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SOCIO-ECONOMIC AND ENVIRONMENTAL ATTRIBUTES OF WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE) RECYCLING IN ASIA

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Abstract

Due to ever increasing demand, the electronics industry has been growing at a rapid pace, and therefore handling and management of Waste Electrical and Electronic Equipment (WEEE) has become one of the key problems in the modern world. Improper handling and management of WEEE in developing countries can cause a huge environmental damage and threats on human health. In some developed countries, policies have been set up and *strategies have been implemented by aiming recuperation of materials from WEEE while conserving resources and controlling environmental pollution. For instance, in Japan, the home appliance recycling law like strategies have been implemented for achieving a recycling-oriented society.*

In this study, socio-economic and environmental effects from end-of-life home appliances recycling such as washing machines, Refrigerators, Air conditioners and Televisions have been assessed. Recycling mechanism of end-of-life home appliances in Fokuoka Prefecture under Japan's home appliances recycling law was evaluated via life cycle assessment perspective. Life cycle based methodology was developed for the assessment considering all the phases life cycle of WEEE recycling such as collection, primary and secondary transportation, pre-processing (dismantling), recycling and material recovery. Net greenhouse gas (GHG) emission and net resource savings potentials were quantified as the key indicators to measure the major environmental impacts while green jobs creation potential and income based community well-being was quantified to assess the socio-economic attributes of end-of-life home appliances recycling. Further, recycling mechanism in India was assessed and the results obtained from the case studies was compared for identifying the most appropriate approach of recycling and then for supporting policy making process.

In the case of Japan, the results demonstrated that it would be possible to avoid more than 50% of GHG emissions and 55-80% of abiotic resource consumption as for all kind WEEE recycling that would some way or another happen through the production of equivalent amount of materials from conventional processes. Further, 165 employment opportunities have been created and annual income of 686 million Japanese yen can be generated due to handling and managing of 700,000 units of WEEE. In the case of India WEEE management activities are shown lower GHG emissions potential from recycling process and therefore, it would positively contribute for more GHG savings and fossil resource savings by recuperating significant amount of materials from WEEE. The authors argue that this kind of tangible information will be helpful for decision and policy making process and for strengthening and implementing a set of comprehensive policies and legislations for achieving a recycling-oriented society in Japan as well as other countries.

Keywords: Sustainability, Electronics, WEEE, Recycling, Climate change

1. Introduction

Waste Electrical and Electronic Equipment (WEEE) has been recognised as the world's fastest growing waste streams (Afroz, Masud, Akhtar & BtDuasa, 2013; Echegaray, & Hansstein, 2016) with a growth rate of 3-5% per year, and potentially the main challenge for sustainable waste management (Christia, 2012; Qu, Zhu, Sarkis, Geng & Zhong, 2013). For developed counties, selling old electronic products to exporting waste traders is more profitable than processing. As a result, most of the manufactured electronic products end up at the dump sites in the poor countries. WEEE contains numerous dangerous and hazardous substances, which can cause severe harmful impact on environment and public health (Echegaray & Hansstein, 2016; Oguchi, Sakanakura & Terazono, 2013). Unlawful trans-boundary movement followed by unsafe handling, management and treatment activities such as crude recycling activities, indiscriminate dumping of WEEE items would create serious environmental impacts as well as posing risks to human health and well-being in developing countries. In these countries, most of the people are not aware about the health risks and environmental consequences of inappropriate handling and management WEEE. Unfortunately, people in most of the developing countries are unaware of the health risks and other environmental impacts of unsafe handling and management of WEEE (Hai, Hung & Quang, 2015; Mallawarachchi & Karunasena, 2012; Afroz et al. 2013). In some developed countries, appropriate policies have been set up and strategies have been implemented by aiming recuperation of maximum amount of materials from WEEE while conserving natural resources and controlling environmental pollution.

2. WEEE Recycling Mechanism in Japan

Since 1990s Japan's environmental policies and sustainable strategies have been persuaded in enhancing resource productivity and environmental sustainability. Through the fundamental law of Sound Material-Cycle Society, the idea of increasing resource efficiency and productivity has been strengthen in field of waste management and recycling policies (SAPIENS, 2015). As far as WEEE management is concerned, Extended Producer Responsibility (EPR) based regulations (e.g. home appliance recycling law) have been implemented between 1990s to early 2000s for successfully management and enhancement of the resource productivity. Home appliance recycling law asserts that the producers should responsible for take back and recycle the four major home appliances namely; refrigerators, watching machine, televisions and air conditioners. In general, recycling has been identified as a key strategy for reducing environmental pollution and depletion of finite resources, as well as for increasing energy savings (Echegaray & Hansstein, 2016). Recently WEEE recycling has been recognised as a secondary source of valuable metals, as it securing a steady supply of metals while contributing for natural resource conservation, environmental pollution control and managing material cycles (Hai et al. 2015; Oguchi et al, 2013). Further, the recovered metals and materials would be useful to enhance the resource efficiency and to replace virgin resources.

WEEE recycling process chain in Japan is not a one-step process, and it consists of four different major routes such as; formal route under home appliance recycling law, second hand market for reuse, collection of unused items by informal sector and collection by local authority and treated as general waste stream (Menikpura, Santo & Hotta, 2014). Most of the collected WEEE units (e.g. 65% of collected WEEE) are handled and managed following the formal route of recycling under the home appliance recycling Law. In year 2011, 676,000 tonnes of WEEE (air conditioners, refrigerators, washing machines and televisions) was collected through the formal route, in which 82% was recycled to recovered valuable metals/materials (AEHA, 2014).

At present, both developed and developing countries have shown some interest on conducting studies and evaluating the potential implications related to WEEE management. However, yet there are hardly any quantitative studies exist which could provide evidence-based tangible information for decision and policy making processes. Further, lack of knowledge and awareness among the stakeholders who are involved in recycling process chain would negatively influence on sustainability of WEEE management. Hence, this study was carried out by Institute for Global Environmental strategies for providing evidence-based tangible information in order to facilitate policy and decision making process in Japan and elsewhere for promoting sustainable WEEE recycling programs.

3. Methodology

3.1 Identification of the Study Area

Fukuoka prefecture was selected as the study location in order to assess sustainability of WEEE recycling mechanism in Japan. According to WEEE generation rate, Fukuoka prefecture represents the situation of high-density population areas where the population density is 1,021.30 persons/km^2. Among 47 prefectures in Japan, this prefecture has been ranked as the 7th highest population-density prefecture (Statistics Japan, 2015). For WEEE collection, this prefecture follows the procedure under the home appliance recycling law. The retailer shops are being collected the generated WEEE within the prefecture and transported to the chosen stockyards. Sometimes, consumers takes the responsibility of transporting their WEEE directly to the nearby municipalities or to the stockyards. Under such situation, the municipalities are responsible for transportation of the received WEEE from their collection points to the stockyards.

3.2 Development of LCA Framework for Sustainability Assessment

In order to access the sustainability of WEEE recycling, Life Cycle Assessment (LCA) based framework was developed since such framework would provide a systematic approach to evaluate a recycling process chain considering all the phases of life cycle (Menikpura, Sang-Arun & Bengtsson, 2013).

As the next step, a functional unit was defined as the basis for the assessment, taking into account the key variables such as unit size, mass, and type of materials and specifications of major home appliances. Average unit weight of each type of discarded WEEE for recycling have been considered as the functional unit in this study with respect to selected four major appliances. Further, life cycle inputs/outputs related to all the phases of life cycle (e.g. collection, primary and secondary transportation, pre-processing/dismantling, recycling and material recovery WEEE recycling) have been assessed per functional unit of each type of WEEE.

3.3 Inventory Analysis

As previously mentioned, life cycle input and output data was gathered in this stage of assessment with respect to all the stages of the life cycle of WEEE recycling. As per the logistical process of WEEE is concerned, all the input and output data was collected with regard to mode of vehicle use for transportation, fuel efficiency of vehicles, specifications of transportation routes, labour power requirement and allocation of labour for different tasks etc. This information is necessary to quantify the socio-economic and environmental impacts related to WEEE collection and logistic movements. Further, a questionnaire was prepared to gather the basic data, from the designated collection points/stockyards and smelting plants within Fukuoka prefecture. Through this comprehensive field survey, data was gathered related to energy consumption (both thermal and electric energy), material consumption, labour power requirement and their wages for different tasks etc. Moreover, to estimate the net socio-economic and environmental impacts of WEEE recycling, data was collected related to virgin production processes of equivalent amount of materials within the Japanese context.

3.4 Identification of Sustainability Indicators

Sustainability assessment of WEEE management requires methods and tools to quantify and compare the environmental, socio-economic impacts. Thus, identification of appropriate indicators are necessary for measuring impacts and then to use the measured tangible information in policy and decision-making process.

Environmental sustainability can be defined as rational resource consumption and reduction of environmental pollution. Recycling has been well-reported as an environmentally-friendly option, which would facilitate to recover a significant amount of valuable materials/metals from WEEE. The recuperated materials/metals from WEEE can conceivably supplant an equivalent amount of materials that would othewise should be extracted from virgin resources for manufacturing of products. In this way, greenhouse gas (GHG) emissions and other environmental impacts, associated with those virgin production process chains can be eliminated. In order to measure the major environmental consequences from WEEE management, net GHG emission, net resource saving potentials were identified as the important indicators.

Further, initiation of a systematic WEEE management programme would improve the standards of living of the people in the community due to the creation of new employment opportunities. Therefore, to assess the socio-economic consequences of WEEE recycling, green jobs creation potential and income based community well-being were used as the indicators.

4. Results and Discussions

4.1 Evaluation of Environmental Sustainability

Net GHG emissions

Measurement of net GHG means, accounting the net impact due to both direct emissions from recycling process chain and the indirect, downstream GHG savings through materials/metals recovery. The estimated net GHG emissions result can imply the overall climate impact or benefit of WEEE management for climate change mitigation. In this study, net climate impact from WEEE recycling has been measured as per functional unit. As previously mentioned, functional unit has been defined as per average unit weight of each type of home appliance in Japan. Thus functional unit weights of television, air conditioner, refrigerator and washing machine are; 28 kg/unit, 43 kg/unit, 58kg/unit and 32kg/unit respectively (Kaden recycle Annual report, 2011). Net GHG emission was estimated considering the overall process flow of recycling namely; collection, primary and secondary transportation, pre-processing/dismantling, recycling and material recovery.

As far as recycling process related GHG emission is concerned (see Figure 1), the highest total GHG emissions resulted from refrigerators followed by air conditioners, washing machines and televisions. The estimated result revealed that except for televisions, more than 70% of total GHG emissions emerge from the smelting phase of all appliances. Despite the fact that logistical movement is a complex process, it adds to the least GHG emissions as compared to the other phases of the life cycle of WEEE recycling, see Figure 1.

Net climate impact from WEEE recycling was estimated by subtracting GHG emissions through the virgin production of equivalent amount of materials from total GHG emissions from recycling, see Figure 2. The results disclosed that as a reward of recycling, notable amount of GHG emissions that would otherwise occur in the virgin production process can be eliminated.

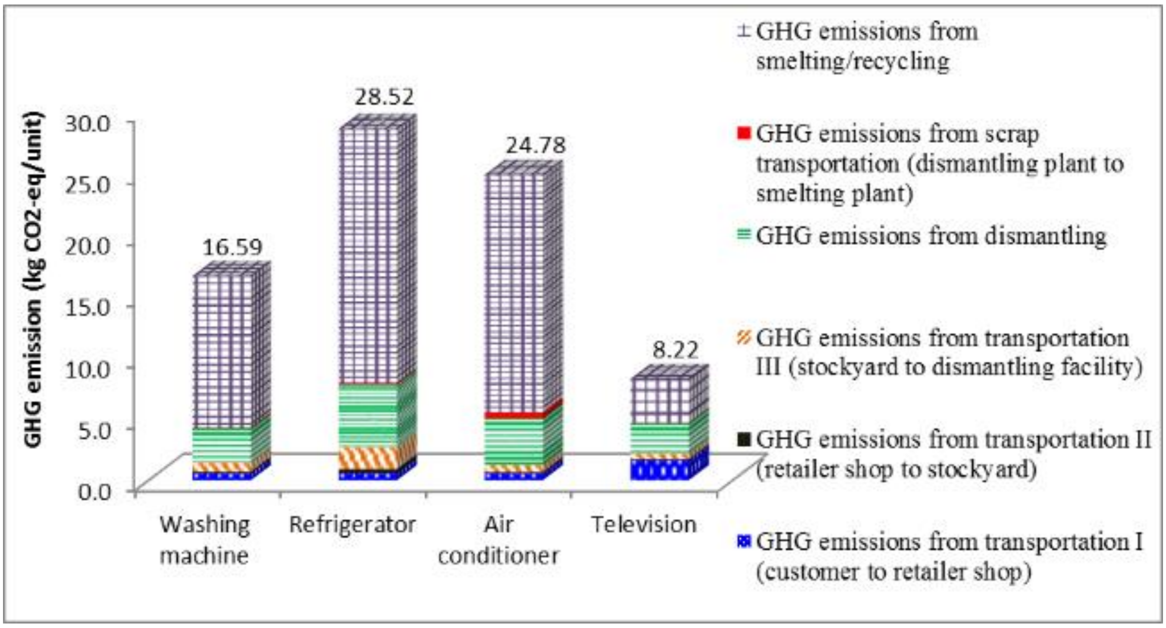

Figure 1: *GHG emissions from WEEE recycling with respect to different phases of the life cycle (calculations have been done per functional unit).*

As shown in Figure 2, the estimated net GHG emissions from recycling per unit weight of washing machines, refrigerators, air conditioners and televisions added up to - 17.70, - 27.34, - 45.62 and - 3.61 kg CO_2-eq respectively.

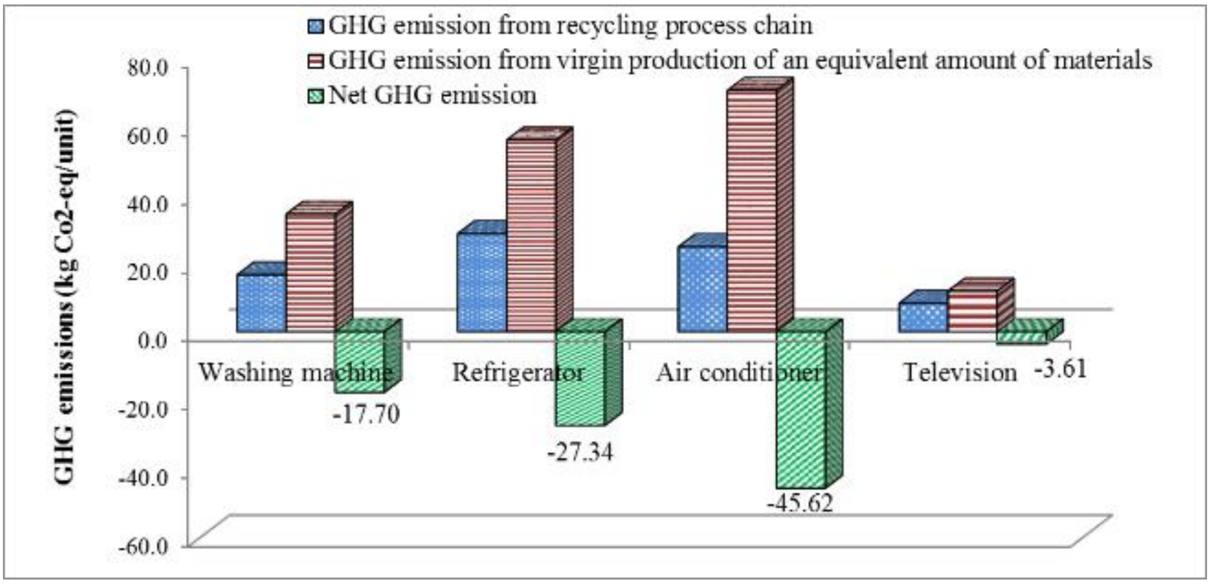

Figure 2: *The estimated total GHG emissions from recycling, virgin production and net emissions from WEEE recycling*

The subsequent net negative values show that there is a notable GHG reduction potential from all types of WEEE recycling. For instance, except televisions, it is conceivable to anticipate more than half of GHG emissions with respect to all other appliance that would some way or another could happen through the virgin production process chains.

Further, in view of the total quantity of WEEE units dismantled in Fukuoka every year, it is added up to 15,611 tonnes of CO_2-equvelent mitigation potential. This is a very good sign of the impacts of WEEE recycling on GHG mitigation and climate co-benefits. Furthermore this results demonstrates that WEEE recycling system would make a crucial commitment to national/worldwide GHG mitigation targets.

Net resource savings of WEEE recycling

On one hand, WEEE management process is associated with fossil energy consumption, especially for primary and secondary collection, transportation and recycling and thereby contributes for depleting finite resources. On the other hand, recycling of WEEE could contribute for a significant amount of resource extraction. Lately, WEEE has been recognized as an optional wellspring of different metals since they contain numerous sorts of metals, including valuable metals and less common metals.

In this study, total fossil energy consumption for both recycling and virgin production of WEEE calculated in terms of MJ of fossil energy equivalent per functional unit (e.g. average unit weight of each type of appliance). Net fossil resource saving is estimated by subtracting fossil-fuel consumption for WEEE recycling from that of virgin production.

According to the analysis, except for televisions, approximately 70% of fossil energy has been consumed for the smelting of scraps since it is an energy-intensive process. Dismantling phase is consumed only 15-25% of the total fossil energy and the least amount of fossil energy have been utilized for the logistical movements.

Materials/ metals that are recovered from recycling of WEEE can be utilized to supplant the virgin materials/metals. Alone these lines, life cycle fossil energy consumption of recycling process was compared with the fossil energy utilization for the production of the equivalent amount of virgin materials in Japan. As indicated by the results, virgin production of an equivalent amount of materials with respect washing machine, refrigerator and air conditioner are required a 4-5 times of fossil energy as compared to the fossil energy requirement for recycling and extracting materials from these appliances . In the case of television, virgin material production is requited 2 times of fossil energy than that of recycling.

The result shows that a considerable amount of fossil energy would be otherwise required for virgin production of equivalent of materials. In fact, 75-80% of fossil energy can be saved by recycling and extracting of materials from washing machine, refrigerator and air conditioner. In the case of television, 55% of fossil energy can be saved when contrasted with the virgin production of equivalent of materials (see Figure 3).

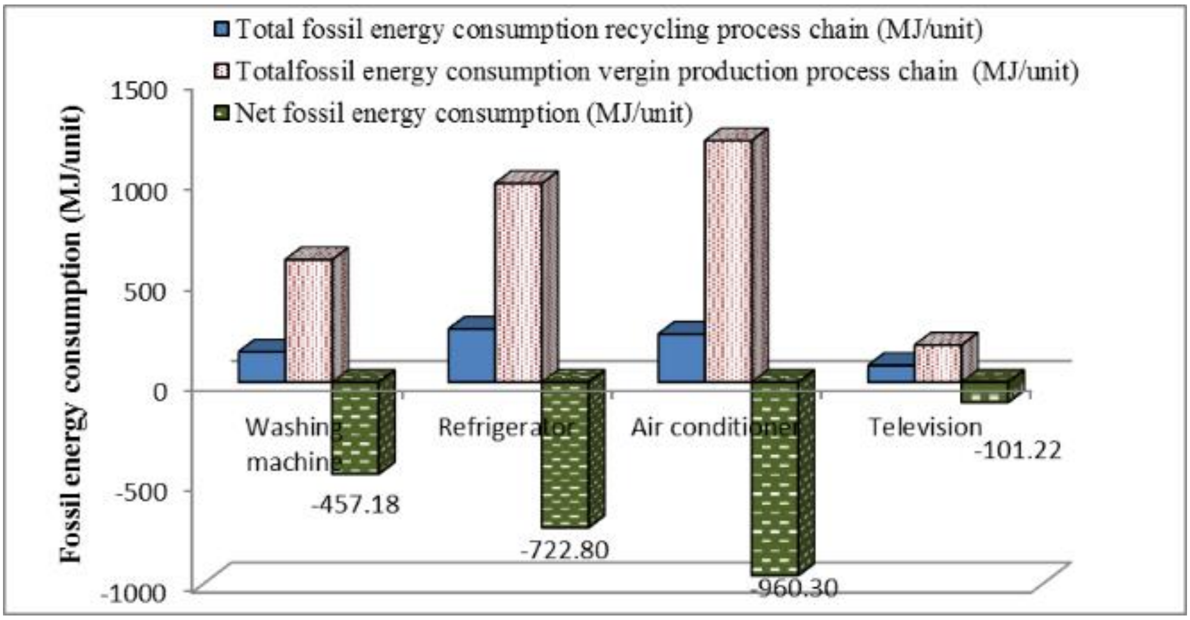

Figure 3: *Fossil fuel requirement for recycling of unit weight of WEEE, virgin production of an equivalent amount of materials/metals and net energy consumption*

Further, in order to understand the significance of recuperation of materials/metals from WEEE, total materials requirement (TMR) that can be avoided as a reward of recycling were accounted by using the TMR values of different materials in Japanese context (NIMS-EMC, 2009). Figure 4 shows the avoided TMR as a reward of recovering materials from WEEE recycling that would some way or another happen through the virgin generation of an equivalent amount of materials. The highest TMR can be avoided by recycling of air conditioners followed by refrigerators, washing machines and televisions. It should be noted that, this estimation has been done only for major recovered materials from recycling of

WEEE and precious metals such as gold, silver platinum, etc. has not been accounted in this study due to unavailability of the data.

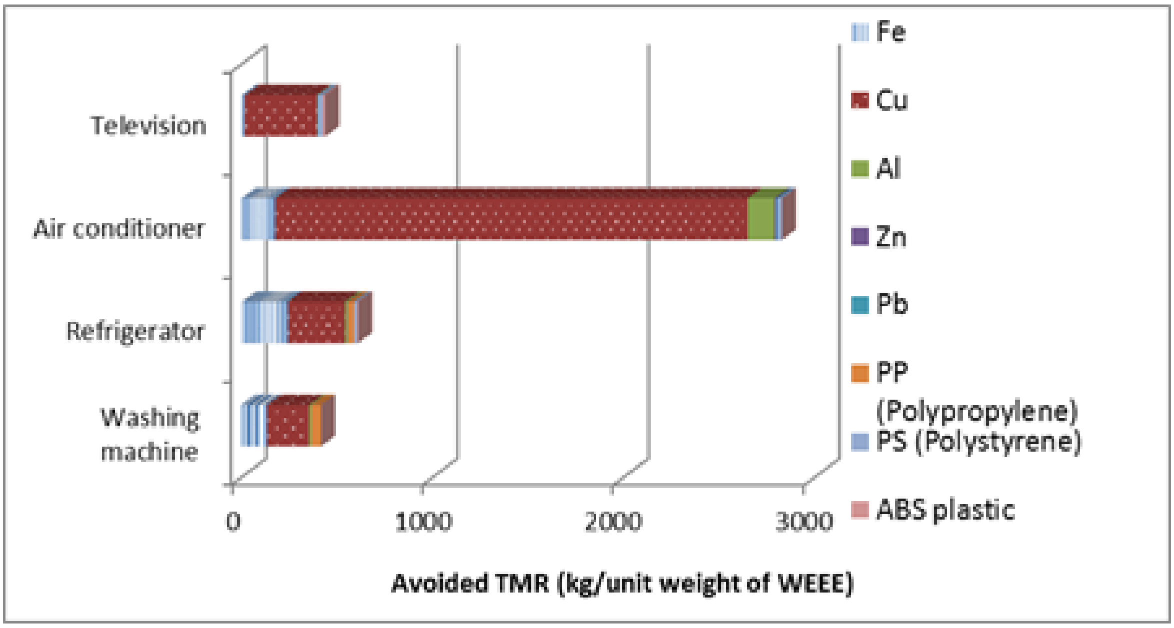

Figure 4: *Avoided TMR as a reward of recovering materials from WEEE recycling*

4.2 Evaluation of Socio-economic Sustainability

Green jobs creation and income based community well-being

Start of a proper WEEE management system would improve the expectations for everyday comforts of the community due to creation of decent employment opportunities. Estimation of potential skilled employment opportunities from a properly designed WEEE management system would be a good indicator to convince other developing countries in the region about the future social benefits from appropriate WEEE management system.

In the case of Fukuoka, a significant number of employment opportunities has been created for the logistical movements from retailer shops to stockyards and stockyards to the dismantling facilities which are amounted to 8 and 17 full-time job positions respectively. Highest number of job opportunities has been created at the dismantling facilities, which is amounted to 165. In addition, another full time two job position can be allocated for the transportation of scraps for different smelting facilities.

Total job opportunities which have been created as a result of WEEE management activities in Fukuoka is amounted to 165. Job openings from WEEE recycling and related income generation potential at the different phases of the life cycle has been presented in Figure 5. Total annual income generation potential due to all those employment opportunities would be 686 million yen. This money would indeed positively contribute to cover the monthly expenses of the worker as well as the family members, and enabling to have a better quality of life.

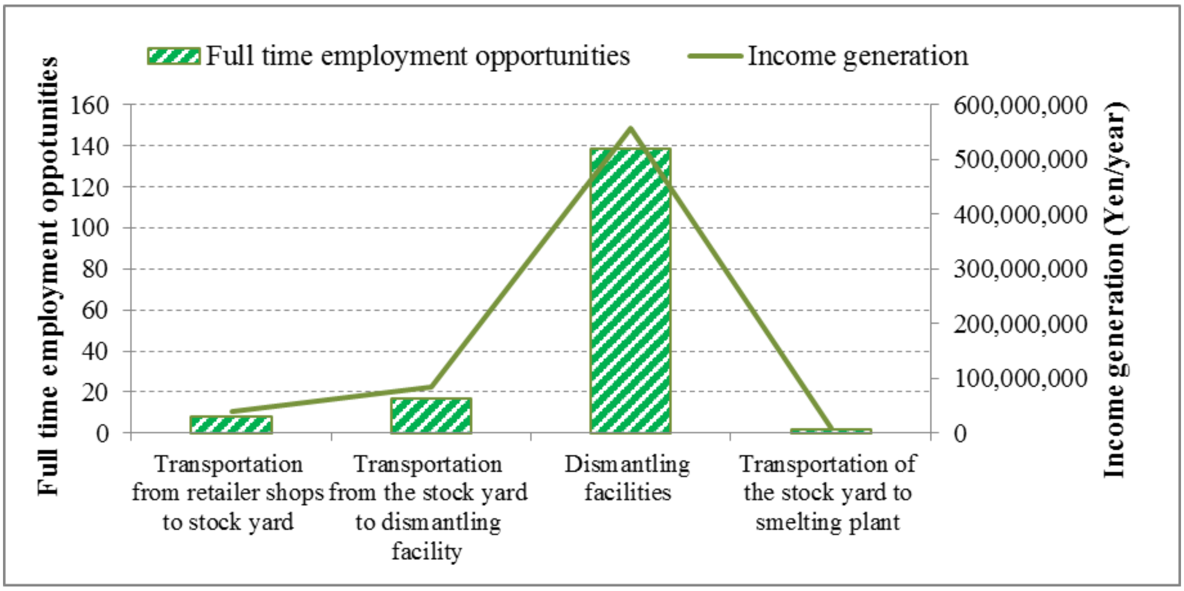

Figure 5: *Employment opportunities and wages based income generation potential from WEEE management in Fukuoka*

4.3 Comparisons of Sustainability Issues of WEEE Recycling in Other Asian countries

WEEE recycling system in India has been assessed and the result would be very useful for making policy mechanisms on sustainable WEEE management. In India, WEEE consists of six major electronic items such as PCs, Televisions, Mobile phones, Air conditioners, Washing Machines, Refrigerators and total WEEE generation will surpass 2.15 million tonnes by 2018. In 2014, total registered WEEE dismantling/recycling capacity in India is about 344,047 tonnes per annum. According to industry estimation, just 5% of the WEEE go through the formal dismantling/recycling route.

Unlike in Japan, there is no national plan on logistical arrangement of WEEE and logistical movements might be varied one province to another province. Thus according to the information provided by recycling companies, transportation of WEEE by heavy dutytrucks (32 feet) with the average load of WEEE transported 15 tonnes/trip were considered. The estimated average WEEE transportation distance is 600 km in where the dismantling facility is located. As far as dismantling process is concerned, diesel fuel and grid electricity are utilized for operational activities. Technology profile of Indian dismantlers shows that downstream items from their operations are either going to neighbourhood market or ship to Europe, Japan, Hong Kong and USA. But they are not getting the full value of exported materials. Non-of the companies interviewed in the questionnaire survey has not provided the detailed data related logistics of dismantled metal/materials and smelting of the recovered resource with respect to the major home appliances considered in this study. Therefore, for the comparison analysis, climate impact from logistical movement and dismantling activities are only considered.

Logistical movements of WEEE would contribute for significant amount of GHG emissions. As shown in Figure 6, GHG emission from both logistical movements of WEEE and dismantling activities is higher in Japan as compared to the situation in India. In the case of Japan, logistical movement is a complicated process and a significant amount of fossil fuel is consumed for transportation by using different types of trucks, which has resulted higher GHG emissions from primary transportation as compared to India. In addition, Japan GHG emissions from dismantling activities is significantly higher than in the case of India that may be due to higher level of fossil fuel consumption for processing WEEE through more automated systems. In India, after dismantling the processed materials should be transported to other countries like Japan or China. GHG emissions from smelting phase would be more or less similar to the emissions from smelting in Japan. After considering all these factors GHG emission from WEEE management in India would be lower as compared to the situation in Japan. It should be noted that a significant amount of metals/materials can be recovered if the scraps received from India is recycle in Japan. Thus it would facilitate to avoid production of an equivalent amount of material from conventional processes and associated GHG emissions from virgin production can be stopped. In the case of Japan, despite high GHG emissions potential from recycling activities, there is a possibility to avoid 50% of GHG emissions that could otherwise happen through equivalent amount of virgin materials production process. In the case of India, GHG emissions from recycling activities would be lower than Japan and therefore there is a possibility for contributing higher amount of GHG savings as compared to the situation in Japan.

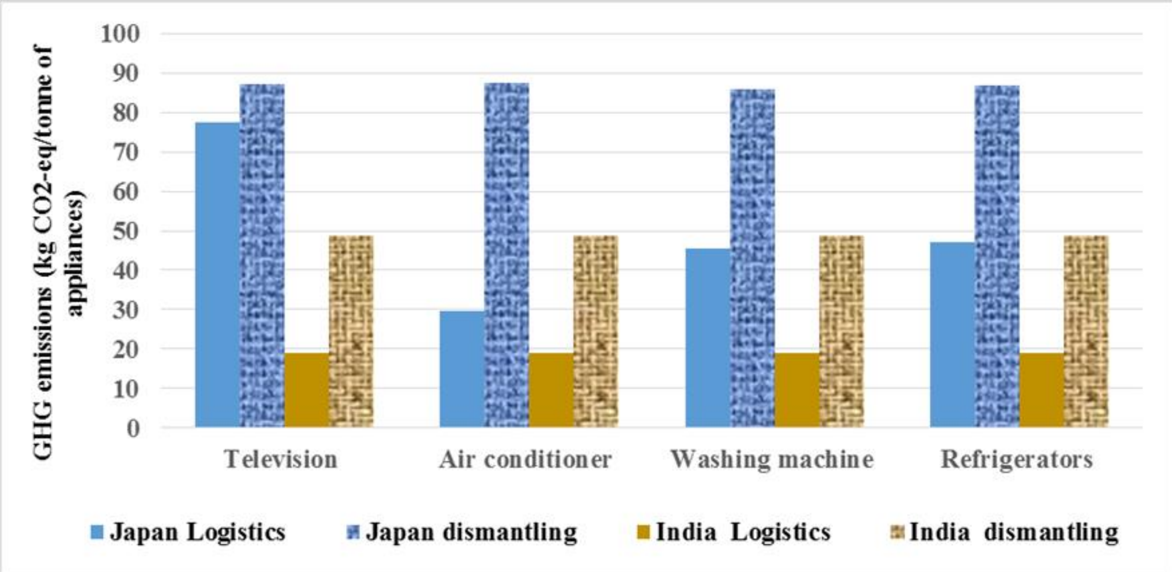

Figure 6: *GHG emissions related to logistics and dismantling activities in Japan and India*

As far as green jobs creation and income based community well-being is concerned, in Japan, sophisticated machineries and automated systems can be seen and that would be resulted for less labour power. In contrast, in India, manual based recycling system is implemented which leads for creation of more employment opportunities to the society.

5. Conclusions

The findings of this study disclosed that the start of a proper WEEE recycling project would contribute to world's finite-resource savings as well as make a critical commitment to accomplishing national/worldwide GHG mitigation targets. For instance, in the case of Japan, it is conceivable to avoid more 50% GHG emissions with respect to recycling of all electronic devices except televisions, that would some way or another could happen through the virgin production process chains. Furthermore, 75-80% of fossil energy can be saved by recycling and extracting of materials from washing machine, refrigerator and air conditioner as compared to the virgin production of equivalent of materials. In the case of television, 55% of fossil energy can be saved. In India, WEEE management activities are shown lower GHG emissions potential from recycling process and therefore, it would positively contribute for more GHG savings and fossil resource savings by recuperating significant amount of materials from WEEE.

Besides, by initiating an appropriate WEEE recycling program, socio-economic benefits can be created which are directly contribute for enhancing the well-being of the society. In Fukuoka, 165 employment opportunities have been created and annual income of 686 million Japanese yen can be generated due to handling and managing of 700,000 units of WEEE. In India, manual based recycling system is implemented which leads for creation of 40 times more employment opportunities to the society as compared to Japan.

The outcome of this study through the best practice encounters from Japan and preliminary recycling activities in India will be to a great degree valuable for improving existing policies and implementing proper legislation and new strategies in nations over the Asia-Pacific for developing sustainable WEEE management programs. In addition, systematic recycling systems explained in this study would be useful to enhance the methodical approaches of WEEE recycling and initiating sound material recycling programs in other countries.

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REFERENCES

AEHA, (2014). Annual Report, Association for Home Appliances, Japan. Retrieved from: http://www.aeha.or.jp/recycling_report/pdf/kadennenji23.pdf.

Afroz, R., Masud, M.M., Akhtar, R., & Bt Duasa. J. (2013). Survey and analysis of public knowledge, awareness and willingness to pay in Kuala Lumpur, Malaysia - a case study on household WEEE management. *Journal of Cleaner Production*, Vol 52, pp.185-193.

Christia, G.E. (2012). *End-of-Life Management of Waste Electrical and Electronic Equipment for Sustainable Development. Centre for International Sustainable Development Law*. McGill University, 3644 Peel St., Montreal, Quebec, H3A 1W9 Canada.

Echegaray, F., & Hansstein, F.V. (2016). Assessing the intention-behavior gap in electronic waste recycling: the case of Brazil, *Journal of Cleaner Production*, http://dx.doi.org/10.1016/j.jclepro.2016.05.064.

Hai, H.T., Hung, H.V. & Quang, N.D. (2015). An overview of electronic waste recycling in Vietnam. *Journal of Material Cycles and Waste Management*, DOI 10.1007/s10163-015-0448-x.

Kaden recycle Annual report, (2011). Association for Electric Home Appliances, Japan, 2011. Retrieved from: http://www.aeha.or.jp/about/outline.html.

Mallawarachchi, H. &Karunasena. G. (2012). Electronic and electrical waste management in Sri Lanka: Suggestions for national policy enhancements. *Resources, Conservation and Recycling*, Vol 68, pp. 44– 53.

Menikpura, S.N.M., Santo, A. & Hotta. Y. (2014). Assessing the Climate Co-benefits from Waste Electrical and Electronic Equipment (WEEE) Recycling in Japan. *Journal of cleaner production*, Vol 74, pp. 183-190.

Menikpura, S.N.M., Sang-Arun,J, & Bengtsson, M. (2013). Integrated Solid Waste Management: An Approach for Enhancing Climate Co-benefits through Resource Recovery. *Journal of Cleaner Production*, Vol 58, pp.34-42.

NIMS-EMC, (2009). Total Materials Requirement (TMR). Retrieved from: http://www.nims.go.jp/genso/0ej00700000039eq-att/0ej00700000039ld.pdf

Oguchi, M., Sakanakura,H. &Terazono, A. (2013). Toxic metals in WEEE: Characterization and substance flow analysis in waste treatment processes. *Science for the Total Environment*, Vol 463-464, pp.1124-1132.

Qu, Y., Zhu, Q., Sarkis, J., Geng, Y. &Zhong, Y. (2013). A review of developing an e-wastes collection system in Dalian, China. *Journal of Cleaner Production*, Vol 52, pp.176-184.

SAPIENS, (2015). *Surveys and Perspectives Integrating Environment and Society*, Institute Veolia Environment, Sablons 75016 Paris, France. ISSN: 1993-3800.

Statistics Japan, (2015). Statistics Bureau, Ministry of Internal Affairs and Communications, Japan, 2012. Retrieved from: http://www.stat.go.jp/english/index.htm.