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Evaluation Study of Sustainable Recycling for Solid Waste Materials: A Case Study

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***Abstract*—Solid-waste recycling in Libya is helpful, relying almost entirely on oil production, preserving its natural reserves, and boosting its economy. Many are still hesitant due to the lack of understanding of the economic feasibility and environmental benefits of solid waste recycling in Libya, which needs to rebuild its entire infrastructure. This research focuses on the economic and ecological potential of recycling solid waste, according to Libyan plans 2012-2030. The estimation indicated that by 2030, 268,000 tons of waste paper would be recovered in Libya. Expected benefits of solid waste include increasing the country's GDP by about USD 734,000, creating new jobs about 1,134, and a lower value of 0.57 million tons of carbon dioxide emissions during 2012-2030.**

Keywords—Libya State; Solid-waste recycling; economic feasibility; Environment Conservation.

I. INTRODUCTION

Libya is located in northern Africa, between 18º to 33º north latitude and 9º to 25º east longitude. It is the eighth largest oil-producing country in the world. The Libyan economy is based on the oil sector funded too socially and economically over the past forty years. Migration rural to urban areas internally and increasing the number of workers from outside the country have increased the urban population. For the last 35 years, Libya's population growth at a rate of 2.2% annually. Approximately the total population is 5,8 million in 2012 [1]. Most people's concentration in cities increases Municipal Solid Waste (MSW) in major cities, which created a major environmental and health problem, as there are no real solutions to get rid of it [1,2]. This paper aims to focus on the possibilities on the economic and ecological potential of recycling the solid waste in Libya to benefit from it in generating electricity or any other industries that contribute to the increase of the country's GDP according to the Libyan plan 2012-2030.

Municipal solid waste (MSW) is known as a vital recycling material and energy source. The MSW is beneficial for an immense and unquestionable like Libya and other oil-producing countries, saving their natural reserves in different oil-producing states [2]. In Libya, the MSW practices solve the landfill site conflict by the waste should not be dumped on land. The recycling program is done on low-cost land because this accomplishment is unachievable [2-4]. The recycling process currently works as a label metals collector and trash sorters cardboard through a rubbish container on a large scale. It produces about 2.4 million tons per year with a usual quantity of 1.3 kg/day; the MSW data is shown in Table 1. The wastes production in Libya include organic materials 56.3%, paper13.5%, plastics 10%, mineral 3.7%, glass 2.6%, wood 2.8%, textile 10.8% [7]. The average production rate is due to the lack of community-wide environmental awareness programs that help minimize MSW production and enhance recycling. WTE technology is a vital source of a renewable form of electricity that is much eco-friendly than other US EPA sources [8]. WTE minimizes 80% reduction in mass and 90% reduction in volume, as MSW amount deposited at landfill areas [9]. Incineration reduces the odor emission of methane and leachate formation. According to global warming, perspective 21 times methane more harmful than carbon dioxide (CO_2) [10-11]. The waste deposited areas fully occupy most of the Libyan land. With an additional dumping area, the number of undesirable by-products like leachate, sludge, methane, and other odor emissions and all health hazards increasing [12].

TABLE I. LIBYA'S POTENTIAL DATA FOR MSW

Years	Citizen (pears)	Waste Indicators (kg/pres/day)	Waste Quantity (kg/pres/day)	Waste Quantity (ton/year)	Waste Cumulative Amount
2012	5878100	1.3	7641530	2789158	2789158
2015	6759815	1.3	8787759	3207532	5996690
2020	7773787	1.3	10105923	3688325	9685015
2025	8939855	1.3	11621812	4241665	13926680
2030	10280833	1.3	13365083	4878225	18804905

Recycling in Libya is nearly insignificant, and non-governmental and private sectors rule recycling in Libya. It is found that neither national nor local government had the official accounts that legalize the private recycling sector; not even the companies allowed guaranteeing their compliance with health and environmental regulations. As a result, this

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provides a low recycling rate as compared to the generation of recyclables. Table 2 shows that the recycling process in Libyan cities, which is summarized in a simple concept. It mainly focuses on removing impurities, then cutting and pressing after packing or selecting production-based, as shown in Figure 1. Then what is manufactured and shipped to recycling firms in Libya is genuinely concentrated on recyclable materials. It is used as a raw material for other manufacturing industries, very cheap as non-recyclable raw materials. As it turns out, some recycling factories primarily deal with different plastic materials like plastic bags, sheets, and bottles, having second priority to processed cardboard, paper, and metal cans.

TABLE II. RECOVERABLE POTENTIAL RATE OF RECYCLING MATERIALS

Description	Recovery Rate %
Tissues	30
Plastic	60
Paper and cardboard	60
Metal	85
Glass	50

Fig. 1. Process of preparing materials for recycling [2]

II. METHODOLOGY

Forecasting the MSW recycling faces many variables, which are challenges that affect forecasting accuracies, such as growing population, urbanization rate, public awareness, living standards, legal and organized outline, and the country's monetary conditions. The plan 2012-2030 has considered that the country's population growth is increasing at a rate of 2.2% every year. This rate's choice reflects the average population growth for five decades and the probabilistic financial development that will result from the country's 2030 plan. The expected average rate of local solid waste generation per capita was 1.3 kg daily. Recycling waste can generate significant financial assistance for the Libyan state if properly succeeded and well used.

Papers are the most usable and popular materials used in packaging, come in different shapes and colors, and are referred to as grooved boards. The materials are recyclable from different factories like cartoon packaging instead of dumping the recycling process to save money. Recycling paper is the reuse of solid multi-layer papers or thicker boards that are known as waste. Cardboards are made up of recyclable products, including cartons and waste printing paper and boxes. Further analysis was made of the potential for the recovery of waste paper to estimate recycling's economic viability. The study was identifying the cost of paper recycling in Libya [13]. The information calculated the profitable benefits of recovering paper waste in Libya, as illustrated in Tables 3 and 4. The paper waste generation tables' predictable data was used to acknowledge the employment opportunities in the recovered paper industry, the total market paper waste value, and its contribution to Libyan domestic income up to 2030. The annual average waste paper recovery rate is 75%, with the expectation that the prices of recovered paper will increase annually at a rate of 2%. Waste paper recovery gives high environmental benefits over the life of the paper. The presented data in Table 5 acknowledged the functions of the recycled industry in Libya.

TABLE III. COST OF WORKERS IN PAPER RECYCLING FOR ONE SITE

Job Description	Job Requirements	Number	Salary ($)	Total Salary ($)
Production Supervisor	Supervision & Control	1	1100	1100
Labor Operation	Production & Processing	5	800	4000
Production Manager	Project Management	1	1500	1500
Total per year		6600 dollars/month		

TABLE IV. MATERIALS COST FOR A LIBYAN CITY

Material description	Quantity	Unit ($)	Cost ($/20 ton)
Chemicals & Reagents	40 kg	0.83	33.2
Abiotic Acid	0.36 ton	363	130.68
Paper-Making Additives (pulp)	3.6 ton	272	979.2
Mixed Cardboard	16 ton	70	1120
Total per year	2263.08 dollars/year		

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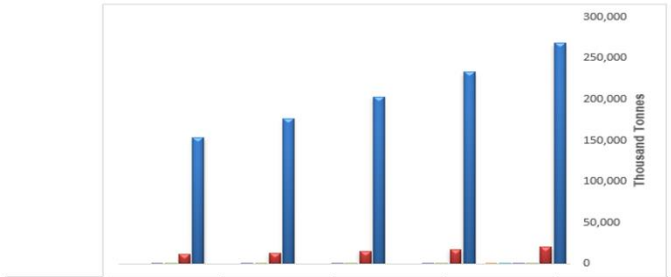
TABLE V. ECOLOGICAL BENEFITS OF REUSING THE PAPER INSTEAD OF RAW MATERIALS FOR NEW PAPER PRODUCTION [14,15]

Parameter	2012	2015	2020	2025	2030	Recycled paper	Saving
Wood use, trees	9.6	11	12.7	14.6	16.8	0	16.8
Total energy, oil barrel	3.1	3.6	4.1	4.7	5.4	3.8	1.6
GHG, million ton of CO_2 equivalent per year	1.1	1.2	1.4	1.7	1.9	1.33	0.57
Water usage, m^3	23	26	30	35	40	28	12
Solid waste, kg	445	512	588	677	778	544	234

III. RESULT AND DISCUSSION

A. *Waste Recycling Possibility*

The potential recycling results forecast four materials, such as textiles, plastic, glass, and paper, to all parts from 2012-2030. The total recyclable waste materials produced in Libya in 2012 were about 2.7 million tons. It is expected to be reached nearly 4.8 million tons in 2030, as shown in Figure 2. The glass waste production for the year 2012 was estimated at 380 thousand tons and is expected to reach 646 Thousand tons in 2030. Textiles production was about five Thousand tons in 2012, and it is estimated to reach nine Thousand tons in 2030. Plastic waste was around 11.5 Thousand tons in 2012 and is expected to reach 20.1 Thousand tons in 2030. Paper waste was estimated at 153.4 Thousand tons in 2012, and it is expected to reach 268.3 Thousand tons in 2030.



yaer	2012	2015	2020	2025	2030
total waste	2,789,158	3,207,532	3,688,662	4,241,961	4,878,255
paper	153,404	176,414	202,876	233,308	268,304
plastic	11,505	13,231	15,216	17,498	20,123
glass	380	437	502	577	664
Textiles	5	6	7	8	9

Fig. 2. Recycling potential materials from 2012 to 2030

Recovered materials have great benefits if utilized well, originate significant GDP revenues, and provide excellent employment opportunities. According to research and studies, recycling in Libya is almost non-existent [2]. From recyclable waste, Libya is losing its economic opportunities. Moreover, waste recycling has a significant influence on environmental impacts. It can drastically reduce the adverse ecological effects of municipal solid waste [16-17]. As paper recovery can significantly contribute to a country's GDP growth, it provides more job opportunities and opens up surplus economic investment occasions. Table 6 shows the direct financial potential profits of paper recovery in Libya by 2030.

TABLE VI. POTENTIAL ECONOMIC BENEFITS FROM PAPER RECYCLING FROM 2012 TO 2030

Parameter	2012	2030
Collected paper value, $	10.7 million	18.7 million
contribution to the country GDP, $	238520	734867
The number of jobs in the paper industry	653	1143

B. *Challenges in Recycling Waste*

The MSW management process in Libya faces problems in integrated management and the lack of suitable recycling systems. Probably a small proportion of MSW recycling, and the rest is disposed of landfills. Moreover, the country is losing opportunities to invest in the recycling and reuse of waste. Among the difficulties facing paper recycling in Libya:

- The policy of exporting recycled materials needs legislation from the government.
- There is no sorting of municipal solid waste from the population and lack of community awareness programs to reduce industrial to household-level waste.
- Waste disposal in landfills is difficult to sort and reduce waste by waste producers.
- The mechanism for collecting and exhuming waste in landfills is a usual practice, and along with substantial risks to health and safety.

IV. CONCLUSION

Managing MSW that converts waste into energy in Libya to solve disposal problems and balance the deficit in electricity. If the paper is recycled in the country, it could contribute about 734 thousand US dollars to Libya's economy and creating new job opportunities of about 1134. An amount of 1.6 million barrels of crude oil and 0.57 million tons of carbon dioxide could be saved from greenhouse gas emissions from 2012 to 2030. However, waste recycling, paper recycling industries, and energy generation from waste are still almost non-existent in Libya. It requires effective measures and well-organized plans to support, enhance, and protect the recycling industries.

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