Building Resilient Cities through 3R Principles and Higher Resource Efficiency

C. Visvanathan
Department of Environment, Energy and Climate Change,
School of Environment, Resources and Development,
Asian Institute of Technology,
PO Box: 4, Khlong Luang, 12120 Pathumthani, Thailand
Email: visu@ait.ac.th

Abstract: *The global phenomenon of urbanization is here to stay. With more than 60% of the total population expected to reside in urban areas by 2050, it is imperative to strongly consider the environmental and economic implications of this global trend. Under the risk of the climate-induced disasters and natural calamities, emergence of technological breakthroughs and fluctuations in the global economy, the importance of various approaches to building 'resilient' cities has garnered interest and concern all over the world. In fact, it has also been reiterated in sustainable development goal 11 (Make cities and human settlement inclusive, safe, resilient, and sustainable). The resilience of cities encompasses a broad range of issues including building efficient recovery systems (engineering and multi-equilibria resilience) in the cities or planning means of adaptation to the increasing environmental, economic or socio-cultural stresses (socio-ecological resilience). It can also be described in terms of transformation brought about by technological advancements. On the whole, it is a matter of utmost importance to ensure that the expansion of existing cities or development of new ones is guided by principles of strong governance or an institution that can adopt technology or absorb the need for innovations. It must also be considered that the cities foster networked material and energy flow which evolve around the idea of resource efficiency and 3R.*

Keywords: *circular economy, recycle, reduce, resilience, resource efficiency, reuse*

1. INTRODUCTION

Cities have grown to become the centers of economic activities and have a wide range of institutions and infrastructure. In 2014, 54% of the world's population lived in urban areas which are significantly higher than the 30% in 1950. It is predicted that by 2050, 66% of the population will reside in urban areas (Heilig, 2012). Although they offer economic advantages, growing cities are vulnerable to uncontrolled expansion, environmental pollution and degradation and hence unsustainable growth. In addition, increasing population and their growing needs have brought enormous challenges to the supply-demand balance of resources. At present, most cities around the world are dependent upon the resources, including human workforce, food, water, and energy, which lie outside their geographical and demographic territory, meaning that they are resource dependent and can easily experience shocks from either a hike in the prices or scarcity of resources. Over-dependence on other places for resources is also a general indication of the fragile economic status of the cities.

Higher resource consumption implies higher waste generation in all the three forms: solid, liquid and gas which, in turn, indicate that the cities are more vulnerable to their own habits of resource usage. However, the issues associated with urbanization are not limited to the environment alone but encompass issues of increased vulnerability and reduced resilience of the cities. Higher resource consumption leads to greater issues in the urban areas which have both short-term as well as long-term social and economic implications in addition to the environmental impact. As cities become more and more dependent on the resources from outside their geographic territory, the short-term impact of resource consumption could be seen in the scarcity of resources resulting in loss of jobs due to the price rise of the resources, environmental damages due to pollution from the manufacturing and disposal, reduction of GDP etc. Long-term damages to the cities could be observed in the deteriorated health of the population, psychological and mental health deterioration (caused by the cluttered environment), irreversible environmental impacts, and climate-induced natural disasters in the cities.

Urban areas account for 75% of the total resources use and considering the fact that these cities comprise only 2% of the total land area, the resource consumption of cities is significant. Cities also account for 75% of the total emissions of Green House Gases (GHG) like carbon dioxide, methane,

and nitrogen oxide cumulatively (Lindfield & Steinberg, 2012). Similarly, cities also account for higher energy consumption up to 80%.

Figure 1 represents the land coverage, resource consumption, Gross Domestic Product (GDP) generated, carbon emitted and energy consumed of the urban and rural areas. As shown in the figure, urban areas use a significant amount of resources in comparison to rural areas.

2. SUSTAINABLE DEVELOPMENT GOALS (SDGS) AND CITIES

Sustainable Development Goal 11 (Make cities and human settlements inclusive, safe, resilient and sustainable) and 12 (Ensure sustainable consumption and production patterns) are primarily aimed at improving resource efficiency by promoting successful waste management principles like 3R. Goal 11, in particular, targets to plan cities and human settlement. This goal also highlights resilient cities. Various principles like sustainable transportation, sustainable housing, gender equality, social security, etc. have more direct linkage with this goal. However, as cities tend to consume unsustainably, the resource demand and its dependency on virgin extraction can be considered as the major uncertainties. One of the popular approaches in this direction is the concept of Circular Economy (CE) which explains that the resources need to move in a closed loop eliminating the need for raw materials. The implication of 3R and Resource Efficiency in Goal 11 needs more careful evaluation to understand its potential role. The targets that would require consideration of 3R and resource efficiency are presented in ***Table 1.***

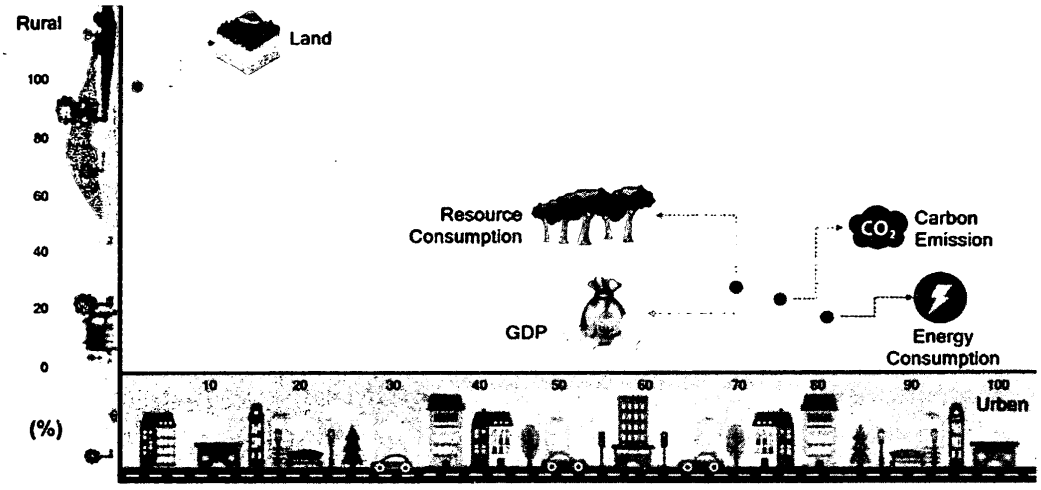

Figure 1 Urban versus rural resource consumption

Goal 12 is specially targeted to increase sustainable consumption and production globally. The implications of 3R and Resource Efficiency along with the evolving approaches like 'circular economy' carries more profound influence on this goal. Since over 75% of the resources are consumed in the cities, the success of Goal 12 strongly relies on the policies and strategies that cities implement to minimize resource consumption. Further, the choice of resources that the cities use to produce various products also have a direct implication on this goal. Moving the resources in a circular loop through various circular business models will help achieve sustainable production.

Table 1 SDG Implications a to 3R and Resource efficiency

Target No	Targets	3R and Resource Efficiency Implication
11.3	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	Sustainable human settlements would require planning for the resources. 3R principles can help reduce resource usage. They can also ensure the sustainable usage of resources.
11.6	By 2030, reduce the adverse per capita environmental impact of cities, including paying special attention to air quality and municipal and other waste management	Adopting the principles of the circular economy which emphasizes reduced resource consumption and reduced externalities. The circular economy in addition to emphasizing 3R also focuses on a business model that can reduce the need for resources.
11.a	Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	As urban areas are dependent upon the resources from peri-urban and rural areas, the supply chain management approach to resources can be adopted. One of the key areas to improve the supply chain will be the food supply chain where most of the resources get wasted.
11.b	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels	Considering 3R opportunities in planning such policies with the socio-ecological approach.
11.c	Support least developed countries, including financial and technical assistance, in building sustainable and resilient buildings utilizing local materials	In additional to the use of local material, the life cycle impact of the materials must be considered.

3. CONCEPT OF RESILIENCE AND RESILIENT CITIES

Resilience can be seen as the opportunities to develop the required capacity among cities to resist such sudden shocks which can result in chaos in societies, damage the infrastructure and nose-dive economies (Folke, 2006). One of the stresses of cities lies in the excessive usage of the resources. Currently, the resource usage trend is more linear in nature which implies that the raw resources are processed to the final product, consumed by the societies and disposed of in the landfills or external

environment. This conventional model strongly relies on the production of raw materials. However, the irony of the usage of raw materials is that most cities themselves do not produce raw materials.

Figure 2 shows the vulnerabilities and resilience that the cities can develop as they build their capacities to cope with vulnerabilities. Engineering resilience, as shown in the figure, focuses on the recovery from economic, environmental and socio-cultural shocks. The infrastructure needs to consider this resilience with the use of various technologies. Multi-equilibria resilience regards that there could be more than one equilibrium that the distorted system can bounce back to after the shock. This resilience gives the idea of evaluating the resilience for the longer stability of the system and increasing the resilience through adaptation.

Socio-ecological resilience, which has a broader perspective, regards system to be more complex. The impact in one of the sub-system can influence another sub-system of the city. For example, the energy crisis in a city could lead to the vulnerability in the water supply of the city as well. Thus, it brings the concept of transformation of the cities by developing capacity in the economy, societies, and ecology in addition to recovery and adaptation. Moreover, it is a holistic way of incorporating sub-systems of the cities and does not limit itself to the resilient infrastructure but also elaborates the resilient economy. Long-term stability of the cities can be achieved when the resilience is planned for the co-benefits.

Cities can be considered an intricate network of many sub-systems or components that interact with each other. To develop resilient cities that can bounce back to their initial state within a short time

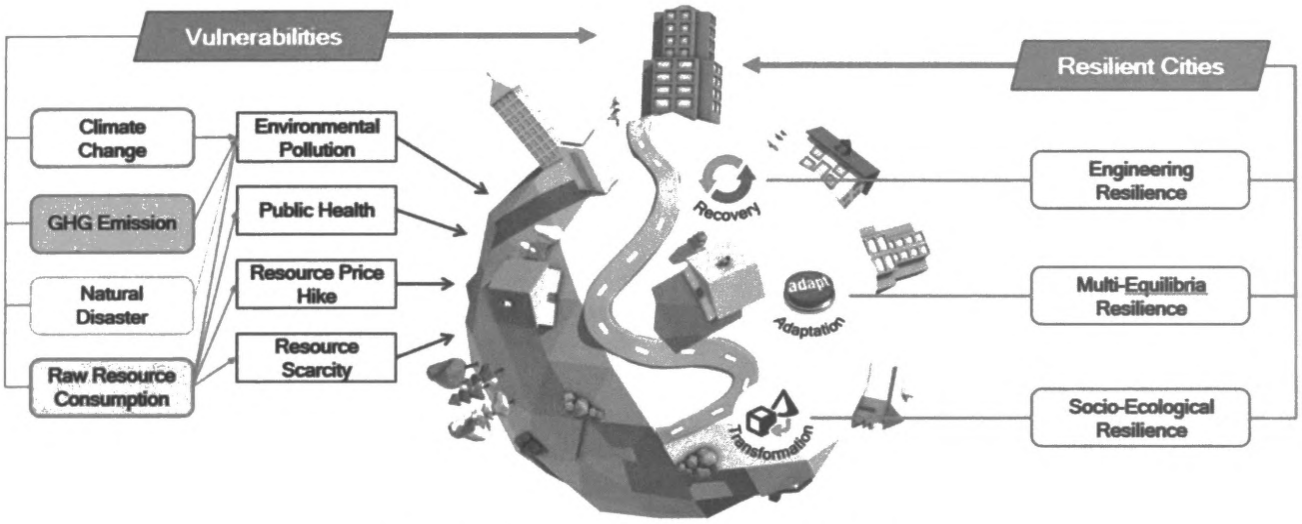

Figure 2 Building resilience in the cities

Figure 3 shows the interconnected components of resilient cities, viz. government networks, network material and energy flow, urban infrastructures and forms, and socio-economic dynamics of the city. As cities differ in the physical and political geography, the path to resilience cannot be generalized for all. As such, it is imperative to form a vision and long-term strategy to deal with all the components holistically that best suit the need of a city.

Figure 3 also shows the roles of stakeholders within the government network component (such as ministries and departments, universities, financial institutes, consumers etc.) that need to be clearly defined. To clarify further, ministries and departments can frame and execute policies for waste management, clean energy, and sustainable consumption of resources whereas universities can function as the fountainhead of knowledge through their research and capacity development programs. Since resilience is not possible without technology and innovations, universities and other research institutes can contribute significantly through R&D.

Another crucial aspect of resilient cities is the networked material and energy flow. It refers to the materials produced and consumed in cities. The materials include water, energy, food, waste, etc. From the perspective of resource efficiency, this subsystem plays an important role and more innovative ideas are required to reduce the material inflow into this system.

The component "Urban Infrastructures and Forms" includes infrastructures of the cities like buildings, transportation network, utility services, parks, etc. Strategies and policies in this sector can reduce

consumption of resources by the cities. At the same time, resilience against various externalities like disasters, material crisis, urban sprawl, etc. need to be carefully planned. Hence, a resilient thinking is needed where optimum usage of technology is made.
The socio-economic dynamic component of the resilience spectrum includes monetary capital, demographics, justice, equity, education, health, etc. The unexpected growth or decline in the sub-components of this system can influence other components of the resilient cities. For example, cities can face a problem if they fail to adequately anticipate immigration rate.

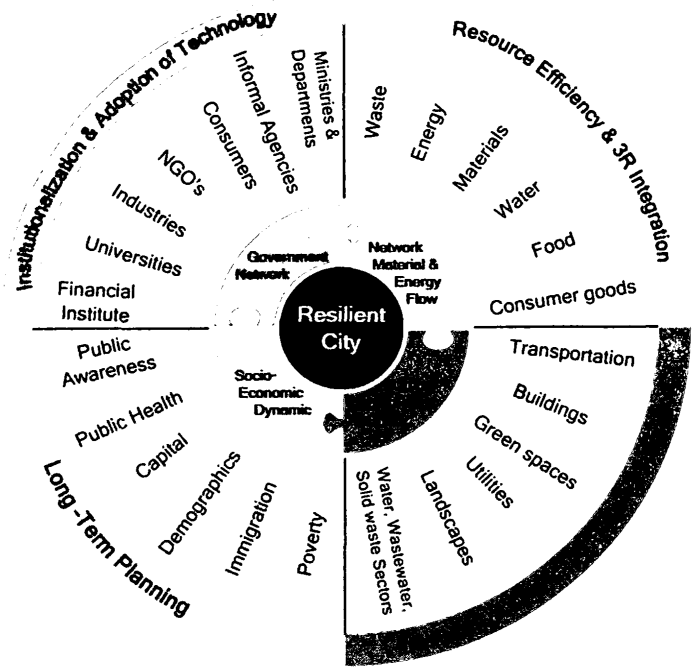

Figure 3 Components of resilient cities

4. OPPORTUNITIES AND CHALLENGES

The track to resilient and sustainable settlement is challenged mostly because of the inertial actions and consequences of human activities compounded over time. Much of this revolves around the consumption of resources, or unsustainable usage thereof. It has been estimated that global material usage increased significantly from USD 23.7 billion tonnes/year in 1970 to USD 70.1 Billion/tonnes/year in 2010. This rate of resource consumption is greater than the rate of global population growth. The annual growth of population from 1970 to 2010 was 1.6% while that of the resource consumption was 2.7%. During the past decade (from 2000-2010) the population growth slowed down to 1.2% per annum while the rate of growth of resource consumption climbed to 3.7% per annum. One of the contributing factors to this trend is the increase in the global GDP which grew by 3.1 % per annum between 1970 and 2010 (Schandl, et al., 2016) which, in turn, was fueled by the high rate of resource consumption. This signifies that the resource consumption is not sustainable and is also not limited to the basic needs of the population growth alone but also to the quality of living.
Waste management is also a major concern of the cities today since it can occupy a significant portion of the cities' management costs and can be a financial burden to the municipalities. A study on 20 different cities by Wilson et al (2012) found that most of the city's waste management budget ranged from 3 to 10% of the total municipal budget and differed according to the income level of the cities. It was also found that the waste management cost differs according to the income levels as informal sectors are seen to be more active in the lower-income countries than in the higher. However, the current waste management is often limited to landfills and the concept of resource efficiency and 3R, though being realized, still need to be institutionalized in the urban context.

Other crucial challenges to attaining resilience comprise the ability of the cities to adopt appropriate technologies that reduce usage of resources or efficiently recycle the used materials, their institutional capacity to absorb technological innovations and focus on reduction of resource consumption through the concept of 3R. Public awareness with respect to resource consumption and 3R is also a major issue since programs and policies to address problems like unsegregated waste, improper disposal of hazardous waste, degraded quality of the waste water etc. can be addressed only through consumer awareness and participation.

As resource efficiency and 3R focuses on decreasing the resource consumption without compromising the quality of the product, the opportunities on offer are immense. Moreover, the social and environmental benefits of the application of these principles are also significant when compared to the traditional 'Take-Make-Use-Dispose' process where the resources end up in the landfill or external environments such as water bodies or atmosphere. Resource security, along with food, water, and energy security can make the city resilient and these principles provide innovative means of turning waste back into the resources; hence, bending the linear model of consumption into a circular one where the resources can be reused, remanufactured, recycled, and more efficiently repaired to elongate the product life cycle.

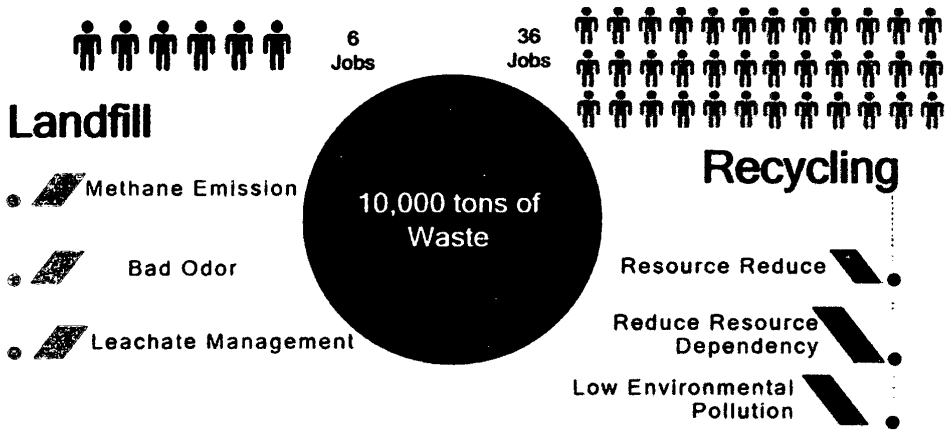

Figure 4 Employment prospects from recycling of waste against landfilling

Resource efficiency and 3R focuses on re-defining the resources consumption pattern by recycling the waste and looping it back into the system. Financially, it is attractive for cities as new jobs are created while reducing the resource dependency simultaneously. As shown in 4, it is estimated that recycling of 10,000 tons of waste creates six times more jobs than landfilling the same amount of waste. In other words, landfilling 10,000 tons of waste creates only 6 jobs whereas recycling it create
36 jobs. Recycling also reduces the environmental impacts like a bad odor, groundwater contamination through leachate seepage and GHG emission that commonly occur at the landfill sites. Moreover, the fuel cost of solid waste haulage is significantly reduced. Thus, increased jobs, reduced resource usage, and financially attractive nature of recycling the waste makes recycling a sustainable activity.

Circular economy advocates the creation of economy where resource efficiency and 3R principles lie at its center. It looks at the management of material flow by reducing the need for using raw resources and utilization of existing resources through business models that either focus on reducing, recycling or reusing of products. The circular economy also provides an opportunity for companies to develop their environmental responsibility toward the societies while generating greater revenues. The business models can be divided into five types, which are presented in ***Table 1 .***

One of the examples of the circular economy is the recycling of beverage carton. Beverage cartons consist of paper, plastic and aluminum foils and constitute 13% of the total municipal waste in cities like Bangkok. The current trend of the beverage carton, which serves as packaging material, is its disposal at the landfill which is not a sustainable method. Recycling of beverage cartons provides an opportunity for urban mining and turning waste into building materials. One of the characteristics of a sustainable city is

its ability to treat waste as a resource which makes urban mining an innovative solution. Similarly, due to the emerging technology, waste can now be converted into building materials, and since cities are expanding, these building materials could provide an opportunity for sustainable housing and buildings. The flowchart has been shown in Figure ***5.***

Table 2 Circular business models

Circular business model dynamic	Description
Circular input model	This model replaces virgin resources with renewable and recyclable resources. E.g. Designing the products that are easily recyclable, replacing the electric generator with a solar panel.
Resource recovery	This model aims at recovering the resources for usage in its next life cycle. E.g. Recycling of papers and plastic.
Product life extension	This model aims at prolonging the life of a product by designing it for easy maintenance and easy upgrade.
Shared platforms	This model targets reducing the need for resources by creating a platform where the products or their value can be shared.
Product as a service	This is a service-based model. The customers in this model buy the value of the product rather than the product itself. This model relieves the consumers of the nuisance of upgrade and maintenance of the product as it is the service providers who are responsible for the same.

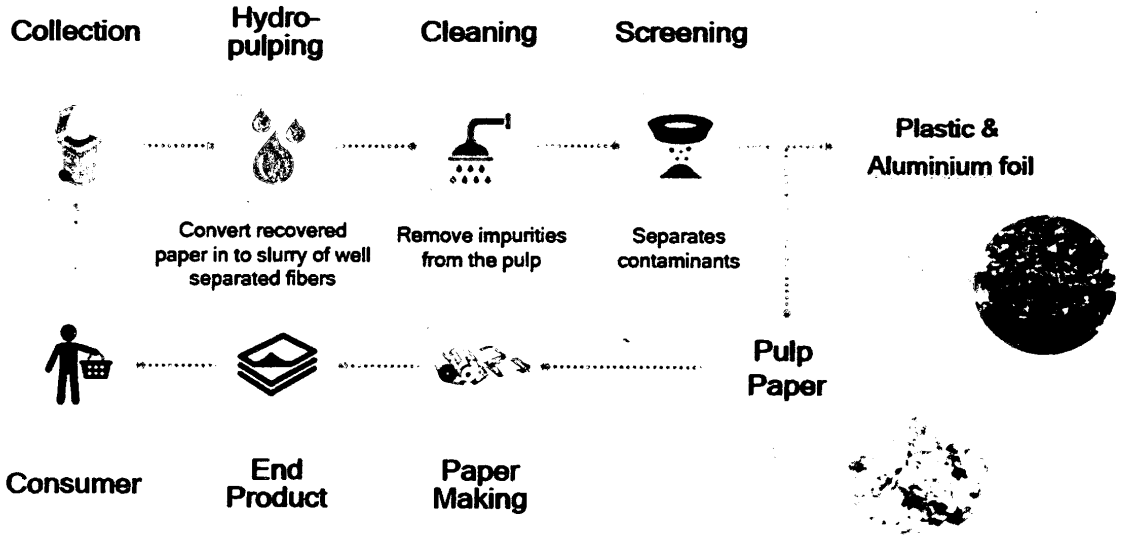

Figure 5 Beverage carton to paper

5. CONCLUSION AND THE WAY FORWARD

Developing resilience in cities against the resource scarcity, resource price rise, climate-induced disaster, and natural calamities are essential. Improving resource efficiency and adopting the principles of 3R, though challenging and often financially unattractive for cities, could provide a sustainable solution to many vulnerabilities. Developing resilience in the cities through the resource efficiency in the cities is also parallel with two of the SDGs. SDG goal 11 has a target to make cities and human settlement inclusive, safe, resilient and sustainable while the SDG goal 12 targets to ensure sustainable consumption and

production patterns. Resource efficiency and 3R can ensure the sustainability and serve as tools for cities to attain its sustainability goal.

Reducing consumption of resources is the first step toward resilience which needs a strong policy, the capacity to institutionalize it, and a shift in the consumer behavior. Technologies that reduces the need for resources can play a vital role to minimize the resource consumption. Resource efficient technologies like LED lights, vertical farming, cleaner production technologies, etc. have already proved to consume fewer resources without compromising the quality. Some of the innovative business models which revolve around the philosophy of circular economy have also reduced the need for resources to enjoy the quality value of the product.

Reusing of products can also reduce the need for extracted raw materials. A product can be designed efficiently so that it can be upgraded without the need of replacing the whole product (e.g.: modular phones, refurbishment of jeans). Even at the household level, the reusing of resources is possible (e.g.: Rainwater harvesting, gray water reuse in gardening) but it needs a change in both the consumer behavior and policies that demand the use of such technologies. Recycling of the waste can also reduce the need for raw resources. Institutionalizing the recycling industries requires careful planning and investment. It needs policies that demand segregation of waste at household and industrial level, requires industries to produce more recyclable products, ensures the role of informal sectors in urban mining, and provides an incentive to initiate new supply chains and businesses related to recycling.

It is in this context that circular economy comes into play since it advocates the creation of economy where resource efficiency and 3R principles lie at the heart of the model. It looks at the management of material flow by reducing the need for using raw resources and utilization of existing resources through business models that either focus on reducing, recycling or reusing of products. It also provides an opportunity for companies to develop their products responsibility toward the societies while generating greater revenues.

Therefore, while planning new cities, or expanding existing ones, it is imperative that integrated economic, environmental and socio-cultural planning be conducted such that required plans and policies can be rolled out to bring behavioral changes. This will also ensure that technologies can be efficiently integrated into policies and replicated when and where necessary, without enduring immense financial burdens. This will then help cities leap towards resilience and to move from the conventional silo approach of resources (energy, transport, water, waste, industry, etc.) to holistic urban resources management.

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Keynote Address

Development of Multi-Hazard Early Warning System in Indonesia

by

Prof. Armi Susandi, PhD

(Professor of Meteorology, Bandung Institute of Technology, Indonesia.)

Dr. Susandi is an expert in climate changes and has conducted numbers of outstanding researches in the areas of increasing global temperature, changing rainfall patterns, sea level rise and mitigation and adaptation to climate changes. In addition, his research interests also include application of meteorology, economics and application of statistical techniques in environmental issues. Moreover, he has extended his service as a technical expert in many engagements locally and internationally. He holds a doctoral degree from Max Plank Institute for Meteorology in University of Hamburg, Germany. Currently, he is the head of the Department of Meteorology in Bandung Institute of Technology, Indonesia.