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Sales Energy Promotion Efficiency and Policy Utilization Plan for Energy Facilities

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Abstract

Purpose: The purpose of this study is to enhance sales promotion efficiency for using solid refuse fuel facilities. Renewable energy technology using Solid Refuse Fuel (SRF) is an economic efficiency technology that recovers waste by burning various wastes. A survey on the pollutants discharged from the solid fuels facilities was investigated so that the SRF facilities could be expanded, distributed and reflected in the policy. **Research design, data, and methodology**: In this study, 9 business sites using SRF and Bio-SRF as main raw materials were investigated for 2 years. The characteristics of target business sites such as the type of fuel used, combustion method, combustion temperature, daily fuel consumption and environmental prevention facilities were studied. **Results**: The average pollution & ammonia concentration of Bio-SRF facilities was found to be 88.15% higher than that of SRF facilities. But the average acetaldehyde concentration of SRF facilities was found to be 88.15% higher than that of Bio-SRF facilities. **Conclusions**: The main issue is how much electric power generation using combustible materials affects air pollution. The waste recycling law provides the standard value according to the fuel property, but there is a considerable gap with the mixed fuel. Therefore, for efficient utilization of facilities using solid fuel products, additional research is needed to improve the distribution structure of exhaust pollutants is needed.

Keywords: Energy Promotion Efficiency, Solid Refuse Fuel, Air Pollution Emissions, Odors, Renewable Energy

JEL Classification Code: Q40, Q42, Q53, Q54, Q56

1. Introduction

With the background of Korean energy problems becoming energy problems of the world, it becomes critically significant to analyze energy efficiency and policy performance from the perspective of energy facilities. Technological evolution will continue to accelerate the future in this modern world of rapid high-technological changes (Lakhwani et al., 2020; Rentnosari & Ramana, 2019). Solid refuse fuels with fluff type feedstock were fabricated from municipal solid wastes (Park et al., 2020). To reduce air pollution, clean fuel will be used even if the fuel cost burden increases (Yan & Na, 2012). The proportion of domestic energy generation in 2017 was 45.4% for coal, 30.3% for nuclear power, 16.9% for liquefied natural gas (LNG), 6.2% for renewable energy, and 1.3% for others respectively. However, nuclear and coal power generation will be reduced, and the share of renewable energy generation will increase to 20% which reflects efforts for greenhouse gas reduction for climate change, high concentration of fine dust (PM10, PM2.5), and environment-friendly energy generation. Based on this background, the target value proposed by the government

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will remain 11 years from now. In particular, although renewable energy is reduced to renewable energy, it reflects the target value, but the part to consider is substantial. In addition because of the high initial investment costs, energy generation facilities have problems to be overcome at present, such as the expansion of technology diffusion, stable supply system, establishment of business ecosystem, and acceptance of residents (Lee & Yun, 2015; Lee, 2005).

In Europe, which is leading the renewable energy sector, 20% is the target, similar to that in Korea (Klessmann et al., 2011). However, the target values are difficult to achieve at present, except for some countries (Shahbaz et al., 2020).

It is widely recognized that energy efficiency is the most cost-effective and affordable means of solving many of the problems of energy supply, including energy security, socio-economic impact of rising energy prices and climate change mitigation (Yessekina & Urpekova, 2015).

First, there is a problem of some small and some major opposition in respect to the location of the power generation facilities largely because of the environmental problems, due to this it's not easy to find acceptance among local residents with respect to renewable energy. (Lee & Yun, 2015). In addition, it is known that the electricity cost increases due to the increase in electric power production, which is higher than the existing power generation cost. Depending on the modernization of industry, regular monitoring, reporting and evaluation of the implementation of institutional reforms in the energy sector, active implementation of innovative technologies and ways to use renewable energy sources in order to achieve hydro-power (Smagulova & Mukasheva, 2012), a good energy policy can be made. Government intervention in the market is required because typical price mechanisms have a number of limitations that cannot bring social benefits to all parts of the national economy (Kari et al., 2017: Shadkam & Bijari, 2015). In order to restrain the increase of electricity and to establish new and renewable energy successfully, a research to determine how to improve the acceptance among residents is necessary. In case of recovering energy by using ancillary products generated by human activities such as bio-wastes, in particular, distrust of the project due to its operation, may cause the residents to damage the environment and the surrounding areas (Lee, 2008; Mazmanian et al., 1990). In addition, as a result of industrialization and urbanization, waste generation will become inevitable, and measures must be taken to address it. Therefore, it is necessary to identify the basic data and emission characteristics for the preparation of atmospheric management plan and propose measures thereafter. Since Korea is a resource-scarce country, the problem of production and development of renewable energy should be urgently resolved (Lee, 2010), which in turn can also become major alternative to nuclear power generation and coal. The pollutant emission amounts from solid fuels over large areas have rarely been evaluated (Deng et al., 2020). The purpose of this study is to provide basic data for the management of air pollutants by analyzing the characteristics of the emission materials through field survey and measurement of solid fuel facilities. From the perspective of sustainable economic development analysis, environmental costs can be considered as the cost of environmental downgrade (Zhao, 2016).

The predicted results indicated that future mitigation policies should not only focus on the industrial sector and heavily polluted areas where emission fluxes will remain intensive, but also focus on pollution control of the transportation sector to prevent rising NOx emissions in some regions (Lu et al., 2020). The ultimate goal of this study is to determine how to maximize energy production by utilizing solid fuel production facilities and to utilize them efficiently and widely. It is expected that this cost-effective and high-efficiency treatment technology would be great for the advancement and distribution of new and renewable energy industry in Southeast Asian market (Kwon et al., 2017).

2. Research Method

2.1. Target Facilities and General Status

Our research examines how energy firms' processing facility behaviors affect their energy efficiency. Korea like other countries faces the problems of balancing the goals of economic growth with environmental protection.

Paying attention to Korea's energy efficiency is of special significance to the national energy use and promotion of efficiency. For instance, the rapid development of express logistics industry has yielded carton waste, and how to utilize them as a resource has become an important issue in the recent years (Wang et al., 2020). Active and dynamic processes of globalization, international interaction, scientific and technical breakthroughs and the introduction of digital technologies in all spheres of the life of society exacerbate the contradictions between the economic and environmental trends in the development of region and city (Shmelev et al., 2018). In this study, nine sites using SRF and Bio-SRF were investigated. The survey was conducted for the years - 2016 and 2018, and 18 samples were collected. It was found that the target facility uses one or two types of workplaces that employ dedicated combustion boilers as installation facilities prior to December 31, 2014. Table 1 shows the characteristics of the workplaces surveyed in this study, including the type of fuel used, combustion method, combustion temperature, daily fuel usage, and environmental protection facilities. Workplaces A to E, were listed as SRF business sites that use industrial wastes and municipal wastes as fuel and sites F to I were categorized as Bio-SRF business sites that use wood pellets, waste wood, and solid fuel chips as main fuel.

The "twin pillars" of any sustainable energy policy nowadays emphasize on energy efficiency and renewable energy sources. The electricity system facilities of most countries, especially those in under-developing and developing countries, are old and unreliable, and are dependent on expensive and carbon intensive fuels, which lead to high technical and commercial losses. The combustion temperature of plant B using the circulating fluidized bed system, was the lowest at 800°C, and plant H where the wood pellets were burnt, recorded the highest at 1,200°C. The air pollution & control facility installed is equipped with Selective Non-Catalytic Reactor (SNCR), bag filter (B / F) and Semi-Dry Reactor (SDR), a selective catalytic reduction device (Selective Catalytic Reactor, SCR), a flue gas desulfurizer (FGD), a wet scrubber, and a hybrid electrostatic precipitator (Hybrid EP).

Table 1: Survey facility characteristics and fuel types

Div.	Fuel Type*	Combustion Method	Stack Temperature (℃)	Fuel Consumption (Ton/day)	Environmental Protection Plants**
A	SRF / W·W	Stoker type	172.3	140	SNCR→SDR→B/F→STACK
B	SRF / M·W	Circulating fluidized bed type	195.2	380	SNCR→SDR→B/F→SCR→STACK
C	SRF / M·W	Circulating fluidized bed type	150.8	450	SNCR→SDR→ B/F→STACK
D	SRF / M·W	Circulating fluidized bed type	161.9	150	SNCR→SDR→B/F→B/F→STACK
E	SRF / M·W	Turning method type	63.4	30	SNCR→SDR→B/F→STACK
F	Wood pellets	Wood pellet boiler	147.4	1,200	SNCR→SCR→B/F→Hybrid EP→STACK
G	BIO-SRF	Stoker type	169.4	300	SNCR→DR→B/F→Scrubber→STACK
H	BIO-SRF	Circulating fluidized bed type	148.6	450	SNCR→SDR→B/F→STACK
I	BIO-SRF	Stoker type	173.4	270	SNCR→SDR→B/F→SCR→STACK

* H·C: Hard Coal, W·W: Workplace Waste, M·W: Municipal waste
** B/F: Bag-filter, EP: Electrostatic Precipitator, SNCR: Selective Non-Catalytic Reactor, SCR: Selective Catalytic Reactor, SDR: Semi-Dry Reactor, Scrubber: Wet Scrubber, FGD: Flue Gas Desulfurizer

2.2. Metrics

Five items, i.e., fine dust (PM10), ammonia (NH3+), hydrogen chloride (HCL), formaldehyde (HCHO), and acetaldehyde (CH3CHO) were used as measurement indices. The statistical analysis was done using Studio (Version 1.1.463).

2.2.1. PM_{10} Sample Collection

At present, the measurement of fine dust on the atmospheric emission source is based on the atmospheric process test weight concentration method (ES 01317.1). This test method is mainly used for measuring the amount of PM10 in an atmospheric emission source by measuring the weight before and after the filter paper and deriving the result wastes. In this study, PM10 was cased from the inside of the outlet of the stack using Sampling Train (Clean Air Experiment, Method-5) as shown in Figure 1.

(Grad 934-AH, IW-AH4700) with suction at the same rate in consideration of the water speed, temperature, pressure, and water content in the stack. The collected filter paper was heated at 110°C for 4 hours or more for 3 hours to remove the carbon and organic substances completely, and the filter paper was transferred to a desiccator and dried for 24 hours. The filter paper was weighed at least three times, as a representative value.

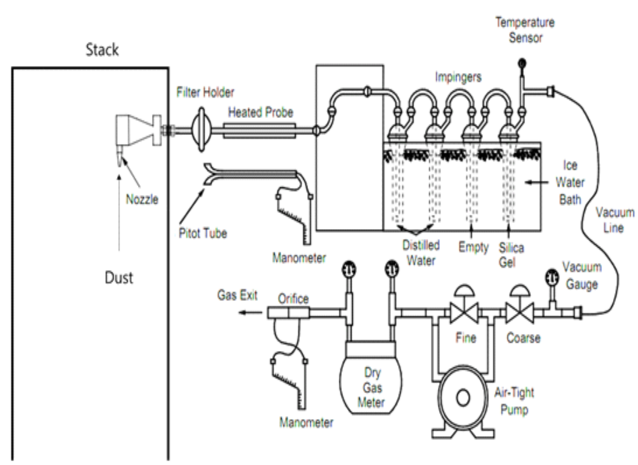

Figure 1: In-stack PM_{10} Sampling Train

2.2.2. Gaseous Sample Collection

Gaseous samples were collected from the inside of the stack using the same equipment as PM_{10}, as shown in Figure 2 with suction nozzle, sampling pipe, pitot tube, differential pressure gauge, impinge train, gas suction, and flow measurement. For sampling of hydrogen chloride and ammonia, reference was made to the air pollution process test standard ES 10305.1. The concentration of ammonia measured at 640 nm using a UV/VIS Spectrometer (Lambda 25, Perkin Elmer). The concentration of ammonia measured at 640 nm using an ion chromatograph (DIONEX, ICS-3000).

Formaldehyde and acetaldehyde were sampled at a rate of 1 liter per minute by the method of ES 01606.1 Tether Bag (SKC-23205), the air pollution process test standard, and 350 mg of 2,4-dinitrophenylhydrazine (1.0 mg DNPH) were used to adsorb the inner sample of Tedlar Bag. The adsorbed DNPH cartridge was desorbed with 5 mL of acetonitrile for HPLC grade and quantitatively analyzed by high performance liquid chromatography (HPLC) and standard solution (Supelco Inc., USA).

Figure 2: Sampling fine dust and gaseous substances

3. Results and Discussion

3.1. Fine Dust (PM_{10})

In Korea, renewable energy deployment and energy efficiency are two main energy environmental goals. Energy efficiency policy to reduce fine dust pollution is a crucial consideration globally due to the demands of the modern lifestyle quality. The analysis of PM_{10} showed that the filter paper was broken, as shown in Figure 3, due to the internal heat source at the outlet of some plants. Data in Table 2 was obtained after being treated as missing values. In the SRF facility, the standard deviation (SD) was 0.29 with a minimum concentration of 0.20 mg / m^3 and a maximum of 1.00 mg / m^3. On the other hand, for Bio-SRF, S.D. was 2.98 at a minimum of 0.50 mg / m^3 to a maximum of 7.00 mg / m^3.

This is lower than 40 mg / m^3 in terms of the air pollution & emission allowance of Korea PM_{10}, but it differs up to 7 times compared to SRF plant. Likewise, Jang (2017) focuses on combustible solid wastes such as waste plastics, which are used in the SRF plant, while the main raw materials of Bio-SRF, widely used as a fuel, are vegetable residues such as agricultural wastes, peanut shells, and plywood. Therefore, it can be interpreted that the measured concentration is wide due to the influence of the fuel property. Kim (2012) explains that incomplete combustion occurs repeatedly because the fuel supply is not applied according to the fuel injection method due to the characteristics of the solid fuel, insufficient facility management, and aging of the Prevention Facility Act. Therefore, in order to accommodate the residents, it is necessary to establish and manage appropriate measures for the prevention facilities first.

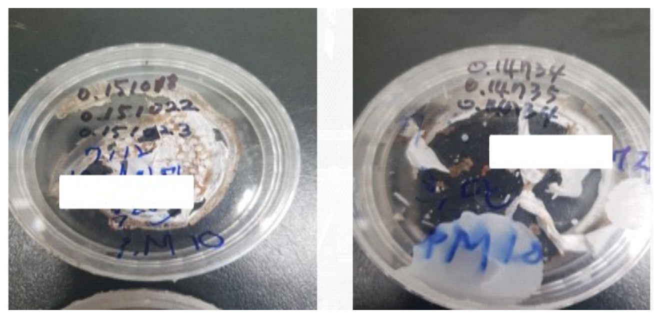

Figure 3: Damage to filters due to heat source

Table 2: Analysis Results of PM10 (Unit: mg/m3)

Division	Average	Median	S.D.	Min.	Max.
SRF (n=10)	0.45	0.40	0.29	0.20	1.00
Bio-SRF (n=8)	3.80	3.85	2.98	0.50	7.00

3.2. Ammonia (NH3+)

NH_3^+ has a stinking odor with a distinctive irritating stench. At present, the emission standard for odor prevention is based on the principle of measuring complex odors from the outlet, and in case of designated odor substance, it is measured from site boundary. Table 3 shows the measured results from the outlet. For the SRF plant, the measured range was 0.32 ppm at the minimum concentration and 19.83 ppm at the maximum, indicating that S.D. was 5.81. On the other hand, the minimum concentration of Bio-SRF was 3.31 ppm, while the maximum was 32.00 ppm, and the maximum concentration was 0.61 times higher than that of SRF. As shown in Figure 4, the SRF site has 70% distribution of 0.33 to 0.66 ppm, while the Bio-SRF site has a distribution of 62.5%, which is lower than that of SRF. The maximum concentration is 32.00 ppm in some samples. This exceeds the air pollutant & emission limit of 30 ppm. The production of NH_3^+ is generally a reaction due to the formation of NOx in the non-catalytic reduction process (SNCR), resulting in incomplete reaction of urea and hydrocarbons as a result of the process to remove NOx. It is known that the untreated product is discharged. The optimum reaction temperature of the reducing agent is about 870℃ to 980℃. When the reaction temperature is lower than the range mentioned above, the reaction is incomplete without reduction treatment whereas the detection concentration is high due to ammonia slip. Therefore, the use of a wet scrubber can prevent ammonia from being discharged to prevent the detection of excess ammonia.

Table 3: Analysis Results of NH_3^+ (Unit: mg/m^3)

Division	Average	Median	S.D.	Min.	Max.
SRF (n=10)	4.50	2.79	5.81	0.32	19.83
Bio-SRF (n=8)	11.36	5.71	11.22	3.31	32.00

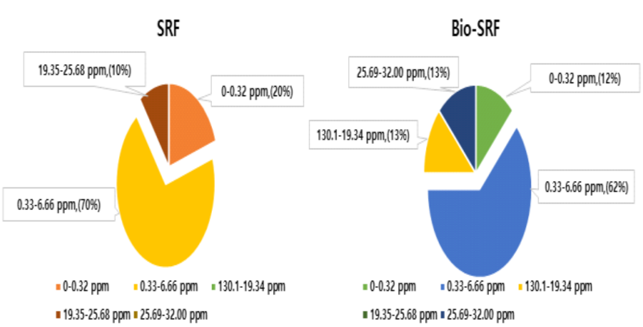

Figure 4: NH_3^+ Concentration

3.3. Hydrogen Chloride (HCL)

It is recognized that HCL is generated during the combustion process of chloride and vinyl chloride, and its emission concentration is determined by factors such as waste component, type of incinerator, and operating conditions. Considering this, the concentration of HCL is higher in the SRF facility made of municipal solid waste than in Bio-SRF facility, which uses by-product fuel such as waste wood. The results of HCL measured in this study are shown in Figure 5. The SRF facility has a minimum concentration of 0.39 ppm, a maximum of 14.91 ppm, and an S.D. of 5.53. On the other hand, in the Bio-SRF facility, the minimum concentration was 0.59 ppm, the maximum concentration was 3.31 ppm, and the SD value was 1.03. HCL concentration measured in this study was 3.5 times larger than that of the Bio-SRF facility (Wilcox test). The median value of the sample for the deficiency of Bio-SRF, 0.02 ($p > 0.05$) was found to be of significant difference. Sung (2010) estimates that when the chlorine (Cl) content in the municipal waste is 0.35 ppm, the actual exhaust gas concentration will be 23.36 ppm, which is also the arithmetic mean (AM) when the recycling screening facility residues are 50%. Therefore, considering the specificity of fuel used for SRF, there is a need to design it considering the possibility that high concentration chlorine is injected because the emission limit standard for the use facility of solid fuel products is 20 ppm in the current Air Quality Preservation Act.

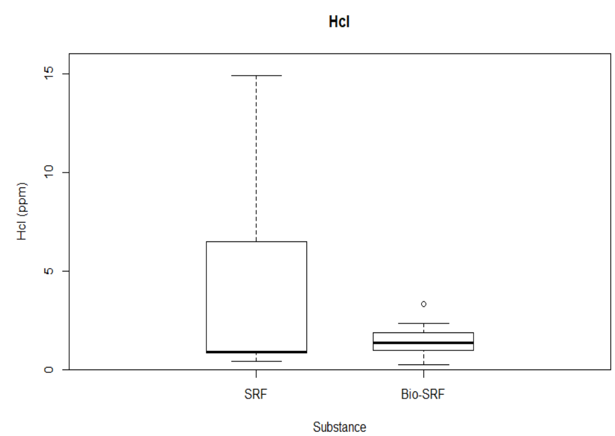

Figure 5: HCL Box Plot Analysis

3.4. Formaldehyde (HCHO)

HCHO is shown to act as a precursor to ozone by causing photochemical reactions in the atmosphere, while formaldehyde is designated as a major odor substance. The current air emission standard is less than 10 ppm and the minimum detection concentration is 0.05 ppm. The results of this study are as shown in Figure 6. In SRF facilities, the minimum concentration was 0.006 ppm, the highest concentration was 0.268 ppm, whereas Bio-SRF L.C. was 0.022 ppm, H.C 0.116 ppm, and S.D 0.034, which were within the limits of air emission standards. In addition, Wilcox test ($p < 0.05$) showed no significant difference (0.3711). The concentration of HCHO in the SRF facility was higher than that of other chemicals such as phenol resin, melamine resin, urea resin, and ethyl acetate used in paints and printing ink. Further, it is considered to be higher in the SRF facility. Therefore, in order to use it as a waste fuel, it is necessary to develop it as an eco-friendly material from the manufacturing process.

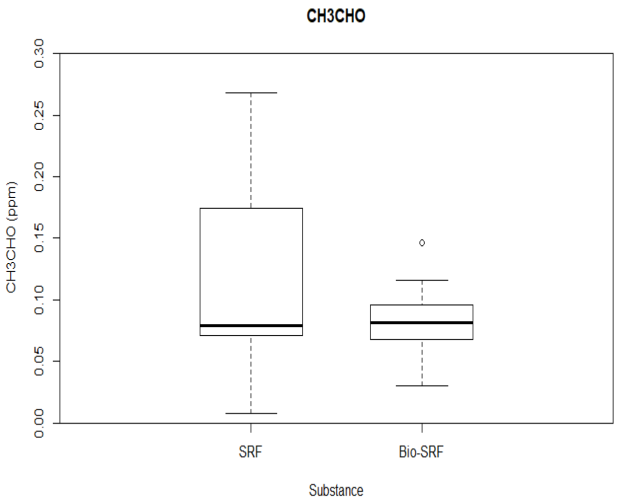

Figure 6: Analysis results of CH_3CHO

3.5. Acetaldehyde (CH_3CHO)

In the case of CH_3CHO, air pollution & emission standards for solid fuel facilities will be set in 2019. At present, CH_3CHO corresponds to designated odorous substance. It should be less than 0.1 ppm in the industrial area of the site boundary, 0.05 ppm or less in other areas, and 0.1-0.05 ppm in the strict area.

Table 5: Analysis results of CH_3CHO (Unit: ppm)

Division	Average	Median	S.D.	Min	Max
SRF (n=10)	1.122	0.787	1.330	0.039	4.424
Bio-SRF (n=8)	0.408	0.225	0.459	0.049	1.376

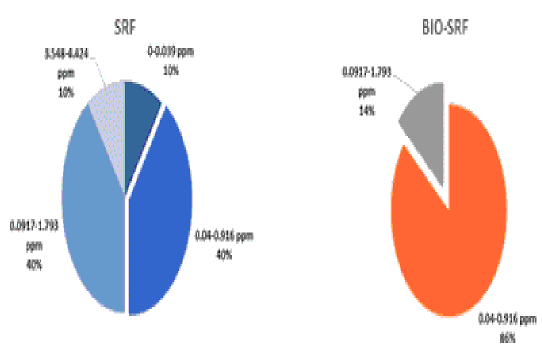

Figure 7: CH_3CHO Concentration

The results of this study are shown in Table 5. 0.039 to 4.424 ppm were the values found in SRF facilities, 0.049 to 1.376 ppm in Bio-SRF facilities, whereas an S.D. of 0.459 in the SRF facility was found, which was 2.2 times higher than that in the Bio-SRF facility, that 0.6289 ($p < 0.05$) was not significant in the Wilcox test results. In contrast, as shown in Figure 7, Bio-SRF accounts for 87.5% in the range of 0.04 to 0.916 ppm, while it occupies 40% in the SRF facility. Considering this fact, and the minimum detection concentration of CH_3CHO is 0.0015 ppm, it can be concluded that CH_3CHO is influenced by seasonal and diffuse factors. CH_3CHO can be deodorized by chemical absorption using a neutral substance, therefore, it is desirable to install a chemical cleaning facility in the SRF facility.

3.6. Correlation between Acetaldehyde (CH_3CHO) and Formaldehyde (HCHO)

It is known that CH3CHO reacts with various types of organic compounds during combustion and has a similar reaction rate because it has OH as HCHO. However, the rate of reduction is different from the rate of reaction. Under the same conditions, the reduction rate of CH3CHO is 94% and that of HCHO is 97%. However, the difference in the rate of decline may vary depending on the fuel material, the operation of the preventive facilities, and the combustion conditions. Therefore, the correlation between CH3CHO and HCHO formation was determined from the scattering coefficient. The result of the same for SRF facility is given in Figure 8. When the slope was 0.0531, the coefficient of determination was 0.8763, showing a strong correlation. On the other hand, the Bio-SRF facility showed a low correlation coefficient of 0.3737 when the slope was 0.449 as shown in Figure 9. The result of the fact that Bio-SRF facility has a lower correlation as compared to the SRF facilities can be seen from the status of manufacturing, use, and import of solid fuel products in Korea in the second quarter of 2018. SRF does not import municipal waste, waste synthetic resin, waste synthetic fiber, waste rubber, waste tires, and waste timber, but 30.23% of Bio-SRF is imported. Most of the imports come from countries such as Indonesia, Vietnam, Malaysia, Thailand, Australia, and South East Asia, and include imports of palm (50%), waste wood (43%), and cashew nuts (7%). Kang et al., (2014) explained that amount of HCHO is increases during processes such as spraying and burning preservatives and pesticides for raw materials used in Bio-SRF for transportation and customs clearance. Although additional research is needed, it is believed that a large amount of chemicals, such as sprayed preservatives and insecticides, are absorbed into the interior during long-term transportation and the fuel absorbed in the chemical is mixed heterogeneously, which affects the HCHO concentration during combustion.

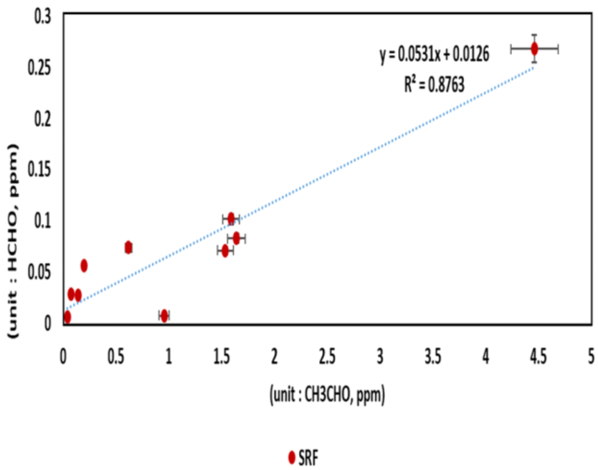

Figure 8: Correlation between CH_3CHO and HCHO in SRF plants

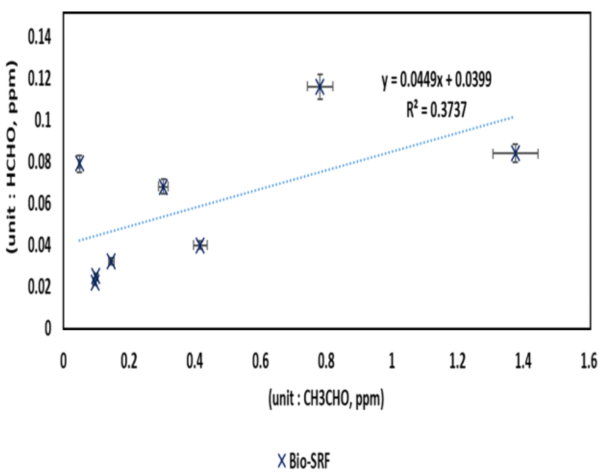

Figure 9: Correlation between CH_3CHO and HCHO in Bio-SRF plants

4. Conclusion

Processing energy efficiency, an important component of Korea's energy policy, has gradually attracted the attention of clear energy and efficiency. In this paper, we first explored how firms' energy performances vary across firms with different materials and compared the energy efficiency performance of different concentrations. Leaders from both specific markets and regions are looking at the opportunities and challenges associated with the so-called energy production revolution ushered in by the new means to access natural gas and other fuels (Hojjat, 2014). The Korean Government plans to enhance the ratio of combustible waste converted into SRF from 16% in 2014 to 100% in 2020, by increasing the number of facilities that make and use SRF (Kim et al., 2017). Global climate change is demanding various changes in environmental policy, along with energy policy. To this extent, trade implications and competitiveness effects have been of a prime concern to energy and climate policy makers (Vrontisi et al., 2020). The main issue is how much electric power generation using combustible materials affects air pollution. The world generates more than 2 billion tons of solid waste per year now, and this amount is expected to increase drastically to 3.4 billion tons in 2050 (Wang et al., 2020). In Korea, research on renewable energy using solid fuel is insufficient to secure clean energy. The results of this study are as follows:

1) As a result of analyzing PM10 and ammonia, the average concentration (AM) of Bio-SRF facilities was higher than that of SRF facilities.

2) As a result of analyzing a chlorine (Cl) & HCHO, the average concentration (AM) of SRF facilities was higher than that of Bio-SRF facilities.

Our results also suggest that the increased levels of efficiency through innovation in processing energy can promote country's energy policy, when air pollution intensity is low. The waste recycling law provides the standard value, according to the fuel property, but there is a considerable gap between the mixed fuel construction and demolition waste (C&D waste) recycling is identified as significant for waste minimization and natural resources conservation (Liu et al., 2020). Finally, in order to cope with climate change actively, environmental policy by the government is needed, and integrated research for the development of environmentally friendly fuels together with air pollution prevention facilities should be continued. Meanwhile, emission control of NO_x, SO_2, NH_3 and non-methane volatile organic compound (NMVOC) synergistically are highly needed because the impact of multiple pollutants on $PM_{2.5}$ and O_3 concentrations is nonlinear (Cai et al., 2017). It is thought that such efforts will contribute to the improvement of waste pollutant facilities and the distribution structure of the pollutant reduction device. For the further sustainable development of country, it is necessary to continue environmental reforms, stimulating production using green technologies, encouraging foreign and domestic eco-innovations, as well as connecting nongovernmental organizations and members of the public to support environmental reforms (Shmelev et al., 2018). Southeast Asia hopes that Korea's environmental industry, such as energy-reduction facilities, waste disposal facilities and final disposal businesses, can work alongside it (Jung et al., 2018).

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