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Creating a Circular Taiwan

Industrial Waste and its Role in the Circular Economy

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Executive Summary

Despite an exploding global population putting an ever greater strain on finite global raw material stocks, the global industrial economic system remains stagnant in a "take-make-dispose" economic model. Determined to transform our linear economic model into a regenerative system, many countries are assimilating principles of the Circular Economy into national policies—with the ultimate goal of completely designing out waste.

Even though Taiwan has gained a global reputation for excellent recycling, attaining the position as the world's second-best recycler,[1] a staggering seven million tons of waste fail to be reintroduced into the supply chain every year. In order to better utilize global resources, Taiwan, along with other environmental leaders, has included principles of the circular economy in its national development model. Until now, the conversation on the Circular Economy has mostly centered around the recycling of consumer goods. While improving the municipal waste recycling system would certainly benefit society, focusing too much attention on a relatively narrow sector of the recycling ecosphere ignores the huge potential industrial waste recycling can play in the new circular economic model. The volume of industrial waste has steadily grown since the industrial revolution, and has recently exploded in wake of the rising electronics and technology industry. This paper specifically focuses on waste solvent and Incinerator Bottom Ash (IBA), while also including three short case studies on waste acid, ammonia nitrogen waste water, and sludge, with the intention of providing a well-rounded perspective on the potential the Circular Economy can have on industrial waste products, specifically those generated by the high technology and electronics industry.

Incinerator Bottom Ash

Incinerator Bottom Ash (IBA) refers to the noncombustible by-product leftover after thermal waste treatment. Following vigorous treatment, IBA can act as a sustainable replacement for aggregate material for construction projects, replacing unsustainably extracted raw materials, such as sandstone and limestone. Rather than treating IBA for re-use, many municipalities choose to deposit IBA into landfills, even as available landfill space continues to shrink.

The idea that IBA is toxic is a common misconception. Prior to treatment, IBA can contain heavy metals and dioxin, that could potentially harm populations. However, since Taiwan began repurposing IBA over ten years ago, rigorous heavy metal and dioxin standards have ensured recycled IBA does not contaminate groundwater, soil, or otherwise harm local populations.

Setbacks in Incinerator Bottom Ash (IBA) Recovery

1) Public Resistance: Despite rigorous standards that have ensured IBA is treated to a safe level, there is still large public resistance to the use of recovered IBA in construction projects.

2) High Cost: Many IBA treatment companies are reluctant to spend extra time and money to process IBA to such a high standard, instead treating IBA to the lowest acceptable standard, and disposing of it in a landfill.

3) Government Standards: Current IBA standards are not rigorous enough to ensure consistency in the final quality of IBA, limiting its potential for construction projects.

Policy Suggestions

1) **Create Greater Public Awareness**

   The government needs to spread information to assure the public that IBA standards protect environmental and public health, emphasizing the social benefit IBA recycling has on Taiwan. This will help create a more educated public, and improve public support for IBA recovery.

2) **Include Recovered Incinerator Bottom Ash in National Recycling Targets**

   By including recovered metal and aggregate material from IBA as part of national recycling targets, it can boost Taiwan's national recycling rates, with an added bonus of further improving public support for IBA treatment and recovery.

3) **Subsidize Incinerator Bottom Ash**

   As the market price of IBA doesn't reflect the benefits repurposing IBA brings to society, including saving landfill space and preventing the depletion of non-renewable resources, we recommend the government use subsidies to deflate the price of IBA.

4) **Improve Incinerator Bottom Ash Regulations**

   We recommend Taiwan implement policy similar to the Green Deal in the Netherlands to raise IBA standards to a level where it can be repurposed for a wider variety of construction projects. In addition, we recommend the government strengthen enforcement to ensure that new regulations are being properly implemented.

Solvents

Taiwan's waste policy evolved out of a need to exert control over illegal waste dumping that was inflicting serious damage on environmental and public health. Over time, industrial waste disposal regulations have become more and more stringent; however, policies encouraging industrial waste recycling are still quite limited.

Solvent is an important component of operations across industries. As the global economy continues to expand, waste solvent generated from this industries is also projected to swell. This section will discuss the current state of solvent recycling in Taiwan and its role in the Circular Economy, introducing the obstacles that prevent Taiwan from improving the solvent recycling system and finally offering policy suggestions to expedite this process.

Setbacks for Solvent Recycling

1) **High Cost:** It is often more expensive to restore solvent to its original quality than to purchase new solvent. As there exists little demand for fully restored solvent, very few solvent treatment companies offer this product, instead treating solvent to the lowest acceptable standard and disposing it as waste effluent.

2) **Poor Interdisciplinary Communication:** In Taiwan, there exist few institutional mechanisms to encourage interdisciplinary communication, resulting in poor access to information and limited opportunities for cooperation. Both of these have an effect on economic growth.

3) **Limited Resources for Pollution Control and Research and Development:** In order to stay afloat in a highly competitive market, Taiwan's recycling providers tend to drop their rates to the lowest possible level. Low profit margins leave little room for investment in pollution prevention or research and development, and limits potential for growth.

4) **Disposal-Focused Industrial Waste Policies:** Taiwan's waste treatment policies are overly focused on safe disposal, without enough focus on encouraging recycling. This type of regulation fails to spark innovation in industrial waste recycling.

Policy Suggestions

1) **Encourage Industrial Synergies**

   We suggest the Taiwanese government establish "support organizations" to facilitate communication between key actors, including industry managers, recycling and environmental service professionals, government officials, universities and research institutions. There is much evidence to suggest that establishing trust and spreading accurate information about recycling possibilities is vital to improving recycling rates.

2) **Facilitate Communication between Recycling Companies**

   We suggest the Taiwanese government help open communication channels between recycling and environmental services companies, in order to encourage cooperation, reduce cost, and improve the overall effectiveness and efficiency of the recycling system.

3) **Fund Innovation**

It is well-established that public funding is critical to advancing research. We recommend the Taiwanese government increase public subsidies and grants that fund research and encourage experimentation, in order to help uncover new and more efficient recycling methods.

1 In 2016, Taiwan recycled 49.5 percent of municipal waste (Source: Taiwan Environmental Protection Agency (TEPA). Linian gonggao ying huishou feqiwupin ji rongjiliang tongji 歷年公告應回收廢棄物品及容器回收量統計 [National Report on Statistics on Recycled Products and the Recycling System]. Taipei, Taiwan, 2016.), second to Germany, with a rate of 57.6 percent (Source: "Waste Treatment" Eurostat. 2014.)

The Circular Economy: An Introduction

An island about the size of the Netherlands, covered so heavily with high mountains that a population of 24 million is forced to squeeze into a mere third of the total area, Taiwan is very familiar with the idea of scarcity. Despite this very obvious limitation, and without any raw materials to speak of, Taiwan has remarkably positioned itself as the "Silicon Valley of Asia," acting as a key link in the global supply chain for smartphones and other electronics.

Taiwan's lack in raw materials and mineral ores has not only challenged Taiwan's industrial development, it has also served as a driving force in pushing Taiwan to become the second-best recycler in the world, following only Germany. Despite this impressive feat, Taiwan has a long way to go before it can achieve a 100 percent recycling rate. In order to truly become a "Zero Waste" nation, as it set out to do in 2005, Taiwan is taking steps to adopt the principles of the Circular Economy to their current economic model, joining the ranks of other global environmental leaders.

This paper provides a brief introduction to Taiwan and its role in the Circular Economy, followed by a close examination of the industrial waste recycling sector, through the lens of two critical non-municipal waste products—Incinerator Bottom Ash (IBA)[1] and solvent recycling—that have so far been largely ignored by the Circular Economy revolution.

Challenges of the Linear Economy

The current industrial economy exists in a linear mode of resource consumption that has not veered much from the original model first put into practice at the beginning of the industrial revolution. Since that time, we have not strayed far from this unsustainable "take-make-dispose" pattern. We "take" resources, use them to "make" consumer goods, and then "dispose" of these goods after they have reached the end of their lifecycle. While this linear model is responsible for rapid economic growth leading up to the 20th century, finite global resources are unable to continue to support this unsustainable system.[2]

Global population is expected to expand to a whopping 9.7 billion people by 2050, increasing by over 600 percent since 1900.[3] Alongside massive population growth, material consumption is showing no signs of slowing down. Quite to the contrary, a staggering 65 billion tons of raw materials entered the economic system in 2010—this number is expected to swell to 82 billion tons by 2020,[4] partly as a result of the predicted 500 million to members of the middle class.[5] According to the World Wildlife Foundation, at our current rate of resource consumption, it would take 1.5 years for the Earth to fully regenerate the resources that people use in one year. Put another way, we would need 1.5 Planet Earths in order to support our current linear economic model.[6]

Despite this severe shortage of resources, our current economic model is full of inefficiencies. For example, according to a study conducted by the Ellen MacArthur Foundation, in Europe the average car is parked 92 percent of the time, 31 percent of food is wasted along the value chain, and the average office is used only 35-50 percent of the time, even during working hours.[7]

Introduction to the Circular Economy

According to the Ellen MacArthur foundation, a circular economy is designed to be restorative and regenerative, aiming to maintain the utility and value of products, components, and materials. Driven by its ultimate goal to become a continuous cycle that preserves and enhances natural capital, policies that perpetuate the circular economy carefully manage non-renewable resources and renewable flows. Unlike current environmental policy that functions to mitigate the negative externalities often caused by a linear system, the circular economy represents a systematic shift that creates a positive and self-reinforcing development cycle, generating business and economic opportunities and environmental and social benefits.[8]

The main goal of the Circular Economy is to transform the traditional, linear economic model into a regenerative system. At its core, the Circular Economy aims to design out waste, optimize products for an eternity of disassembly and reuse, and redesign systems to incorporate these changes.

Waste Management in Taiwan

As recently as 1984, Taiwan was known for its "garbage mountains" that decorated the sides of public highways, and was thus bestowed with a rather unflattering nickname: "Garbage Island." At that time, only 2.4 percent of waste was properly treated before final disposal—the remaining 97.6 percent of waste was haphazardly dumped on public land or in isolated mountain valleys, causing a multitude of environmental and public health problems.[1]

In just twenty years, Taiwan managed to completely turn around its waste management system.[2] In order to combat rising waste problems, Taiwan implemented its first recycling program in 1988, which eventually evolved into its current form, the "4-in-1 Recycling Program". This program was designed using elements of the Extended Producer Responsibility concept, which shifts the responsibility of final disposal upon the companies that manufactured the products. Under this program, product manufacturers and importers contribute to a national Recycling Fund, which is then used to subsidize resource collection and recycling.[3] As a result of this remarkably successful program, Taiwan has boosted its national recycling rate to nearly 58 percent (including compost and recycled bulk waste),[4] following only Germany as the most efficient recycler in the world.

1 Taiwan Environmental Protection Agency (TEPA). *Linian gonggao ying huishou feqiwupin ji rongjiliang tongji* 歷年公告應回收廢棄物品及容器回收量統計 [National Report on Statistics on Recycled Products and the Recycling System]. Taipei, Taiwan, 2016.

2 "Energy-from-Waste: A Practical and Efficient Solution to the Global Waste Crisis". *ECOVE Environmental Corporation.* 2017.

3 Recycling Fund Management Board. *Resource Recycling: Evolution of the System.* 2017.

4 Taiwan Environmental Protection Agency (TEPA). *Linian gonggao ying huishou feqiwupin ji rongjiliang tongji* 歷年公告應回收廢棄物品及容器回收量統計 [National Report on Statistics on Recycled Products and the Recycling System]. Taipei, Taiwan, 2016.

For more information on Taiwan's waste management success, please refer to ECOVE's earlier publication: "Energy-from-Waste: A Practical and Efficient Solution to the Global Waste Crisis"

Benefits of the Circular Economy

The Circular Economy is expected to improve society in three important ways. First, the Circular Economy is expected to create economic value when compared to the current development scenario. For example, the Ellen MacArthur Foundation estimates that by adopting Circular Economy principles, Europe can create a net benefit of €1.8 trillion (USD 2.1 trillion) by 2030, or €0.9 trillion (USD 1.1 trillion) more than under a linear model trajectory.[9] The European Gross Domestic Product (GDP) could increase by as much as 11 percent by 2030 and 27 percent by 2050, compared with 4 and 15 percent under the current development scenario.[10]

Second, by adopting a circular economic approach, businesses could achieve material cost savings and increase their profits.[11] For example, redesigning equipment can make maintenance easier and improve energy efficiency. Small improvements across businesses can result in large payouts. Indeed, according to an analysis conducted by the World Economic Fund, the Circular Economy has the potential to add USD 700 billion in material savings to the global economy.[12]

In addition to increasing economic value and saving costs, a circular economy development path could also significantly mitigate negative environmental externalities. According to one study, greenhouse gas emissions could be 50 percent lower in 2030 compared to today's levels.[13] Other negative externalities, such as those resulting from the linear use of virgin materials and water, and the consumption of synthetic fertilizers, would also decrease. According to an analysis conducted by the Ellen MacArthur Foundation, virgin material consumption would be 24 percent lower in 2030 and 38 percent lower in 2050 compared with the current development path. Water usage in the construction industry would be 19 percent lower in 2030 and 24 percent lower in 2050, while synthetic fertilizers and pesticide use would be 45 percent lower in 2030 and 71 percent lower in 2050 compared to the current development path.[14]

The Circular Economy in Taiwan

Although there have been no economic analyses conducted to estimate the benefit a Circular Economy system would have on Taiwan specifically, the global implications of a Circular Economy are undeniably beneficial. The Taiwanese government has already recognized the benefit a transition to a Circular Economy would have on resource-scarce Taiwan, and has included the Circular Economy as a main point of focus in their "5+2 Industrial Innovation Plan".[15]

As of now, the majority of discussions on the Circular Economy have focused on recycling of consumer goods, such as plastic bottles, kitchen appliances and E-Waste. This paper does not seek to undermine the importance of these discussions; rather, we are hoping to expand the conversation to include industrial waste. While Taiwan boasted an impressive 77.4 percent recycling rate for industrial waste in 2016[16] (compared to a 58 percent[17] municipal waste recycling rate), Taiwan also generated nearly three times more industrial waste than m unicipal waste (18,973,038 metric tons[18] versus 7,411,184 metric tons[19]). As a result, the amount of non-recycled industrial waste amassed to a colossal 3,238,882 tons[20]—not much less than non-recycled municipal waste in Taiwan.[21]

In Taiwan, a large proportion of this industrial waste originates from rapid growth in the high technology and electronics industry. Industrial waste products from the high tech industry have kept pace alongside this massive expansion, and are accumulating faster than current recycling mechanisms are able to handle. This paper will attempt to draw attention to these critically important industrial waste products from the standpoint of the Circular Economy.

There is enormous potential for improvements to the industrial waste recycling system in Taiwan—3,238,883 tons of potential, to be exact. This paper specifically focuses on waste solvent and incinerator bottom ash, while also including three short case studies on waste acid, ammonia nitrogen wastewater, and sludge, with the intention of providing a well-rounded perspective on the potential the Circular Economy can have on waste products generated by the high technology and electronics industry.

This paper will closely examine each of these sectors, first providing background information on the current state of affairs and an introduction to current policies put in place to regulate each of these sectors. Thereafter, each section will briefly outline the obstacles each of these sectors face in achieving a 100 percent recycling rate, followed by a short list of potential policy options to help overcome these obstacles.

> ***"Population is expanding, demand for new products isn't slowing down. If we want to keep producing materials, we need to gain control of our raw materials—the Circular Economy offers this control. Products become raw materials, which become products, which then become raw materials...this is a system that can go on forever."***
>
> —Qi-Da Zhang, Deputy CEO of the Taiwan Green Productivity Fund

1 Incinerator bottom ash is the by-product from waste incineration, and contains a combination of municipal, commercial, and non-hazardous industrial waste. Even though IBA also contains municipal waste products, we are considering it as a non-municipal waste product for the sake of simplicity.

2 "The Case for a Circular Economy in India". *The Ellen MacArthur Foundation*. 2016.

3 The United Nations Department of Economic and Social Affairs. *World population projected to reach 9.7 billion by 2050.* 2015.

4 World Economic Forum. *Towards the Circular Economy: Accelerating the scale-up across global supply chains.* 2014.

5 Kharas, Homi. "The unprecedented expansion of the global middle class: An update". *Brookings Institute.* February 28, 2017.

6 The World Wildlife Foundation. *Living Planet Report 2012: Biodiversity, biocapacity and better choices.* 2012.

7 "Cities in the Circular Economy: An Initial Exploration". *The Ellen MacArthur Foundation.* 2017.

8 "The Case for a Circular Economy in India". *The Ellen MacArthur Foundation.* 2016.

9 "Towards a Circular Economy: Business Rationale for an Accelerated Transition". *Ellen MacArthur Foundation.* 2015.

10 "Towards a Circular Economy: Business Rationale for an Accelerated Transition" *The Ellen MacArthur Foundation.* 2015.

11 "The Case for a Circular Economy in India" *The Ellen MacArthur Foundation.* 2016.

12 World Economic Forum. *Towards the Circular Economy: Accelerating the scale-up across global supply chains.* 2014.

13 "Cities in the Circular Economy: An Initial Exploration". *The Ellen MacArthur Foundation.* 2017.

14 "The Case for a Circular Economy in India". *The Ellen MacArthur Foundation*. 2016.

15 "The 5+2 Industrial Transformation Plan". *Taiwan Business Topics.* 47, no. 5 (2017).

16 Wu Sheng-Zhong. “Feiqiwu Guanli MolaiZhanwang: Cong Ziyuan Xunhuan Zhi Xunhuan Jingji” 棄物管理未來展望：從資源循環制循環經濟. [Prospects for the Future of Waste Management: from Resource Recycling to the Circular Economy]. *Taiwan Green Productivity Fund.* 2015.

17 Taiwan Environmental Protection Agency (TEPA). *Linian gonggao ying huishou feqiwupinji rongjiliang tongji* 歷年公告應回收廢棄物品及容器回收量統計 [National Report on Statistics on Recycled Products and the Recycling System]. Taipei, Taiwan, 2016.

18 Taiwan Environmental Protection Agency (TEPA). *Shenbao Shiye Feiqiwu Chanshengliang.* 申報事業廢棄物產生量 [Reported Industrial and Commercial Waste Quantities] 2016.

19 Taiwan Environmental Protection Agency (TEPA). *Zhixing Jiguan Lese Qingli Gaikuang.* 執行機關垃圾清理概況 [A Survey of the Implementation Mechanisms for Waste Treatment]. 2017.

20 Taiwan Environmental Protection Agency (TEPA). *Shiye Feiqiwu Shenbao Tongji* 事業廢棄物申報統計 [Statistics for Reported Industrial and Commercial Waste]. 2017.

21 In 2016, 4,271,178.81 tons of Municipal Solid Waste (MSW) entered waste incineration facilities. See: Taiwan Environmental Protection Agency (TEPA). *Daxing Lese Fenhuachang Caozuo Yingyun Qingxing* 大型垃圾焚化廠操作營運情形 [Large-Scale Waste Incineration Operations]. 2017.

Case: Waste Acid

Background

Etching chemically removes material from the surface of the wafer that could otherwise short out a circuit or obstruct movement of the micromechanical device, and is a critical step in the semi-conductor manufacturing process. Semi-conductor manufacturers rely on large volumes of hydrochloric acid, hydrofluoric acid, and phosphoric acid to complete the etching process. Following use, semi-conductor manufacturers are responsible for arranging the proper treatment and final disposal of these waste acids—this is an extremely important step in the process, as mistreatment or improper disposal can result in serious environmental pollution.

Current Scope of Treatment and Recycling

Waste acid can be treated by adding a neutralizing alkaline solvent—this process transforms waste acid into a non-hazardous waste product, allowing it to be safely disposed. Waste acid can also be treated by adding other chemicals to create a useful chemical by-product. For example, waste hydrofluoric acid is often treated by adding calcium hydroxide (slaked lime) to create calcium fluoride sludge.

Waste acid can also be recycled and used to replace raw materials in other industrial and production processes. For example, aluminum sulfate, ferrous sulfate, and ferrous chloride can be used to treat wastewater, and fluorite can be used in steel making to lower the melting point of raw materials to remove impurities.

Current Problems with the Waste Acid Recycling Sector

Waste acid can be treated to an industrial-waste standard to be useful for applications such as wastewater treatment and steel making, which has been relatively effective at reintroducing waste acid into the supply chain. However, as the electronics industry has experienced massive growth in the last several years, volumes of waste acid are increasing faster than demand for industrial-waste standard acid. Although an expanding electronics industry also means that demand for electronics-grade acid has increased, treating waste acid to electronic-grade quality results in a final product that is more expensive than acid purchased directly from a chemical supplier. The high technology and electronics industry tend to prefer the most cost-effective route, resulting in a large volume of waste acid that cannot be reintroduced into the electronics supply chain.

While investment in research to develop less expensive and more effective recycling technologies would help fix this problem, so far there has been little development in this direction.

Potential Solutions

In order to solve this problem, we recommend the government further subsidize research to develop more economical production processes in order to treat waste acid to its original standard, and closing the loop in the lifecycle of electronic-grade acids.

Furthermore, the establishment of a secondary market for recycled acid would help facilitate communication between waste acid treatment providers and manufacturing companies that require acid in their production process. This could better connect supply of recycled acid with demand, increasing the percentage of waste acid that re-enters industrial and production processes every year.

Incinerator Bottom Ash

Background

Incinerator Bottom Ash: A Sustainable Building Material

In this paper, Incinerator Bottom Ash (IBA) refers to one of the main by-products of thermal waste incineration, mostly composed of incombustible materials that represent the largest percentage of the solid waste stream, including rock, stone, concrete, glass, and metal. Incombustible materials leave behind a substantial amount of IBA—for each incoming ton of waste, about 180-250 kg of IBA is generated.[1] IBA is a sustainable replacement for aggregate material—sand, gravel, or crushed stone—used in foundation material or to construct roads or noise barriers. In Taiwan, IBA is typically used to replace unsustainably extracted aggregate material that originates from naturally occurring limestone or sandstone, nonrenewable raw materials that require thousands of years to replenish.

In contrast, there is a steady stream of IBA produced in Taiwan every day. Despite having both the technology and the capacity to recycle 100 percent of IBA every year, over 30 percent of IBA was deposited in landfills in 2016.[2] As Taiwan is a small mountainous island-nation, land scarcity is a very real and present issue. As landfill space continues to dwindle, Taiwan needs to be actively promoting opportunities to salvage valuable resource.

Replacing natural aggregate material with IBA solves both of these problems—not only does this process save Taiwan's valuable land resource, it also reduces the extraction of non-renewable resources.

"Bottom Ash is Toxic" — A Common Misconception

Stemming from the early days of towering piles of rotting waste that tainted the landscape of the 1980s, and frequent reports of improperly disposed industrial waste that contaminated ecosystems and wreaked havoc on public health, Taiwanese people are very familiar with the negative side effects of mismanaged waste. Partly due to this historically influenced attitude towards waste treatment, Taiwanese are generally apprehensive about reports of IBA being used in public works projects, associating IBA with the piles of untreated garbage that seep dangerous heavy metals into soil and groundwater.

As waste incinerators treat all different kinds of waste, IBA contains a wide variety of minerals and metals, mostly aluminum, silicon, sodium, and calcium. However, IBA is carefully treated before it is repurposed for use in construction projects, ensuring heavy metal and dioxin levels stay well within government regulations. Indeed, since Taiwan began repurposing IBA over ten years ago, rigorous heavy metal and dioxin standards have ensured recycled IBA has not contaminated groundwater, soil, or otherwise harmed local populations. Under current treatment standards, IBA reaches a high enough standard to be used in a wide range of construction activities; however, due to its poor public image, many construction companies opt to use unsustainably sourced raw materials instead of recycled IBA to avoid public backlash against construction projects.

New Policies

Although IBA has been treated to a safe level since the inception of the IBA recycling program, public opposition to IBA recycling is still quite intense, mostly due to IBA's particular odor, and the occasional presence of impurities. In order to appease the public, the Taiwan Environmental Protection Agency strengthened IBA regulation standards in July 2017.[3] These new regulations are based on the highly effective IBA recycling systems of countries such as Denmark, where 99 percent of IBA is repurposed every year.[4] This policy is meant to tackle the two main points of contention regarding recycled IBA: odor and impurities in the final product.[5]

Taiwan's new standards require IBA to undergo additional treatment before use in construction projects. IBA treatment providers can choose to implement stabilization, wet or ageing treatment[6] before use in construction products, in order to diminish IBA's distinct odor. Although the presence of an unusual odor does not harm the surrounding environment or water sources, it can arouse suspicion among local residents who may not be familiar with IBA's extensive treatment process.

An advanced sorting process is a second important component of the new policy, in an attempt to limit the presence of impurities, based on the highly effective system of the Netherlands.[7] Advanced sorting not only reduces the presence of impurities in the final product and increases the rate of metal recovery, it also improves the overall quality and can result in higher quality sustainable building materials. Taiwan has recently implemented new measures that are pushing IBA recovery in this direction, encouraging IBA treatment centers to sort IBA particles based on grain size, and working to implement more advanced metal sorting technology.

Setbacks for Incinerator Bottom Ash Recovery

Incinerator Bottom Ash (IBA) has been unable to reach a 100 percent recovery rate in Taiwan, due to two highly addressable problems. This section will briefly introduce each of these problems, while the following section will offer policy recommendations that help to solve these problems.

1) Public Opposition

Despite rigorous standards that have ensured IBA is treated to a safe level, there is still large public resistance to the use of recovered IBA in construction projects. This opposition has been so intense that projects have been delayed, or even cancelled. As a result, construction companies that use recovered IBA are reluctant to share this information with the public in order to ensure projects are completed on time.

2) High Cost

In order to achieve the high standards regulated by the government, IBA must first undergo a rigorous, time-consuming, and expensive treatment process before it can be used in construction projects. To avoid this extra cost, many IBA treatment facilities treat IBA to the lowest acceptable standard, and dispose of it in a landfill.

In order to be approved for use in construction materials, IBA must be rigorously treated. This treatment process raises the final cost of IBA—as such, unsustainably sourced raw materials extracted from vulnerable areas are much less expensive than sustainably recovered IBA. While mandates on municipalities to utilize IBA in public works projects helps absorbs this extra cost, there are few mechanisms to encourage the use of IBA in construction projects in the private sector, as businesses are inclined to use the most cost-effective materials in their projects. As a result, a large portion of IBA is not reintroduced into the supply chain, and municipalities are forced to dispose of it in landfills.

3) Government Standards

Although there is considerable demand for construction materials in Taiwan, this demand can only be met by unsustainably sourced raw materials, as current standards limit IBA for use as a replacement for aggregate material used in coarser applications, such as road foundations or noise barriers—for which there is relatively limited demand. IBA is restricted to this relatively narrow category due to inconsistency in final quality. While Taiwan has recently strengthened IBA standards, current enforcement policies prevent IBA from being consistently treated to a high-quality level. For example, current inspection methods only ensure the quality of a relatively small sample of total IBA, as IBA treatment providers are only required to submit a small sample for evaluation.

Current IBA standards are not rigorous enough to ensure consistency in the final quality of IBA, limiting its potential for construction projects. This IBA can accumulate into large amounts of low quality construction material, for which there is little demand, and eventually finds its way into a landfill.

Policy Suggestions

As Taiwan is an island-nation with limited natural resources, it has been eager to adopt Circular Economy concepts in its policies. However, it has failed to include IBA recycling as part of this policy. This is rather surprising, as IBA recycling achieves the core objective of the circular economy: transforming waste into resources. Treating IBA and re-using it for construction and infrastructure purposes not only preserves Taiwan's precious (and scarce) land resource but also reduces the demand for nonrenewable building materials.

We offer the following suggestions to improve the public image of IBA, and allow it a space in discussions related to the Circular Economy.

1. Create Greater Public Awareness

"Environmental preferable products", including building materials, are defined by the United States government as products that have a "lesser or reduced effect on human health and the environment when compared to competing products that serve the same purpose."[8] Although aggregate material recovered from a steady stream of waste products prevents the depletion of non-renewable resources, and is treated to a high enough standard to ensure it will not adversely affect the surrounding environment, it is not considered a sustainable material. Green construction companies instead favor materials such as sustainably sourced timber; concrete reinforced with timber, bamboo or natural fibers; and geo-textiles made from crops.

One of the biggest reasons IBA has yet to join the ranks of sustainable materials is a public misconception of IBA, and a lack of awareness about the positive effects recycled IBA can bring to society. Public awareness is critical for inspiring change. Where the term "green architecture" did not exist as recently as the 1980s,[9] current professionals in architecture estimate over 60 percent of their projects will be green by 2018.[10] Respondents attribute this rapid increase in green architecture to be mainly driven by intense demand from the market.[11] If the government hopes to not only gain public acceptance of recycled IBA, but create a national movement driving for the use of sustainable IBA in public works construction projects, it needs to vigorously promote IBA recycling to improve public awareness.

In order to drive public support for IBA recycling, the government should first work to widely publicize efforts made in strengthening current policy on IBA recycling—this will help raise awareness that IBA standards are completely in harmony with environmental and public health. To take it one step further, we recommend the government set a national goal for IBA recycling, similar to the Green Deal in the Netherlands. In this deal, all operators of Waste-to-Energy plants signed a "Green Deal: Bottom Ash" with the Dutch government, promising to a) recover at least 75 percent of non-ferrous metals larger than 6 mm present in IBA and b) ensure that by 2020 IBA granules are clean enough to be 100 percent applied for useful purposes.[12] Doing so has not only helped Dutch IBA treatment providers improve the quality of their final product, and increased possibilities for reuse by emphasizing IBA's crucial role in the Circular Economy, it has also garnered public support for IBA recycling, improving the public image of IBA.

It is the government's responsibility to increase public awareness about policies and programs that improve the public welfare. It is not impossible to completely change the public perception of projects that had previously been viewed as distasteful. The city of Copenhagen, for example, managed to transform a long-time sufferer of poor public image—waste incineration plants—into a centrally-located recreation center, equipped with jogging paths and a ski slope (See: Turning Garbage into Gold). Similar to Copenhagen's brilliant plan to alter the public perception of waste incineration plants, citing the benefits of renewably generated electricity and heat, the Taiwanese government needs to spread information about the positive effects recycled IBA can have on Taiwanese society.

Copenhagen: Turning Garbage into Gold

Energy-from-Waste plants, more commonly known as waste incinerators, are long sufferers of a poor public image. However, Denmark has given them a chance to gain favor in the public eye. The city of Copenhagen opened an international tender between the world's leading architects to construct an Energy-from-Waste facility in the heart of Copenhagen. The ultimate goal of the project was to increase the sustainable value of the Energy-from-Waste plant by offering electricity and heating to the residents of Copenhagen; however, the Danes took this concept one step further—they wanted to turn an Energy-from-Waste plant into a leisure destination. As part of the proposed project features, the city of Copenhagen required at least 30 percent of the building to be used for recreational purposes.[1]

Bjarke Ingels, an internationally acclaimed architect, won the international tender with his plan to construct an all-year ski slope on the roof of the waste incinerator. Running paths and recreational courts are also included as part of the design.

This project proves to the world that waste treatment can contribute to society in more ways than one, simultaneously treating waste, generating electricity, providing hot water, and, now, offering a new place to spend the weekend—without the slightest negative impact on air quality.[2]

1 A Waste Incinerator with a Rooftop Ski Run". *Foresight: Climate and Energy Business.* July 7, 2017.

2 "Copenhill—A Danish Waste to Energy Icon is Born" *Waste Management World.* September 14, 2014.

2. Include Recovered Incinerator Bottom Ash in National Recycling Targets

Taiwan boasts a nearly 50 percent municipal recycling rate,[13] closely following Germany at 57.6 percent.[14] However, as recycled material definitions differ across borders, cross-country comparisons of recycling rates are rather difficult and not always accurate. For example, Germany and Wales respectively include metal and aggregate material recovered from incinerator bottom ash—neither of which are counted towards Taiwan's national targets.

According to a study conducted by the Local Government Association (an organization which comprises local authorities in England and Wales), if IBA recycling were appropriately verified and counted in England as recycling, it could contribute up to an additional seven percentage points to the recycling rate by 2020.[15] Reusing IBA for construction purposes embodies the concept of the circular economy, as it transforms a waste product into a valuable resource.

As such, other than public distaste and an overly narrow definition of recycling,[16] there is little reason that aggregate recovered post-incineration should not be included in national recycling goals. If Taiwan were to include recycled IBA in national recycling targets, Taiwan would not only add percentage points to the national recycling rate and bring us one step closer to "closing the loop" of waste management, it would also further galvanize public support for IBA recycling.

3. Subsidize Incinerator Bottom Ash

As IBA undergoes a rigorous treatment process before it can be used in construction projects, the price of IBA is higher than unsustainably sourced raw materials. However, the market price of IBA doesn't reflect the benefits repurposing IBA brings to society, including saving landfill space and preventing the depletion of non-renewable resources. As such, we recommend the government use subsidies to deflate the price of IBA, so that the true value of IBA is reflected in the price.

4. Improve Incinerator Bottom Ash Regulations

As mentioned earlier, increasing demand for construction materials is putting pressure on non-renewable raw material deposits, as standards limit IBA recovery to coarser applications such as road foundations and noise barriers—for which there is limited demand. While Taiwan has recently improved government regulations, these new regulations still aren't enough to allow IBA to be recovered for use in a large portion of construction projects. Furthermore, the government is falling short on enforcement, resulting in considerable inconsistencies in IBA standards.

In order to raise standards to a level to which IBA can be repurposed for a wider variety of construction projects, we recommend Taiwan implement policy similar to the Green Deal in the Netherlands. Under this plan, the Netherlands has set a goal to ensure that 100 percent of IBA granules are clean enough to be used for useful purposes by 2020. This new policy encourages IBA treatment providers to develop new treatment methods to ensure IBA is treated to a high enough standard to reach the Green Deal's ambitious goals.[17] This policy has been successful partly due to the efforts of the Dutch government, that has conducted thorough inspections throughout the course of the new program.

A similar policy in Taiwan could increase consistency in IBA standards, and increase the overall quality to a high enough standard so that IBA can be reused for a wider range of construction applications. Doing so would not only prevent the disposal of useful building material into landfills, it could also reduce the extraction of non-renewable raw materials. In order for this policy to be effective, we recommend the Taiwanese government take care to not only create the legislation, but to also conduct more stringent audits for IBA treatment providers across the country.

1 "IBA from WTE Plants: Metal Recovery and Utilization" *International Solid Waste Association.* 2015.

2 The IBA recycling rate in 2016 was 66.8 percent. See: "Huang, Yu-Lin. (2017) "Fenhua Dizha Jinhua Zailiyong Guanli" 焚化底渣進化:再利用管理 [The Evolution of Incinerator Bottom Ash: Recycling Management]. *Taiwan Construction Research Institute.* 414: 1-75."

3 "Lese Fenhuachang Fenhuadizha Zailiyong Guanli Fangshi Xiuzheng Zongshuoming" 垃圾焚化廠焚化底渣再利用管理方式修正總說明 [Explanation of Revised Methods for Incinerator Bottom Ash Recycling Management]. *Taiwan Environmental Protection Agency.* 2017.

4 2014 Figure. "IBA Fact Sheet" *Confederation of European Waste-to-Energy Plants.* 2014.

5 Including paper fragments, metal impurities, and oversized particles.

6 If IBA treatment providers use the "ageing treatment" to treat IBA, they must let IBA sit exposed to the elements for at least 30 days before it can be used in construction projects.

7 Born, Jan-Peter. "Dutch Green Deal IBA (IBA): Status 2016." *Dutch Waste Management Association.* 2016.

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12 Government of the Netherlands. Green Deals *Overview: Progress report Green Deals 2011-2015.*

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14 Eurostat. *Waste Treatment*. 2014.

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16 Recycling is the process of converting waste materials into products, materials, or substances, while Recovery refers to waste products being used to serve a useful purpose by replacing other materials (i.e. heat waste from incineration being used for electricity, or IBA being used to replace natural aggregate materials).

17 Government of the Netherlands. Green Deals *Overview: Progress report Green Deals 2011-2015.*

Case: Sludge

Background

Sludge is the solid by-product created following either organic or chemical wastewater treatment. It is categorized into organic, inorganic and mixed organic/inorganic sludge. As most industries generate wastewater in some capacity, proper sludge treatment and management touches all sectors of the economy.

Current Scope of Treatment and Recycling

Following treatment, sludge can be used in several different ways, including:

1. As fuel: Organic sludge can be used as a supplementary fuel in thermal power plants.
2. As building material: Inorganic sludge or mixed organic/inorganic sludge can be used as building materials.
3. As fertilizer: Organic sludge can be processed to create fertilizer and cultivate soils.
4. Restoration: Calcium fluoride sludge can be processed back into its original state (fluorite).

Problems with the Sludge Recycling Sector

Although a large amount of sludge is produced every day, demand for sludge in production is relatively limited. A significant amount of sludge cannot find a way back into the production line, and is disposed of as waste.

Even though the use of sludge as supplementary fuel in thermal power plants can both reduce cost and reduce Taiwan's reliance on imported fuels, most power plant managers are reluctant to add sludge as a supplementary fuel. This is because government regulations require coal-fired power plants to register fly ash (a by-product of coal-fired power plants) with the Environmental Protection Agency before they can recycle it—but only if they add organic sludge as a supplementary fuel. If coal-fired power plants burn purely coal to generate electricity this additional procedure is not required.

Furthermore, current legislation completely restricts the use of sustainably-sourced organic sludge as fertilizer. Instead, many farmers purchase expensive chemical fertilizers from agricultural companies, a significant portion of which is imported from abroad.

Solutions

The government should include circular economic principles in the sludge recycling sector and encourage the re-use of sludge across industries, in order to reduce the amount of sludge wasted every year.

For instance, if the government were to follow the example of other countries and regulate that a certain percentage of fuel from thermal power plants required supplementary fuel, it could both prevent the waste of a large portion of waste sludge, and also reduce Taiwan's dependence on imported fuels.

Solvent Recycling

Background

Introduction

In the 1980s in Taiwan, a staggering 97.6 percent of waste failed to receive proper treatment prior to disposal.[1] Improperly disposed industrial waste, including waste solvent, caused rampant environmental and health problems at the time. As such, when Taiwan began strengthening waste management regulations, the main point of focus was sanitation and public health.

Taiwan's waste management policies originated out of a need to execute control over unscrupulous waste treatment providers. Policies were designed to punish businesses or waste treatment companies who failed to comply with clearly defined standards, executing safe waste treatment policies using "command-and-control" style regulations.

These policies have been continuously modified to better control illegal waste dumping by increasing standards, implementing harsher punishments, and strengthening monitoring mechanisms. Indeed, Taiwan was one of the first countries to require waste producers to track and report their waste—from generation to final disposal. While this method has been incredibly effective at reducing incidents of illegally dumped waste, it lacks policies designed to spur significant innovation in waste recycling and recovery—one fifth of industrial waste fails to be reintroduced into the supply chain every year.[2]

Solvents are used across industries to dissolve or dilute other substances or materials, typically treated and disposed of as waste effluent following use. In Taiwan, most solvent recycling initiatives begin at the industrial level, as businesses are realizing that treating and reusing solvent can both save waste treatment fees, and also reduce expenditures on solvent purchasing.

The following section will briefly introduce the current state of industrial waste recycling in Taiwan, in which solvent plays a crucial role. Afterwards, this paper will discuss current setbacks in achieving a 100 percent solvent recycling rate, and offer policy solutions to help overcome these setbacks.

Industrial Waste Recycling in Taiwan

In 2008, Taiwan officially implemented a policy to assist the development of Environmental Science and Technology Parks (ESTPs), focusing on the development of green industry, including industries that recover and convert resources into new products.[3] In order to encourage industries to participate in the ESTPs, approved companies were offered a 50 percent subsidy for rent, in addition to subsidies for production and Research and Development.[4] There are currently four Environmental Science and Technology Parks in Taiwan. While each of these parks is generally focused on a certain sector of industry, they were designed to encourage cross-industrial cooperation and re-use of waste products. These ESTPs have had a significant positive impact on the economy and the environment, creating 2,692 jobs, generating nearly USD 1.3 billion in annual revenue, and recycling 2.57 million tons of waste.[5]

At the same time, many companies in both traditional Science and Technology Parks and Industrial Parks are organically establishing industrial symbioses, reusing waste chemicals and solvents in their own factories, or treating them internally and selling them to recycling companies (See: TSMC). TSMC, the largest semi-conductor manufacturer in Taiwan, saved over NTD 500 million (USD 167 million) by reducing use of inputs, including solvents and chemicals, and generated an additional NTD 420 million (USD 140 million) in selling recycled chemicals and other wastes.[6] The potential savings and additional revenue possibilities from chemical and solvent recycling are encouraging more waste producers to find a market for their waste products, and to treat waste on-site.

While Taiwan has already made great strides in advancing industrial waste recycling, there is still considerable room for improvement. The annual industrial recycling rate in Taiwan is just over 77.4 percent[7]—over 40 percent of which is steel slag and coal ash.[8] In other words, nearly a fifth of industrial waste fails to be reintroduced into the production line, wasting millions of tons of potential resources every year.[9]

TSMC and Solvent Recycling

TSMC was the first semi-conductor manufacturer to re-introduce sulfuric acid, a by-product of their wafer production line, into other internal uses. Specifically, TSMC reused sulfuric acid to eliminate ammonia gas emissions. In doing so, it saved 46,889 tons of sulfuric acid purchases, while also reducing ammonia concentrations in effluent waste. This project was such a success, that TSMC began implementing internal solvent recycling schemes at other parts of the production line. In total saving NTD 503 million (USD 16 million) by reducing solvent and chemical waste, while also generating over NTD 420 million (USD 14 million) by reselling recycled chemicals and other wastes.[1]

The TSMC example demonstrates the significant environmental and economic impact circular solutions can have on an individual business alone. If these principles were applied across an entire nation, one would expect these benefits would multiply.

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Setbacks for Solvent Recycling

The solvent recycling sector has the potential to reintroduce solvent into production processes across industries. Governments around the world are playing a crucial role in opening communication channels across industries and disciplines, opening the door to more industrial waste recycling populations—in industrial parks across the world, cross-industrial cooperation is increasing the rate of waste solvent recycling (in addition to other industrial waste products).

The Taiwanese government can intervene in industrial waste recycling to help raise the industrial recycling rate even higher than its current 77.4 percent. Qi-Da Zhang, the Deputy CEO of the Taiwan Green Productivity Foundation, asserts that the main reasons for Taiwan's inability to raise its recycling rate and diversify recycling is due to high cost, poor interdisciplinary communication, an over-supply of small- and medium-scale recycling companies, and a lack of pro-recycling incentives in current policy. This section will briefly introduce each of these problems, while the following section will offer solutions in the form of policy recommendations.

1) High Cost

As Taiwan is home to some of the most sophisticated recycling technology in the world, the biggest hindrance to improved solvent recycling rates is not a technological one, but a monetary one. The electronics industry in Taiwan is responsible for consuming a large amount of solvent every year—in order to recycle this solvent to electronic-grade quality, solvent treatment providers must make a substantial investment in equipment, technology, and time. As the electronics industry is changing and developing at a rapid pace, any related recycling technology must keep pace in order to stay relevant. Many solvent treatment providers simply cannot afford to keep up.
If solvent were to be treated using more advanced recycling processes, the final price would be relatively high compared to solvent purchased directly from a chemical company. As a result, most waste solvent treatment providers treat solvent to the lowest acceptable standard, and then dispose it as waste effluent. This not only wastes potentially valuable solvent, it also hinders developing in the recycling technology sector.

2) Poor Interdisciplinary Communication

In a functioning system, there should be extensive communication between key actors, including government officials, universities and research institutions, industry managers and environmental services companies. However, Taiwan lacks the institutional mechanisms to encourage interdisciplinary communication. Poor access to information at the company-level hinders innovation, indirectly affecting economic growth.

Furthermore, without an effective communication forum, government officials lose a valuable opportunity to hear feedback from the business sector (industry managers and environmental services and recycling companies) and the academic sector (universities and research institutions). Without this feedback, ineffective policies remain unchanged, further holding back development.

3) Limited Resources for Pollution Control and Research and Development

In Taiwan, there are over a thousand waste treatment and recycling providers.[10] Over 60 percent of these companies operate on a small-scale (1-5 employees).[11] While competition can help regulate a fair price and prevent a handful of companies from controlling the market, the excessive competition in the recycling business has arguably caused more harm than good. In order to remain competitive, recycling providers have dropped their rates to the lowest possible level, barely scraping a profit. These low profit margins leave very little room for investment in pollution prevention, which has resulted in several incidents of improperly managed waste.[12] Furthermore, there is minimal budget allocated for Research and Development, stagnating potential for increasing efficiency and discovering new, more effective methods for recycling.

4) Disposal-Focused Industrial Waste Policies

As mentioned in the previous section, Taiwan's industrial waste treatment policies evolved from a need to execute control over waste treatment providers. As such, Taiwan's current policies exist to ensure that industrial waste is disposed of safely, without jeopardizing environmental or public health. Any company that fails to comply with these standards is fined. This "command-and-control" method of waste disposal has been very effective in reducing incidents of illegally disposed waste. However, there are no provisions that encourage industrial waste recycling, or improve the efficiency of treatment processes that already exist. This type of regulation method fails to spark innovation in industrial waste recycling, which has prevented Taiwan from achieving its Zero Waste goal.

Policy Suggestions

1. Encourage Industrial Synergies

As raw materials become more expensive and less available, industries are searching for new ways to turn waste into valuable resources and improve their bottom line. To this end, more and more companies are engaging in By-Product Synergy (BPS) projects. These projects match waste, or under-utilized resources, from one facility with potential users at another facility to create new revenues or savings, and reducing negative environmental and social impact caused by excess waste. By-product synergies have been demonstrated to reduce waste and cut costs at industrial parks around the world. The United States Business Council for Sustainability has established a database to facilitate by-product synergies, resulting in massive savings across industries and significant reductions in waste. The Greater Houston Region alone has experienced USD 4.5 million in annual cost savings and an annual reduction of 32,000 metric tons of non-renewable resources.[13]

As implementing a successful recycling program crosses disciplines and industries, many governments have established "support organizations" to facilitate communication between key actors, including industry managers, recycling companies, environmental service professionals, government officials, universities and research institutions. These initiatives have been widely successful, and have served the essential role of establishing trust and spreading accurate information about the benefits and cost-savings of recycling.[14] Indeed, lack of trust or communication across firms and a perception of high costs are two of the major hurdles to establishing successful by-product synergies.[15]

China became the first country to take this concept one step further and establish national standards for Eco-Industrial Parks in 2006,[16] which are composed of multiple industries working together to reintroduce waste into the supply chain, based on the idea that "one man's trash is another man's treasure". China has been particularly successful at opening interdisciplinary communication channels between key actors by establishing support organizations, such as the Chinese Association of the Circular Economy (CACE). CACE encompasses key actors from governments, industrial parks, research institutions and universities.[17] This has played a critical role in coordinating key actors to work together to implement circular thinking in industrial parks.

Taiwan has already made the first step in implementing policy to promote by-product synergies between various industries through its promotion of Environmental Science and Technology Parks (ESTPs). As mentioned above, these ESTPs have both resulted in tangible improvements to the local economies, while also reducing waste. The next step is to expand the conversation to other key actors in recycling. As demonstrated in the US and China examples, encouraging communication between key actors is essential to increasing recycling efficiency and implementing circular thinking in the industrial sector, thereby helping industries save material resources and improve their bottom lines.

The Taiwanese government should establish support organizations composed of key actors in recycling—governments, industry owners, recycling and environmental service companies, research institutions and universities all have valuable insight to bring to the conversation on waste recycling. These organizations can help drive innovation, establish trust, and promote new policies. Furthermore, it creates a forum wherein non-governmental actors can offer feedback and suggestions to the government, further strengthening policies and regulations.[18]

2. Facilitate Communication between Recycling Companies

In Taiwan, industrial waste recycling is a big business, and is growing even bigger—the total production value of recycling and reuse of industrial waste grew from NTD 24.9 billion (USD 829 million USD) in 2002 to NTD 65.9 billion (USD 2.2 billion) in 2014.[19] Partly due to the huge opportunity in treating and recycling industrial waste, more and more companies started entering the recycling business to meet this demand—the number of recycling firms has ballooned from a mere 100 firms in the 1980s and 1990s[20] to over 1,400 resource management companies in operation as of 2014.[21] Of all these, 60 percent operate on a small-scale (1-5 employees).[22]

As Taiwan's waste products are treated by hundreds of different recyclers, the per-unit cost of recycling is relatively high compared to a system with only a handful of firms. Due to the small-scale of business and the low profit margins, these companies lack the financial and technical resources to invest in pollution prevention at their sites, which has resulted in several incidents of improperly managed industrial waste.[23]

As reported in the previous section, a collaborative environment between industries has been demonstrated to increase innovation, productivity, and profits. We suggest that Taiwan further apply this principle to the recycling and environmental services industry specifically, establishing a supportive organization to facilitate communication between recycling and environmental services companies. This would serve the purpose of connecting reliable and financially stable environmental firms, with smaller, financially insecure firms, encouraging collaboration on recycling techniques and technology, and eventually improving the efficiency, scope, and profitability of the recycling industry in Taiwan.

3. Fund Innovation

In 2005, Taiwan set its own Zero Waste goal, and has recently committed to adopting the principles of the Circular Economy into current legislation. Innovation is a key driver to productivity in all industries, including recycling. If Taiwan hopes to increase productivity in the recycling sector, it will need to make strides in creating opportunities for innovation. Public investment in science and basic research can play an important role in furthering innovation.

Industrialized economies around the world use a mix of direct and indirect instruments such as tax credits and support for innovative clusters.[24] The Fraunhofer

Society in Germany is a model example of this phenomenon. It operates in a dynamic equilibrium between application-oriented fundamental research and innovative development projects, boasting an average of three invention disclosures per working day, and more than two patent applications every working day.[25] While most of their funds come from private enterprises, a substantial (30 percent) sum still originates from the public sector.[26]

Victoria, Australia operated under a similar principle, differing in the execution. In order to accelerate reductions in the volume and hazard of hazardous waste, an estimated AUD 30 million was made available over the course of four years for research and development projects that researched a new material for reuse in a product, or conducted testing to obtain new information on a sustainable solution.[27] Several dozen companies applied for the project, resulting in dozens of successful innovations to divert waste from landfill.

While Taiwan already has some policies in place to fund innovation in research, we suggest Taiwan further divert resources towards this critically important sector. In order to do so, we recommend the Taiwanese government increase public subsidies and grants that fund research and encourage experimentation. The introduction of public funds into research could uncover new and more efficient recycling methods, positively impacting the Taiwanese society, environment and economy—improving the profitability of the recycling sector, reducing the cost of industrial waste recycling, and increasing the volume of recycled material.

> ***"Our policies define 'waste', but they don't define 'resources'. If something isn't a resource, then it's a waste. We need to turn around this thinking--instead of separating products into 'waste' and 'resources', we need to separate products into different types of resources."***
>
> —Qi-Da Zhang, Deputy CEO of the Taiwan Green Productivity Fund

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Case: Ammonia Nitrogen Wastewater

Background

Ammonia nitrogen wastewater is a very common effluent generated across industries, from electronics manufacturing to agriculture. As these industries, especially the electronics industry, continue to expand, ammonia nitrogen wastewater is likely to continue to increase in volume in the coming decades.

In order to avoid improper treatment and disposal of ammonia nitrogen wastewater, which can result in significant damage to environmental and public health, government policies regarding ammonia nitrogen wastewater treatment and disposal have continuously been modified and strengthened over the last several years. Industries that produce this waste product must adhere to stringent regulations, and carefully arrange this waste product's final treatment and disposal.

Current Scope of Treatment and Recycling

Ammonia nitrogen wastewater treatment varies depending on the industry. Most industries produce low-concentration ammonia nitrogen wastewater, which can be either biologically or chemically treated, and then safely disposed.

Electronics manufacturing industries generate highly concentrated ammonia nitrogen wastewater, and also produce a large quantity of waste sulfuric acid. As such, electronics companies are well-positioned to conduct internal recycling of both of these products, which chemically react to create ammonium sulfate.

Ammonium sulfate can be further recycled into solutions that can be used across industries. By adding calcium hydroxide (slaked lime) to ammonium sulfate, recycling companies can create ammonia solution and calcium sulfate. Calcium sulfate occurs as an odorless white powder that can be used for as a building material, in addition to many other purposes that span across various industries.

Problems with the Ammonia Nitrogen Wastewater Recycling Sector

There is not enough demand for the current by-products that are created through ammonia nitrogen wastewater processing. Although calcium sulfate is a very useful product that can be used across many industries, the supply far exceeds the demand.

Potential Solutions

We recommend the government subsidize encourage research and development in the ammonia nitrogen wastewater sector in order to encourage innovation. This can help improve the recycling technology, increasing the final quality of the product. Funding for research can also encourage development of more cost-effective methods of treating ammonia nitrogen wastewater to improve the economic competitiveness of the final product.

Conclusion

Taiwan is one of the greatest recyclers in the world; however, nearly seven million tons of waste are still treated without being reintroduced into the supply chain, around half of which is classified as industrial waste. In order to improve the resilience of the Taiwanese economy and create a reliable source of raw materials, Taiwan has committed to including Circular Economy principles as part of its development plan. Reintroducing industrial waste products into the supply chain is an important part of the Circular Economy; however, this has yet to be seriously included in the conversation on the Circular Economy.

We hope this paper can serve as a starting point for discussion on industrial waste recycling in context of the Circular Economy, a discussion we hope can expand into other sectors of industrial waste recycling.

ECOVE (TPEx: 6803) — an affiliate of CTCI, a global engineering services provider — is an environmental services provider specializing in Energy-from-Waste (EfW), waste management, wastewater recycling, solar power and PET recycling. Founded in the midst of Taiwan's waste crisis in 1994, we quickly became a leader in effective waste management and resource recovery. With our main focus on recovering more value from otherwise wasted resources, we have continuously increased efficiency across our EfW, solar power, and recycling plants. Public and private entities in Taiwan, Macau, mainland China, Southeast Asia, India and the United States have trusted ECOVE for environmental services in operations and maintenance, consulting, and investment and development.

ECOVE