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The Potential for Energy Recovery from End-of-Life Tire Recycling in Cameroon: A System Dynamics Approach

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Introduction

With rapid population growth, increased industrialization, and massive waste generation, environmental degradation and energy emergencies have become critical worldwide [1]. Cameroon is a developing country in Africa that is facing environmental degradation and an energy crisis since 2000 [2]. Although energy demand for industrial use and household consumption has been on the rise, energy supply has been insufficient. Given this, investments have remained low and many households continue to suffer from the crisis [2]. Cameroon's major source of energy is hydroelectricity, which is greatly underdeveloped [3]. Its old electrical infrastructure (dams and hydroelectric power stations) with an efficiency rate of less than 55% lacks quality maintenance. Due to frequent power cuts and the rationing of electricity, energy expenses have increased in Cameroon's industries with the use of diesel generators [3]. Hence, it is necessary to provide other feasible solutions for energy generation in the country. The increasing demand for vehicles has led to a corresponding increase in the demand for tires, and end-of-life tire (ELT) recycling for the recovery of energy has been adopted by many countries as an alternative source of renewable energy [4]. The recycling of ELTs in Cameroon would be a potential source for energy generation in Cameroon. This study therefore estimates the amount of energy recovered from non-metallic components of ELTs.

Methodology

In this study, the system dynamics model (SDM) is used to estimate the amount the energy recovered in megajoules (MJ) from the potential recycling of ELTs in Cameroon. Hedayati [5] adopted the SDM for a sustainable business on energy recovery from automobile shredder residue in Australia. A "stocks and flows" diagram (Figure 1) is used to facilitate the simulation of SDM, and scenario analysis was conducted for model verification and validation [5]. System dynamics modeling has illustrated significant usefulness across various fields to forecast the behavior of complex systems and guide policy makers [6]. Cameroon aims to become an emerging economy by 2035 [7], the model projections considered the next 15 years. Analysis was based on 2018 data mainly due to data availability.

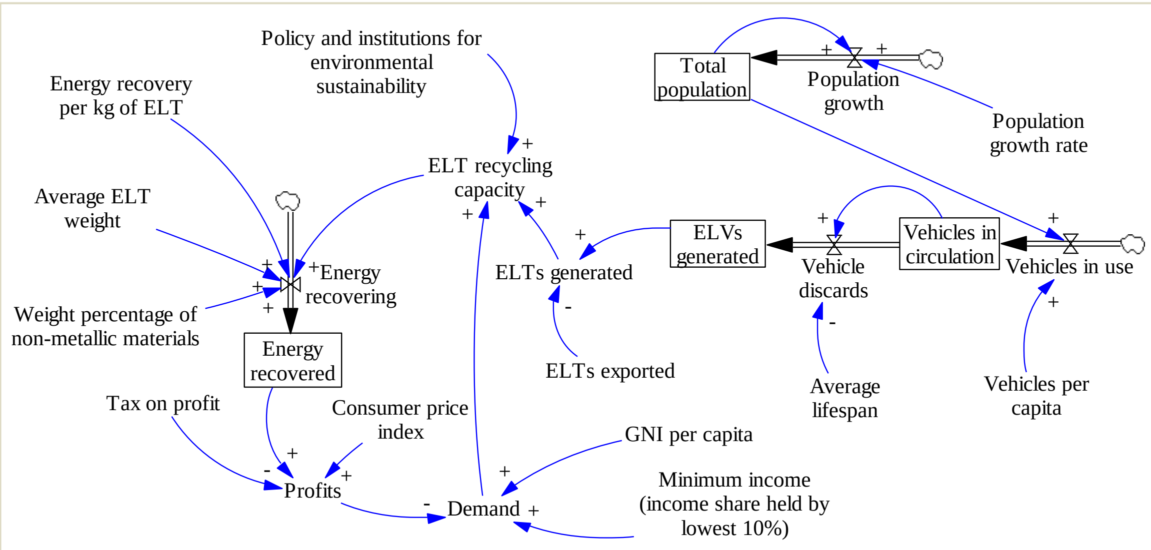

Figure 1: Stocks and Flows Diagram of the System Dynamics Model

The equations of key variables are as follows:

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$X_{elt} = 4 \times X_{elv} - E_{elt}$,

$C_{elt} = f(X_{elt}, X_{policy}, X_{demand})$,

$R_e = C_{elt} \times X_{atw} \times X_{wnm} \times H_e$,

where, X_{elt} is the number of ELTs generated, X_{elv} is the number of end-of-life vehicles (ELVs) generated (unit vehicle), E_{elt} is the number of ELTs exported (unit tire), C_{elt} is the ELT recycling capacity (unit tire), X_{policy} represents policy and institutions for environmental sustainability (per year), X_{demand} is energy demand (USD), f is function, R_e is energy recovering (MJ), X_{atw} is average ELT weight (kg per tire), X_{wnm} is weight percentage of non-metallic material (% per tire), H_e is energy recovery (MJ per kg).

Results

Case 1 is based on estimating the amounts of energy recovered given different average vehicle lifespan scenarios (1 and 2). The current average vehicle lifespan is unknown owing to the absence of policies regulating the use of vehicles in Cameroon. We assumed a vehicle lifespan of 20 years projected for Zambia [8], which is similar to Cameroon's case. Analyses of scenarios 1 and 2 were performed considering the increasing and decreasing average vehicle lifespans of 21 and 19, respectively. From the results shown in Figure 2, scenarios 1 and 2 will decrease and increase energy recovered by 0.18644e+19 and 0.20261e+19, respectively. Case 2 is based on estimating the amounts of energy recovered, given different policy scenarios. With the absence of ELT policy, we used the rating of 3.5 (1=low to 6=high), according to World Bank classification, for Cameroon's current policy and institutions for environmental sustainability. The policy scenarios had ratings of 3 and 4, representing cases when policy worsens and improves, respectively. Both policy scenarios showed no changes on energy recovered.

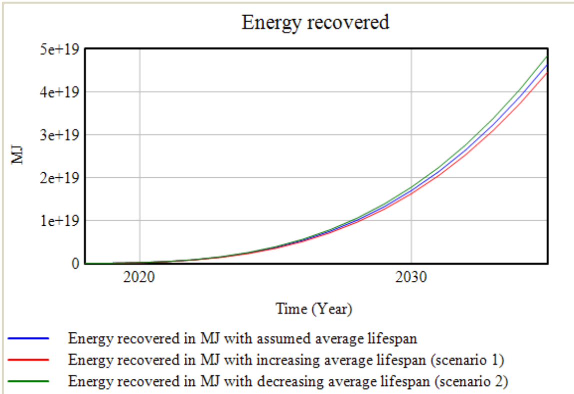

Figure 2: Average lifespan scenarios for energy recovered from ELT recycling in Cameroon

Conclusion

In case 1, scenarios 1 and 2 revealed that changes in the average vehicle lifespan will change the amount of energy recovered from recycling ELTs. In case 2, policy scenarios revealed no changes on energy recovered. Because policy influences the average vehicle lifespan [5], the policy itself does not have a direct impact on energy recovered, although it does have an indirect impact through the average vehicle lifespan. The recycling of ELTs in Cameroon will therefore provide a feasible source of energy and also reduce the environmental pollution and degradation they cause.

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