LINK & LOOP

Technical Report

A Life Cycle Assessment of Waste Paper RDF in Taiwan

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Date Issued:
May 15th, 2020

Linking innovations and closing Loops

Table of Contents

Executive Summary

Global waste generation is continuing to increase. In 2016 global waste production disposal reached 2.0 billion tons per year, and it is expected to reach 3.4 billion tons by 2050 (World Bank). Proper waste disposal and treatment remains a crucial issue for countries. Refuse derived fuel (RDF) manufactured from waste is one common treatment that both decreases the cost of waste disposal and increases resource efficiency.

In this report, the life cycle assessment (LCA) approach is used to analyze the impacts of RDF made from wastepaper on the environment. This analysis includes paper rejected from standard paper processing. Environmental impacts are 16.5% - 19.4% of the impact of coal. Even if RDF is transported to other boilers outside the plant, the impact on the environment is much lower than coal (*Current regulations in Taiwan limit this type of RDF-5 to only include internal factory use).

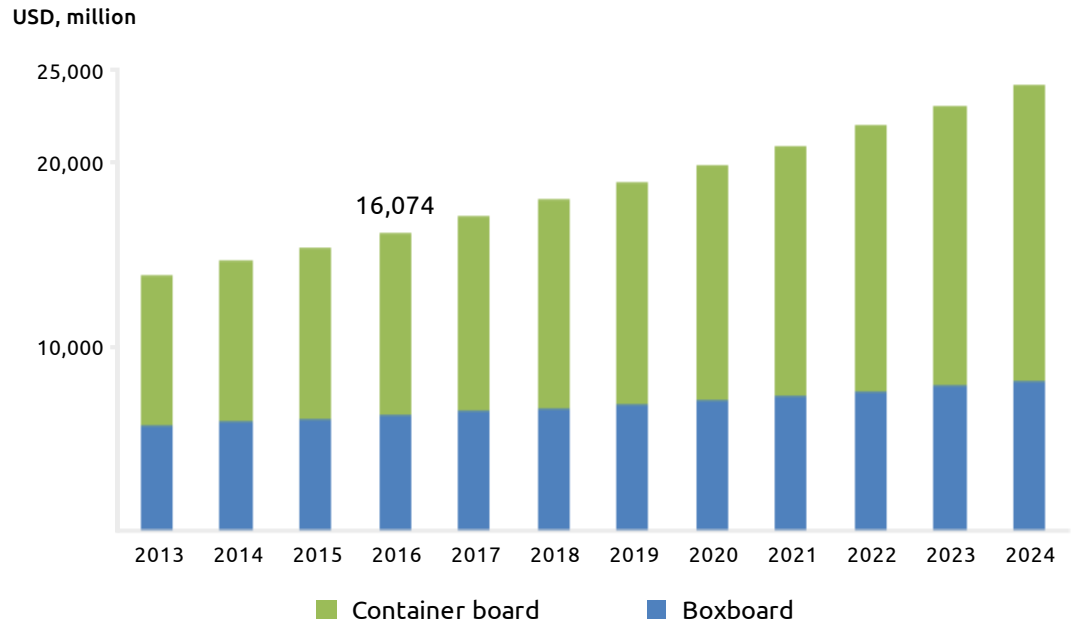

Source: Sinotech

Refuse Derives Fuel (RDF)

Industrial ecology seeks to change supply chains from linear to circular, to use waste as a resource. For example, waste or by-products produced by one factory might be new materials or energy for another factory. The pulp and paper industry in Taiwan has strong resource saving potential. In the past, the pulp and paper industry used large amounts energy and resources. In recent years, the pulp and paper industry has reduced pollution of the pulping process and utilizes energy efficiency. Technical changes have led to a high waste paper utilization rate, high recovery rate, and high paperboard production ratio.

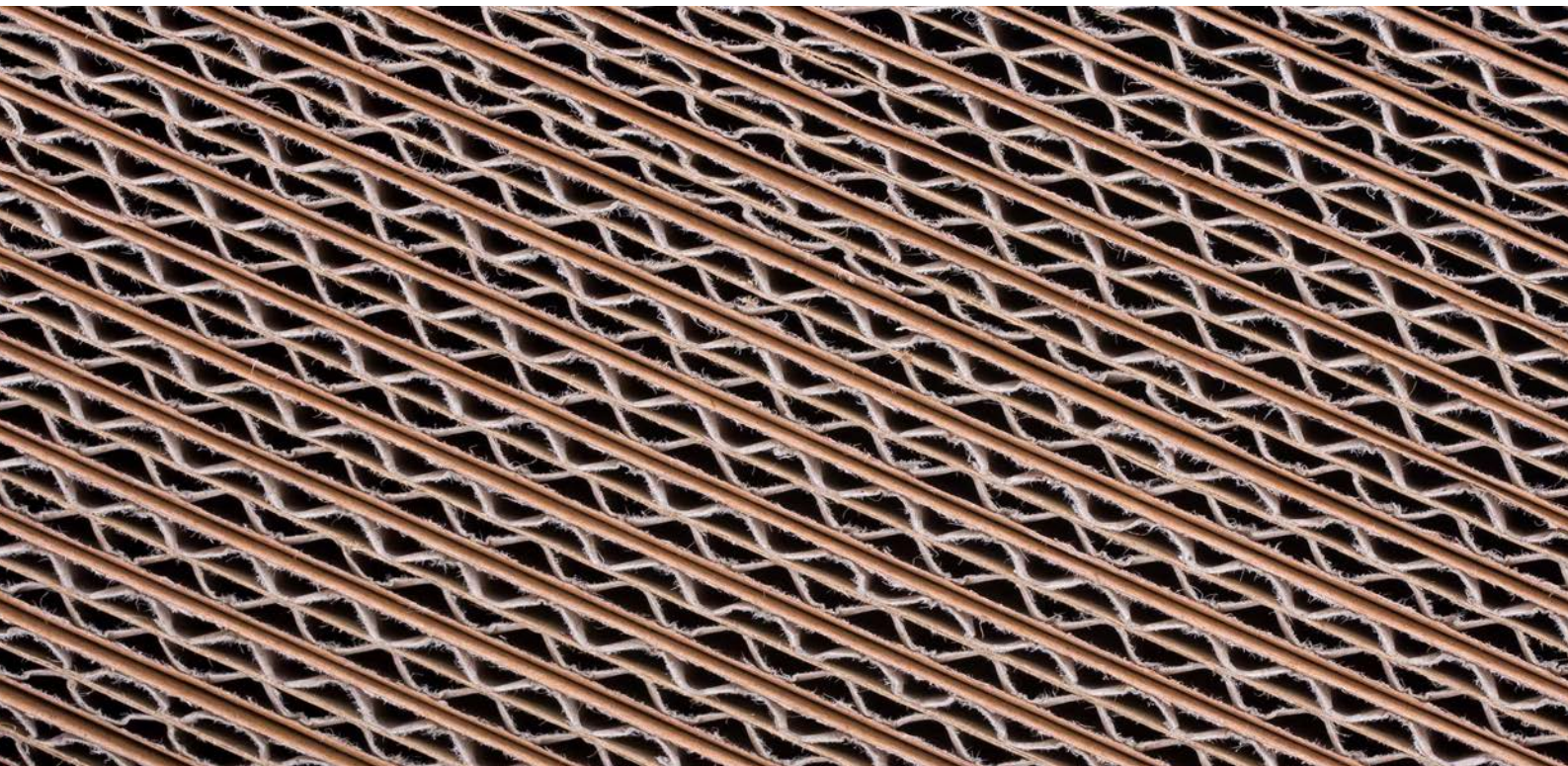
Paper sludge and rejected material are the coarse residue of the pulping process. According to the regulations of reuse in Taiwan, paper sludge and RDF-5 manufactured from rejected paper can be used in fuel boilers. By using these alternatives factories can decrease coal usage in boilers. This has not only cutback the cost of waste management of paper sludge and paper rejects, but also reduced the amounts of waste disposed in incinerators and landfills.

The packaging industry in recent years has grown considerably due to the increase of purchasing power in previously lower income countries. The popularity of e-commerce also stimulates the demand for paper packaging. Thus, as paper maintains its popularity, sustainable systems are essential to avoid exhausting natural resources or harming human health.



Source: Global Market Insight

Figure 1 US paper packaging market size, by product



Rejected Paper Recycling

Paper rejects are one of the largest waste streams from pulp and paper factories. It can be made into RDF-5, a replacement fuel for boilers.

ASTM International divides RDF into 7 categories from RDF-1 to RDF-7, among which RDF-5 is most well-known. The difference between RDF-5 and RDF-3 is that RDF-5 is manufactured through granulation. RDF-5 has characteristics of lower moisture and a smaller size, which is suitable for transportation. RDF-3, on the other hand, is produced without granulation, making it lighter and fluffier, thus contributing to higher transportation costs. According to the regulations in Taiwan, paper rejects are not allowed to be produced as RDF-5 and used within a factory.

The manufacturing process of RDF is shown in the **Figure 2**. RDF made from paper rejects are manufactured through rough crush, wind selection (for screening sand and stone), magnetic separation (for metal materials), and granulation.

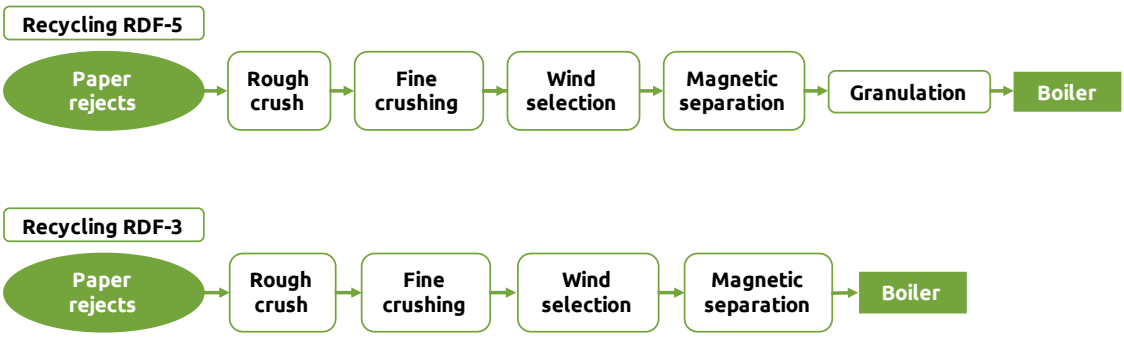


Figure 2 The manufacture process of RDF-5 from paper rejects

Life Cycle Assessment

According to the definition of ISO 14040, a Life Cycle Assessment (LCA) is the "consolidation and evaluation of inputs and outputs and potential environmental impacts in the life cycle of the production system from the acquisition of raw materials to the final disposal", that is, it serves to assess the impact of the product's overall lifespan on the environment.

The entire life cycle of the product consists of five stages: "raw material", "manufacturing", "transportation", "use" and "end of life". The impact types include human health, ecological impact, and resource use. The assessment targets a specific product, process or service, and the evaluation phase can be an overall life cycle or part of the phase, so it can be used as an environmental assessment tool for enterprise product development, or the public sector to develop sustainability policies.

The life cycle assessment of this report is carried out in accordance with the ISO 14040 process. The life cycle impact assessment mode is selected and evaluated by IMPACT 2002+ for environmental impact.

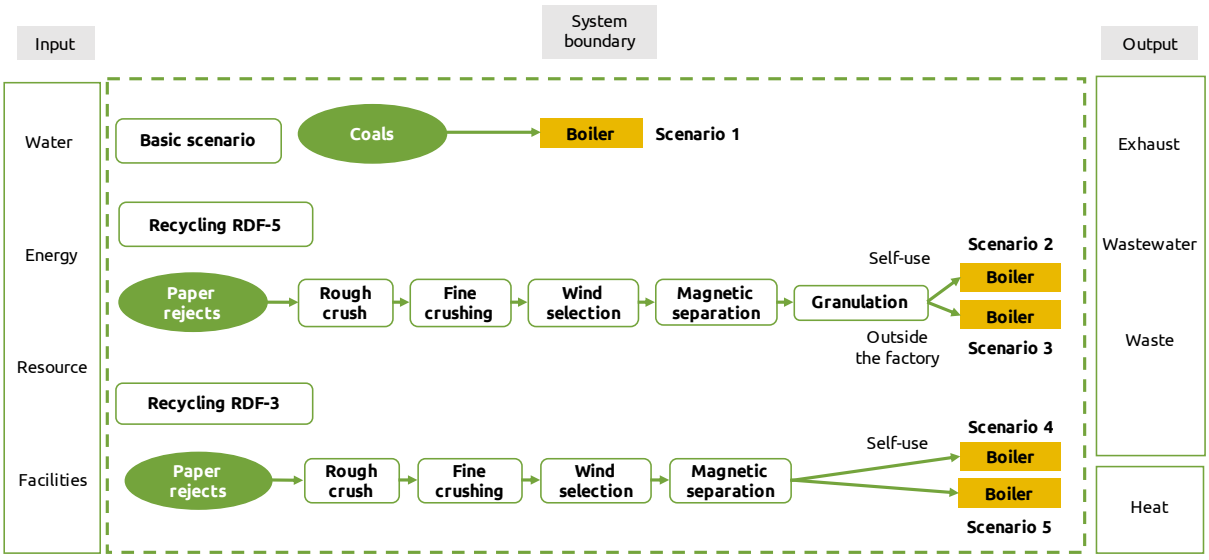
- IPCC GWP 100a is widely used to evaluate the carbon reduction benefit analysis of products. In the impact evaluation method, the carbon dioxide equivalent (CO_2 eq) is used as the unit of measurement to calculate the carbon dioxide equivalent impact of greenhouse gas emissions during the 100 years after product formation.

- The IMPACT 2002+ impact assessment method classifies environmental impact into 17 impact categories and summarizes the impact results into the following four main groups: Human health, Ecosystem quality, Climate change, and Resources.

Boundary Settings and Scenarios

The life cycle assessment of this report uses RDF produced from paper rejects from paper mills as the evaluation targets. The assessment scope includes transportation, processing, and combustion heat generation stages. All energy, resources, equipment inputs and emissions in the process are included in the calculation.

The system boundary is set as shown in **Figure 3** and the scenarios are setting as follow.
Scenario 1: one ton of coal as boiler fuels (basic scenario).
Scenario 2: RDF-5 from paper rejects are used as boiler fuels in the factory.
Scenario 3: RDF-5 from paper rejects are used as boiler fuels outside the factory (considering the transportation distance is 10, 30, and 150 km).
Scenario 4: RDF-3 from paper rejects are used as boiler fuels in the factory.
Scenario 5: RDF-3 from paper rejects are used as boiler fuels outside the factory (considering the transportation distance is 10, 30, and 150 km).



Note: Since the raw materials used in the study are scraps, according to the life cycle assessment cut-off criteria, the production process of raw materials is not included in the scope and can be ignored.

Figure 3 Life cycle assessment system boundary and scenarios

Results and Analysis

Climate change is the main impact of rejected paper recycling. Greenhouse gas emissions resulting from RDF burning is the main impact. For the baseline scenario (coal), the main impact is from the GHG emission because of combustion.

The environmental impact of RDFs produced by paper rejects is much lower than coal. Total environmental impact includes impacts on human health, ecosystem quality, climate change, and resources. The total environmental impacts of RDFs produced by paper rejects are 18.0% (**Scenario 2**) and 16.3% (**Scenario 4**) of that of coals. In Scenario 3 and Scenario 5, they are 16.5% - 19.4% of that of coals respectively after considering RDFs' transportation to outside factories.

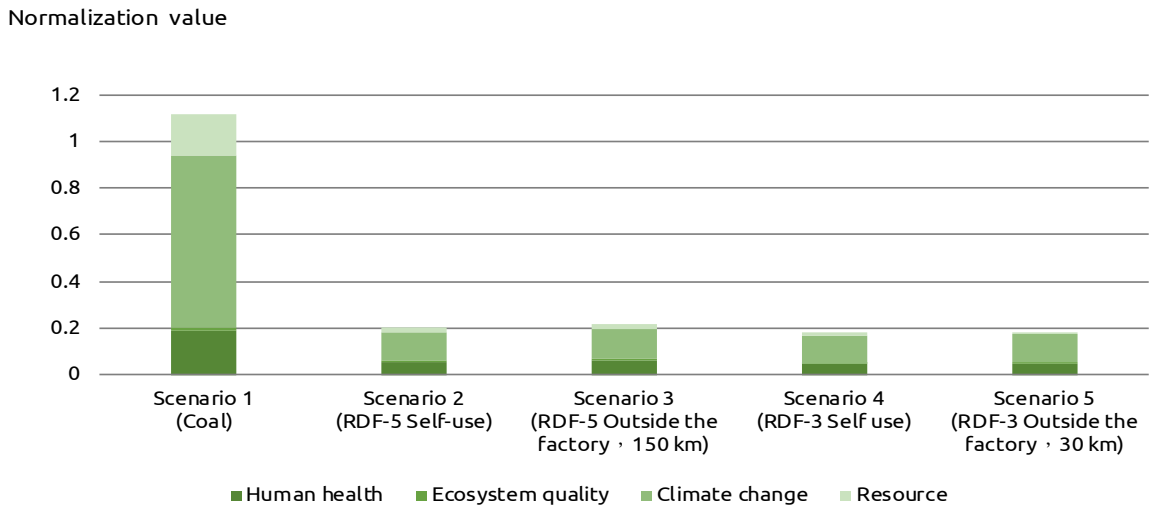


Figure 4　Life cycle assessment results

Results and Analysis

The main impact of transportation on environment is climate change, considering outside factory transportation. For **Scenario 3** and **Scenario 5**, assumptions for transportation (10, 30, and 150 km) of RDF to reach outside factories were made. The LCA results show that the main environmental impact is climate change, the second being human health.

Compared with coal, RDFs produced by paper rejects have benefits of carbon reduction after considering transportation. 1.15 tons of RDFs produced by paper rejects replaces 1 ton of coal based on the heating value. The carbon emission increases by 2.43 kg CO_2 eq per 10 km after considering the impact of carbon emissions for transportation distance.

RDF-5 is suitable for transportation, but it requires energy. RDF-5 is suitable for transportation because of granulation. However, the processes of granulation require energy and costs. Based on other case studies and the energy density of rejected paper RDF the following conclusions can be made.

- There are economic benefits and environmental benefits for RDF-3 when the transport distance is within 30 km;
- There are economic benefits and environmental benefits for RDF-5 when the transport distance is between 30 km and 150 km;
- The transport costs are high and there are no economic benefits and environmental benefits when the transport distance is more than 150 km.

Conclusions and Suggestions

- Paper sludge and rejects are the main wastes from paper mills. Paper sludge and RDF-5 manufactured from paper rejects can replace boiler fuels. It not only decreases waste management costs but it also reduces coal consumption.

- The life cycle assessment model in this report is selected and evaluated by IMPACT 2002+ for environmental impact and IPCC GWP 100a for carbon reduction. The baseline scenario for this report is coal-fired boilers. RDF produced from paper rejects from paper mills are the evaluation targets.

- The total environmental impacts of RDF produced from paper rejects are much lower than coal, which is only 16.3% ~ 19.4% the impact of coal. RDF produced by paper rejects have carbon reduction benefits after considering transportation. The carbon emissions increase by 2.43 kg CO_2 eq per 10 km.

- RDFs produced from paper rejects decrease the management costs paper rejects, consumption of coal, GHG emissions, and the amount of wastes disposed in incinerators and landfills.

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Supported by | INDUSTRIAL DEVELOPMENT BUREAU, MINISTRY OF ECONOMIC AFFAIRS 經濟部工業局

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