**Title:**

# The Economic and Environmental Value of Electronic Waste Recycling in the GCC countries

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## Abstract

**Purpose**: This paper aims to examine the economic benefit of electronic waste production and recycling until the year 2040. Also, the environmental impact and value of efficient handling of electronic waste are analyzed.

**Methods**: The global electronic waste generation is estimated to surpass 52.2 million metric tonnes (Mt) with an annual growth of 3 to 5%. The quantities of electronic waste and its economic value in GCC countries were estimated based on known and published statistics of population, electronic waste generation per capita, and composition of valuable materials within electronic waste products. The term electronic waste referred to all electronic and electrical equipment (WEEE) discarded by the owner that are not suitable for reuse purposes.

**Results**: With adequate policies and regulations in place, the resource depletion and pollution issues could be reduced through efficient recycling of electronic waste. The significant economic growth in the Gulf cooperation council (GCC) countries over the past decades have been accompanied by urbanization and population growth along with the high standard of living. It is a well evident phenomenon that electronic waste and living standards are linearly proportional, and therefore the electronic waste in the GCC is constantly increasing.

**Conclusions**: The findings of this study will serve as a base study for further research in electronic waste in the GCC countries along with formulating adequate guidelines and regulations.

***Keywords***: Electronic waste; Waste from electrical and electronic equipment (WEEE); Economic; Environmental impact, Gulf cooperation council (GCC) countries

## 1. Introduction

The Gulf cooperation council (GCC) countries including Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) have experienced a huge growth in population along with urbanization and living standards (Alghazo and Ouda, 2016; Ouda et al. 2015; Nizami et al. 2015 and 2016). This led to a huge increase in waste production of all kinds including but not limited to electronic waste (Ouda et al. 2016). The developments in technology combined with throw-away and annual upgrading of electronic devices result in shorter life-spans of electronic waste (Baldé et al. 2017). The adequate management and recycling of electronic waste is a real challenge in both developed and developing countries. However, the issues regarding electronic waste in developing countries are significant due to lack of regulations and facilities.

Electronic waste includes all electrical and electronic equipment discarded by end users, and are not meant to reuse (Roychowdury et al. 2016). Electronic waste is classified into various categories, and their percentages include small IT and telecom devices 8.72%, small electrical equipment 37.58%, screens and monitors 14.76%, large electrical equipment 20.36%, lamps 1.57%, and cooling and freezing equipment 17% (Baldé et al. 2017). These devices as electronic waste contain a range of materials such as plastic, wood and plywood, glass, ferrous and non-ferrous metals, ceramics and rubber, and printed circuit boards. Iron steel is found in 50% of electronic waste, 21% of electronic waste contains plastic, and 13% contains non-ferrous metals including aluminum, copper and valuable metals including gold, platinum, silver, palladium, and others. Electronic waste also contains hazardous materials like mercury, arsenic, lead, selenium, hexavalent chromium, cadmium and flame retardants that sometimes exceed the acceptable threshold levels (Alghazo and Ouda, 2016; Allam and Inauen, 2009; Khatib, 2011).

It has been estimated that the amount of electronic waste produced globally in 2016 was around 44.7 million metric tonnes (Mt) and 20% was estimated to have been recycled through regulated channels (Baldé et al. 2017). This amount is expected to grow up to 46 (Mt) in 2017 and exceed 52.2 (Mt) by 2021. Asia produced 40.7% of the electronic waste generated in 2016, Oceania produced 1.57%, Europe produced 27.52%, Africa produced 4.92%, and the Americas produced 25.28% (North America 15.67%, Central America 2.68%, and South America 6.71%) (Baldé et al. 2017). The environmental and economic value of electronic waste in GCC countries has not been investigated despite the economic potential and environmental risks (Meenakshisundaram and Sinha, 2011). The population worldwide is increasing and is estimated to reach 9.6 billion by 2050 (UN-DESA, 2012), and therefore electronic waste will remain increasing as population increases.

The electronic waste production in GCC countries is not well documented in the literature, and some studies have predicted the per-capita electronic waste generation (Baldé et al. 2017). However, studies suggest that countries with high income produce higher waste per capita as compared the low-income countries. It is evident that income level and urbanization are correlated driving factors for the increase of all kinds of waste including the electronic waste (Bhada-Tata et al. 2012). This study aims to examine the economic and environmental value of electronic waste production and recycling until the year 2040. The basis for this estimation is the population increase as well as the expected per capita electronic waste generation.

## 2. Methodology

### *2.1 Electronic waste in GCC countries*

The GCC countries have excellent economic growth and high standard of living making the per-capita waste generation among the highest worldwide. This presents a great challenge for policymakers as waste in GCC countries is disposed of in landfills with limited or no recycling. It has been estimated that the GCC countries would produce around 120 (Mt) of waste in the year 2020 increased from 94 (Mt) in the year 2015 (Ouda et al., 2015, 2016; Bhata, 2016; Nizami et al., 2016). However, electronic waste is not segregated from the waste in landfills. The quantity of electronic waste was estimated to be around 738 kilotonnes (kt) in GCC countries in 2016 (Table 1). The scarcity of electronic waste recycling facilities and electronic waste management policies and regulations is clear in GCC countries (Alghazo and Ouda, 2016; Hassanin, 2016; Alameer, 2014).

Table 1. Electronic waste production in GCC production during 2016 (Baldé et al. 2017).

| Country | Population (1000) | Per capita electronic waste (kg) | Total electronic waste Kilotons (kt) |
|---|---|---|---|
| Bahrain | 1319 | 15.5 | 20 |
| Kuwait | 4225 | 15.8 | 67 |
| Oman | 3957 | 14.9 | 59 |
| Qatar | 2578 | 11.3 | 29 |
| Saudi Arabia | 32013 | 15.9 | 508 |
| United Arab Emirates | 9856 | 13.6 | 134 |
| Total electronic waste in GCC in tons | | | 738 |

### *2.2 Electronic waste production forecast*

The forecast of electronic waste in the GCC countries will help in predicting the economic and environmental value of electronic waste now and in the future. Various forecasting models and algorithms were proposed in the previous literature and were used to the proposed forecast model in this study (Yu et al. 2009; Zeng et al. 2016; Guo and Yana, 2017, Polák and Drápalová, 2012, Breivik et al. 2014). A forecast model for GCC production of electronic waste was developed based on 3 scenarios such as low, medium and high. These scenarios were based on the United Nations forecast for the population growth (UN Datam, 2017). Following is the mathematical model developed for the forecast.

$$EG = \frac{(P * [N + (N * \beta) * \{i - i(0)\}])}{1000}$$

Where EG is estimated growth including high, medium, and low scenarios, P represents population (high, medium and low), Ni is per capita electronic waste produced in Kg/inhabitant, Beta is a marginal percentage assumed for the growth in per-capita electronic waste production. The low, medium and high scenarios estimations of electronic waste in the GCC countries are shown in Table 2.

The raw material in electronic waste globally was estimated at 55 billion Euros in 2016, and the global electronic waste production was 44.7 (Mt). The GCC portion based on the determined production of 738 (Kt) would be 1.651% of the 55 billion which is 885.5 million Euros. This is equivalent to 1,199. 86 Euro per ton of electronic waste. This number will be a pivotal value used in the economical estimation of the electronic waste in GCC countries. Using this number as a base of calculation, the potential economic value of electronic waste up to the year 2040 is shown in Table 3 for low, medium and high scenarios respectively.

## 3. Results and Discussion

No study has been reported so far that indicates the characterization and composition of electronic waste in GCC countries considering all types of waste. The electronic waste is currently part of the waste and sent to landfills and disposed of the same way as regular waste. The total estimated production of electronic waste in GCC countries during 2018 for low scenario is 857 thousand tons (Table 2). Among GCC countries, Saudi Arabia produced the highest amount of electronic waste in 2018 with a value of 533 thousand tons (Table 2). It is estimated that by 2040 the total produced amount of electronic waste in the GCC countries will be 1094 thousand tons, including Saudi Arabia (675 thousand tons), UAE (167 thousand tons), Qatar (40 thousand tons), Oman (95 thousand tons), Bahrain (34 thousand tons), and Kuwait (83 thousand tons) (Table 2).

As the electronic waste is not quantified and segregated in the GCC countries, thus an accurate estimation of the economic value of electronic waste is not possible. However, with assumptions combined with the electronic waste forecast in the previous section, this study showed a huge economic value in electronic waste in GCC countries. The total estimated economic value of electronic waste in GCC countries during 2018 for low scenario is 1,028 million Euros (Table 3). Among GCC countries, Saudi Arabia has the highest economic value of 640 million Euros during 2018 (Table 3). It is estimated that by 2040 the total economic value of electronic waste in the GCC countries will be 1,312 million Euros, including Saudi Arabia (810 million Euros), UAE (200 million Euros), Qatar (48 million Euros), Oman (113 million Euros), Bahrain (41 million Euros), and Kuwait (100 million Euros) (Table 3).

Table 2. Electronic waste generation and its forecast until the year 2040 in GCC countries

| **Electronic waste generation forecast-low scenario (thousands of tons per year)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Years | Bahrain | Kuwait | Oman | Qatar | Saudi Arabia | UAE | Total |
| 2018 | 25 | 66 | 72 | 30 | 533 | 130 | 857 |
| 2020 | 26 | 68 | 77 | 32 | 552 | 134 | 889 |
| 2025 | 29 | 73 | 83 | 34 | 593 | 143 | 955 |
| 2030 | 31 | 75 | 88 | 37 | 626 | 151 | 1008 |
| 2035 | 33 | 80 | 91 | 39 | 653 | 159 | 1056 |
| 2040 | 34 | 83 | 95 | 40 | 675 | 167 | 1094 |
| **Electronic waste generation forecast-Medium scenario (thousands of tons per year)** | | | | | | | |
| 2018 | 25 | 67 | 72 | 31 | 536 | 130 | 861 |
| 2020 | 27 | 69 | 77 | 32 | 557 | 135 | 897 |
| 2025 | 30 | 74 | 85 | 35 | 606 | 145 | 975 |
| 2030 | 32 | 80 | 91 | 38 | 650 | 156 | 1046 |
| 2035 | 34 | 85 | 96 | 40 | 688 | 166 | 1109 |
| 2040 | 36 | 89 | 100 | 42 | 721 | 176 | 1165 |
| **Electronic waste generation forecast-High scenario (thousands of tons per year)** | | | | | | | |
| 2018 | 25 | 67 | 73 | 31 | 541 | 132 | 869 |
| 2020 | 27 | 70 | 78 | 32 | 565 | 136 | 909 |
| 2025 | 30 | 76 | 87 | 36 | 623 | 148 | 1000 |
| 2030 | 34 | 83 | 94 | 39 | 677 | 161 | 1088 |
| 2035 | 36 | 89 | 100 | 42 | 726 | 173 | 1168 |
| 2040 | 39 | 96 | 106 | 45 | 771 | 186 | 1242 |

In GCC region, the key element that will encourage investors and governments to invest in electronic waste recycling plants would be the availability of enough electronic waste to keep the plants running. This is referred to as feedstock. High volumes of feedstock are required to ensure that the electronic waste recycling plans are sustainable and economically viable (World Bank, 2012). The choice for a suitable location for the electronic waste recycling facility or industry should include the requirement of having a high volume of feedstock. Based on the estimations of electronic waste production in GCC countries as shown in Table 2, this location should be between Saudi Arabia and the United Arab Emirates (UAE). This area should be declared as a free zone area where all GCC countries can export their feedstock for processing electronic waste while at the same time considering an international agreement that limits the export of waste and electronic waste.

Table 3. The economic value of electronic waste and its forecast until the year 2040 in GCC countries

| Economic value of electronic waste- Low scenario forecast (millions of Euros) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Years | Bahrain | Kuwait | Oman | Qatar | Saudi Arabia | UAE | Total |
| 2018 | 30 | 79 | 87 | 36 | 640 | 156 | 1,028 |
| 2020 | 32 | 82 | 92 | 38 | 663 | 161 | 1,067 |
| 2025 | 35 | 87 | 100 | 41 | 711 | 171 | 1,146 |
| 2030 | 37 | 90 | 106 | 44 | 751 | 182 | 1,210 |
| 2035 | 39 | 96 | 110 | 47 | 784 | 191 | 1,267 |
| 2040 | 41 | 100 | 113 | 48 | 810 | 200 | 1,312 |
| Economic value of electronic waste- Medium scenario forecast (millions of Euros) | | | | | | | |
| 2018 | 30 | 80 | 87 | 37 | 643 | 156 | 1,033 |
| 2020 | 32 | 82 | 93 | 38 | 669 | 162 | 1,076 |
| 2025 | 35 | 89 | 102 | 42 | 727 | 174 | 1,170 |
| 2030 | 39 | 96 | 109 | 45 | 780 | 187 | 1,255 |
| 2035 | 41 | 102 | 115 | 48 | 826 | 199 | 1,331 |
| 2040 | 43 | 107 | 120 | 51 | 865 | 211 | 1,398 |
| Economic value of electronic waste- High scenario forecast (millions of Euros) | | | | | | | |
| 2018 | 30 | 80 | 88 | 37 | 649 | 158 | 1,042 |
| 2020 | 32 | 84 | 94 | 39 | 678 | 164 | 1,090 |
| 2025 | 36 | 92 | 104 | 43 | 747 | 178 | 1,200 |
| 2030 | 40 | 100 | 113 | 47 | 812 | 193 | 1,305 |
| 2035 | 44 | 107 | 120 | 50 | 872 | 208 | 1,401 |
| 2040 | 46 | 115 | 128 | 54 | 925 | 223 | 1,490 |

There are great environmental and economic benefits in electronic waste provided proper legislation for the effective handling of electronic waste (Baldé et al. 2017). As stated in the introduction section, iron steel is found in 50% of electronic waste, 21% of electronic waste contains plastic, and 13% contains non-ferrous metals; aluminum, copper and valuable metals such as gold, silver, palladium, platinum, and others. Another study estimates metals at 60%, plastic 15%, metal-plastics 5%, cables 2%, screens 12%, printed circuit boards 2% (Herat and Agamuthu, 2012). For example, an estimated 0.340 kg of gold, 0.140 kg of palladium, 3.5 kg of silver and 130 kg of copper, can be found in one ton of cell phones, with an estimated market value of 15,000 USD (Premalatha et al., 2014). Overall, the economic value of electronic waste is evident, and the environmental value of recycling electronic waste is evident. Federica et al. (2015) presented a detailed study of recycling of WEEEs.

The economic and environmental value of electronic waste or what is left after extracting the valuable materials through efficient recycling plants can be used in waste-based biorefineries that will provide an additional economic and environmental value for electronic waste (Nizami et al. 2017; Ouda et al. 2016). Electronic waste is considered the most valuable waste material as compared to other waste types and is growing very fast from 3-5% on an annual basis. The raw material contained in electronic waste if recycled will reduce the need for virgin sources in manufacturing (Cucchiella et al., 2015). Electronic waste contains some devices that contain some valuable material as well as rare earth items, such as photovoltaic (PV) panels, liquid crystal displays (LCD), cathode ray tubes (CRT), light emitting diode (LED) display, monitors, notebooks and handhelds, printed circuit boards, hard disk drives (HDDs), solid-state drives (SSDs), cell phones and smart phones (Cucchiella et al. 2015). As previously mentioned, electronic waste contains precious metals such as gold, palladium, platinum, and silver. It also contains what is referred to as critical materials such as beryllium, antimony, cobalt, cerium, europium, dysprosium, gallium, gadolinium, lanthanum, indium, palladium, neodymium, praseodymium, platinum, yttrium and terbium. In recycling a desktop computer, it is estimated that revenue for one desktop will be € 8.61 (UNEP 2013) based on the prices of raw material at certain time. A similar study should be carried out for the current prices and demands for such elements.

Though some of the GCC have in place some regulations towards the E-waste disposal and recycling, yet as a whole the GCC region is still in need of comprehensive rules, regulations, standards, and processes for the proper disposal and/or recycling of E-waste (Alghazo and Ouda, 2016). In addition, it is proposed in this paper that a free zone be established for the GCC countries in which all GCC countries can send their E-waste to state of the Art recycling plants setup in the proposed freezone. However, there are some international agreements, laws and regulations that govern the import and export of waste in general and E-waste in particular and thus proper regulation should be approved through the GCC council in this regards.

## 4. Conclusions

The potential for electronic waste as an economic asset in GCC countries is evident because even in the low estimate scenario by 2020 the electronic waste value in GCC countries would be worth 1 billion Euros. The extended version of the paper would contain the value of the medium and high scenarios. By considering electronic waste into proper recycling scheme, the environmental potential of electronic waste is also realized as electronic waste is causing the hazardous material to pollute the urban areas. In addition, when electronic waste is removed from the mix of waste, around 738 (Kt) of electronic waste is removed from the landfills along with removing of 836 (Kt) electronic waste from landfill by 2020.

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