El rol de la Academia en la investigación de los RAEE

Ramzy Kahhat, Ph.D.

PELCAN

Departamento de Ingeniería

Pontificia Universidad Católica del Perú

Jornadas de Investigación

Gestión de residuos eléctricos y electrónicos: desafíos en la era de la transformación digital

7, 8 y 9 de Diciembre del 2020

PROSIC Programa Institucional Sociedad de la Información y el Conocimiento

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La academia cumple un rol importante en:

- **Investigación**
- Innovación
- Formación en el pregrado y posgrado
- Formación continua
- Capacitación especializada
- Consultoría especializada

… y su rol en la investigación de los RAEE incluye:

- **Generación de nuevo conocimiento** para así brindar información, directa o indirectamente, en el proceso de toma de decisiones vinculados con el manejo de los RAEE
- **Desarrollo de metodologías** para apoyar la generación de data
- **Crítica constructiva** de políticas públicas orientadas al manejo de RAEE
- **Generación de tecnologías**
  - Recuperación de recursos de los RAEE
  - Mitigar los impactos ambientales en el reciclaje
- **Desarrollo de estrategias** para de sistemas de manejo de RAEE
- **Formación de capacidades** entorno a las RAEE: Investigadores, etc

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¿Cuál ha sido el rol de la Academia en la investigación en los RAEE?

China. Source: BAN and SVTC 2002

A continuación y en base a mi experiencia … algunos ejemplos del rol de la academia en los RAEE

¿Qué se esconde dentro del ***container***?

El primer ejemplo que les quiero mostrar es el rol de la investigación en evidenciar lo que algunos sabían pero que no era considerado en la toma de decisiones…

¿Qué se esconde dentro del *container*?

Diversa fuentes de financiamiento:

US National Science Foundation

Commission for Environmental Cooperation of North America

Arizona State University

Pontificia Universidad Católica del Perú

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¿Qué se esconde dentro del ***container***?

Environ. Sci. Technol. **2009,** *43,* 6010–6016

Product or Waste? Importation and End-of-Life Processing of Computers in Peru

RAMZY KAHHAT*,† AND ERIC WILLIAMS†,‡

Center for Earth Systems Engineering and Management, Department of Civil, Environmental and Sustainable Engineering, Arizona State University, Tempe, Arizona 85287, and School of Sustainability, Arizona State University, Tempe, Arizona 85287

computers deemed obsolete or unnecessary by a user and includes computers that will be reused via secondary markets or handled as waste via end-of-life management. Environmental concerns regarding this waste stream include exposure to toxic materials, particularly to informal recycling practices in the developing world. Environmental and human health damages produced by informal recycling are indisputable as shown by research and media coverage of informal electronic recycling sites located in China, India, Ghana, Nigeria, and others locations (*5*–*9*). In response to this growing waste stream, governments in different parts of the world have implemented electronics-related policies including takeback and recycling systems (e.g., WEEE in Europe), mandating content of hazardous materials (e.g RoHS in

¡No todo lo que se exporta esta destinado para el reciclaje informal!

¿Qué se esconde dentro del *container*?

Export MFA

Shipment-level Trade Analysis (Class I)

Import MFA (Class II)

Regression Analysis (Class III)

Williams, E. and Kahhat, R. Feasibility Study for the Characterization/Quantification of the Flow of Used Electronics Equipment in North Ameri
March 2010. Final report presented to the Commission for Environmental Cooperation of North America.

Resources, Conservation and Recycling 67 (2012) 67–74

Contents lists available at SciVerse ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

Materials flow analysis of e-waste: Domestic flows and exports of used computers from the United States

Ramzy Kahhat[a,*], Eric Williams[b]

[a] Department of Engineering, Pontificia Universidad Católica del Perú, Lima, Peru
[b] Golisano Institute for Sustainability, Rochester Institute of Technology, Rochester, NY, USA

ARTICLE INFO

Article history:
Received 8 March 2012
Received in revised form 27 July 2012
Accepted 27 July 2012

Keywords:
Electronic waste (e-waste)
Material flow analysis
End-of-life

ABSTRACT

The management of electronic waste (e-waste) presents new sustainability challenges, prominent among these is informal electronic recycling in the developing world fed by both international and domestic sources. There is a need to mitigate environmental impacts of informal recycling while maintaining social and economic benefits of refurbishment and reuse. The development of appropriate social responses is hindered by critical data gaps, which include lack of data on trade flows of used and scrap electronics, flows invisible to trade statistics of many countries. We address this data gap by proposing and implementing an approach to quantify the exportation of used and scrap equipment from a particular country or region to the rest of the world. The approach is based on material flow analysis and combines collection of primary survey data from residential and business/public sectors with secondary data from available recycling, landfill and computer adoption studies. Exports are estimated through materials balance: exports = generated – reuse – recycling – landfill. The proposed methodology is implemented in a case study of desktop (excluding monitors) and laptop computers in the United States (US) in 2010. Results indicate that 40 million used and scrap computers entered the end-of-life management sector, from which 30% were reused domestically, 6–29% were exported, 17–21% were landfilled in domestic sites and 20–47% were collected for domestic recycling in 2010. The range in results reflects uncertainty arising from inferring end-of-life fate from individual and institutional users. Given sufficient resources to conduct a survey, the proposed materials flow analysis method can be widely applied to other devices and nations.

Desarrollo y aplicación de metodología para entender la exportación de “e-waste”…

¿Tienen sentido las estrategias que estamos aplicando?

Environ. Sci. Technol. **2008**, *42*, 6446–6454

Environmental, Social, and Economic Implications of Global Reuse and Recycling of Personal Computers

ERIC WILLIAMS,*,†,‡ RAMZY KAHHAT,† BRADEN ALLENBY,† EDWARD KAVAZANJIAN,† JUNBEUM KIM,† AND MING XU†

Department of Civil and Environmental Engineering and School of Sustainability, Arizona State University, Tempe, Arizona 85287

Received September 7, 2007. Revised manuscript received April 4, 2008. Accepted April 14, 2008.

Reverse supply chains for the reuse, recycling, and disposal of goods are globalizing. This article critically reviews the environmental, economic, and social issues associated with international reuse and recycling of personal computers. Computers and other e-waste are often exported for reuse and recycling abroad. On the environmental side, our analysis suggests that the risk of leaching of toxic materials in computers from well-managed sanitary landfills is very small. On the other hand, there is an increasing body of scientific evidence that the environmental impacts of informal recycling in developing countries are serious. On the basis of existing evidence informal recycling is the most pressing environmental issue associated with e-waste. Socially, used markets abroad improve access to information technology by making low-priced computers available. Economically, the reuse and recycling sector provides employment. Existing policies efforts to manage e-waste focus on mandating domestic recycling systems and reducing toxic content of processes. We argue that existing policy directions will mitigate but not solve the problem of the environmental impacts of informal recycling. There are many opportunities yet to be explored to develop policies and technologies for reuse/recycling systems which are environmentally safe, encourage reuse of computers, and provide jobs.

respectively, from 1993−2003, with exports of scrap steel reaching 5.7 million tons in 2003 (*2*).

At least as far as the public is concerned, the focus issue related to international reverse supply chains has been the environmental impacts of informal recycling activities. End-of-life electronics, for example, are often exported from developed to developing countries and then recycled via a "backyard industry" using primitive processes (*3*). Similar problems have been found for other products, such as informal dismantling of end-of-life ships (*4*). In response to this situation, U.S. nongovernmental organizations (NGOs) have called for bans on trade-in end-of-life goods deemed toxic (*3*).

Reverse supply chains also interface with economic and social issues. While reuse and recycling sectors are often neglected in economic analyses, they can be a significant source of employment and revenue (see section 4) (*5*). From a social perspective, markets for used goods play a role in developing countries in providing broader access to technologies important to both consumer and industrial sectors. A variety of products, including automobiles, computers, and cell phones, are too expensive for many in the developing world to purchase new. The significantly lower price of used goods can make the difference between access and unavailability.

In this article we explore the environmental, social, and economic aspects of a particular international reverse supply

Crítica constructiva a las estrategias mundiales para enfrentar el problema de los RAEE…

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¿Tiene sentido prohibir la exportación de electrónicos usados?

Environ. Sci. Technol. **2010**, *44*, 3232–3237

Forecasting Global Generation of Obsolete Personal Computers

JINGLEI YU,† ERIC WILLIAMS,*,‡
MEITING JU,† AND YAN YANG‡

Department of Environmental Science and Engineering, Nankai University, Tianjin, 300071, P.R. China, and School of Sustainable Engineering and the Built Environment and the School of Sustainability, Arizona State University, Tempe, Arizona 85287

Received November 3, 2009. Revised manuscript received February 7, 2010. Accepted February 15, 2010.

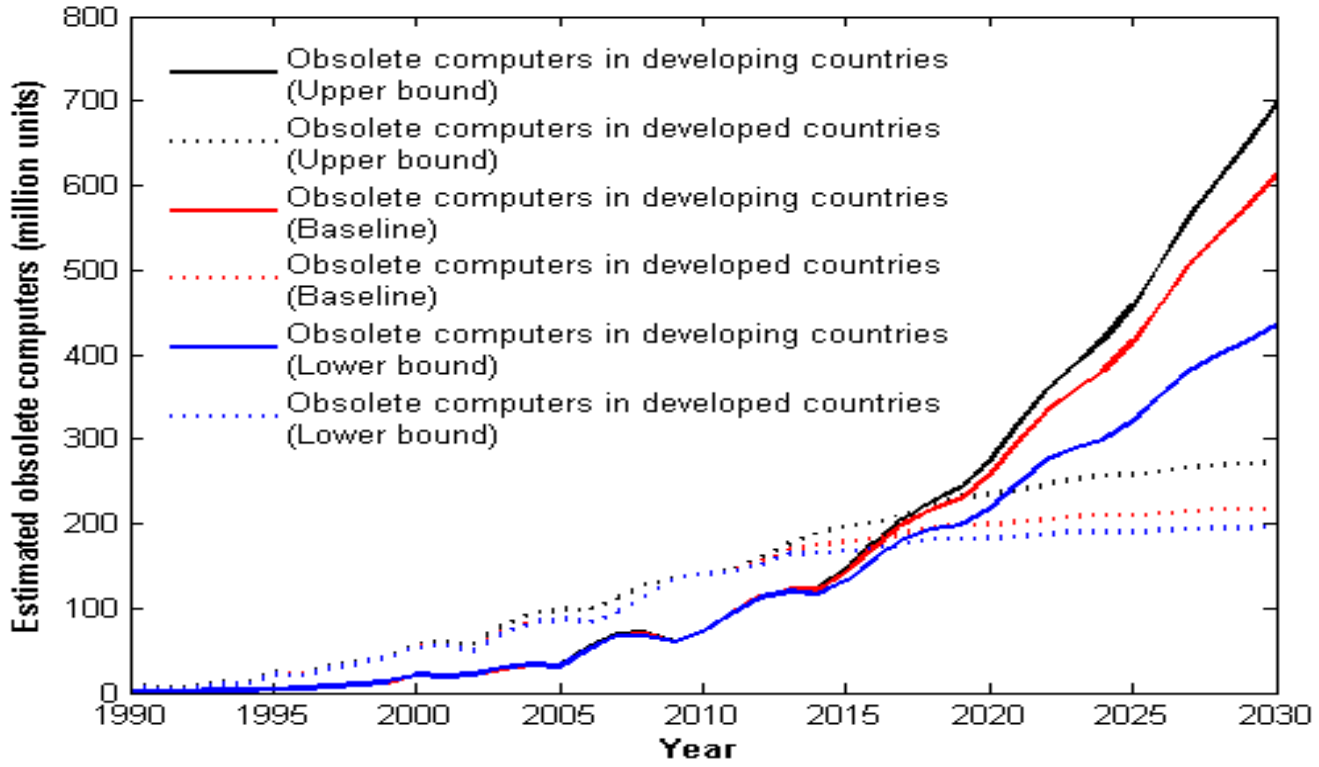
Electronic waste (e-waste) has emerged as a new policy priority around the world. Motivations to address e-waste include rapidly growing waste streams, concern over the environmental fate of heavy metals and other substances in e-waste, and impacts of informal recycling in developing countries. Policy responses to global e-waste focus on banning international trade in end-of-life electronics, the premise being that e-waste is mainly generated in the developed world and then exported to the developing world. Sales of electronics have, however, been growing rapidly in developing nations, raising the question of whether informal recycling in developing countries driven by international trade or domestic generation. This paper addresses this question by forecasting the global generation of obsolete personal computers (PCs) using the logistic model and material flow analysis. Results show that the volume of obsolete PCs generated in developing regions will exceed that of developed regions by 2016−2018. By 2030, the obsolete PCs from developing regions will reach 400−700 million units, far more than from developed regions at 200−300 million units. Future policies to mitigate the impacts of informal recycling should address the domestic situation in developing countries.

other pollutants. Circuit boards are treated to extract copper and precious metals using acids and cyanide, polluting local water systems. NGOs and media reports have shown serious environmental impacts from informal recycling in China, India, Ghana, Nigeria, and other locations (*1*–*4*). Scientific studies in Guiyu (in China) have confirmed that informal recycling does lead to serious pollution (*5*, *6*).

Investigations of informal reuse and recycling sites revealed that processed e-waste mainly comes from the developed world (data on several cases of international transboundary movements of e-waste are shown in Supporting Information (SI) Section S7) (*7*, *8*). The informal recycling problem is primarily viewed as an issue of transboundary movements of waste (*9*, *10*). The main policy solution to informal recycling in the public discourse is banning international trade, the argument being that stopping international trade in e-waste should in turn stop informal recycling (*7*–*16*).

At the international level the main relevant policy is the Basel Convention, a multilateral environmental agreement controlling trade of wastes classified as hazardous (*10*). Some categories of e-waste not intended for reuse are classified as hazardous. The Basel Convention requires prior notification between signatories when trading wastes classified as hazardous. There is also a proposed amendment to the Convention, the Basel Ban, which forbids international trade in all the materials categorized by the Convention as hazardous. This amendment has not been ratified.

Partly in response to concerns over informal recycling, a number of countries have implemented bans or restrictions on imports of e-waste. In 2000 and 2002, China introduced legislation that prohibited the import of e-waste (*11*). India, Indonesia and Vietnam have also decided to prohibit import of e-waste (*12*). There is currently a bill under consideration in the U.S. Congress, H.R. 2595, which restricts certain exports of e-waste from the U.S (*13*). The question of when end-of-first-life electronics should be considered as used electronics versus e-waste is complex. Different countries take different positions on this issue. Indonesia has banned the import of used TVs, radios, and other second-hand equipment, while Thailand requires that the imported used



Product or Waste? Importation and End-of-Life Processing of Computers in Peru

RAMZY KAHHAT*,† AND ERIC WILLIAMS‡,§

Center for Earth Systems Engineering and Management, Department of Civil, Environmental and Sustainable Engineering, Arizona State University, Tempe, Arizona 85287, and School of Sustainability, Arizona State University, Tempe, Arizona 85287

Received December 17, 2008. Revised manuscript received April 27, 2009. Accepted June 2, 2009.

This paper considers the importation of used personal computers (PCs) in Peru and domestic practices in their

computers deemed obsolete or unnecessary by a user and includes computers that will be reused via secondary markets or handled as waste via end-of-life management. Environmental concerns regarding this waste stream include exposure to toxic materials, particularly to informal recycling practices in the developing world. Environmental and human health damages produced by informal recycling are indisputable as shown by research and media coverage of informal electronic recycling sites located in China, India, Ghana, Nigeria, and others locations (*5*–*9*). In response to this growing waste stream, governments in different parts of the world have implemented electronics-related policies including takeback and recycling systems (e.g., WEEE in Europe), mandating content of hazardous materials (e.g RoHS in Europe) and managing the trade in end-of-life equipment (e.g., the Basel Convention) (*10*–*12*). The driving assumptions of these policies are primarily the following: due to the content of toxic materials in computers, landfilling of electronics is an environmental hazard and should be banned. Also, computers should be designed to contain fewer toxic materials; informal recycling of computers and other electronics should be managed by banning exports from the

¡Tal vez no tenía sentido!

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¿Quién los representa?

Ghana . Source: National Geographic 2008

Creando sistemas de manejo de RAEE que los consideren…

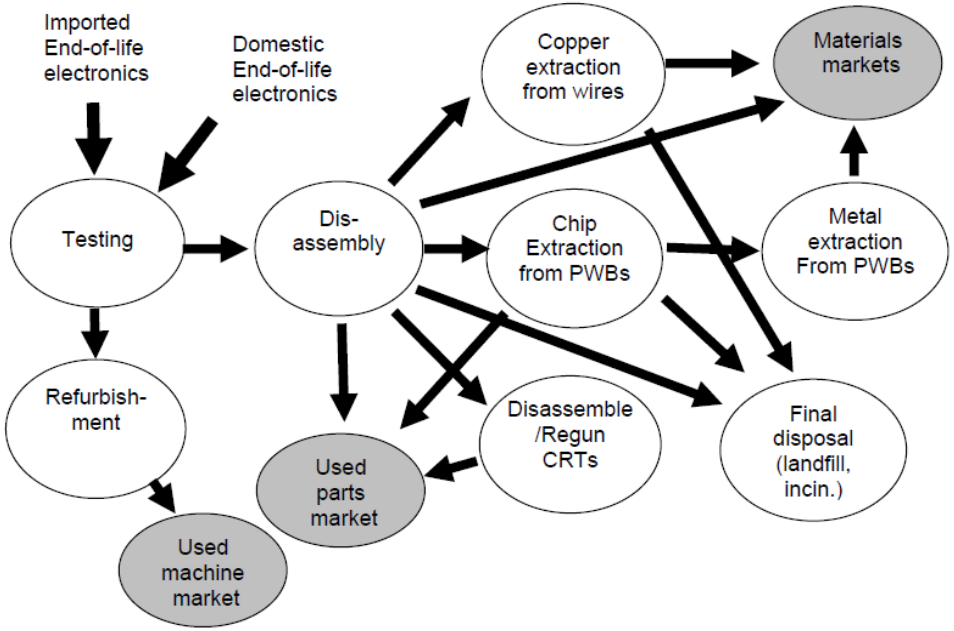


Figure 1: Process network in the informal recycling sector for IT equipment (PWB = Printed Wiring Board, CRT = Cathode Ray Tube)

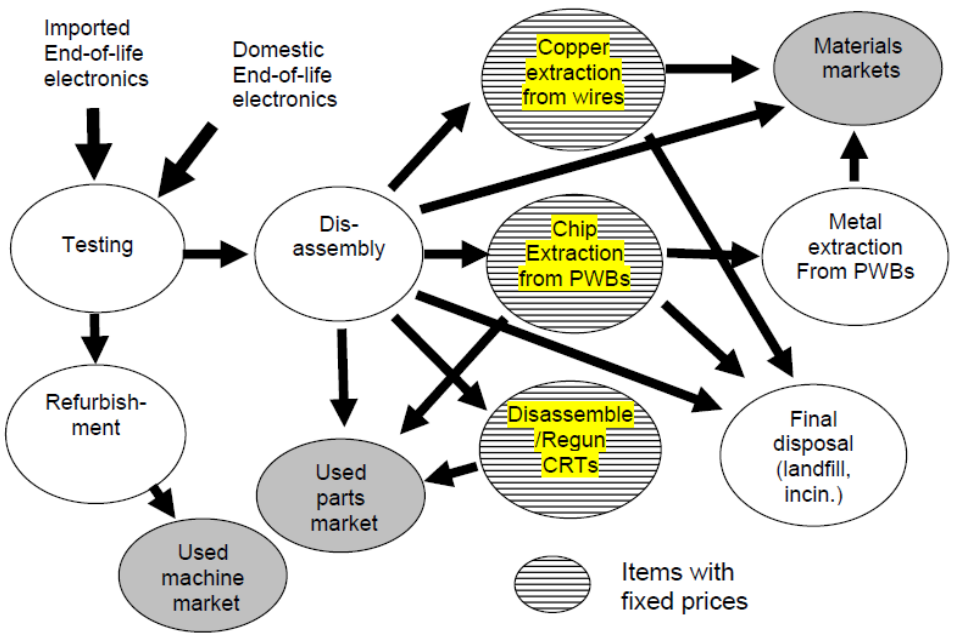


Figure 2: Reuse/recycling system with fixed prices to avoid informal processing for environmental "hotspots"

Williams 2005

Proponiendo la integración de actores formales e informales…

Challenges **2013**, *4*, 136-153; doi:10.3390/challe4020136

OPEN ACCESS

challenges

ISSN 2078-1547

www.mdpi.com/journal/challenges

Article

Linking Informal and Formal Electronics Recycling via an Interface Organization

Eric Williams [1,*], Ramzy Kahhat [2], Magnus Bengtsson [3], Shiko Hayashi [3], Yasuhiko Hotta [3] and Yoshiaki Totoki [3]

1 Golisano Institute for Sustainability, Rochester Institute of Technology, Rochester, NY 14623, USA

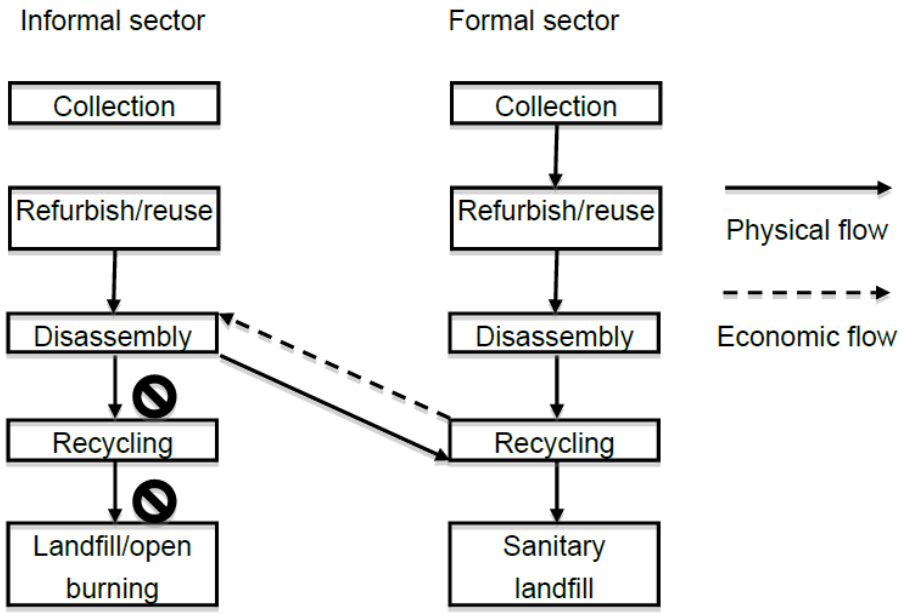
2 Department of Engineering, Pontificia Universidad Católica del Perú, Lima 32, Peru; E-Mail: ramzy.kahhat@pucp.pe

3 Institute for Global Environmental Strategies, Hayama, Kanagawa-ken 240-0115, Japan; E-Mails: bengtsson@iges.or.jp (M.B.); hayashi@iges.or.jp (S.H.); hotta@iges.or.jp (Y.H.); totoki@iges.or.jp (Y.T.)

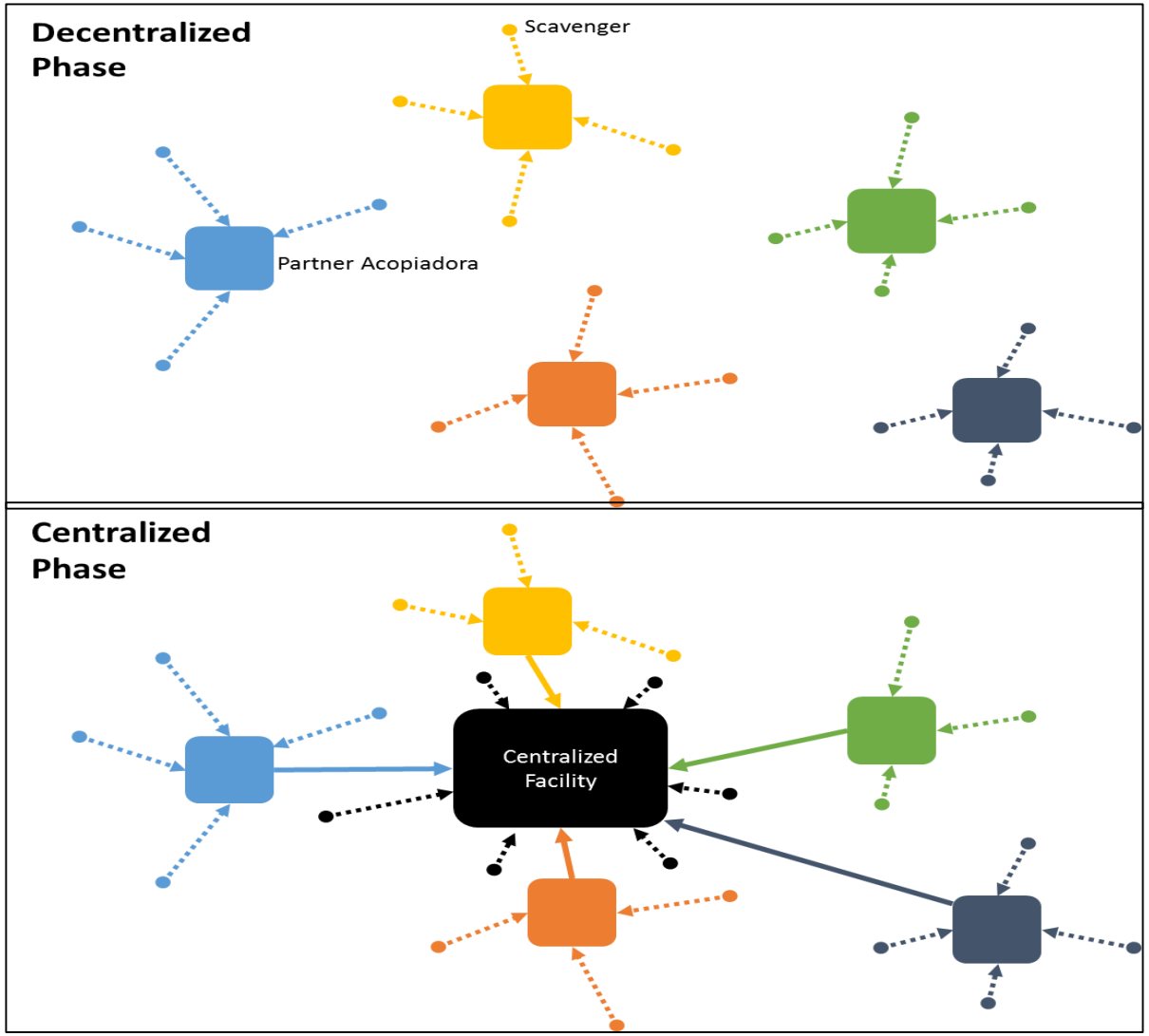
* Author to whom correspondence should be addressed; E-Mail: exwgis@rit.edu; Tel.: +1-585-475-7211.

Received: 26 April 2013; in revised form: 18 June 2013 / Accepted: 11 July 2013 / Published: 23 July 2013

Figure 1. Example of linking informal and formal sectors via an economic instrument.



Creando sistemas de manejo de RAEE que los consideren…



Mexicali en la perspectiva global del residuo electrónico

R. Miller, L McDonald, R. Kahhat, Sara Ojeda

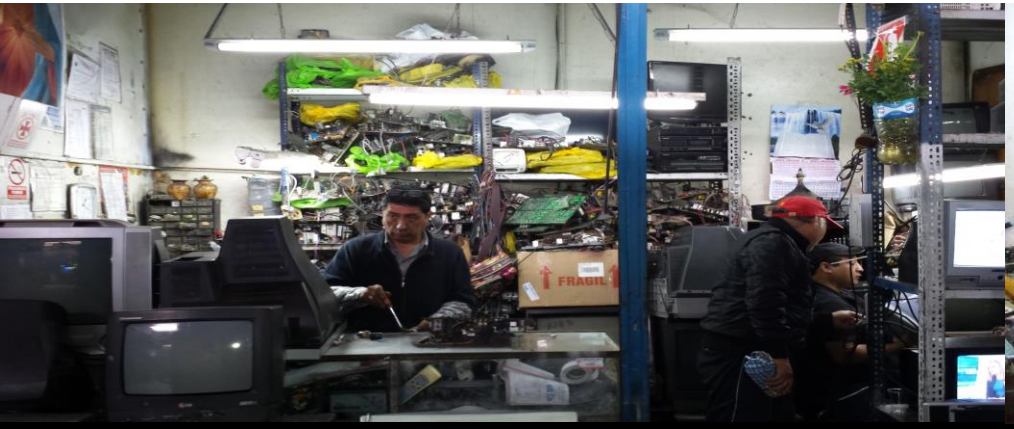
Partners:

- US EPA
- Border Environment Cooperation Commission (created after NAFTA)
- Inter-American Development Bank
- Universidad Autónoma de Baja California

Objetivos a largo plazo del proyecto:

- Beneficiar a la gente de Mexicali en los aspectos socioeconómicos, salud, ambiente
- Beneficiar directamente a los trabajadores informales y sus familias

Creando sistemas de manejo de RAEE que los consideren y fomentando el reuso, reparación y mantenimiento…



Repairing CRT-TVs in Leticia (Downtown Lima) Lima-Peru. Source: Kahhat, R. 2015

Soldering an integrated circuit board to a PCB in a TV repair shop in downtown Mexico City, Mexico Source: Kahhat, R. 2010

"Esta distribución planetaria de los usuarios de iFixit sugiere una distribución archipelágica de la actividad de M&R" (Lepawsky 2020)

Creando sistemas creativos de manejo de RAEE …

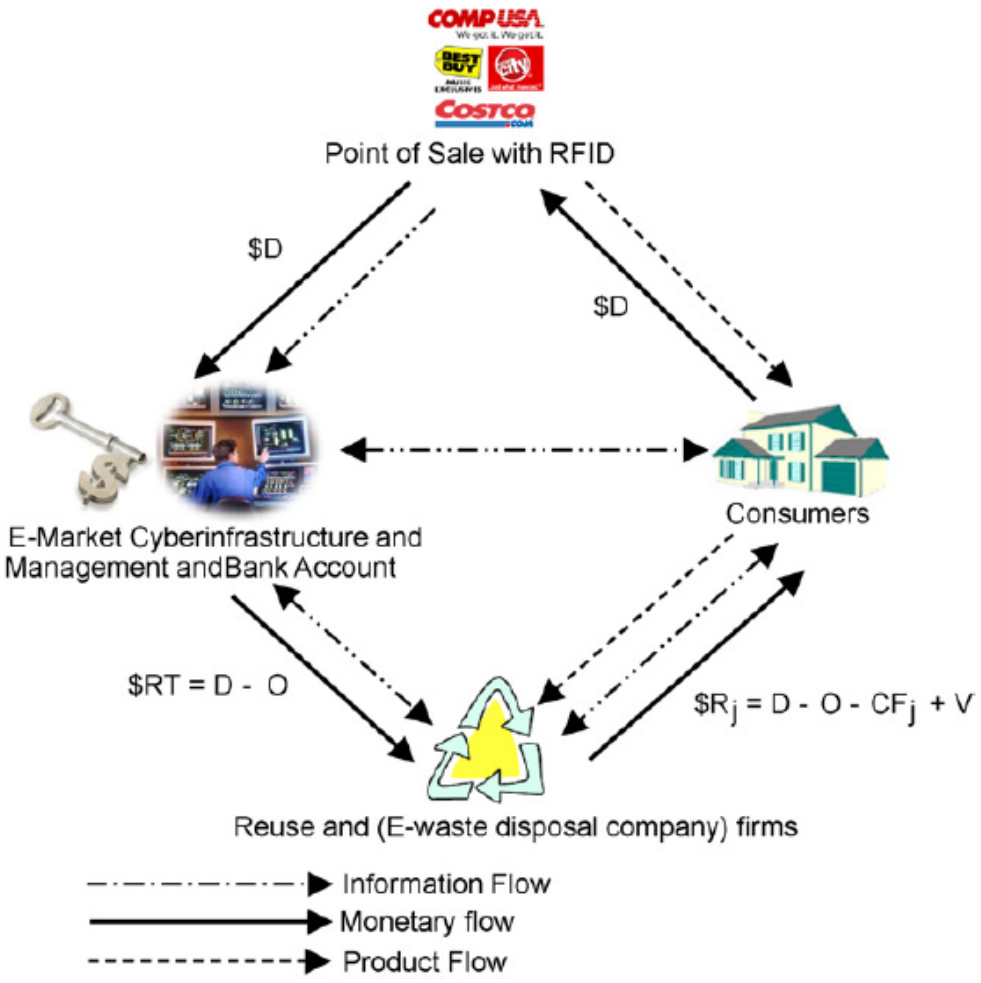


Fig. 1. *e-Market for Returned Deposit* System for given product (D = deposit, O = per product overhead for e-market management, R_j = rebate offered by firm j, CF_j = cost to firm j to recycle, RT = return made by the e-market management, V = e-waste additional value offered to the consumer).

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

Review

Exploring e-waste management systems in the United States

Ramzy Kahhat[a,*], Junbeum Kim[a], Ming Xu[a], Braden Allenby[a], Eric Williams[a,b], Peng Zhang[a]

[a] Department of Civil and Environmental Engineering, Arizona State University, Tempe, AZ 85287, USA
[b] School of Sustainability, Arizona State University, Tempe, AZ 85287, USA

ARTICLE INFO

Article history:
Received 10 October 2007
Received in revised form 6 March 2008
Accepted 12 March 2008
Available online 2 May 2008

Keywords:
E-waste
Collection
Recycling
Reuse
Takeback
Earth system engineering and management
Deposit-refund

ABSTRACT

Quantities of end-of-life electronics (or e-waste) around the world keep growing. More than 1.36 million metric tons of e-waste were discarded, mainly in landfills, in the U.S. in 2005, and e-waste is projected to grow in the next few years. This paper explores issues relating to planning future e-waste regulation and management systems in the U.S. It begins by reviewing the existing U.S. recycling systems in the U.S. to establish the importance of developing public responses. Other countries and regions around the world have already legislated and implemented electronic takeback and recycling systems. To establish the context of existing experience, e-waste management systems in the European Union, Japan, South Korea and Taiwan are explored. The paper then discusses what specific conditions are expected to influence the acceptability and implementation in the U.S. A key consideration is the cultural imperative in the U.S. for market-driven solutions that enable competition. Given this context, a solution is proposed that is designed to ensure a proper end-of-life option while at the same time establishing a competitive market for reuse and recycling services. The solution, termed *e-Market for Returned Deposit*, begins with a deposit paid by consumers to sellers at the time of purchase, electronically registered and tracked via a radio-frequency identification device (RFID) placed on the product. At end-of-life, consumers consult an Internet-enabled market in which firms compete to receive the deposit by offering consumers variable degrees of return on the deposit. After collection of the computer by the selected firm, the cyberinfrastructure utilizes the RFID to transfer the deposit to the winning firm when recycled. If the firm chooses to refurbish or resell the computer in lieu of recycling, the transfer is deferred until true end-of-life processing. Finally the paper discusses the domestic and international consequences of the implementation of the proposed design.

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Comprendiendo el sistema, las decisiones de los usuarios y demás actores…

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

Decision factors for e-waste in Northern Mexico: To waste or trade

Jesús. A. Estrada-Ayub[a,*], Ramzy Kahhat[b]

[a] Global Institute for Sustainability, Tecnológico de Monterrey, Campus Ciudad de Mexico, Calle del Puente, 222 Ejidos de Huipulco, Mexico, DF 14380, Mexico
[b] Department of Engineering, Pontificia Universidad Católica del Perú, Av. Universitaria 1801 San Miguel, Lima, Peru

ARTICLE INFO

Article history:
Received 13 November 2013
Received in revised form 25 February 2014
Accepted 26 February 2014

Keywords:
E-waste
Used computers
Data Flow Diagrams
Waste management
Recycling
Reuse

ABSTRACT

Currently, around the globe, environmental and social problems derive from the inappropriate recycling of electronic products. Moreover, improper recycling is not the only issue to address in electronic products. Others include: energy intensity in their manufacture, employment generation related to the international trade in used electronics, and access to technology by low-income communities. Nevertheless, policies and controls created to provide socially and environmentally sound management of used electronics do not match the complexity of the system. In order to understand the e-waste system, particularly used computers, as a whole, a field study was done between 2010 and 2011 in ten Mexican cities. Ninety-five diverse stakeholders were interviewed to uncover factors regarding the decision to waste or trade still-usable computers. Structured analysis was used to create Data Flow Diagrams (DFDs) to describe the critical parts of the system. The results show that perceived value and geographical location determine the rate in which computers are disposed and the opportunities to waste or trade them, including the trade of their materials. Among businesses and other organizations, legislation has a stronger effect. Technological change is another important factor, largely driving the change in materials and new products. Designing policies responding to this diversity may prevent unforeseen problems and stimulate solutions.

Televisión Digital

¿Problemas en el fin de vida de los RAEE?

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¿Economía Circular? Perdiendo el potencial…

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Full length article

Electronic waste after a digital TV transition: Material flows and stocks

Marco Gusukuma, Ramzy Kahhat*

Department of Engineering, Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel, 15088, Lima, Peru

ARTICLE INFO

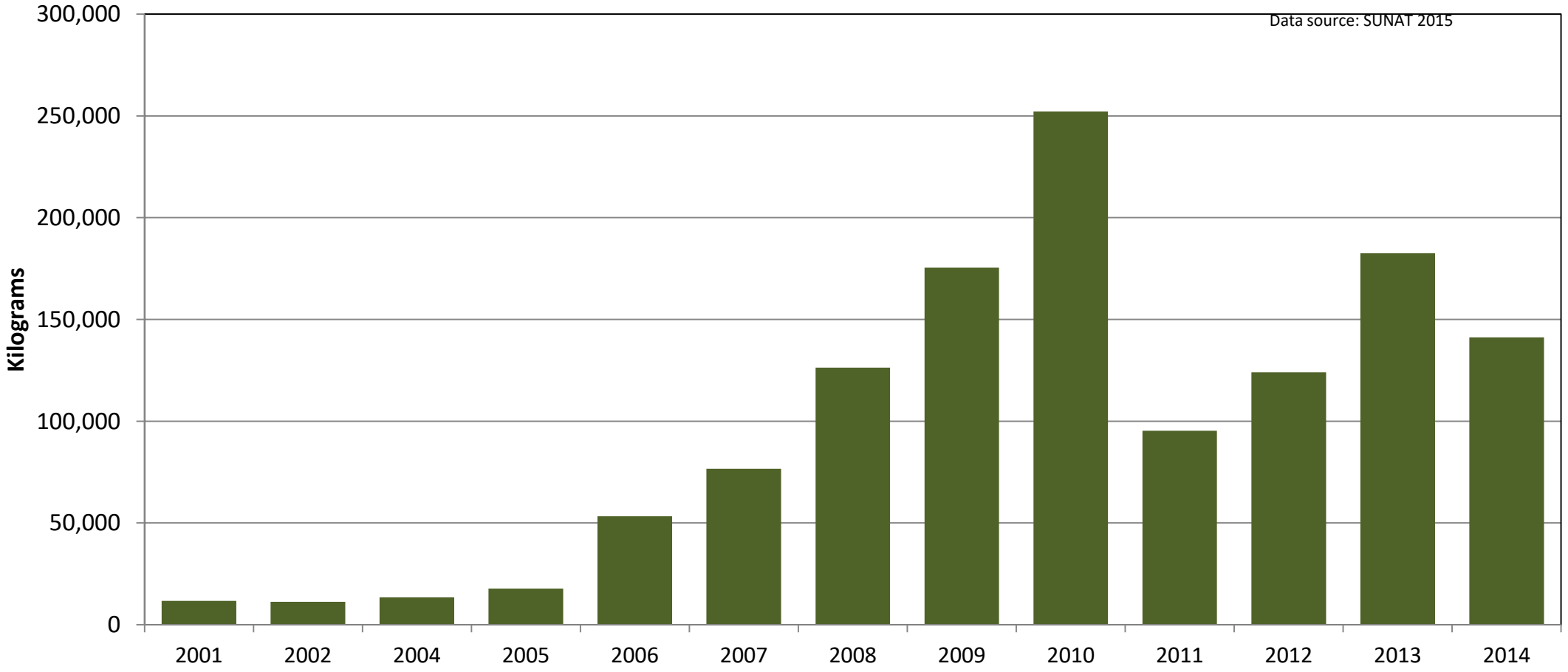
Keywords:
Analog switch-off (ASO)
Cathode Ray Tube television (CRT TV)
Dynamic MFA
Electronic waste (e-waste)
Material Flow Analysis (MFA)
Urban mining

ABSTRACT

As with every technology, televisions (TV) are prone to replacement due to technological evolution of the equipment itself (e.g. CRTs to flat panels) or the system (e.g. signal). While the former is commonly a gradual change that depends on the consumer, the latter could be sudden, as it depends on national regulations. When an abrupt change happens, it can generate an abnormal volume of equipment at the end of life. Thus, the principal motivation of this research is to estimate the amount of CRT TV sets that will be stored by users in 2025, the end of the analog switch-off (ASO) in Peru. Dynamic Material Flow Analysis (D-MFA) was applied to estimate flows and stocks of CRTs from residential, business and public sources between 2005 and 2017. Because of data constraints in the Business and Public (B&P) sector, two scenarios were modeled to lower the uncertainty of the estimated number of TV sets. Results show that between 2.6 and 5.7 million CRT TV units, equivalent to 41,100 and 68,200 metric tons of leaded glass and 4500 and 8000 metric tons of lead, were placed in residential and B& P facilities in 2017 and will have become obsolete at the end of ASO. Projections for 2025, the final ASO year, indicate that between 0.27 and 5.86 million CRT TV units will be stored in those places. If planned correctly, resources embedded in CRT TV could create an urban mining opportunity, but an inadequate waste management plan that excludes appropriate recycling technologies could generate significant environmental impacts.

Crédito: Kahhat, R. 2020

Exportación de tarjetas electrónicas usadas



HS Code: 85429, 711299, 877350

Tecnologías para la recuperación de recursos contenidos en los RAEE…

Crédito:
Gusukuma y
Pillihuaman

El rol de la academia en la investigación de los RAEE es de vital importancia…

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… y el impacto social de la investigación ha sido notorio en algunas estrategias vinculadas al manejo de los RAEE en el mundo.

…pero tal vez siempre con una tardanza en su impacto social.

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Nunca debemos perder de vista la necesidad de que esta investigación siempre sea **independiente** y se realice comprendiendo los **“tiempos” de la academia**… vitales para permitir un proceso iterativo de reflexión y maduración.

Independencia de la investigación…

Debemos buscar siempre una aplicación **transparente** del método científico, **reproducibilidad** de los resultados, garantizar un proceso de validación y **revisión de pares**, entre otras características importantes relacionas a una investigación seria…

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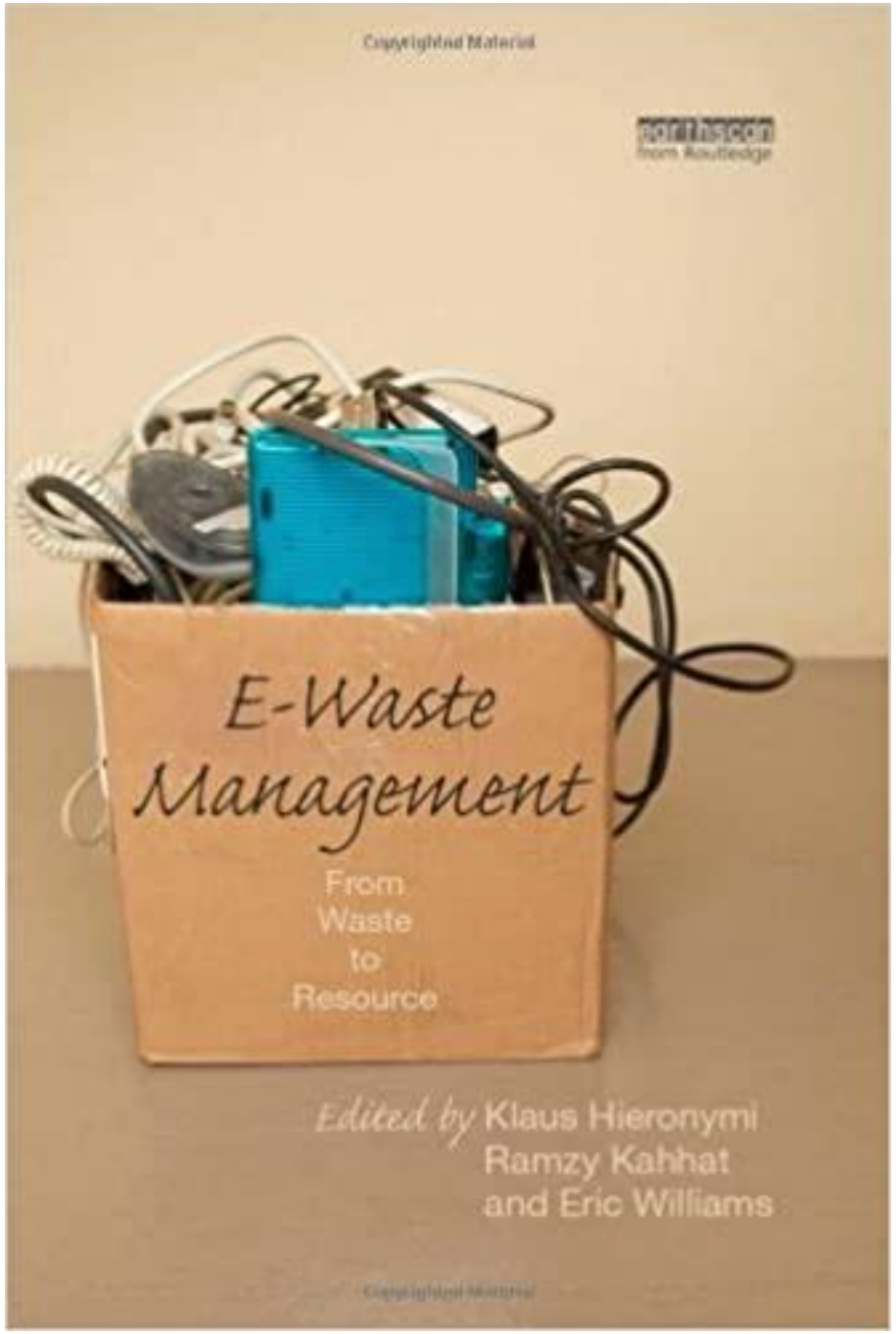
Rol de la Academia en la investigación de los RAEE en la región

En la región aun existe una **baja valoración** del aporte de su investigación …

Pero esta también es una oportunidad que podemos aprovechar…



¡Muchas Gracias!

ramzy.kahhat@pucp.edu.pe
Profesor Principal

Red Peruana de Ciclo de Vida y Ecología Industrial (PELCAN)

Departamento de Ingeniería
Pontificia Universidad Católica del Perú