PLASTICS RECYCLING OPPORTUNITIES IN ECONOMICALLY DEPRESSED AREAS

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ABSTRACT

The objective of this paper is to evaluate the business opportunity of recycling durable plastics from obsolete automobiles and home appliances in labor surplus areas of the world. This is important for two reasons: first, to save the environment by reducing solid waste production; and second, to create job opportunities in economically depressed areas. In this sense, recycling durable plastics could become one of the various economic approaches through which societies make use of their throwaway resources to produce goods and services to satisfy the desires of their present and future members.

RÉSUMÉ

L'objectif de cet article est d'évaluer les possibilités de créer dans les régions à main-d'oeuvre abondante des entreprises de recyclage de matières plastiques récupérées sur les automobiles et les appareils électro-ménagers abandonnés. De telles entreprises pourraient à la fois contribuer à la protection de l'environnement et à la création d'emplois dans les régions qui souffrent de dépression économique. Le recyclage de matières plastiques pourrait ainsi devenir l'une des approches économiques permettant la transformation de ressources jusqu'alors gaspillées en nouveaux produits pour satisfaire aux besoins des populations.

1. INTRODUCTION

Solid waste production is increasing worldwide. Most noticeable on the streets, in areas where garbage and discarded items are not picked up regularly, and where no landfills or incineration facilities exist, is plastics waste (bags, water and milk bottles, car parts, and home appliances). Plastics is a family of

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synthetic polymers that are made from petroleum derived products. There are two major classes of plastics: thermoplastics and thermosets. Thermoplastics are plastics that can be melted by heating so that they can be remolded into new products and shapes. Thermosets are plastics that when cured cannot be remelted. Therefore, since thermosets cannot be remolded, thermoplastic are more readily recyclable than thermosets.

Thermoplastics include polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), acrylonitrile-butadiene-styrene (ABS), polycarbonates (PC), and nylons. Thermosets include polyurethane foam, epoxies, phenolics, and rubber. Different grades of each of these plastics have also been made. For example, polyethylene is the most widely used plastic marketed as low density (LDPE), medium density (MDPE), high density (HDPE), ultrahigh molecular weight (UHMW) polyethylene, and the thermoset cross-linked polyethylene. It can also be foamed into a flexible polyethylene foam.

Unlike food waste, yard waste, and natural fibers (wood), plastics are generally not biodegradable and therefore they continue to accumulate in the environment or in landfills for hundreds of years. Most plastics in solid waste streams are of the thermoplastic type which can be remelted and recycled into new products such as lumber board, flower pots, park benches, lamp posts, fencing materials, and construction materials. They can also be mixed with virgin materials to make new products such as car parts. The biggest obstacle to the recycling of these plastics in developed countries is the high cost of collection and sortation. Separation or sortation of the plastics from other materials and from each other is necessary because plastics are in general not compatible with other materials and not compatible with each other. For example, milk jugs are made of high-density polyethylene (HDPE), and soda bottles are made of polyethylene terephtalate (PET). Both of these materials are thermoplastics.

However, when the two are mixed and processed together they produce a material that has poor properties because the two are not compatible and therefore do not bond together well. In spite of all of the research directed toward the development of automated processes for separating the plastics from the non-plastic materials in the solid waste stream and from each other, no cost-effective mechanical or physical separation systems exist yet for most waste streams, and manual sorting is expensive.

China, however, was successful in importing some of the industrial waste that is rich in plastics such as that generated from shredded home appliances and manually separated some of the plastics and reprocessed them into products. Some of these products were exported to industrialized countries. This was possible because the labor cost in China is low compared to that in the industrialized countries. Economically depressed areas that have low cost unskilled labor could benefit from developing some of the labor-intensive industries that do not require large capital investment in equipment such as plastics recycling. Revenues from such industries might be used to automate these processes in the future, and to train skilled labor to drive the automated processes. However, extra care should be exercised to insure that these areas do not get polluted, especially with hazardous waste that would be costly to clean up.

2. RECYCLING METHODOLOGIES

Recycling may be defined as a process that can produce marketable and reusable products or raw materials for making new products from what is considered waste. The four recycling modes are: the primary, secondary, tertiary, and quaternary. They have been practiced on different streams. These four modes are described below.

2.1. Primary Recycling

Primary recycling generally refers to the recycling of uncontaminated scrap material within the industrial manufacturing sector. Primary recycling could also apply to the separation of individual components from the post consumer waste stream, with the intention of using them as parts in a working piece of equipment (such as a radio in a car), or grinding these components for blending with virgin resin. This type of recycling can be achieved by dismantling components of a car or a refrigerator or a computer for use in another devise. Separation of such components is generally done manually with the help of tools by a semi- skilled laborer. For example, many discarded appliances from the U.S. are shipped to Mexico and other countries for parts. Some of these discarded appliances are also repaired and used when the cost of repairs, using parts from other discarded pieces, is economically attractive.

2.2. Secondary Recycling

This recycling mode results in reclaiming materials from the waste stream, mostly post consumer materials, for use in making products with less stringent properties than what can be made with the individual virgin materials. For example, mixed plastics, with lower strength factors, can be used to make lumber boards, fence posts, flower pots, and park benches. These products are not sensitive to weight issues, esthetics, color, and strength as will be required in making plastic parts for vehicles or airplanes. To separate the plastics as a mixture by physical and mechanical means is much simpler and less costly than separating them from each other.

However, the value of the mixed plastics stream is less than the value of the individual plastics. For example, while the value of recycled clean individual plastics (> 99% purity) is about $0.20 to $1.00 per pound, the value of a mixture of non-compatible plastics is about $0.05 per pound. Therefore, a trade-off analysis is necessary to determine the optimum product mix that must be derived from the waste stream. The key limitations of this type of recycling have been (1) the market for such products is limited in developed countries, (2) the cost of making such secondary products is not insignificant. In general, in industrialized countries, secondary products are, at best, only marginally competitive with their counterparts that are made of virgin materials (such as wood, sand, and gravel). In areas where wood is expensive and labor is not, plastic lumber may be an acceptable and economical alternative in building affordable housing, especially for those with low incomes.

Furthermore, recent experience in using recycled plastics from municipal solid waste streams in manufacturing of fence posts and guardrail posts for highways in Florida State is encouraging. The U.S. Department of Energy also evaluated the use of recycled plastics as an additive for "polymer concrete." In general, the conclusions appear to indicate a lower compressive strength for the polymer concrete; the process could be economically desirable and feasible.

2.3. Tertiary Recycling

Tertiary recycling or chemical processing of the waste could be used to produce value-added products (such as monomers, solvents, light hydrocarbons, and/or solid, liquid and gaseous fuels) from the hydrocarbon-based fraction of the waste stream (plastics, rubber, paper, organic oils and fluids, and wood). Processes that may be employed for this purpose include: pyrolysis (thermal treatment in the absence of air), hydrolysis (reactions with water or steam at elevated temperatures), selective dissolution (dissolving the desired materials selectively in a solvent and then recovering the material from the solvent by techniques such as evaporation), hydrogenation (reactions with hydrogen), and gasification (producing gaseous organic compounds, such as fuels, by reacting the solid or liquid organic waste material with steam at high temperatures and pressures). These processes are generally equipment intensive and energy intensive and are very costly to implement. They also require highly skilled labor. Therefore, this mode of recycling is not likely to be cost effective in labor surplus and capital poor areas.

2.4. Quaternary Recycling

Quaternary Recycling is burning the waste material to recover its energy value from the combustion gases. This energy can be used to produce steam and/or electricity. Plastics have heating value of about 20.000 Btu per pound which is about double that of an average coal. Municipal solid waste has a heating value of about 400-5000 Btu per pound. Shredded rubber tires have been successfully burned with coal in powér plant boilers and in cement kilns. Key parameters that have to be examined before such recycling is adopted include:

1. The average heating value of the waste material.
2. The composition of the waste steam, with special emphasis on chlorinated compounds and heavy metals content. These increase the potential for producing harmful combustion products and air pollutants.
3. The potential for concentrating harmful species such as heavy metals.
4. The availability of markets for the energy produced. For example, if the incineration plant produces steam, and the plant has no electric generators to produce electric power, the steam has to be used within a few miles distance from the plant. Otherwise, it will condense and be of no value. Therefore, unless there is a customer for the heat nearby, the heat will be uneconomical to recover and/or transport to the customer.
5. Cogeneration of steam and electricity may also be an attractive alternative. To take advantage of the economics of scale, power plants are generally large. Therefore, waste steams can be used to compliment other fuels.

3. A FEW EXAMPLES OF RECYCLING APPLICATIONS OF DURABLE PLASTICS FROM OBSOLETE AUTOMOBILES AND HOME APPLIANCES

Two examples of specific recycling applications which may produce jobs with minimal investment in equipment are presented below. These are: recycling of plastics from obsolete automobiles and recycling of obsolete home appliances.

3.1. Recycling of Plastics From Obsolete Automobiles

In the U.S. alone, over 10 million vehicles reach the end of their useful life every year, and over 14 million cars are junked annually in Europe, and about 5 million in Japan. The obsolete vehicles are generally acquired by dismantlers, who remove from them parts that are in good working condition for resale. Parts that require repairs are generally not removed because of the high cost of labor required in repairing them. After that, they sell the hulk to the shredders who shred it to recover the metals. On average, an obsolete car hulk (after the dismantler recovers reusable parts from it) has about 1 short ton of ferrous metal, 0.1 tons of non-ferrous metals, and about 0.1 tons of plastics. These plastics include PP, PE, ABS, PVC, PC, flexible polyurethane foam, nylons, and polyester. The ferrous scrap is worth about $110-$150 per ton, and the non-ferrous scrap (aluminum, copper, etc.) is worth between $800-$1300 per ton. The plastics and other non-metallic materials in the vehicles are considered waste and are disposed of in landfills at a cost of about $20-$50 per ton in the U.S. This stream is commonly called "automobile shredder residue or ASR."

In Europe the disposal cost for ASR is about 15 to 25 times higher. In addition, many industrialized countries in Europe have either passed or are expected to pass stringent regulations governing the disposal of this waste in landfills. The ASR is generally contaminated with automotive fluids, heavy metals, and PCBs. It also contains about 5%-10% by weight metals that were not recovered by the metals recovery processes. Again, hand-picking of these metals from ASR is not economical in industrialized countries because of the high cost of labor. It could be a revenue generator in labor surplus areas. This is especially true if the pickers also pick plastics for recycling. A trained picker can pick about 1 ton of mixed plastics (including rubber parts) in an 8 hour day from ASR. He can also pick about 500 pounds of metals. The value of the plastics is about $100 and the value of the metals is about $30. The plastics will require some cleaning and additional separation before they can be used to produce products.

Manual dismantling of the plastics off the vehicles before shredding to avoid the contamination that occurs during the shredding process was proven uneconomical in Europe and in the United States. This is primarily because of the high cost of labor. Manual dismantling in labor surplus areas can produce repairable parts for resale (electronic components, whole seats, tires, glass windows, door panels, etc.) and clean metals and plastics for recycling into new products. The metals might have to be exported for processing in industrialized countries because of the high capital cost associated with building steel mills. The plastics can be processed domestically and exported as finished products. Some of the mixed streams and unusable components such as worn out tires may be used as an energy source. If the plastics are separated at high enough purities, they will be worth between $0.20 to $1.00 per pound when sold to make new products. If the plastics are dismantled off the cars before the cars are shredded to recover the metals, the contamination of the plastics can be kept to a minimum. Therefore, the mixtures can be significantly upgraded using simple and inexpensive techniques such as sink/float that take advantage of their different densities. Markets for many of these plastics are already established.

For example, the U.S. imports about 400 million pounds of scrap polyurethane foam from Europe annually at prices ranging from $0.20 to $0.70 per pound. It takes about 10 to 20 minutes to manually remove about 15-20 lbs of polyurethane foam from car seats, using a knife to slit the seat open, and one can get a used foam baler for about $5,000 to bale the foam and get it ready for shipping. Similarly, over 100 lbs of plastics parts such as bumpers, door panels, dashboards, carpets, hoses, and ducts from under the hood, can be readily dismantled from an average vehicle. Some of these parts may be reusable as parts. Others can be granulated. The granulated material can be upgraded by further simple separation processes such as density gradient methods when required to produce materials with acceptable and marketable qualities. The foam and the plastics, when manually dismantled, should have minimal contamination. Therefore, they can be washed and recycled. The hulk that remains after the polymers are separated manually can be sold to a shredder to recover the ferrous and the nonferrous metals. Because the plastics have been removed, the shredder will end up with about 25% less waste to dispose of than if the obsolete vehicle is shredded before removing the synthetic polymers. Therefore, the hulk should be worth more than before the polymers were manually removed because there will be less materials to dispose of after shredding.

One possible business scenario could be to partner with dismantlers in developing countries to receive obsolete vehicles, dismantle them to recover the plastics and any repairable parts, and then ship back the hulk and the separated plastics back to the original dismantler in the industrialized country.[1] Another scenario would be to make arrangement with shredders in industrialized countries to receive ASR, hand-pick metals, and plastics from the ASR and then dispose of the residual material in an appropriately designed landfill. In both cases, domestically produced vehicles could also be processed.

3.2. Recycling of Obsolete Home Appliances

Home appliances such as refrigerators, freezers, air conditioners, washers, dryers, computers, telephones, microwaves, and toys contain high-value engineered thermoplastics. The computers and some other electronic equipment also contain precious metals. Some of the appliances may also contain old capacitors which may contain PCBs. Generally, home appliances are amenable to manual dismantling by trained unskilled workers. The metals can be exported for further processing in industrialized countries or can be processed domestically. The plastics can be processed domestically and exported as finished products. In the case of refrigerators, freezers, and air conditioners, the Chloroflourocarbon (CFCs) based refrigerants can also be reclaimed and purified for resale. Because the production of many of the CFCs is banned in many countries, the market for these recycled materials is excellent because most systems in operation all over the world are designed to use these materials.

The primary plastics for recycling in the appliances are the ABS, PC, ABS/PC alloys, and high impact polystyrene. These are all high value materials that can be separated from each other at high purities, using existing and simple technologies. These plastics can also be used in numerous applications and products. Modifiers and additives to improve their strength and other properties are also commercially available. Their market values as recycled materials can be between $0.25 for high impact polystyrene and $1.00 for the polycarbonates. An average refrigerator, for example, can produce about 20 pounds of ABS and high impact polystyrene. The U. S. refrigerators contain about 15 pounds of ABS and 5 pounds of high impact polystyrene. The European refrigerators contain about 5 pounds of ABS and 15 pounds of high impact polystyrene. The refrigerator also contains about 75 pounds of metals, primarily steel and copper. The average value of the metals is about $0.075 per pound.

Manual dismantling of the appliances can be done by unskilled labor with minimal training, using inexpensive tools and equipment. For example, a vacuum tank can be used to recover the refrigerants from the compressor assembly. The compressor lines can then be cut and the compressor is then removed. Similarly, the condenser (tubes and fins) can be cut and removed. An electric saw can be used to remove the steel panels, the plastic door panels, the insulation, and the plastic liners.

4. EVALUATION OF A RECYCLING BUSINESS OPPORTUNITY

In the business, there are a number of important factors to evaluate before a decision is made to go ahead. There are also a number of issues that will have to be addressed before developing a recycling business because this business involves handling waste materials that may have adverse environmental and health effects and also including other related issues. Some of these business issues are discussed below.

4.1. The Availability of Discarded Materials to Recycle

Waste materials such as obsolete cars and household appliances may not be available in large enough quantities in many developing countries to economically justify investment in a recycling business. In addition, cars and household appliances are kept for a longer period of time than is the case in industrialized countries because it is more economical to keep repairing them than to replace them. The positive side of this is that the market for replacement parts is excellent, and should be considered as part of the recycling business. As stated earlier, obsolete U.S. refrigerators are being repaired or used for parts in Mexico and the market has expanded into a few countries in countries in Central America.

4.2. Availability of Land and Water Resources

Manual dismantling facilities require large areas of land for its activities, including:

* Areas for storing the obsolete cars and appliances before dismantling.
* Working areas for dismantling.
* Areas for storing dismantled parts and products prior to shipping to the next user.
* Sops to repair and market the products.
* Areas to hold residue materials before final disposal.

We estimate that about 100 acres of land will be required for such a facility. In addition water will be required to wash parts and products and for upgrading the plastics mixtures by simple techniques such as sink/float processes. The water does not have to be of good quality and could be reused over and over again. The plant must be equipped with an appropriate waste water treatment facility to guard against polluting rivers and streams of underground water resources.

4.3. Business Environment

Business practices differ from country to country. Because a recycling business is likely to rely on imported items for recycling, business practices and limitations in some countries may create obstacles to the export of such materials. International regulations governing transportation of waste materials will also have to be observed. Economic and political stability in any country would encourage foreign investment and partnerships. This could be the impetus to get a recycling business going along with the technology, the equipment, and the marketing know-how.

4.4. Financial Support

Even though recycling programs as suggested in this position paper may not require a major investment, some investment will be needed up front to obtain the land, the tools, and to pay for transportation, salaries, rent, and taxes until revenues are generated. In other words, a certain amount of cash flows is needed to develop, operate, and maintain the business.

4.5. Worldwide Competition with Well Established Companies

Every business experiences tremendous levels of competition. With today's business environment, even recycled products will have to compete with other recycled materials and with their virgin counterparts. Furthermore, the already existed and well-established companies might try to buy and/or crush the recycling programs, especially those that are established in developing countries. Technical reasons such as damaged dismantled parts might be another real or invented technical excuse for preventing third world companies from selling their products to developed countries. Therefore, long-term rights and markets should be investigated and negotiated before the waste items are received. In addition, unlike many other businesses, the recycling business may not be able to support itself by relying only on local or even national markets. It might have to look for markets beyond the national border. Countries from which the waste is received could serve as markets for some of the products.

4.6. Training Programs

Even though primary and secondary recycling do not require highly skilled labor, short vocational training programs can be developed to train people to be more skilled in the process. Such training programs could include general information about different kinds of waste, cleaning processes, dismantling processes, etc. The program could give lectures about topics such as hazardous environments, economic incentives, sustainable development, and so on.

Advanced training programs could also be developed for those who would like to better their lives and careers. They could be used to train people with elementary school diplomas to work in both chemical and physical recycling plants.

Finally, national educational campaigns could be adopted by both public and private sectors of society to ensure the importance of recycling programs within their countries with the emphasis on the economic aspect of recycling. The recycling programs should also be integrated into the daily cultural and socio-economic character of society. It has been documented in related literature that recycling programs that collect about 50 percent of reusable materials in a given city would create hundreds of jobs and a payroll of thousands of dollars.

5. THE ROLE OF THE HUMAN FACTOR IN ESTABLISHING RECYCLING BUSINESSES

As Adjibolosoo (1993, 1995) has convincingly argued, any efforts and resources directed at alleviating the problems of society, including the reduction of the amount of materials that end up in the landfill as a waste, must place a high priority on the development of the appropriate human factor characteristics in the labor force. The human factor (HF) is "the spectrum of personality characteristics and other dimensions of human performance that enable social, economic, and political institutions to function and remain functional over time . . . . These dimensions and attributes of the HF are over and above mere human resource development and human capital acquisition through education and training. Instead, HF attributes involve dedication, responsibility, accountability, honesty and integrity in life and work." When there is a well prepared people who have acquired the appropriate HF characteristics, people will be equipped to develop, organize, and manage relevant institutions and relationships that will pave the way for development and the well-being of their own society.

Investors and prospective buyers in a recycling business must be able to feel comfortable with the long term commitment and reliability of the business. They must be able to trust the national logistics system, banking practices, quality control, resource management, accountability, and the integrity of the management running the business. When the appropriate HF traits are available, foreign investors will be willing to take the necessary risks involved. Collectively, however, these factors can only flourish within an environment that enjoys political, social, and economic stability, as well as strong and deep rooted human factor characteristics. History, for example, has shown that investors from developed countries are not fond of doing business with companies where social and economic uncertainty are the rule rather than the exception and when the practice of bribery and favoritism are the norm. They want reliable communication, transportation, and banking systems. These are only possible if the existing labor force has acquired the necessary HF traits (Adjibolosoo, 1995, pp. 33-53).

However, we must realize that to reach a level of collective consciousness about both the appropriate human factor characteristics and recycling, we must also begin at the fundamental level—teaching school children that recycling is an essential natural mechanism that has created and sustained life on Earth for thousands of years. Furthermore, we must also teach the school children that "successful economic growth, social development, gender balance, sustainable environment, and effective leadership, do not only depend on the availability of economic resources, but also on a well-prepared people who have acquired the human factor" (Adjibolosoo, 1995). Indeed, without well-developed human factor characteristics such as accountability, responsibility, commitment, and integrity, development will not happen. With these human qualities in place, social, economic, and political institutions will function effectively as expected. This will provide the most fertile environment for the establishment, development, and operation of successful recycling business programs.

Note

1. Such indigenous technology, foundries in Ghana, Nigeria, Zimbabwe, Kenya, Tanzania, and many other developing countries could serve as links in this chain (see details in Adjibolosoo, 1996, pp. 45-59).

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