend to minimize time-related risks [26].

$$DPP = \frac{\text{Initial Investment}}{\text{Annual Cash Inflow}} \quad (3)$$

NPV is the sum of all cash inflows and outflows as they are discounted to the present worth by the given interest rate and was calculated using Equation (4). It is not only consistent with the shareholders' value or wealth maximization objective but also uses all cash flows occurring over the entire life of a project in calculating its worth and reflects properly the time value of money and its effect on profitability. Hence, it is considered a measure of a project's true profitability. In general, a positive NPV indicates that a project is acceptable, and can be thought of as the additional wealth that will be generated by undertaking the project. Hence, the higher its NPV, the better the potential project.

$$\begin{aligned} NPV &= \sum_{t=1}^n \frac{C_t}{(1+r)^t} - C_o \\ &= \left[\frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \frac{C_3}{(1+r)^3} + \dots + \frac{C_n}{(1+r)^n} \right] - C_o \\ &= \text{present value of cash inflows} - \text{present value of cash outflows} \end{aligned} \quad (4)$$

where C_1, C_2 represent net cash inflows in year 1, 2, ..., r is the interest rate, C_o is the initial investment cost and n is the expected life of the plant.

The discounted cash flow rate of return (DCFRR) is the interest rate at which all the yearly cash flows are discounted in order to bring the NPV to exactly zero. Since it depends on the cash flows of a project rather than any outside factor, it is commonly referred to as the internal rate of return (IRR). As it equates the investment outlay with the present value of cash inflow received, IRR represents the highest after-tax interest or discount rate at which the project can just break even [23]. It is used to determine whether a project is acceptable or not by comparing its calculated value with the interest rate used in calculating NPV. If the DCFRR is greater than the interest rate, the project is acceptable at that interest rate but when it is less than the cost of capital, the project is not acceptable at

that interest rate. IRR was computed by determining the discount rate at which NPV equals zero. This was done both graphically, as shown in **Figure 4**, and by linear interpolation using two discount rates obtained from iteration, one that gave a positive NPV and one that gave a negative NPV, in Equation (5).

$$\text{IRR} = \frac{\text{interest rate that gives a positive NPV}}{\text{interest rate that gives a negative NPV}} + \frac{\text{Difference between the two discount rates}}{\text{Value of the positive NPV}} \times \frac{\text{Range of the NPV Values}}{\text{Range of the NPV Values}} \quad (5)$$

The present value ratio (PVR) is the ratio of the present value of cash inflows, at the required rate of return, to the initial cash outflow of the investment. PVR of unity for a project represents a break-even situation. Values greater than unity indicate profitable processes, whereas those less than unity represent unprofitable projects. When comparing projects with different investment levels, PVR is preferred to NPV because the NPV of a project is greatly influenced by the level of fixed capital investment [23]. Equation (6) was used to compute the PVRs of the plants.

$$\text{PVR} = \frac{\text{Present Value of cash inflows}}{\text{initial cash outlay}} = \frac{\text{Present Value of All Positive Cash Flow}}{\text{Present Value of All Negative Cash Flow}} \quad (6)$$

Sensitivities of NPV to production scale, interest rate and plant life were investigated. Scales investigated were 15,000, 25,000, 40,000, 50,000 and 60,000 ton/yr of waste plastics. The interest rate varied from 10% to 45%, and the plant life was prolonged to 15 and 20 years.

3. Results and Discussion

The total capital cost of the catalytic plant is higher than that of the thermal plant (refer to **Table 1**). This is due to the addition of a catalyst regeneration unit to the catalytic plant. The higher cost of materials in the catalytic pyrolysis plant (refer to **Table 1**) is mainly due to the cost of catalyst. Making efforts to use

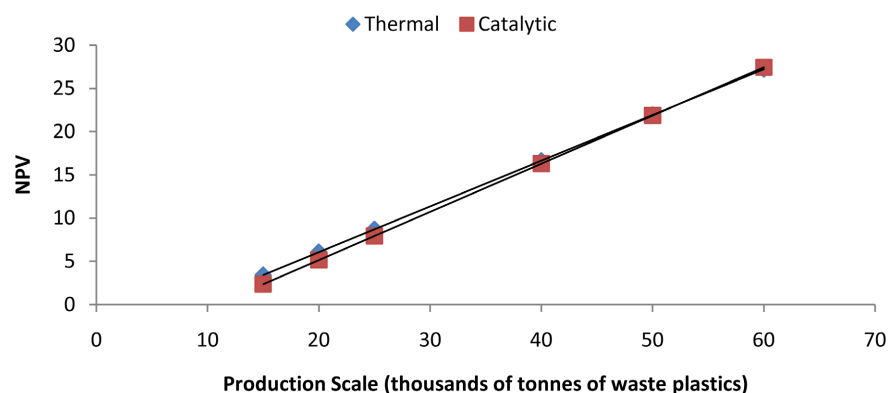


Figure 4. Variation of NPV with production scale.

low-cost but effective catalysts or reducing the quantity of the catalysts used, where possible could go a long way to reducing the material cost of the catalytic pyrolysis plant. From the same **Table 1**, the total operating cost of the catalytic plant is also higher than that of the thermal plant due to the cost of catalyst, and the additional heating requirements in the catalyst regeneration unit.

It is observed from **Table 2** that the baseline financial performance of the two plants are encouraging, with positive NPVs (₦ Millions) of 2426.4 and 2060.8, estimates of 42.01% and 34.88% IRR, and PVRs of 2.1 and 1.7 for the thermal and catalytic plants, respectively. The plants are profitable as their NPVs are positive, their IRR values are higher than the 20% interest rate used in this work, and their PVRs are greater than unity. The thermal plant is slightly more profitable than the catalytic plant. Payback periods of 2.52 and 3.14 years, are reasonably good since they guarantee against loss by minimizing time-related risks and the plants are low-risk, although values less than 2 years would be preferred [27].

NPVs of the plants are highly sensitive to production capacity, discount rate and economic life. In **Figure 4**, a significant economy of scale is observed in the proposed plants, as an increase in production scale produces a significant increase in the NPVs of the two plants. As the production capacity increases by 5000 tons, the NPV (₦ millions) of the thermal plant increases by about 1000, while that of the catalytic plant increases by 1120. For 50,000 and 60,000 ton/yr, NPVs (₦ millions) of the thermal plant were 9,838 and 10,896.8, respectively, while the catalytic plant had 9861.1 and 10,976, respectively. An increase in the profitability of a waste plastics pyrolysis plant with plant capacity was also observed in earlier studies [8] [28] and is due to better cash flows achieved at higher production capacity due to cost savings. Total capital costs tend to increase very slowly as production capacity increases, implying that a larger production capacity augments the profitability of the liquid fuels production process because of its relatively small amount of capital costs. NPVs of the plants approached each other with increasing scale, showing a better scale economy for the catalytic plant.

NPVs of the plants decrease significantly with a rise in the interest rate used for discounting cash flows (**Figure 5**). As the interest rate increases, revenues

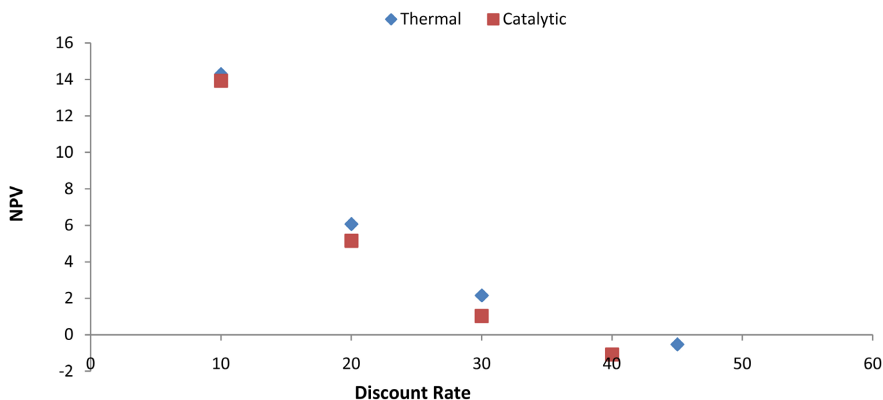


Figure 5. Variation of NPV with discounted rate.

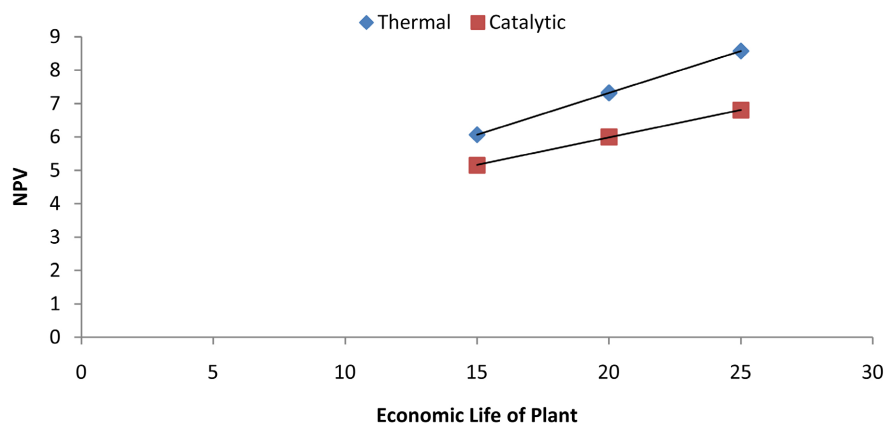


Figure 6. Variation of NPV with plant life.

from sales of products near the end of the project are heavily discounted since cash flows are discounted to time zero, whereas the capital investment at time zero remains constant. As a result, NPVs of the plants decreased with a rise in interest rate.

NPVs of the two plants increased with the lengthening of economic life. This is obvious since the lengthening of economic life gave the plants longer periods of time to gain revenues from sales of products and by-products. The difference in the NPVs of the two plants became larger with the lengthening of their economic lives, showing a better increase in the NPV of the thermal plant with increasing economic life (refer to **Figure 6**).

4. Conclusion

In this study, the techno-economic potentials of thermal and catalytic pyrolysis plants for the conversion of heterogeneous waste plastics to liquid fuels were investigated using ASPEN PLUS Software Package. Based on 20,000 tonnes/year of feed and 20% interest rate, discounted payback period (DPP), net present value (NPV) (₦ millions), internal rate of return (IRR) and present value ratio (PVR) were obtained as 3.14 years, 2208, 34.88% and 1.703 for the catalytic plant, respectively, and 2.52 years, 2426.4, 42.01% and 2.099 for the thermal plant, respectively. Sensitivity analysis at a feed rate of 50,000 tonnes/year gave rise to a slightly higher NPV for the catalytic plant – thermal (9838) and catalytic (9861) – making it a more economically efficient method of processing large amounts of waste plastics into liquid fuels. The thermal plant had slightly higher profitability, while the catalytic plant showed a better scale of economy and would produce higher quality fuels. Hence, it can be concluded that for commercial conversion of heterogeneous waste plastics to liquid fuels, catalytic pyrolysis is superior to thermal pyrolysis. In the future, prior to the implementation of the design of the catalytic pyrolysis plant, purchase and transportation costs of waste plastics, as well as multiple-parameter sensitivity analysis and energy integration should be performed on the plant to gain a greater insight into the economics and risks of investments in waste plastics pyrolysis.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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