Innovating the Design and Implementation of an Integrated and Sustainable Waste Management System (ISWMS)-A hybrid approach

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Abstract

The paper proposes a hybrid approach to design and implement an integrated and sustainable waste management system that is carbon-efficient and cost-effective. This system will bring benefits for socially and economically disadvantaged communities. Former research has shown that relying only on a bottom-up approach might fail to resolve conflicts and garner for sufficient external resource support; relying merely on top-down approach could fail to obtain community's trusts and sustain the system. The paper suggests combining community-led innovation and top-down policy/regulatory changes to avoid the tension. The paper recommends using both academic and action research methods to design and implement such a system. As for the academic research method, the paper suggests conducting institutional and stakeholder analysis. As for the action research method, the paper suggests assisting the target communities to establish and utilize an inclusive and adaptive governance structure, in order to mobilize social, political and economic resources.

Why do we need an ISWMS?

Due to the climate change concern and political commitment to reduce carbon emission, the waste reduction and recycling have received increasing attention, and been developed into a financially viable industry estimated to be worthy of US$ 2,149.6 billion by 2027. Many new jobs can be created in labor intensive waste recycling industries (e.g., textile recycling). For instance, in the EU, recycling 115 million tons of textiles, including woods, ferrous and non-ferrous metals, plastic, paper, bio-waste, and glasses, can create 160,900 indirect and 80,400 induced jobs (Leblanc 2019).

Designing and implementing an integrated and sustainable waste management system (ISWMS) is an innovative approach for waste reduction and recycling. Waste reduction and recycling has attracted rising interests of many academic journals to such as Journal of Cleaner Production, Risk Analysis, Lancet, Policy Studies Journal, Urban Studies, Waste Management, Nature, Journal of Hazardous Materials, Water Resource Management, Journal of Corporate Real Estate, Sustainable Development, Environmental and Earth Law Journal, Sustainability, Worldwide wastes: Journal of Interdisciplinary Studies, Resources, Conservation and Recycling. Many international conferences about waste management have been emerging, Waste Management Conferences, Sustainable Waste Management Conference, and International Conference on Waste Management and the Environment.

An ISWMS has great potential to have positive social, economic and political impacts

- Socially, it can change public perception of wastes as something to be disposed to those as valuable 'resources. It can create new knowledge that changes the organization of social life. It will improve the eco-environment and reduce the long-term public health risks in a wholistic manner.
- Economically, it can generate income from wastes, create new jobs for graduate students and unemployed people, and can reduce the cost of living and the cost of public services. It can attract investment and entrepreneurship for developing affordable technology for local communities and later expanding service markets beyond the local communities.
- Politically, an ISWMS will enhance public support for waste reduction regulations that make businesses, public organizations and individual citizens internalize the costs of waste management, and ultimately change their preferences and behaviors in the production, delivery and consumption of services and goods.

What is an ISWMS?

An integrated and sustainable waste management system has the following attributes:

- It is tailored to the local community needs, with effects of retaining existing jobs, improve job conditions and creating new quality job opportunities for people with disadvantaged social-economic status.
- It balances considerations of carbon-emission minimization, cost-efficiency, labor welfare and community stakeholder satisfaction.
- Political/administrative/knowledge institutions that stand in the way of its smooth implementation, such as public attitudes and preferences, waste management policy regimes and regulatory framework, need to be understood and changed.
- It educates and trains the interested public to scale up the innovation.

How can an ISWMS work?

The challenges of waste reduction and recycling include obtaining political and social support of siting, building infrastructure, financial investment and associated regulatory changes. While technically, the hazards of solid and bio waste treatment facilities such as waste-to-energy incinerators in Netherlands, plastic recyclers in Germany (Dobush 2019), bio waste treatment plant in Denmark (Aikan Technology 2021), medical waste treatment plant (Gient 2021), and to a lesser extent the textile recycling factories can be lowered, the high economic costs and uncertainty of risks often deter policymakers from initiating the discussions on controversial decisions.

An effective ISWMS shall involve an open siting process. Such a process was found to be able to garner public support for hazardous waste management facilities. It involves the following steps: (1) establish general environmental criteria, (2) broad public consultation, (3) invitation to participate, (4) consultation with interested communities, (5) site investigations, (6) community referendum, and (7) site decision. If such a process is carried out by an independent task force, is transparent in technological criteria as well as environmental and economic impact, address concerns of and shares decision-making authority with stakeholders involved, the site selection is more likely to be successful (Kuhn and Ballard 1998).

An ISWMS is based on the concept of 'circular economy' where wastes are recycled and recovered for manufacturing new products. The economic benefits a circular economy entails can also enhance the political and social support for the waste management facilities. According to Stahel (2016, p. 435), "a 'circular economy' would turn goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste. It would change economic logic because it replaces production with sufficiency: reuse what you can, recycle what cannot be reused, repair what is broken, remanufacture what cannot be repaired." According to Kemp and Pearson, a "circular economy" refers to "The production, application or exploitation of a good, service, production process, organizational structure, or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and the negative impacts of resource use (including energy use) compared to relevant alternatives" (2007)

Other approaches that can be used in an ISWMS to reduce wastes include "bio-based economy" and "consumer demand management". "Bio-based economy" refers to the use of biomass, such as agriculture crops and residues from industry and agriculture, to substitute fossil fuel materials in economic and social activities (e.g., Sanders and van der Hoeven 2008). "Consumer demand management" refers to prioritizing waste minimization over wastes generation, recycling and disposal in purchase decision-making and household management (Ene 2008; Price and Joseph 2000).

The technological, governance and managerial tools that can be applied in ISWMS have been developed in the areas of zero-waste manufacturing, low-carbon emission building, empowering sustainable grassroots community (Middlemiss and Parrish 2010; Cho and Chae 2016; Sunpreet, Ramakrishma and Gupta 2017). "Zero-waste manufacturing" refers to the manufacturing system that produces goods and fulfills needs without contributing towards wastes. That means, goods and services produced by the manufacturing system can satisfy multi-utilities and be reused reliably and consistently (Singh, Ramakrishna and Gupta 2017).

Smart Manufacturing and Industry 4.0 revolution characteristic of mobile, big data analytics, cloud, 3D printings, cyber-physical production system, can be utilized to integrate and automate waste *resource* management in the customized manufacturing and service production processes (Agolla 2018). Regulations, policies, and economic development models need be innovated to facilitate the application of digital technology (e.g., Artificial Intelligence) compatible with sustainable development goals, such as alleviating poverty and enhancing gender equality.

To adapt producers and users' behavior for an ISWMS, paradigm changes of seeing wastes as 'resources' are needed. Effective regulatory and publicity tools can be adopted to shift the costs of waste management from government to waste producers, and to enhance the perceived fairness of siting waste treatment facilities. For instance, government subsidies and tax concession can be provided to businesses and users who purchase goods and services produced from an ISWMS. The EU frame includes a raw material resource tax, reuse/repair tax relief, and a waste hierarchy tax at the end of life of products (Milios 2021). The positive socio-economic impacts (such as job creation and carbon emission) of shifting waste management cost from government to waste producers can be estimated by comparing effects on different categories of activities (e.g., landfills, incineration) (Rodrigues et al. 2016).

Designing ISWMS

The ISWMS approach seeks to integrate waste resource management facilities/infrastructure in the structure and surrounding area of the buildings. This approach is suitable for places where land is in shortage, and cost of large-scale waste treatment facilities have been high (Fabian and Lou 2019). Although the amount of energy recovered from the large-scale waste incineration facilities can fulfil the on-site heat and electricity requirements, they still need external energy input and increase green gas emission (Iqbal, Zan, Liu and Chen 2019).

An ISWMS requires thorough and careful source separation of wastes before incineration, which can reduce air pollution due to incineration emission. For instance, in Finland and Denmark, organic waste is not allowed to be deposit in the landfills, instead, they are put under the anaerobic treatment and CH_4 emission reduction efficiency is estimated to be 90% compared with landfill treatment (Tuhkanen, Lehtila and Savolainen 1999).

In populated urban areas, an ISWMS requires building small scale waste treatment facilities in each community regardless of their property price. This approach has the following advantages:

- It can garner wider public support and reduce social conflicts because this could be perceived as being fair by lower-income and more populated communities.
- It can reduce carbon emission and air pollution by avoiding the need for long distance transport of the wastes.
- It can utilize the existing spaces of urban areas and reduce the needs for land reclamation for large waste treatment facilities.

The small-scale waste treatment facilities are available from the markets at affordable prices. For instance, mobile and resource-efficient waste incinerators and disinfection machines can be provided by commercial suppliers (e.g., INCINER8, Hengchenghb 2021). They can be purchased in bulk at affordable prices to collect, separate, disinfect and incinerate medical, domestic and food wastes, including contaminated face masks disposed every day to urban dustbins in huge amount after the outbreak of Covid-19.

An ISWMS requires authoritarian waste reduction regulations. In places where tools such as banning micro-plastics and unit pricing waste charging system are adopted, harmful wastes are effectively reduced (Mosquera, 2019). By contrast, in places where such tools are lacking, the recovery rates of municipal solid wastes, domestic waste, and commercial & industrial wastes have been low and declining; the amount of MSW landfill quantities have been rising (Hong Kong Environment Protection Department 2020).

An ISWMS requires installing small scale clean energy generation facilities, equipping sensing-techniques to reduce building energy consumption, and designing water collection, treatment and supply system into the building areas. Such designs can reduce the demand for external energy and water supply, which will be both economically beneficial and environmentally friendly (Aladenola and Adeboye. 2010; Weng and Agarwal 2012; Heiskanen, Nissila and Lovio, 2015). The incineration of wastes

produced by these buildings can be utilized to recover energy. The bottom ash from the incineration can be used to fertilize plantations surrounding the buildings, and to create carbon-efficient cements and valuable metals (e.g., quartz, calcite, gehlenite, and hematite) (Šyca et al. 2020)

An ISWMS uses social media platforms to reduce wastes. The estate management companies can install closed internet networks connecting estate users, buyers and sellers. The networks can be used for multiple types of information exchange and sharing, including selling, buying, borrowing and exchanging household and workplace items, so as to reduce household and business wastes and expenses. In the municipal real estate management approach (vis-à-vis corporate real estate management), the networks of individual estates can be used to enhance user participation in the property management service design and to monitor the service quality, such as designing public spaces for sports, caring and entertaining activities in line with government policy goals (Van den Beemt-Tjeerdsma and Veuger 2016). The internet networks of different estates can be connected, so as to expand the social ties and business networks, to promote information exchange and sharing, and to facilitate collaboration of diverse social groups and organizations (Rodriguez 2011).

A Hybrid Approach of Designing and Implementing ISWMS

Experimenting a demonstration project of ISWMS is recommended. Political environment for imposing waste reduction laws needs be favorable. Support and participation by the general public, the business sector, governing political parties and incumbent political executives and legislators are needed for enacting these laws. To achieve this, the long term social and economic benefits the regulations can bring about need to be shown to these stakeholders.

A hybrid approach combining community-led innovation and top-down policy/regulatory changes can be useful for designing and implementing such a demonstrating project. The project shall fulfil multiple goals of reducing wastes, developing circular economy, improving the health of natural and social environment of the communities. The hybrid approach is systematic and wholistic. Former research has shown that relying only on a bottom-up approach might fail to resolve conflicts, identify feasible technical solutions and garner for external resource support (Horsbøl and Lassen 2012; Lam and Li 2018); relying merely on top-down approach could fail to obtain citizens' trust and mobilize social resources for the ISWMS (Bergmansa et al. 2015).

The demonstrating project is suggested to use both academic and action research methods to design and implement the ISWMS.

As for the academic research methods, the project team can conduct *institutional and stakeholder* analysis, including:

Researching existing regulations, government policies and professional guidelines that will increase wastes, such as food safety regulations (e.g., compulsory disposal of food exceeding the expiry date), public health regulations (e.g., compulsory use of single-use medical equipment and facemasks) and accounting guidelines that are unfriendly to the reuse of products.

Researching the public attitudes towards the ISWMS, including considerations of costs, privacy concerns, priority of service needs, knowledge and perception of health risks associated with the built-in facilities.

Researching the preferences and concerns of government, NGOs and business stakeholders involved in the target communities.

Conducting technical feasibility, legal-risk and cost-effectiveness analysis of the ISWMS.

As for the action research methods, the project team can assist the target communities to take the following actions:

-Set up a governance structure that is inclusive and adaptive to the changing needs of stakeholders.

-Set up the deliberation agenda and decision-making timetable.

-Identify external resources, mobilize internal resources, and search for external experts to conduct cost-benefit analysis.

-Monitor the implementation of the project and evaluate the pre-conceived social, economic and environmental impacts of the project.

-Publicize the project progress, lessons and impacts.

Conclusion

Due to the climate change concern, the waste reduction and recycling have received increasing attention. Designing and implementing an integrated and sustainable waste management system (ISWMS) is an innovative approach for waste reduction and recycling. An ISWMS has great potential to have positive social, economic and political impacts. It is tailored to the local community needs, beneficial to the people with disadvantaged social-economic status; it balances considerations of carbon-emission minimization, cost-efficiency, labor welfare and community stakeholder satisfaction; and it educates and trains the interested public to scale up the innovation.

The paper proposes a hybrid approach to design and implement an ISWMS that is carbon-efficient and cost-effective, combining community-led innovation and top-down policy/regulatory changes to avoid the potential tension. The paper also recommends using both academic and action research methods to design and implement such a system. The academic research methods include conducting institutional and stakeholder analysis. The action research methods assist the target communities to establish and utilize an inclusive and adaptive governance structure, in order to mobilize social, political and economic resources.

References

Agolla, Joseph Evans. 2018. Human Capital in the Smart Manufacturing and Industry 4.0 Revolution. In D*igital Transformation in Smart Manufacturing*. Edited by Antonella Petrillo, Raffaele Cioffi, Fabio De Felice. Coatia: IntechOpen. 41-58.

Aikan Technology. 2021. That's How It Works. https://aikan.dk/home-2/how%20does%20it%20work.html

Aladenola, Olanike Olowoiya and Omotayo B. Adeboye. 2010. Assessing the Potential for Rainwater Harvesting. *Water Resource Management*, 24: 2129-2137.

Bergmansa, Anne, Göran Sundqvistb, Drago Kosc and Peter Simmonsd. 2015. The participatory turn in radioactive waste management: deliberation and the social–technical divide. *Journal of Risk Research*, 18(3): 347–363.

Cho, Su-Hyun and Chang-U Chae. 2016. A Study on Life Cycle CO2 Emissions of Low-Carbon Building in South Korea. *Sustainability*, 8: 579.

Dobush, Grace.2019. The Brutal Reality of Being the World's 'Best' Recycler July 19. https://www.huffpost.com/entry/germany-recycling-reality_n_5d30fccbe4b004b6adad52f8.

Ene, Corina. 2008. Consumer Behavior concerning Post-consumer Waste. Petroleum-Gas University of Ploieti. *Research Gate Net*.

Fabian, Nele and Loretta leng Tak Lou. 2019. The Struggle for Sustainable Waste Management in Hong Kong: 1950s-2010s. *Worldwide wastes: Journal of Interdisciplinary Studies*. 2(1): 10, 1-12.

Gient. 2021. How to build an ecological centralized medical waste treatment plant https://www.youtube.com/watch?v=d3JQbcxO-WA

Heiskanen, Eva, Heli Nissila and Ramlo Lovio. 2015. Demonstration buildings as protected spaces for clean energy solutions- the case of solar building integration in Finland. *Journal of Cleaner Production*, 109(16) December: 347-356.

Hengchenghb. 2021. Medical Polluted Water Treatment Facilities (医疗污水处理设备).
http://hengchenghb.com/products/product.php?lang=cn&class2=17

Hong Kong Environmental Protection Department. 2020. Monitoring of Solid Waste in Hong Kong. https://www.wastereduction.gov.hk/sites/default/files/msw2019.pdf

Horsbøl, Anders and Inger Lassen. 2012. Public Engagement as a Field of Tension between Bottom–up and Top–down Strategies: Critical Discourse Moments in an 'Energy Town'. In *Citizen Voices: Performing Public Participation in Science and Environment Communication*. Edited by Louise Phillips, Anabela Carvalho, and Julie Doyle. Bristol: NBN International. 163–186.

INCINER8. 2021. https://www.inciner8.com; http://www.elastec.com.

Kemp, R. and P. Pearson. 2007. Final report MEI project about measuring eco-innovation, 10, UM Merit, Maastricht.

Lam, Wai-fung and Wei Li. 2018. Network structure and collaborative innovation processes — A comparative analysis of two elderly service networks in Shanghai. *Public Administration and Development*. 38(2): 87-99. https://doi.org/10.1002/pad.1821

Leblanc, Rick. 2019. Recycling and New Job Creation. https://www.thebalancesmb.com.

Iqbal, Asad, Feixiang Zan, Xiaoming Liu, Guang-Hao Chen. 2019. Integrated municipal solid waste management scheme of Hong Kong: A comprehensive analysis in terms of global warming potential and energy use. *Journal of Cleaner Production*, 225: 1079-1088.

Middlemiss, Lucie and Bradley D. Parrish. 2010. Building Capacity for low-carbon communities: the role of grassroots initiatives. *Energy Policy*. 38: 7599-7566.

Milios, Leonidas.2021. Towards a Circular Economy Taxation Framework: Expectations and Challenges of Implementation. *Circular Economy and Sustainability*, 1(1) June. https://link.springer.com/article/10.1007/s43615-020-00002-z.

Mosquera, Marcela Romero. 2019. Banning Plastic Straws: The beginning of the war against plastics. *Environmental and Earth Law Journal*. 9, 5-31.

Price, Jane J. and Jeremy B. Joseph. 2000. Demand Management- A Basis for Waste Policy: A Critical Review of the Applicability of the Waste Hierarchy in Terms of Achieving Sustainable Waste Management. *Sustainable Development*, 8: 96-105.

Rodriguez, Michael.2011. Making social media Effective in Real Estate. Keller Center Research Report. https://www.baylor.edu/business/kellercenter/doc.php/194319.pdf.

Rodrigues, Joao F. D., Antonio Lorena, Ines Costa, Paulo Ribeiro, and Paulo Ferrao. 2016. An Input-Output Model of Extended Producer Responsibility. *Journal of Industrial Ecology*, 20(6): 1273-1283.

Sanders, Johan and Diederik van der Hoeven. 2008. Opportunities for a Bio-based Economy in the Netherlands. *Energies*, 105-119.

Singh, Sunpreet, Seeram Ramakrishma and Munish Kumar Gupta. 2017. Towards zero waste manufacturing: A multidisciplinary review. *Journal of Cleaner Production*, 168: 1230-1243.

Stahel, W.R., 2016. Circular economy. *Nature* 6e9. https://doi.org/10.1038/531435a.

Šyca, Michal, Franz Georg Simonb, Jiri Hykšc, Roberto Bragad, Laura Biganzolie, Giulia Costaf, Valerio Funarid,Mario Grossoe. 2020. Metal recovery from incineration bottom ash: State-of-the-art and recent developments. *Journal of Hazardous Materials*. 393:1-17.

Tuhkanen, Sami, Antti Lehtila and Ilkka Savolainen. 1999. The Role of CH_4 and N_2O Emission Reductions in The Cost-Effective Control of The Greenhouse Gas Emissions from Finland. Mitigation and Adaptation Strategies for *Global Change* 4: 91–111. Kluwer Academic Publishers. Printed in Belgium.

Van den Beemt-Tjeerdsma, Annette and Jan Veuger. 2016. Towards a more professionalized municipal real estate management. *Journal of Corporate Real Estate* 18(2): 132-144.

Weng, Thomas and Yuvraj Agarwal. 2012. From Buildings to Smart Buildings-Sensing and Actuation to Improve Energy Efficiency. *IEEE Design & Test of Computers*, 29(4): 36-44.