Discussion paper issued without formal editing

FOR PARTICIPANTS ONLY
15 December 2016
ENGLISH ONLY

UNITED NATIONS
CENTRE FOR REGIONAL DEVELOPMENT

In collaboration with

Australian Government,
Office of Green Industries SA on behalf of the Government of South Australia,
Commonwealth Scientific and Industrial Research Organisation, and
Ministry of the Environment, Government of Japan

SEVENTH REGIONAL 3R FORUM IN ASIA AND THE PACIFIC,
2-4 NOVEMBER, 2016, ADELAIDE, SA, AUSTRALIA

3R and Resource Efficiency Towards Resilient Cities and Societies ~Implications Towards SDGs

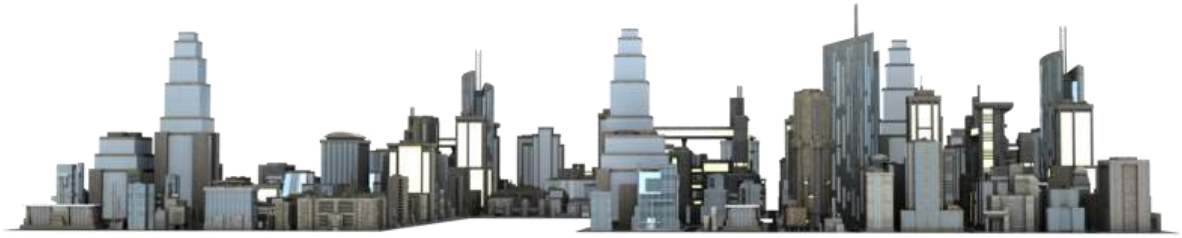
(Background Paper for Plenary Session 2 of the Programme)

Final Draft

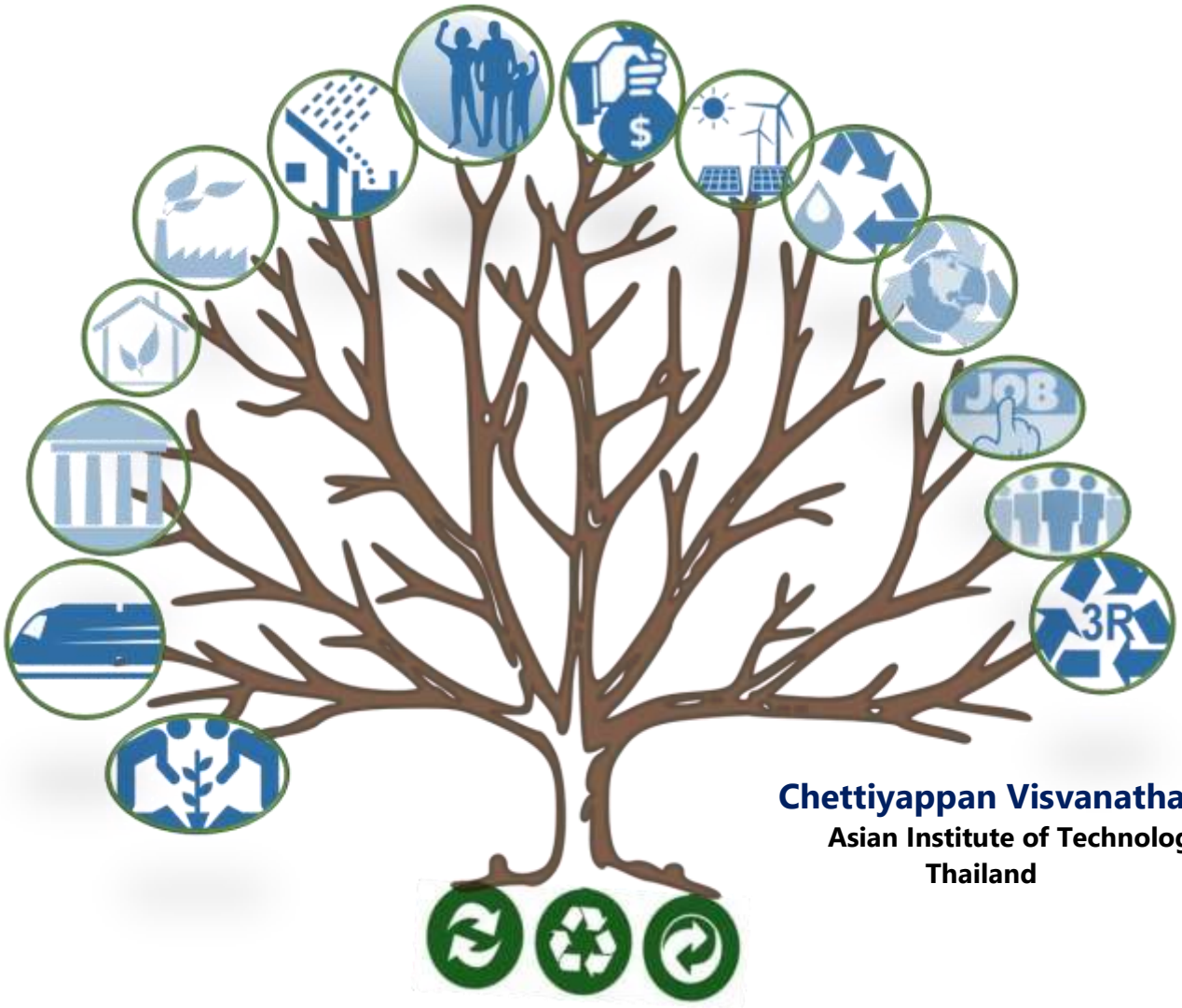
This background paper has been prepared by Professor Chettiyappan Visvanathan, for the Seventh Regional 3R Forum in Asia and the Pacific. The views expressed herein are those of the author only and do not necessarily reflect the views of the United Nations.

Seventh Regional 3R Forum in Asia and the Pacific

2 - 4 November 2016, Adelaide, SA, Australia



3R and Resource Efficiency Toward Resilient Cities: Implications Toward SDG



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Foreword

There is a marginal difference between sustainable cities and resilient cities; these terms can be considered mutually exclusive from the prospect of developing resource efficiency and 3R in the cities. Sustainability of a city is now determined by the ability of a city to treat its waste as resources. Waste here implies industrial waste, municipal waste, waste water, rainwater, etc., which are conventionally discharged either into the landfill or into the open environment.

Resource efficiency implies consuming fewer resources while maintaining the same or superior quality of product or service at reduced environmental cost. 3R provides a framework for the usage of resources. From the viewpoint of resource consumption, it prioritizes the reuse of resources followed by reducing and recycling of resources. Achieving all these features of resource efficiency and 3R need a transformation of cities through technology and innovation.

Resources are the inflows into the cities as cities hardly produce any resources. Thus, cities are dependent upon human resources that live within the cities and the natural resources that lie outside its territory. This can be evaluated as vulnerability of the cities as they are resource dependent and can easily experience shocks from either a hike in the prices of resources or scarcity of resources. Moreover, cities are concerned about food, water, and energy security. Cities' economies are fragile when they are excessively dependent on the external resources.

The problem associated with consumption of raw resources is the global warming which has increased the occurrence of climate-induced disasters. It has been found that production from raw resources has environmental implications and pollution as compared to recycling the resources. Similarly, energy derived from oil is one of the major contributors to greenhouse gas emission. Thus, switching to clean energy sources is important for cities to reduce their carbon footprint globally.

Building resilience is essential for cities to foster a robust economy. A robust economy does not rely entirely on the environment but also on the supply chains within the cities. With technological innovations, consumption of resources can be reduced, products can be reused and waste can be recycled. Technology is the heart of a resilient city and it is now important for the cities to absorb these technologies in their plans, policies, and strategies and constantly innovate.

Resource efficiency and 3R are important for attaining the Sustainable Developmental Goals 11 and 12, which target resilient city and sustainable consumption and production, respectively. Building resilience in the cities is socially, environmentally and economically important as cities need to grow with a vision where the resources are circulated within the cities and importance is given to environmental concerns.

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Executive Summary

This background paper on "3R and Resource Efficiency towards Resilient Cities: Implication Toward SDG" has been prepared to provide insights into and the ideas for discussion in the Seventh Regional 3R Forum in Asia and Pacific. The paper highlights the interconnection between resource efficiency, 3R and their roles in building resilience among the cities. Use of technology and innovations in the city governance is key to developing resilience, which is discussed in this paper. Case studies are presented to support the practical applicability and financial viability of reducing resource consumption. This background paper is presented in four sections:

Introduction

This section highlights urbanization as a global phenomenon and its contribution to the increased resource consumption which, in turn, has resulted in vulnerabilities to the economy and environmental issues in the cities. Under the risk of the climate-induced disasters, natural calamities, and fluctuations in the global economy, the importance of various approaches to build resilience in the cities has been discussed in detail. Resilience, however, is a very broad term and could either be limited to building efficient **recovery** systems in the cities or resilience can also be extended to planning means of **adaptation** to the increasing stresses; resilience could also move one step ahead of the recovery and adaptation, that is, evolving the concept of **transformation,** which needs technology and innovations. The thought process on resilience integrated with technology is essential for cities and it is discussed in with suitable examples to clarify the contradicting concepts of resilient cities. Developing resilient cities is impossible without understanding the components of a resilient city. The components of resilient cities include: strong governance or an institution that can adopt technology or absorb the need for innovations, networked material and energy flow which evolve around the idea of resource efficiency and 3R, urban infrastructures and forms that are planned, retrofitted, or designed considering technologies to develop resilience, and the dynamics of socio-economy which require long-term vision as they can increase stress on the cities if not anticipated. Further, the implications of resilient cities from the perspective of Sustainable Developmental Goals has also been discussed highlighting the SDG Goal 11 (Make cities and human settlement inclusive, safe, resilient, and sustainable) and Goal 12 (Ensure sustainable consumption and production patterns).

Opportunities and Challenges in Achieving Resilient Cities through 3R and Resource Efficiency

Unlike the conventional linear approach to resource consumption, which follows 'Take-Make-Use-Dispose' method, 3R is an environment friendly approach where the product or resource consumption is firstly reduced, followed by efforts of reusing the disposed product through maintenance, repair or refurbishment and finally aims at recycling the product or resource, which demands an ability to treat wastes as resources. Overall, 3Rs target reducing the consumption of resources by increasing the efficiency of consumers, producers and disposal facilities. Similarly, Resource Efficiency targets adopting cleaner production mechanisms that can create environmental and social value to the product and services at reduced cost. Resource Efficiency and 3R are indeed related to each other and advocate the usage of renewable energy, reducing resource consumption, closed looping of the wastes generated and the raw material needed for manufacturing industries, reducing the environmental costs, and increasing the quality of life in societies. However, under the current trend of the linear economy, which strongly relies on the extraction of minerals and disposal of the used products, 3R approaches are yet to gain ground in the cities.

Cities are yet to understand and experience the long-term impacts of consumption of depleting resources and their eventual scarcity. Scarcity of resources also leads to economic shocks due to sudden rise and fall of resource prices. From the perspective of environment, unsustainable use of raw resources results in deteriorated environment. One of the sanitation issue faced by cities due to higher resource consumption is the problem of waste management.

Reasons behind the higher consumption of resources in the cities is their inability to understand the long-term impact of resource consumption coupled with the limited ability to comprehend the importance of technology and innovations driving development. At the individual level, apart from the strong leadership in the cities, lack of consumer awareness to realize the impact of resource consumption is also a challenge to resource efficiency and 3R in addition to the above-mentioned challenges.

Resource efficiency and 3R provides opportunities for cities to reduce vulnerability against the impact of high resource consumption and build resilience against the environmental, social and economic risks that the cities are prone to. These principles can not only reduce the dependency on resources but also build economic resilience by increased jobs. As the resources are used more sustainably, the resultant co-benefits in the form of healthier environment and better public health are inevitable. The financial viability of resource efficiency and 3R can be better described from the perspective of circular economy business models. Innovative businesses that are less dependent on raw resources and more on the 3R are central to these business models. Many new businesses have already emerged under these models. This section also highlights the vulnerabilities of cities and introduces innovative projects that some of the cities have experienced in the verse of developing resilience with suitable case-studies.

Analysis of Various Kinds of Resilience for Cities

This section presents five different models of resilient cities which are, Renewable energy city, Carbon neutral city, Distributed city, Biophilic city and Eco-efficient city. Renewable energy cities are focused on reducing dependency on fossil fuels through the usage of renewable energy sources while the carbon-neutral cities target reducing their carbon footprint by promoting cleaner infrastructure and means of transportation. Reducing carbon emission can also build resilience globally by contributing to lowering the rate of global warming; hence, it is important for cities to reduce their carbon emissions. Similarly, distributed cities emphasize decentralizing their water, wastewater and solid waste management facilities to reduce the risks associated with disasters. They also focus on the household level recycling and reusing of resources like rainwater, discarded food waste, gray water produced, etc. The biophilic cities present the idea of cities rich in biodiversity. They promote green landscapes as they can reduce the problems like flooding, drought, urban heating, etc., and act as a sink for the carbon dioxide. Eco-efficient cities are another complex model which target ecological and economic improvement in the cities. They aim at decoupling economies from resource usage and aim at developing economies of the cities along with increasing their natural capital like forest, faunas, green belt, etc. This section highlights these models and the opportunities for resource efficiency and 3R.

Way Forward

This section puts forward the possible ways the cities could build their resilience. The possible ways a city could build its resilience are by innovating, replicating resilience of other cities, integrating technology and building long-term leadership.

1. Introduction

1.1 Global Urbanization and the Impacts

The trend of urbanization is an inevitable phenomenon today. With unlimited opportunities for jobs, social security, infrastructure etc., people get attracted to urban areas or cities in search of a better life. In 2014, 54% of the world's population lived in urban areas which is significantly higher than the 30% in 1950. Further, it is predicted that by 2050, 66% of the population will reside in urban areas[1] which can also be termed as cities. Although they offer economic advantages, the cities are vulnerable to uncontrolled expansion, environmental pollution and degradation and hence unsustainable growth.

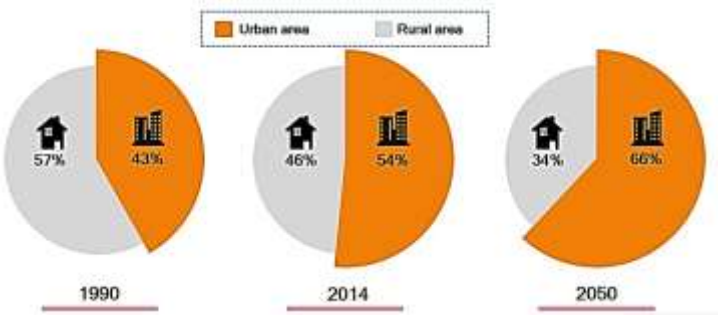
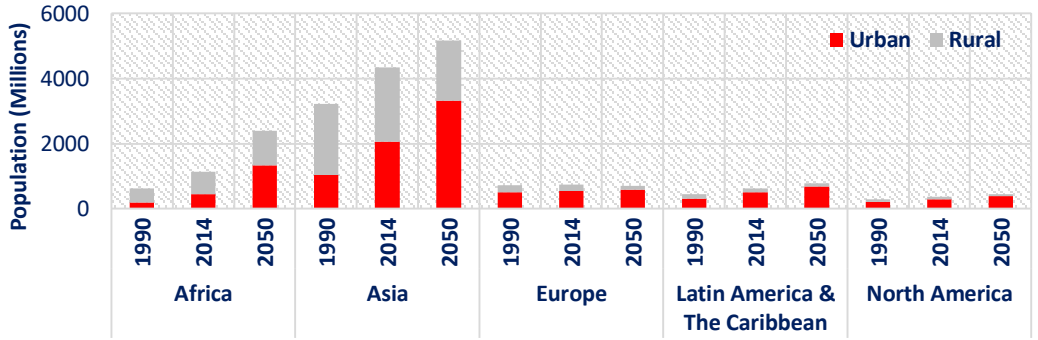


Figure 1.1: Global Urbanization Trend[1]

Urbanization is a global phenomenon that occurs as the economies grow. As seen in **Figure 1.2** more developed continents have higher urbanization rate. Majority of the population in the advanced economies like North America, Latin America & The Caribbean, and Europe live in cities. Similarly, urbanization is growing in Asia and Africa where the proportion of people living in cities is low as per the 2014 data[1]. However, these continents will have a much higher proportion of populations living in cities by 2050.



	Africa			Asia			Europe			Latin America & The Caribbean			North America		
	1990	2014	2050	1990	2014	2050	1990	2014	2050	1990	2014	2050	1990	2014	2050
Urban %	31	40	56	32	48	64	70	73	82	71	80	86	75	81	87

Figure 1.2: Urbanization Trend in various continents[1]

The high population in the cities implies a system with high population density, high income, low natural resources, higher environmental issues, and poor resilience. Thus, sustainable development is one of the major challenges of the cities and this challenge seems to be more conspicuous in the developing countries than in the developed nations. Lower and middle-income countries, where the urbanization is more rapid, are bound to face more sustainable development challenges that can affect

[1] Heilig, G. K. (2012). World urbanization prospects the 2011 revision. United Nations, Department of Economic and Social Affairs (DESA), Population Division, Population Estimates and Projections Section, New York.

the city's environmental, social and economic stability. One such challenge is linked with the increased resource use. Cities account for 75% of the total resources use and considering the fact that these cities comprise only 2% of the total land area, 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[2]. Similarly, cities also account for higher energy consumption up to 80%. **Figure 1.3** represents the land coverage, resource consumption, Gross Domestic Product (GDP) generated, carbon emitted and energy consumed of the urban and rural areas. Urban areas use a significant amount of resources when compared to rural areas.

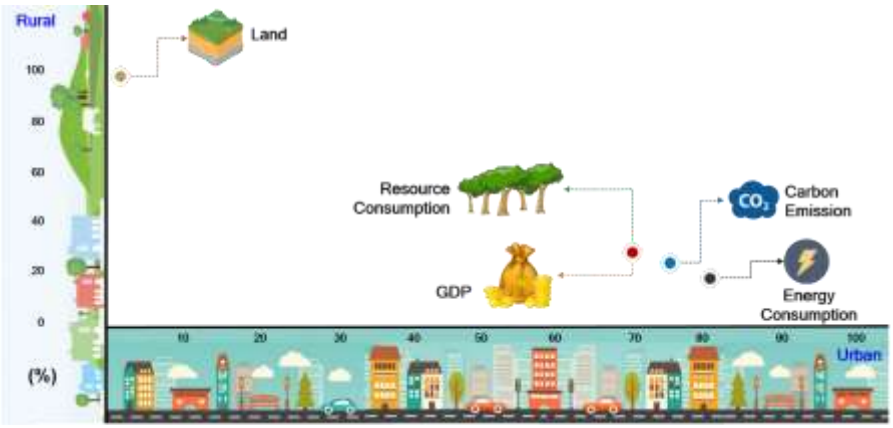


Figure 1.3: Urban versus Rural resource consumption

Higher resource consumption implies higher waste generation in all the three forms: solid, liquid and air which signals 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 they encompass issues of increased vulnerability and reduced resilience of the cities. Higher resource consumption leads to greater issues in the urban which has 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. Cities, due to higher density of population, naturally experience significant impact compared to the rural areas.

1.2 Concept of Resilient Cities

Urbanization increases the vulnerability to shocks and stresses. Resilience can be described as the capacity of a system to absorb shocks and maintain the same level of functionality. Resilience also refers to the self-repairing capacity of a system when there are no impacts of stressors[3]. As mentioned earlier environmental problems such as solid waste management, waste water management, water supply, air pollutant emissions, GHG emissions, etc., are centered on the cities. Moreover, due to the concentrated settlements in the cities, the impacts of a natural disaster, often fueled by climate change, can also make the cities more vulnerable. Thus, it is essential for cities to develop resilience toward such events and it is an important part of urban developmental planning.

[2] Lindfield, M., & Steinberg, F. (Eds.). (2012). Green Cities. Asian Development Bank.
[3] Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. Global environmental change, 16(3), 253-267.

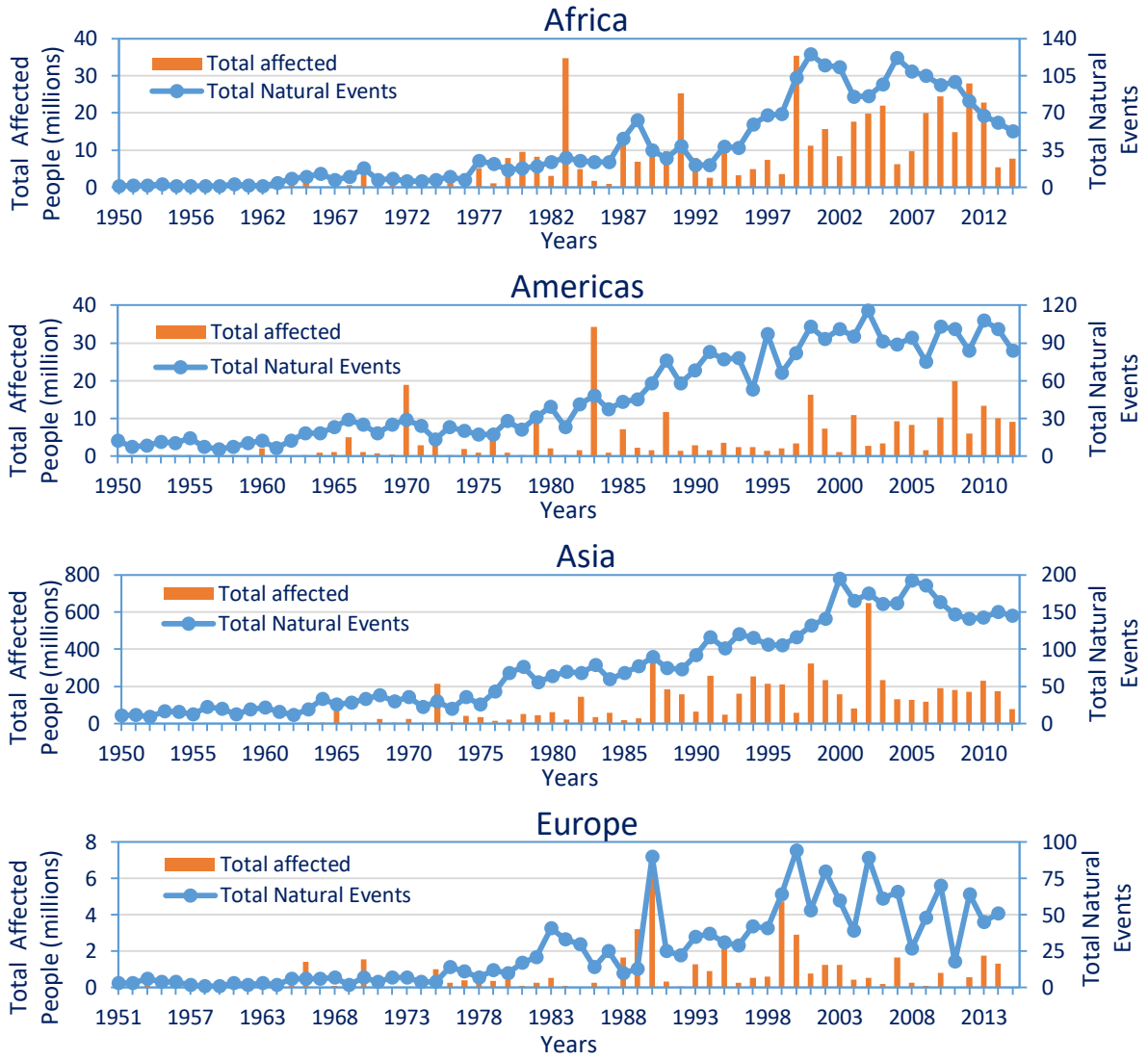


Figure 1.4: Natural disaster and total affected people timeline (EM-DATA[4])

As seen in **Figure 1.4**, frequency of occurrence of natural disasters are on the rise and so are the number of people affected. These disasters include earthquakes, epidemics, flood, landslide, storm, volcanoes, extreme temperature, wildfire, drought, etc., which can also be associated with climate change. Asia is more vulnerable to these events affecting a number of people. Europe, which has higher GDP, is more resilient to these disasters, thus the number of people affected is also less. These disastrous events can destroy the entropy of the cities and it is essential that the resilience is developed to bounce back from these disasters. Resilient infrastructure supported by advanced technology and efficient instrumentation can develop resilience to these shocks. Further, the usage of Information and Communications Technology (ICT) in various public infrastructure is essential to develop resilience[5]. Decentralizing the public utilities like electricity, water supply, wastewater treatment, and solid waste management could also be the alternative means of reducing the risk of cities caused by natural disasters.

Resilience also focuses on resource efficiency as the resources are either becoming scarce or unpredictable in terms of their price. Resource efficiency, which focuses on reduce, reuse and recycling of resources, can be one of the approaches for developing resilience among the cities against

[4]D. Guha-Sapir, R. Below, Ph. Hoyois - EM-DAT: The CRED/OFDA International Disaster Database – www.emdat.be – Université Catholique de Louvain – Brussels – Belgium.

[5]https://w3.siemens.com/topics/global/en/sustainable-cities/resilience/Documents/pdf/Toolkit_for_Resilient_Cities_Summary.pdf

increasing raw material cost, shortage of raw materials and other environmental issues like air emission, effluent discharge, water usage, raw material usage, etc.

Thailand Floods: Economic Resilience

Thailand is a 7th most flood-prone country in the world and flooding has frequent occurrence. In 2011, Thailand experienced one of the worst flood disasters which affected 13 million people and caused a damage of over USD 45 billion. This flood was caused by the Nock-ten tropical storm damaging most part of the country. The devastating flood in 2011 occurred in the fourth quarter, i.e., in October during which the GDP of Thailand was reported to be negative 8.9%.

Inundation of industries during 2011 flood

The impacts were seen in many sectors like housing, transportation, electricity supply, agriculture, tourism, water supply, financial institutes, etc. The major financial damage was to the manufacturing industry. Seven industrial parks were severely affected by the flood. Not only were the impacts seen at the local level but also at the global level. The global industrial production reduced by 2.5% on account of the setback in the global supply chain linked to Thai products. The financial losses to the manufacturing industry were calculated to be about one-third of the total losses caused by the flood.

In additional to the physical losses, psychological impacts were also seen among the investors as they feared further investments. The severe impacts of the flood raised the need for the country to develop resilience to floods. Since human beings have little control over natural calamities, thinking of building resilience of cities to prevent or minimize the impacts of disasters is needed. Moreover, it becomes necessary to formulate long-term technology-led adaptation and transformation strategies to avoid impacts of such disasters in future. The Thai government proposed USD 11 Billion plans for the recovery as well as adaptation plans in the sectors like water management, roads, and forecast and early warning system.

Adapted From http://www.gfdrr.org/sites/gfdrr.org/files/publication/Thai_Flood_2011_2.pdf
UNISDR. Towards a post-2015 framework for disaster risk reduction. Available from ⟨http://www.unisdr.org/we/inform/publications/ 25129⟩; 2012
Picture Source: http://www.nationmultimedia.com/business/Bt5-billion-for-industrial-parks-to-build-flood-ba-30169116.html

Due to the increasing number of climate-induced disasters water, food and energy security have become serious concerns in the cities. Resilience also needs to be developed against both the natural and human-induced disasters that can affect these three basic needs. Water shortage in the cities is one of the most common risks. Cities like Mexico, London, Bangalore, Tokyo, etc., are already facing water shortage and a weak wet season could mean drought to these nations. To develop resilience, Tokyo is already planning for a mega scale rainwater collection program while some of the districts of London recycle waste water back to the water supply.

Resilience thus aims to reduce the stress in the cities and also prepare for the shocks that could create turbulence in cities arising out of resource scarcity hampering social, economic and environmental stability of the cities.

1.3 Types of Resilience

1.3.1 Engineering Resilience

Engineering resilience is one of the most commonly applied resilience in the cities and refers to the recovery capacity of the population, infrastructures and institutions from the shocks or disturbances to the same steady state[6]. Engineering resilience thus emphasizes the recovery back to the same initial state that prevailed before occurrence of the shock. Engineering resilience is also extended to developing resilience by the societies or developing social resilience to absorb external pressures. For instance, it could mean development of infrastructures to avert pressure exerted by the increased immigrations. Similarly, it can also be related to developing economic resilience to the shocks that could disturb the steady growth of the economy. The role of innovations and technology to combat such disturbances in the economies can play a key role but more importantly, the strategy and preparedness achieved through institutional arrangements and infrastructures play a more crucial role in bouncing back from the shocks.

New York Sandy Storm: Need beyond Engineering Resilience

In New York, after the sandy storm in 2012, it took about a week to restore the subways and this resulted in serious economic losses. About 10 million people depend on a network of subways, buses, commuter rail, and bridges in New York and the absence of resilience here had resulted in economic as well as social impact. Engineering resilience, which focuses on recovery or mitigation, is essential for the public infrastructure. However, engineering resilience does not describe the broader perspective. Merely flood proofing and water proofing the equipment with hydrophobic coats and doing regular maintenance and monitoring could only be one of the routine methods of fighting these vulnerabilities. The scope of building resilience does not and shall not limit itself only to the rehabilitation and recovery but should also address the adaptation and transformation of the system which could provide a long-term and financially viable solution. Technology can play a major role. In the case of New York storm, the efforts of making the system robust or shielding from the impacts of disaster only helped the infrastructure to minimize the cost to some extent, but did not have long-term financial benefit. However, when the long-term measures to increase the resilience including investment in smart technologies and infrastructure were evaluated, it was seen that such investments had co-benefits which overweigh the initial CAPEX. Thus, development of resilience in the form of adaptation and transformation could indeed be more financially viable rather than just planning to resist and bounce back from the disaster. 3R indeed is one of the ways which conceptualizes beyond engineering resilience. From the long term cost and benefit perspective, 3R can have benefits in term of: inclusive financial growth of cities (due to the increased jobs and supply chains), improved city sanitation, and reduced mental stress of the people.

Flooded roads during the Sandy Storm in New York

Adapted From: Kaufman, S., Qing, C., Levenson, N., & Hanson, M. (2012). Transportation during and after Hurricane Sandy. https://w3.siemens.com/topics/global/en/sustainable-cities/resilience/Documents/pdf/Toolkit_for_Resilient_Cities_Summary.pdf

Picture Source: http://susancushman.com/mental-health-monday-hurricane-sandy/

[6] Seeliger, L., & Turok, I. (2013). Towards sustainable cities: extending resilience with insights from vulnerability and transition theory. Sustainability, 5(5), 2108-2128.

1.3.2 Multi-Equilibria Resilience

While the Engineering Resilience argues resilience to be the capacity to bounce back to the same steady state, multi-equilibria resilience does not necessarily return back to the same steady state as it regards system to have multiple equilibria. The system that prevails after the shock will be invariably different from the initial steady state. This re-recovered or modified system followed after the shock can be regarded as a state of different equilibrium than the one prior to the shocks.

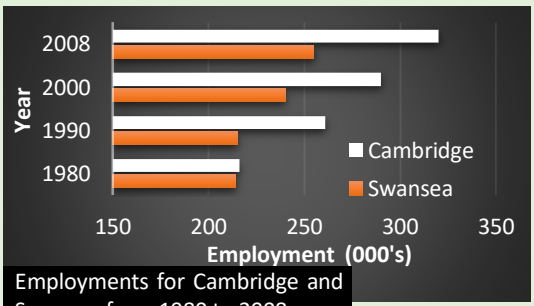
Thus, robustness of a city is the key element of multi-equilibria resilience and it focuses on the stability of the system[7] rather than the state of the system before and after the shocks. However, unlike the engineering resilience, this theory is not limited to the recovery. It introduces the principles of adaptation. This theory prioritizes the adaptation of cities to increase their ability to resists the stress and shocks.

1.3.3 Social–ecological resilience

Socio-ecological resilience highlights the interaction that exists between the social and ecological components of cities. Cities and communities have various natural systems, which are linked to each other. For example, resources required for consumption in cities are mostly generated by the rural populations and are strongly dependent on these producers. The resilience of this system is essential as the system is vulnerable on both the social and environmental front. Both conflicts and deteriorating environment can put the system at risk. One of the important aspects of the socio-ecological concept is that it considers cities to be dynamic systems where there are interactions at different levels. When one of the subsystems is evaluated, the impacts on the resilience of another sub-system is also considered. Socio-ecological resilience mainly focuses on transforming the city rather than adaptation or recovery. Technology and innovation-based transformation of the cities are the mainstay of this type of resilience.

Transforming Economy Driven by Technology: Socio-ecological Resilience

Socio-ecological resilience focuses on transforming city through technological innovations. However, the socio-ecological resilience assumes the system to be complex and made up of many sub-systems whose impacts must also be considered while developing resilience. One such example can be taken from the case study of the two cities Cambridge and Swansea both of which decided to move to the technology-based economy but took a different approach. These cities were hard hit by the declining mining industries and were identical in their economic status back in 1980. Swansea invited the Foreign Direct Investment (FDI) from Japanese technological giants while Cambridge built a science park and capitalized on local entrepreneurship and universities' capacity to innovate. Over time, Cambridge developed more successfully as a high-tech economy and provided more jobs as illustrated in the figure. Swansea, on the other hand, was relatively less successful as multinational companies had limitations and did not build the capacity of locals. Whereas Cambridge provided a wider market for innovations and startups by choosing the right stakeholders and right model for long-term development.



Employments for Cambridge and Swansea from 1980 to 2008

Adapted From: Simmie, J., & Martin, R. (2010). The economic resilience of regions: towards an evolutionary approach. *Cambridge journal of regions, economy, and society*, *3*(1), 27-43.

[7] Davoudi, S. Resilience: A bridging concept or a dead end? Plann. Theor. Pract. 2012, 13, 299–307.

1.4 Resilient Thinking and Technological Integration

As discussed in the above section (section 1.3) resilience thinking can have three explanations. **Figure 1.5** shows the vulnerabilities and resilience that the cities can develop as they build their capacities to cope with vulnerabilities. Engineering resilience focuses on the recovery from 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.

Figure 1.5: Building Resilience in the Cities

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 as well. Like 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. Technology and innovations are given prime importance in this theory. In the context of cities, socio-ecological resilience which supports the transformation, adaptation and recovery seem to be more appropriate. 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.

Technology and innovations surely play an important role and the integration of technology is necessary when resilience is being considered. One of the roles cities can indeed play is the formulation and execution of programs that facilitate absorption of the relevant technologies by societies, households, companies, and service industries. It can reduce resource consumption and also the environmental pressure as cleaner production techniques are now available. Thus, technology can help cities to build their resilience. The ways the technology can help to build resilience are by:

- Reducing the consumption of resources in the production process
- Reducing the need for the raw resources that flow from outside the city boundary. Technology can help to use the local resources to reduce the dependency on the external environment.
- Reducing the environmental impacts that are likely due to excessive resource consumption.
- Reducing environmental impacts through implementation of clean production technologies.

- Reducing environmental impacts through sustainable transportation which are fuel efficient, run on green energy, and emit lesser GHG.

- Diverting the waste from the landfill for recycling and recovery.

- Reducing the GHG through the usage of renewable energy to make cities contributors to the climate change reduction.

- Making citites disaster proof and also providing environmental-sound approach to the management of disaster waste by introducing the opportunities of reuse and recycle of demolished waste.

- Creating jobs which can help cities to increase their economic resilience. More jobs are created when the materials pass through a cycle of closed loop within the city boundary. Like more jobs are created by recycling than landfilling.

1.5 Components of Resilient Cities

Cities are complex systems that consist 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 frame, these components, and their sub-components, need to be considered. Resilience must be established at the subsystem level**. Figure 1.6** shows the interconnected components of resilient cities, which are government networks, network material and energy flow, urban infrastructures and forms, and socio-economic dynamics of the city. Resilient cities need to have careful planning and long-term strategy for all these components considering the vulnerabilities of the cities. As cities differ in the physical and political geography, the resilience cannot be generalized for cities.

1.5.1 Governance Network

This component includes stakeholders who can play an important role in developing resilience. Technological adoption and initialization of such a process is essential for this component. The role of these stakeholders are as follow:

Table 1.1: *Role of Different Stakeholders in Resilience*

Ministries & Departments	Ministries and departments of the city can frame policy as well as execute them. The ability to improve the plans, policies and regulations by the governance structure is also a part of city resilience[8]. This stakeholder can further influence other stakeholders and determine their role in developing resilience. They can also promote policies and programs that can initiate collaboration between industries, SME's, eco-industrial park and regional infrastructure to attain more resource efficient environment. Technology has the most critical role in building cities' resilience and it is equally important for this stakeholder to innovate through technology.
Informal Agencies	Informal agencies or private sectors, though do not play a direct role in building resilience at the policy level, they still play a role in the resilience. For instance, in waste management, which is challenging in the developing nations, informal actors can minimize the management cost in cities if coordinated well.
Consumers	Consumer awareness can also push the cities to adopt the resilience plans. Willingness to pay in consumers and further adoption of new resilient technologies by consumers can also reduce resource consumption. Usage of

[8] https://w3.siemens.com/topics/global/en/sustainable-cities/resilience/Documents/pdf/Toolkit_for_Resilient_Cities_Summary.pdf

	low energy consuming technology, electric vehicles, shared rides (carpooling), etc., can reduce the need for resources.
NGOs	NGOs can also put pressure on the government or individually play its role in developing resilience of the cities. They can coordinate with municipalities to launch effective developmental programs and help build capacity of the city.
Industries	Adoption of cleaner technology is essential for the industries. Industries must look to reduce emission, reduce usage of resources, and make products that can be easily recycled.
Universities	Universities can function as the fountainhead of knowledge through their strong 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.
Financial institute	The capacity of financial institutions to fund the development initiatives also plays an important role. Building resilience among the cities needs capital and strong financial institutions can speed up this process. They must provide investment and loans for green projects.

Figure 1.6: Component of Resilient cities

1.5.2 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 principles of resource efficiency and 3R can play important role in reducing the inflow of raw material in the city. In addition to reducing the imports of materials, it is also equally important that the materials are recirculated within the system. Increasing the lifecycle of the materials implies increases supply chain and increased economy.

1.5.3 Urban Infrastructures and Forms

This component of the resilient city 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.

1.5.4 Socio-Economic Dynamics

The elements of this sub-system include monetary capital, demographics, justice, equity, education, health, etc. This sub-system can influence the other sub-systems. Careful planning and long-term vision are needed to be applied to this component. 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.

1.6 Sustainable Developmental Goals and Cities

Sustainable Developmental Goals (SDG) are the goals set by more than 150 countries to attain sustainable development; there are 17 goals which aim at the improvements in mainly three sectors: economic development, social development, and environment protection. As cities occupy more than half of the world's present population, they are bound to experience more problems due to growing settlements, it would not be wrong to say that the success of SDG depends on its successful implementation of in the cities. Among the 17 sustainable goals, Goal 11(Make cities and human settlements inclusive, safe, resilient and sustainable) and Goal 12 (Ensure sustainable consumption and production patterns) are primarily aimed at improving resource efficiency by promoting successful waste management principles like 3R.

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' seem to carry more profound influence on this goal. Since over 75% of the resources are consumed in the cities, the success of Goal no 12 will rely on the policies and strategies that cities will be implementing to minimize resource consumption. Further, the choice of resources that the cities will be using to produce various products will also have a direct implication on this goal. Moving the resources in a circular loop through various circular business models will also help to achieve sustainable production. Thus, the 3R and resource efficiency in cities will play a vital role to achieve this goal.

Goal 11, in general, targets to plan cities and human settlement. This goal also highlights the resilient cities. As noted earlier, with more than half the global population residing in cities, the importance of this goal and the difficulties of attaining the same can be enormous. Various principles like sustainable transportation, sustainable housing, gender equality, social security, etc., seem to have more direct linkage with this goal. However, as the cities tend to consume unsustainably, the resource demand and its dependency on virgin extraction can be considered as the major uncertainty in the cities making it important to manage the resources efficiently in cities. 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 the table below:

Table 1.2: SDG implications 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 principals 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.

Sustainability is the end goal of the cities and refers to social and environmental prosperity, resource efficient economy, and quality of life. Resilience, on the other hand, can be thought of as the strategy to ensure long-term sustainability. It is an approach to cope with the risks and uncertainty that can lead to unsustainability.

Addition the development of 3R in the cities can also create jobs and emerge businesses like remanufacturing, recycling, waste to energy, etc. Thus it also has implications to SDG 8 which deals with the 'Decent work and Economic Growth.' As more number of people will reside in cities, it is important to increase the jobs in cities. 3R or circular economy can help cities to attain SDG 8.

2. Opportunities and Challenges in Achieving Resilient Cities Through 3R and Resource Efficiency

With constant increase in the number of people now preferring to live in cities the challenges of cities are also growing by leaps and bounds. Cities have grown to become the centers of economic activities and have a wide range of institutions and infrastructure. However, the concentration of peoples leading the degradation of the natural environment has, in turn, decreased the resilience of cities. Now the cities are being seen as the accumulators of stress. They are more vulnerable to shocks and the resultant impacts are disturbing the steady state of cities.

Resilience can, however, 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. 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 (**Figure 2.1**). This conventional model strongly relies on the production of raw materials. However, the irony of the usage of raw materials is that cities do not produce raw materials.

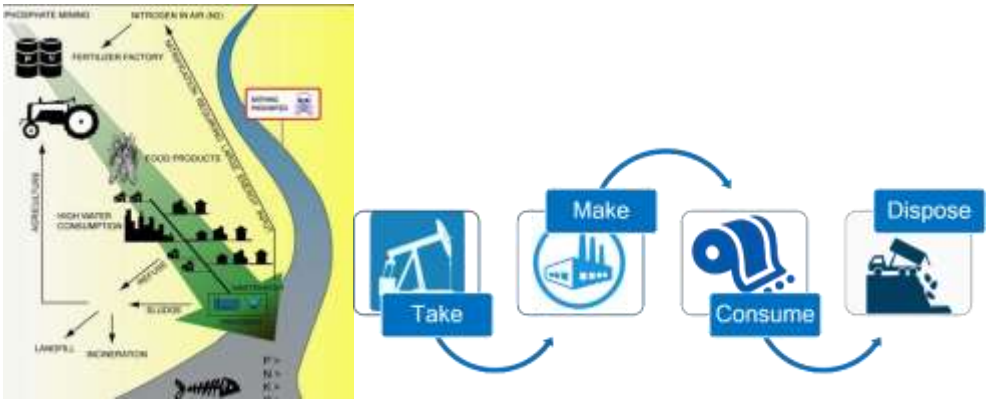


Figure 2.1: Take, Make Consume and Dispose Approach of the cities

Therefore, the opportunities of economic reforms of the cities depend upon reducing the dependencies on raw materials. This is where the need of an approach is felt where the products can be reused or recycled or a new business model could be created where the resources need to be reduced. New business model based on the principles of reducing, reuse and recycle are emerging in the cities. Through the usage of electric vehicles and renewable energy, the dependency on oil can be reduced. Efficient ways of recycling are also being innovated (like the metal mining of mobiles phones which consists of precious minerals). Similarly, through the establishment of service industries providing the value of the product rather than the ownership (Phillips, Xerox), the consumption has also reduced.

In this chapter, the challenges and opportunities associated with the resources and 3R will be discussed in detail from the context of developing resilience among the cities.

2.1 Challenges of Resource Efficiency and 3R

Resource efficiency is one of the key elements of SDG goal number 12 which deals with 'Sustainable Consumption and Production.' Resource efficiency implies minimization of mining of resource, usage of raw resources, consumption of energy, and waste generation. From the life cycle perspective, resource efficiency ensures that the environmental impact is minimized through the extension of the

product life cycle. In other words, the unwanted products or wastes are recycled or reused in a closed loop.

The concept of resource efficiency has wider scope in the cities as cities are the hub of consumption of majority of the global resources. Adoption of principles of resource efficiency ensures that the resources are being consumed in a sustainable way with lower impacts on the environment. In addition, the efficient use of resources can also be financially attractive. Higher recycling rates and diverting wastes from landfills also lead to higher financial savings.

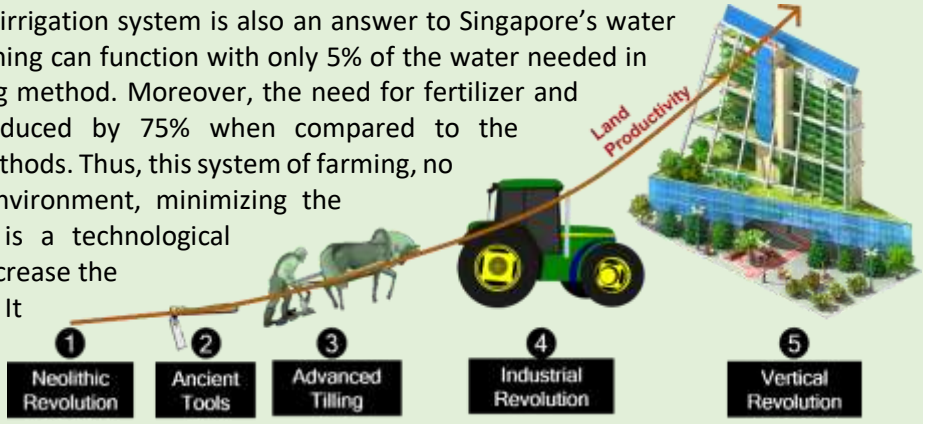
Vertical Farming: Sustainable solution to Cities Food Security


Sky Green Vertical Farming

Singapore is highly dependent on import of food from other countries and only 10% of the food is produced within the country. Thus, Singapore is highly vulnerable to food scarcity and the price rise. Resilience is therefore essential, which can only be achieved by technological transformation.

Farming requires a lot of land areas and is not considered feasible in cities where land is a scarce and expensive resource. However, a step ahead of the conventional horizontal farming is the vertical farming, which has the potential to significantly increase production per unit area making it plausible and financially viable for producing vegetables in the cities. In addition, there lies greater environmental and social co-benefit in terms of job creation and resource efficiency.

Sky Green is one such company in Singapore which grows vegetables in a 6-meter-tall 'A' shaped frame. These frames use very little electricity as they are hydraulically powered and are energy efficient. They also recycle and reuse water back in the system making it water efficient system as well. This closed loop irrigation system is also an answer to Singapore's water dependency. This farming can function with only 5% of the water needed in the traditional farming method. Moreover, the need for fertilizer and pesticides is also reduced by 75% when compared to the traditional farming methods. Thus, this system of farming, no doubt, is a closed environment, minimizing the resource needs and is a technological innovation that can increase the resilience of cities. It further reduces the carbon emission by avoiding transportation of food to cities from rural areas.



Adapted From: http://permaculturenews.org/2014/07/25/vertical-farming-singapores-solution-feed-local-urban-population/

2.1.1 Resource Scarcity

It is understood that the cities depend on external sources for most of their resources, and hence are highly vulnerable to resource scarcity. Food, water and energy security are the emerging issues in the cities in addition to the security of minerals that are vital for the industries influencing the GDP of the cities. Therefore, it is essential for the cities to be resilient to these resource scarcities. **Table 2.1** shows the affected sectors following several resource scarcities. Resource scarcity can thus also affect the economic resilience of cities. It was estimated that the iron and steel shortage could lead to loss of

USD 2 trillion for companies[9] which further implies shocks in the form of job cuts and reduced investments in the cities.

Table 2.1: Resources and sector affected

Resources	Sectors Affected
Minerals (Aluminum, cadmium, lead, lithium, etc.)	Industries, Construction, Consumers
Oil	Industries, Transportation, Service Industries, Construction, Tourism, Consumers
Food	Industries, Tourism, Consumers
Water	Industries, Tourism, Construction, Consumers

Resource Dependency: Threat to resilience

Vehicles waiting for fuel during the fuel crisis in Kathmandu

Nepal is a land-locked country and is highly dependent on the supply of oil from the India. Around five-month long trade blockade in Nepal that started in September 2015 threatened the energy security as it severely affected the Nepalese economy and the livelihoods of millions of people. Transportation and household sectors were hard hit by the energy crisis. People scampered around in the overcrowded public transport vehicles whereas the households struggled to procure groceries to cook their food. People were reported cutting trees for fuel wood and the usage of electricity for cooking further led to more power cut-offs. This incident in Nepal has raised the issue of resilience in cities in the context of resource scarcity and external dependency for critical resources. It is essential for cities to have robust planning against such crisis. Electricity-powered transportation and increase in the production of hydropower could be one of the transformations that Nepal should be considering to develop resilience in the energy sector.

Adapted From: http://www.huffingtonpost.com/anthony-conwright/in-nepal-a-crisis-worse-t_b_9131410.html
Picture Source: http://www.thenepal.net/2016/08/shortage-of-petroleum-products.html

2.1.2 Resource Price Hike

As cities get more and more dependent on raw resources, more will be their vulnerability to the price uncertainties of the resources. As seen in **Figure 2.2** below, the overall rise in the resource price can be observed with some downfall during the 2009 recession. The prices of energy, food, and metals have significantly risen between 2000 and 2014. It is evident, from the long-term perspective, that being dependent on resources will ultimately lead to increased expenditure and cash outflows from the cities. Also, the interesting fact about this graph is the peaks observed in the prices of commodities like energy (in the year 2008), metals and minerals (in the year 2007) and food (in the year 2008). These abrupt rise in the prices of resources can also be seen as the shocks to the cities and the unpreparedness of cities to adapt to the ensuing inflation. Indeed, the global financial crisis in 2009,

[9] World Economic Forum, in collaboration with Accenture, "More with less: Scaling Sustainable Consumption and Resource Efficiency", p. 5, January 2012

affecting many countries and cities, is considered to be the direct consequences of the rise in energy prices seen in the year 2008[10].

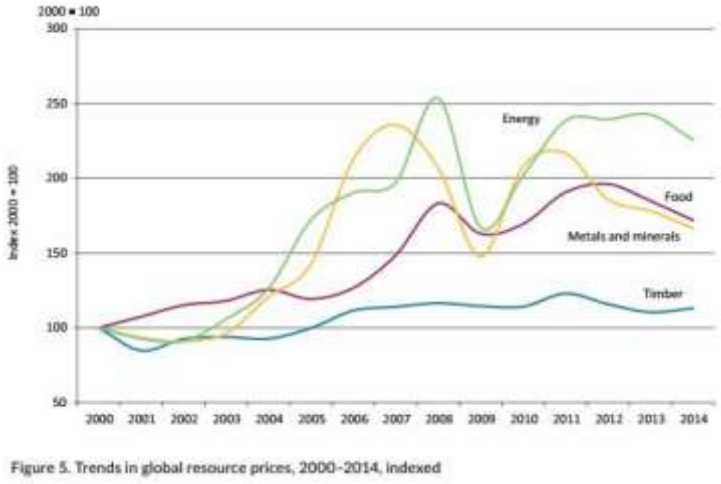


Figure 2.2: Global resource prices, 200-2014 (indexed)[11]

Short-term price shocks and long-term resource price increases can both be threats to the cities. Hence, cities, in order to be economically resilient, need to reduce their dependence on raw materials. This could be achieved by being resource efficient and by adopting the 3R principles. Sustainable transportation that uses electricity could significantly reduce the need for fossil fuels. Similarly, usage of renewable energy can significantly reduce the oils that need to be burnt for generating power for buildings. Similarly, reducing consumption, recycling and reusing of resources in a closed loop can also reduce the demand for the virgin resources.

2.1.3 Unsustainable Usage of Resource

Global material usage has 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 has slowed down to 1.2% per annum while the rate of growth of resource consumption has 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[11] which was fueled by the high rate of resource consumption. This signifies that the resource consumption is increasing unsustainably and is not limited to the basic needs of the population growth alone but also to the quality of living.

Most importantly, the rise in urbanization has significantly contributed to the global resource usage. Urban population grew from 36.5% in 1970 to 51.5% in 2010[12] which means that the global urban population grew by 2.5% annually from 1970 to 2010, which can be better correlated with the growth rate of resource consumption. As the urban population is estimated to reach 66% in 2030, the resource consumption could further be estimated to increase unsustainably unless proper measures are taken.

One of the major indicators of a country's growth is the GDP. However, it only represents the financial success or prosperity of the nation or city and fails to account for the environmental and social aspects

[10] Hall, C.A.S., Groat, A. 2010. Losing Faith in Economics. Energy price increases and the 2008 financial crash: a practice run for what's to come? The Corporate Examiner. 37: No. 4-5: 19-26.

[11] http://unep.org/documents/irp/16-00169_LW_GlobalMaterialFlowsUNEReport_FINAL_160701.pdf

[12] http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

of growth. Inclusive Wealth Index (IWI), unlike the GDP, considers environmental and social parameters when accounting the growth of a nation and can be considered as a better indicator of sustainable growth. It is a holistic indicator which measures natural capital, human capital, and produced capital. When accounting for the natural capital growth, IWI takes into account the fossil fuels, minerals, agricultural land and forest. It also includes health and social aspects of the nation. When evaluating the growth of India from 1990 to 2008, its GDP grew by 120%, which is indeed a big leap. However, its IWI grew only by 9% as its natural capital or ecological assets declined by 31% . The growth achieved with such levels of resource consumption is simply unsustainable.

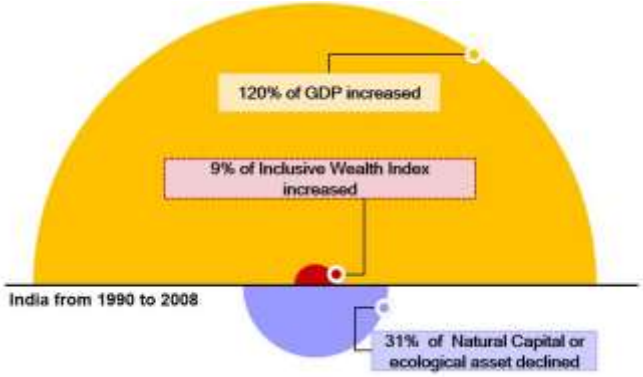


Figure 2.3: Unsustainable Growth of India from 1990 to 2008

2.1.4 Waste Management

One of the major constraints of resource consumption is the waste generation which can occupy a significant portion of the cities' management costs and can be a financial burden to the municipalities. It was found that most of the city's waste management budget ranged from 3 to 10% of the total municipal budget[13] and differed according to the income level of the cities (**Figure 2.4**). 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.

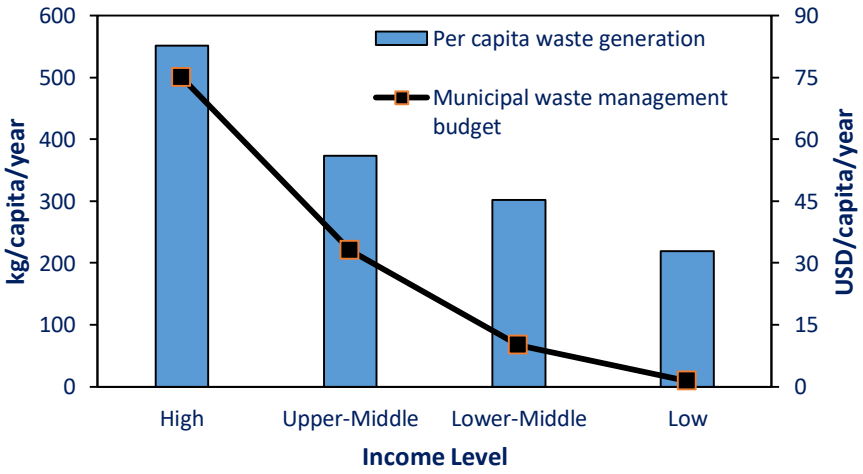


Figure 2.4: Municipal Waste Management Cost[13]

[13] Wilson, D. C., Rodic, L., Scheinberg, A., Velis, C. A., & Alabaster, G. (2012). Comparative analysis of solid waste management in 20 cities. *Waste Management & Research*, *30*(3), 237-254.

Waste collection rate also changes according to the GDP of the city as it is a financial burden to the municipalities to manage the city waste. Higher collection rate implies higher municipal spending. The lower income cities tend to have lower collection rate[14] and uncollected solid waste in the cities can lead to many environmental and social problems like clogging of drainage due to flooding, bad odor, poor aesthetic quality, increase in diseases like diarrhea and respiratory problems, etc.

Thus, poor waste collection rate and higher production of waste are the challenges to resource efficiency and 3R implementation in the cities.

Taiwan Waste Management System

The waste management in the island of Taiwan is an effort to develop resilience against the vulnerabilities that emerged back in 1980 due to the lack of space for landfills followed by community conflicts over the government's decision to incinerate the waste. Resilience was developed in Taiwan by one of the most effective Zero waste management policies in 2003 under a strong community pressure. Under this policy, the recycling rate is targeted to reach 40% by 2011 and 75% by 2075.

Some of the TEPA steps to reduce the waste are as follow:

1. Restricting the weight of packaging.
2. Banning disposable tableware in educational institutes and offices.
3. Imposing fine on supermarkets who fail to reduce their packaging waste to governmental target.
4. The requirement of using reusable chopsticks inside Supermarkets and stores by law.
5. Providing a discount for consumers who can manage to bring their own cups in the fast-food cafes and also giving a discount on the return of disposable cups used by the consumers.
6. Imposing a tax on the materials sold from the manufacturer as part of 'Extended Producers Responsibility'. These tax money are then used for collection, recycling and research and development activities.


Government Certified Waste Bags

7. Household's segregation of recyclable waste in a government certified bags which need to be purchased. This strategy significantly reduced the volume of waste and increased the efficiency of waste segregation.
8. Discarded E-waste needed to be mandatorily taken back by the producers.
9. The segregated food waste is sold to the piggery farms or composted.

These strategies and strict policies reduced the waste generation of Taiwan from 8.7 to 7.95 million tons from 2000 to 2010, while there occurred 47% GDP growth during the same interval. Indeed, waste was decoupled from the economic growth and the per-capita waste was recorded to be 12.7% lower in 2010 than in 2000. Taiwan waste management supported by technology, law, and public awareness is a huge success and a model to the waste management of a city and is replicable if supported by strong leadership. In 2015, TEPA reported the recycling rate of 55%, which implied it was on its way to achieving its 2075 goal.

Adapted From: http://www.no-burn.org/downloads/ZW%20Taiwan.pdf

[14] Wilson, D. C., Rodic, L., Scheinberg, A., Velis, C. A., & Alabaster, G. (2012). Comparative analysis of solid waste management in 20 cities. *Waste Management & Research*, *30*(3), 237-254.

2.1.5 Technological Barriers to Resource Usage

One of the barriers to higher resource efficiency is the inability of cities to innovate or implement the technologies that can transform the cities. It is essential for cities to innovate and adopt technologies that reduce usage of resources. Similarly, technology also needs to be developed that can more efficiently recycle the used materials. One such technology is the 'Econyl Regeneration System'[15] which converts the discarded nylon waste (fish net, carpet, etc.) into fresh fibers that can serve as raw material in various industries. Similarly, CO_2 based dyeing technology of DyeCoo[16] eradicates the usage of water and chemical for the fabric dyeing. This technology has already been adopted by the industries like Nike and Ikea. The absorption of such technology is a challenge to the cities and also the cities might not have the capacity to implement such technologies.

Technological Solution for Reducing Resource Consumption

Sea ports often account for a large resource consumption, especially fuels, as the goods need to be transported by trucks. However, this is not really the case with the port in the city of Gothenburg which handles almost 60% of Sweden's container traffic. The Port of Gothenburg has been transformed to reduce the environmental impact by innovating electric powered railway for transportation of containers to and from the ships. This innovation reduces the usage of energy as almost 700 diesel powered trucks have been substituted and the energy usage for freight transport has been reduced by 70% The co-benefits arising from this strategy are also substantial as the traffic congestion, noise pollution, energy cost, harmful air pollutants, CO_2 emission etc., have been drastically reduced in the port.

Rail port of Gothenburg

Adapted From: http://sustainia.me/resources/publications/4th_Sustainia100_2015.pdf
Picture Source: http://www.logistics-tapahtuma.fi/File/713/b-sjthoren.pdf

2.1.6 Institutional Capacity

Institutional capacity of the cities plays a crucial role in the implementation of concepts of resource efficiency and 3R in the cities. Strong and planned policies that can absorb technological innovations and focus on reduction of resource consumption through the concept of 3R are essential. Hence, it the supporting policies that are of foremost priorities which are then complemented by capacity and ability of the institutions. The institutions should have the necessary capital, human resources and technology to implement 3R and the developing cities with poor economic ability are likely to struggle to implement 3R.

2.1.7 Lack of Consumer Awareness

Public awareness with respect to resource consumption and 3R plays a crucial role in the success of resilience against higher resource usage. Public awareness in the environmental and social aspects of products and services that create higher impacts can help in informed decision making. As green consumerism is on the rise, consumers are increasingly getting attracted to the products that promote sustainability. Consumer awareness is on the rise and more efforts are needed especially in the lower

[15] http://www.econyl.com/regeneration-system/
[16] http://www.dyecoo.com/co2-dyeing/

income nations. Problems like unsegregated waste, improper disposal of hazardous waste, degraded quality of the waste water etc., can also be addressed to a great extent through consumer awareness.

Raising Consumer Awareness: Step to Resilience


Wongpanit Recycle Separation Plant, Thailand

Wongpanit is an informal waste recycling company in Thailand which has raised public concerns about the recycling ever since its establishment in 1974. It has currently 400 branches across Thailand which recycle various types of wastes like metal, paper, glass, plastic, tires, hazardous waste, food residue, electronic waste, EPS foam etc. As it also buys waste directly from the users, it has made efforts on raising public awareness and has made segregation financially attractive in Thailand. It also works with the government in raising awareness about waste management in Thailand. Such efforts in the cities are essential to increase the recycling rate as well as make waste management financially attractive.

Adapted From and Picture Source: http://www.worldaware.org.uk/awards/awards2004/wongpanit.html

2.2 Opportunities of Resource Efficiency and 3R

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 arising out 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.

Previous sections introduced the vulnerabilities of cities against resource consumption, their import, and the price hike that could have multi-sectoral impacts in the cities. Resource efficiency and 3R provides an opportunity to narrow down this gap. 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 take-make-use-dispose into a circular model is called for where the resources can be reused, remanufactured, recycled, and more efficiently repaired to elongate the product life cycle. Resource efficiency and 3R can moreover transform cities with the emerging concepts like green buildings, sustainable transportation, green chemistry, energy and water efficiency, sustainable farming, bio-economy (bio-products, bio-energy, bio-engineering), waste water reuse, etc.

2.2.1 Increased Jobs and Sustainability

Resource efficiency and 3R by focusing on recycling the waste and looping it back into the system create a lot of jobs. Financially, it is attractive for cities as new jobs are created within the cities while reducing the resource dependency. 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.

Figure 2.5: Prospect of recycling of waste against landfilling

Similarly, it can create new jobs and lead to sustainability in the sector of water management as well. The discarded black water and gray water can now be purified to the standards of drinking water through innovative membrane-based technology. Tokyo and Singapore also have a separate distribution network of treated waste water, which can be used for cleaning, flushing, and gardening purposes. This technology not only reduces the need for raw resources but also increases jobs.

2.2.2 Circular Economy Business Model

Circular economy 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 basically revolves around the biological cycle and the technological cycle as seen in **Figure 2.6**. Firstly, the product must be designed in such a way that it can function in this cycle and secondly suitable business models must be created to support the functioning of this.

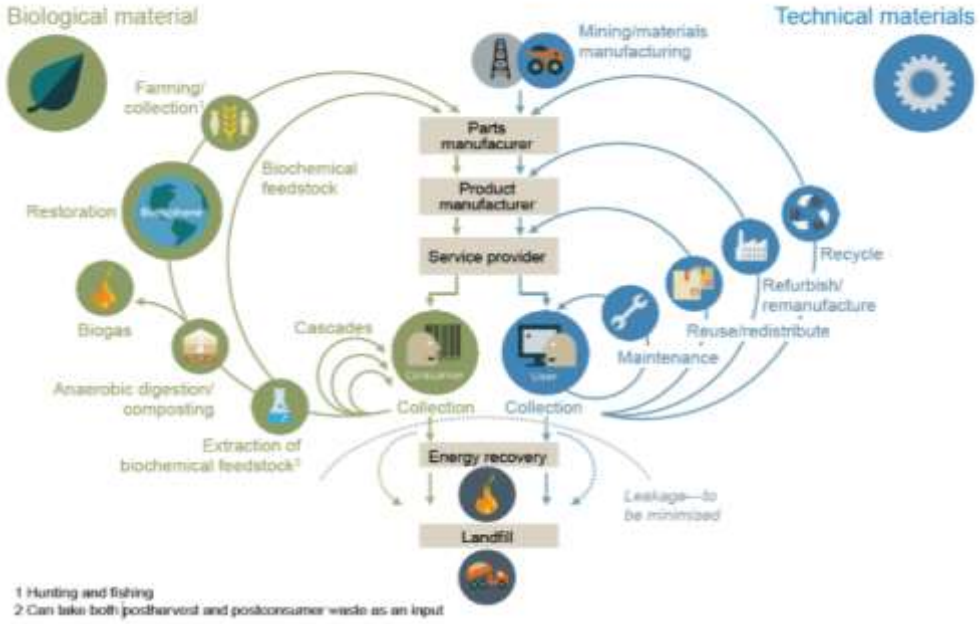


Figure 2.6: Biological and Technical Cycle of Circular economy[17]

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 the table below:

Table 2.2: *Circular Business Models*

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 upgradation. E.g.: Blockphones which can be easily upgraded and customized according to the users' needs.
Sharing platforms	This model targets reducing the need for resources by creating a platform where the products or their value can be shared. E.g.: Car sharing.
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 tension of upgradation and maintenance of the product as it is the service providers who keep the product under great efficiency. E.g.: Phillip scheme of providing lighting rather than light.

One of the examples of 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. Urban mining is becoming popular in cities as it is sustainable. 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

[17] Ellen Macarthur foundation (2013), "Circular economy: Interactive system diagram" [Online]. Available: http://www.ellenmacarthurfoundation.org/circular-economy/circular-economy/interactive-system-diagram

technology, waste can now be converted into building materials and as cities are expanding, these building materials could provide an opportunity for sustainable housing and buildings.

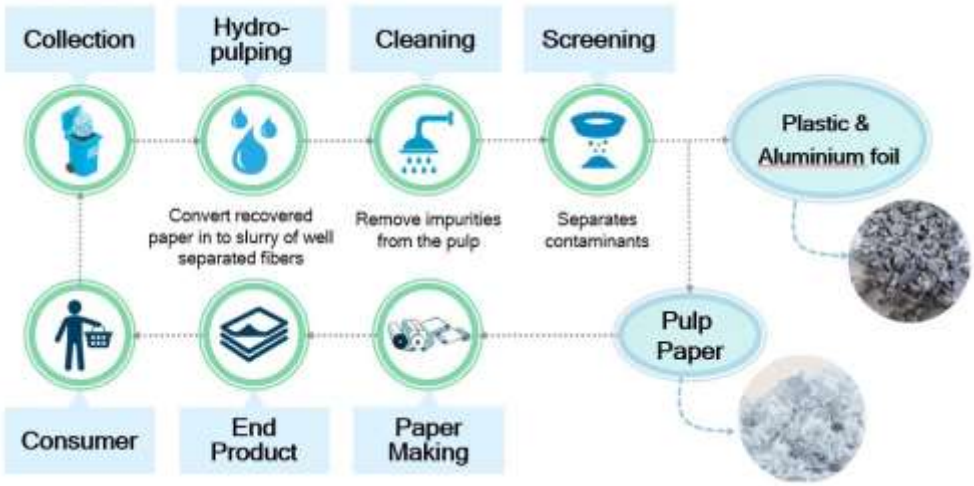


Figure 2.7: Beverage Cartoon to Paper

Similarly, beverage carton waste can be recycled to paper or roofs. The process of converting the beverage carton waste into paper is presented in **Figure 2.7** and can be considered as urban mining. The conversion of beverage carton waste into roofs is presented in **Figure 2.8** and it can be replicated for other types of waste for the creation of building materials. The flows of resources here are circular in nature and it represents a good case of 'Circular Input Model' as presented in **Table 2.2**.

Figure 2.8: Beverage Cartoon to Green Roof

Product as a Service: Vietnam's Dragon Bridge

Located in Da Nang, Vietnam, Dragon Bridge is a beautifully designed 610-meter long bridge in the shape of a dragon. This dragon bridge has become the landmark of the city, especially due to its elegant lighting. However, efficiently maintaining a 610-meter long bridge requires skills and manpower, a cumbersome job for the municipalities. This gap has created a lot of businesses in cities, as cities now are more concerned about the value of the product rather than the ownership of the product. Philip business model, "light as a service", was a right fit for the Da Nang municipality, as they found its management an astronomical task. Philip has installed 2500 intelligent LED lights to lighten the Dragon with different colors. Moreover, the lights have been designed to illuminate in different colors, which makes the dragon bridge more attractive for the tourists. It uses remote monitoring, smart asset management, smart dimming by scene setting and intelligent energy metering to light the bridge efficiently, which would not have been possible for the Da Nang officials as they do not have the required expertise in it. Moreover, since the product is owned by Philip, the company ensures efficient management of its products by taking them back at the appropriate time for recycling or for upgrading. Thus, this model involving lighting as a service, supports the company role in making the product more efficient, while the consumers benefit from lower initial investment, maintenance, and operational cost. Such models can help cities optimize the efficiency of resources while reducing the environmental costs.

Dragon Bridge, Da Nang, Vietnam

Adapted From & Picture Source: http://www.lighting.philips.com/main/cases/cases/bridges-monuments-facades/dragon-bridge.html

2.2.3 Minimization of the Vulnerabilities Associated with Virgin Material

Resource efficiency and 3R creates opportunities for cities to circulate resources within their boundary and reduce demand for raw resources. Thus, it can build resilience against the increased price or reduced supply. Moreover, it can also reduce emission related to extraction of raw materials.

2.2.4 Reduced Environmental Impact

Innovative ideas supported by technology can reduce the environmental impacts when compared to the conventional resource consumption and disposal trend. The technology like an electric train, solar panels etc., can reduce the energy consumption. Similarly, recycling of waste water can improve the quality of rivers. Low-carbon technologies can further reduce the GHG emission.

Transforming Landfill: South Africa

Landfilling is often associated with environmental impacts and is given the last preference in the waste management pyramid. However, Mariannhill Landfill in eThekwini Municipality in South Africa breaks this paradigm through technological transformation of the landfill. The landfill site has been turned into a conservation site of several indigenous plants and registered national bird site.

In order to support the growth of vegetation, landfill capping layer has been provided. The landfill itself is constructed to avoid seepage of toxic leachate into the ground through the usage of impermeable layers beneath the landfill. The collected leachate is then treated through low cost and robust system. The leachate undergoes primary biological treatment followed by treatment through reed bed. The treated effluent is then reused for irrigating the vegetations in the conservation area. The landfill is also protected from storm runoff and wetlands have been built for retention of storm water. These wetlands also supports the bird population.

Mariannhill Landfill, South Africa

One of the engineering highlights of this landfill is the collection of methane emitted from the landfill. Methane gas is a harmful GHG with 24 times more global warming potential than carbon dioxide. The collected methane gas is then converted to electricity. Since this project also reduces carbon emission, it has been funded through carbon finance. This plant offsets 20,000 tons of carbon dioxide each month and the trapped gas is enough to power 3,750 small houses.

Through the usage of 3R principles, Mariannhill landfill has indeed made the landfilling more resilient. The environmental impacts caused by the landfill have been reduced while it has also proved to be financially viable through the selling of carbon credits and tourism.

Adapted from: http://www.rand.org/blog/2014/12/in-south-africa-bold-investments-turn-trash-into-treasure.html
Picture Source: http://africanclimate.net/en/node/9600

3. Analysis of Various Kind of Resilience for cities

3.1 Innovations in Resilient cities

The infrastructure and forms of resilient cities can be classified into seven models[18]. Nevertheless, considering the importance from resource efficiency points of view, five city models can be discussed: Renewable energy city, carbon-neutral city, distributed city, biophilic city, and the Eco-efficient city. These city models have been discussed from the standpoint of 3R and Resource Efficiency. Although there are a lot of commonalities in the features of these seven cities, cities evolve around one or two of these models.

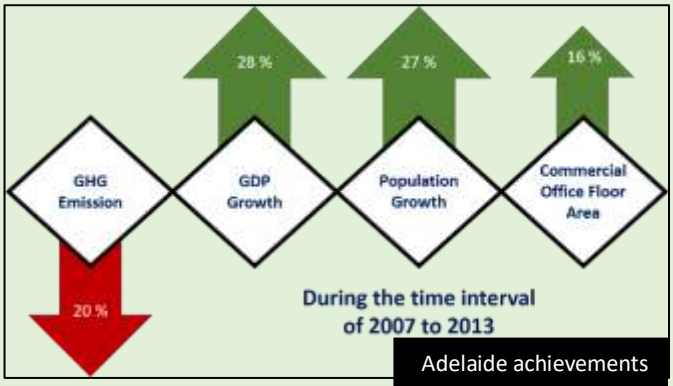
3.1.1 Renewable Energy City

This model of the city focuses on the usage of renewable energy. The use of renewable energy will not only prove to be financially attractive in the long run, it also reduces dependence on the raw materials like coal and oil. Co-benefits of the reduced usage of coals and oils can be further seen in the form of improved health of the people, reduced air emissions resulting in a clean atmosphere.

Decoupling Economy and Environment: Adelaide renewable energy strategy

The city of Adelaide claims to have decoupled carbon emission and economic growth and one of the reasons behind is that the city has succeeded in exploiting renewable energy. During the period of 2007 to 2013, the city reduced 20% of its carbon emission while increasing its gross regional product by 28%.

Adelaide is the main city of South Australia (state) and is home to one-third of the state population. The year 2007 was memorable for South Australia as it introduced its climate change strategy during this year. The contribution to GHG emission has plummeted since the formulation of this strategy. For most cities, a major portion of emissions is contributed by the energy usage of the stationary sources and transportation. It was reported in Adelaide that 60% and 35% of the total city emission were accounted by the stationary energy and transportation, respectively. This led to the need for making the infrastructure and transportation sustainable through the usage of renewable energy. No doubt, technology is the key to cut this emission, without compromising the quality. The city of Adelaide has now upgraded and electrified the railway networks, powered the buses with gas and bio-diesel, and introduced electric buses. Additionally, the city has also resorted to community bicycle sharing scheme for its population who are also equally concerned about the environment. Usage of electricity for transportation does not merely imply green technology but the way the electricity has been produced also plays a significant role. Currently, Southern Australia produces 41% of its electricity from renewable sources. Technology adopted to reduce the use of electricity is also equally important. Although 16% office floor area was observed for the time interval of 2007-2013, the emission of the buildings has declined by 23% as compared to the 2007



Adelaide achievements from 2007 to 2013

[18] Newman, P., Beatley, T., & Boyer, H. (2009). Resilient cities. *Responding to Peak Oil and Climate Change. Washington*.

level. Green building design and usage of energy efficient technologies have certainly played their part in this reduction.

Waste, unlike the other cities, contributes very little to the city's emission. Only 5% of the emission was contributed by waste in 2013. The landfill diversion rate is the highest in Australia (77 %) and the per capita resource recovery rate of SA was found to be 2,070 kg/person/year, which is highest in Australia.

Electric Train in Adelaide

Through the transformation of the city, Adelaide has and will achieve a higher drop of carbon in the future. Resilience has been developed from the perspective of resource need. Renewable energy helps to develop resilience against resource scarcity and price hike. In the meanwhile, it also helps the economy grow, building the economic resilience as well. Societies are provided with more jobs when the resources are either generated within the community or are circulated back in the system.

Adapted From & Picture Source: https://www.adelaidecitycouncil.com/assets/Policies-Papers/docs/STRATEGY-carbon-neutral-2015-25.pdf

3.1.2 Carbon Neutral City

One of the key issues of cities is their massive resource consumption and the resultant environmental impacts. Though cities cover less than 2% of the earth surface, they consume 78% of the world's energy and produce more than 60% of carbon dioxide[19]. They also emit other GHG in large quantities which makes them the hotspots for GHG mitigation and prevention. As the climate change impacts are globally felt and people become more aware of such changes in the cities, the idea of being carbon neutral is being felt in the cities. The city and its infrastructure (buildings, companies, etc.) now have started taking steps to emit less. Carbon-neutral strategy basically covers reducing energy usage, promoting the usage of renewable energy and purchasing carbon credit to offset the carbon emission.

ICLEI–Local Governments for Sustainability's 'Cities for Climate Change', 'Architecture 2030', The Clinton Foundation's 'C–40 Climate Change Initiative' and UN–Habitat's 'Cities for Climate Change Initiative' (CCCI) are some of the initiatives supporting low carbon emission. Moreover, there are rules and policies in place in some of the cities that require the new buildings to meet the standards that are carbon friendly.

Masdar City: Carbon Neutral and Renewable Cities

Masdar City in the United Arab Emirates is designed to be a carbon neutral (zero-carbon) and zero waste city. It will occupy an area of 6 square kilometers, and upon completion, the city can accommodate 45,000 to 50,000 residents and about 1,500 businesses. The economy of Masdar City will center around green technologies and cleaner technologies and will have additional 60,000 commuter.

As the city is themed around technology-led sustainability, the economy of the city is designed to flourish with clean-tech companies. The city also plans to provide a platform for the clean-tech

[19] http://unhabitat.org/urban-themes/climate-change/

researches. Masdar Institute of Science and Technology (MIST) is working to support research and development of innovations to lead the economy.

Highlights of the city

Energy: The city will mostly rely on the renewable energy sources like solar and wind power. Currently, a 10 MW solar plant is already operational which supplies energy to the Masdar Institute of Science and Technology and to the construction site. Additionally, after the completion of the city, the city will also get its power from the 20 MW wind farm and 130 MW rooftop solar plant. Moreover, by the usage of cleaner and advanced technology, it plans to reduce its energy consumption to only 25% of what the other conventional cities consume.

Masdar city and the solar roof

Food: To minimize the chilling and transportation cost, the city plans to produce its own crops and vegetables through soilless vertical farming where the harvests are grown under controlled environment. Aeroponic system is suitable for Middle-East where the arable land is limited. It works on the principle of recirculating nutrients and water for the growth of vegetables. It requires very less energy. This investment is meant to reduce dependency of the city for food and increasing the resilience against food insecurity.

Waste: As part of the initiative of zero-waste, the wastes like metal, paper, plastic, etc., will be recycled while the organic waste will be either composted or will be incinerated for additional energy.

Transportation: There will be an underground transportation network in the city and the conventional vehicles won't be permitted inside the city. The city plans to permit only electric cars and clean energy vehicles. The city will be connected to the main city Abu Dhabi through Light Rail and Metro lines. However, the streets will be over the surface and as they will only be built for pedestrians, the streets will be narrow allowing the wind to canyon through the buildings.

Water: Through the use of advanced technology, good practices, and efficient design the city plans to consume only 60% of what a conventional city consumes. The required water will be produced by the desalination plant powered by solar plants and 80% of the used water will be recycled and used for farming and gardening. Water will be provided by a solar-powered desalination plant and usage is planned to be reduced by 40% through water conservation appliances, facilities, and practices.

Though Abu Dhabi owns 9% and 5% of the world's proven oil and natural reserves, respectively, building economic resilience of the nation by reducing its dependency on fossils fuels can be viewed as resilient thinking. Investing in technology and innovations will not only improve the capacity of Abu Dhabi but will also increase the resilience in many ways.

Adapted From: http://www.museumofthecity.org/project/masdar-city-role-model-for-a-sustainable-future/
Picture Source: http://www.2daydubai.com/pages/masdar-city.php

3.1.3 Distributed City

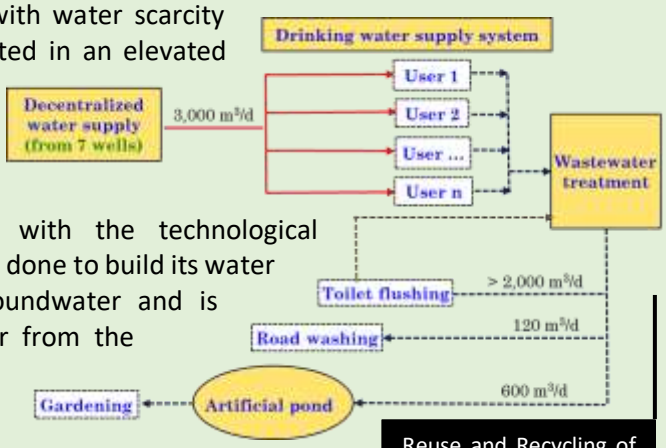
This innovative idea of developing resilience is based on decentralizing the power and water systems in the city. Decentralizing the power and water sources can reduce the ecological footprints of the utility services. Distributed water system approach is also extended to the reduced usage of water through collection and usage of rainwater, usage of local water sources like groundwater, recycling of gray water at the local level and recycling of black water at the regional level. The concept further extends to the usage of locally collected gray water in the parks and gardens and decentralizing the waste management.

Decentralizing the Waste of the City

Household Composting

Waste management in the city is a financially expensive process and requires a lot of manpower and resources. Moreover, the traditional dumping mechanism in the landfill has local, regional and global environmental and social implications. One of the solutions to this challenge could be the decentralizing of the organic waste composting within the households or community which minimizes the waste being dumped. Composting bins, as shown in the figure, were introduced in Kathmandu which is found suitable for urban households who invest in the rooftop farming. The organic fraction of the waste is composted and used for farming. Similarly, decentralized biogas system for communities could be one of the cleaner alternatives than landfilling.

Siyuan College in the Xi'an city in China is one of the examples for decentralized water supply and waste water treatment. The integrated water and wastewater management in Siyuan college have resorted to reusing and recycling the water to cope with water scarcity problem that it faced. As the college is situated in an elevated location and far from the city, supplying water from the central water supply system of the city was not financially viable. The college consists of 25,000 students living on the campus and hence an efficient planning with the technological transformation of the conventional system was done to build its water security. Thus, water is extracted from groundwater and is supplied to the consumers. The waste water from the consumers is then treated in the wastewater treatment plant and recycled for toilet flushing, road washing, and gardening.



Reuse and Recycling of Water at Siyuan College

Adapted from: https://bindubhandari.wordpress.com/2014/06/02/best-from-waste-rooftop-gardening/
http://www.scj.go.jp/en/sca/activities/conferences/conf_7_projects/pdf/7th_wang.pdf

The distribution of power through a central facility also has lower efficiency as there are transmission losses; moreover the peak-hour power demand management also becomes difficult. Further, the uncertainties and risks associated with the centralized facilities are higher as any disorder in the system can result in power-shedding in the entire city. One of the methods of decentralizing power is through the usage of renewable energy sources like wind turbine, biomass to energy conversion plants, solar PV cell, etc. The rooftop photovoltaic system is indeed one of the examples of distributed power system which is energy efficient and beneficial in the long run. It is also more resilient to disasters than

the centralized system where the fault in the main system can lead to power-shedding in the entire city.

3.1.4 Biophilic City

Biophilic cities are cities built with prime importance given to nature. They have rich biodiversity and are green. Such cities consist of both flora and fauna. The infrastructure built in these cities also prioritize the creation of green zones, green buildings with floral wetlands, etc. This concept also emphasizes the production of renewable energy through biofuels. Biofuels crops can be grown on the farms and open spaces in the cities which will also serve aesthetically for the city dwellers. The green belt in the cities also helps to fight against drought, urban heat-island problems, flooding etc. Moreover, they reduce the temperature of the cities.

City of Vaxjo: Biophilic City

Biofuel Station at City of Vaxjo

The city of Vaxjo in Sweden is an example of a biophilic city where the biofuels have been utilized in the heating and transportation sector. The city initially relied on the use of fossil fuels but the vulnerability of the usage of raw materials was realized early in 1996. As the city is surrounded by forest, timber industry flourishes in the Vaxjo and the wastes from timber (wood chips and sawdust) industries are utilized for the district heating whereas other biofuels like ethanol, biogas, etc., are used for the transportation sector. In addition, the city has promoted the use of bicycles for transportation. Additionally, other renewable energy sources like photovoltaic cells etc., are also used in the infrastructures. All these initiatives have reduced carbon dioxide emission by 32% per capita between 1993 and 2007.

Adapted From: http://www.energy-cities.eu/IMG/pdf/Fossil_Fuel_Free_Vaxjo_-_the_story.pdf
Picture Source: https://www.buildinggreen.com/news-article/v%C3%A4xj%C3%B6-sweden-model-sustainability

3.1.5 Eco–Efficient City

Eco-efficiency refers to a concept where more services and well-being is produced by use of fewer resources and energy[20]. The term 'eco' in the 'eco-efficiency' refers to both the economy and ecology for increased profit and lower ecological footprint. The principle of circular economy, which refers to moving the resources in a closed loop system, has created a wider opportunity for waste recycling and reusing and has created new opportunities for the cities to reduce their ecological footprints. Cities, through this strategy, can utilize waste as a resource through innovative technology. It can also minimize the need for resources through service based industries which are established with the idea of providing the consumers with the value of a product and not necessarily its ownership.

Eco-efficient cities thus work to increase capital productivity, labor productivity, energy efficiency, and resource efficiency. Industrial development plays a huge role in this city model as industries are the ones who use a significant amount of energy and resources. Similarly, segregated waste from the municipality can be recovered for further use. Thus, an integrated resource flow strategy, formulated and managed by municipality or city administration is essential for this model of the city.

[20] http://worldcongress2006.iclei.org/uploads/media/E1_MISHRA_Eco-efficient_Cities_-quality_of_life.pdf

Hannover's Merger: Eco-efficient City

The e**co**-efficient city stands for both **eco**logically and **eco**nomically sustainable city. However, the institutionalization of economics and environment can be difficult as they have many contradictions to growth. Hannover city in Germany, however, took a strategic decision by merging the 'Directorate of Environment' and 'Directorate of Economics' By forming the 'Directorate of Economic and Environmental Affairs' in 2005. It had the responsibility of sustaining the city and increasing the urban green space. Some of the efforts taken by Hannover in developing eco-city are as follow:

1. It buys plots in the city, plans and sells them to industries and housing who can maintain a higher ecological standard.
2. Undertakes water, waste, and energy audit of the companies to profit from reducing the consumption of these commodities.

Hannover Greenbelt

3. The city purchases only those products that can prove to be environmentally friendly. Eco-labels are given prime importance in the selection of goods like office supplies, food, construction materials, etc.
4. Public owned buildings are retrofitted for reducing energy consumption. Further, the large roofs of the building are also rented for the production of renewable solar energy.
5. The financial institution is being strengthened to promote and finance sustainable projects.
6. 'Climate Alliance 2020' was initiated by Hannover where the stakeholders like industries, housing sector, and other focal groups committed to reducing their individual emission by 40% by 2020 as compared to 1990 level. Interestingly, the energy consumption level in the city has decreased by 10% from 1900 to 2010 despite its increasing industries and houses.
7. Subsidies are provided to houses which insulated their houses further than the bylaws.

More than 10,000 jobs were created in Hannover between 2006 and 2011 due to these strategies while it was also proclaimed as 'German Capital of Biodiversity' in 2011 where more than 120 cities from Germany participated. The progress of Hannover as an eco-efficient city has certainly added value to its economy and environment.

Adapted From: http://www.hannover.de/en/Government-Service/State-Capital-Hannover/Directorate-of-Economic-and-Environmental-Affairs
Picture Source: https://a2ua.com/hannover/img-003.php?pic=/hannover/hannover-003.jpg

4. The Way Forward

Developing resilience in cities against the resource scarcity, resource price rise, climate-induced disaster, and natural calamities is 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 has already proved to consume less without compromising the quality of the resources. 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 (E.g.: Philips light as a service model).

Reusing of products can also reduce the need for extracted raw materials. 3R, no doubt, can play a greater role in it. Reusing of the product also requires the absorption of the technologies and 3R service models into the policies of the cities. 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 incentive to initiate new supply chains and businesses related to recycling. Perhaps, a resource map that can point the available waste in the cities could be one of the initiative cities can take to make the availability of the waste more transparent.

Resilient cities model as discussed in Chapter 3, also is rooted to the implication of the principles of 3R. Usage of renewable energy in the housings, establishing sustainable transportation, decentralizing the utility services, increasing green belts, etc. were the highlights of the sustainable city models and 3R can act as important tools to ensure it. It can generalize the priorities the cities needs to move toward a resource efficient and sustainable city.

Hurdles to the Cities in the Path of Resilience

However, one of the hurdle to cities is the institutionalization of these approaches in the plan and policies of the cities. Cities need to develop policies, plans, and strategies to firstly increase its capacity and transform it structures to facilitate the implementation or enforcement of 3R and resource efficiency. Strong leadership is often required to guide such transformation which sometimes needs a paradigm shift from the conventional approach. Cities must also look for institutional structure, where long-term leadership is needed. Cities with the ability to take a long-term decision and investment are needed to develop the resilience.

Cities also need to have the capacity to comprehend the technologies that have already applied in resilient cities. Acquiring such technologies for emerging cities could be one of the possible ways to replicate resilience. However, technologies require high capital investment. Thus, as a long-term vision, cities must also look to innovate technologies. The role of the research institutes is also immense, as they can innovate.

Some of the challenges or hurdles in the implementation of 3R and Resource efficiency and the questions that need to be addressed by the 3R Forum in Asia and Pacific are as follow:

1. Behavioral Changes and Policy Developments

The sustainable consumption aspects of SDG goal 12, can be linked mainly to the human behavioral changes and policies. The successful urban sustainable consumption practices in the region can be induced by good policy mechanisms and enforcement. The issues which could be considered for discussion are:

i. How to induce human behavioral changes in the urban context?
ii. Development and implementation of policies to promote sustainable consumption through behavioral change.
iii. What role can government play in guiding the behavior of the consumers?

2. Institutionalization

Innovation and technologies are hard to be absorbed and implemented in cities due to conventional practice (Take-make-dispose) and limitation in the human resources. Hence, the institutionalization of the technology and practice that can augment resilience in cities is challenging. It is also seen that transformation of cities needs long term vision and targets. 3R and resource efficiency principles can guide the transformation in the cities. However, leaders are constrained by their short tenures. Therefore, leadership in institutionalization process is also an important issue. The key questions to be addressed by the 3R forum are:

i. How can the technologies be efficiently integrated into the policies?
ii. Who should provide the required leadership role?
iii. Transforming cities often requires high capital investment and has a long payback period. Thus, cities are often limited to developing short recovery period and adaptation measures that often have no payback. It is important for cities to transform and how can this issue be addressed?
iv. How to build the capacity and mobilize the human resources in all the sectors who can contribute to the sustainability of each sector?

3. Replication of Technology

Some of the technologies that can build resilience and are concentrated around the idea of 3R are highly replicable (E.g. Composting, Rainwater harvesting, electric transportation, etc.) and some cities have already excelled in this area. However, acquiring technology requires high capital investment and for innovating one requires time. Asia Pacific particularly has cities that are highly advanced and also cities that are just emerging and managing to attain a stable economy. Replication of technologies could be one of the options for these emerging cities. However, they have constraints like limited human resources, lower capacity of financial institutions and lack of technologies. Key issues to be discussed in the 3R forum are:

i. Can developed cities help emerging cities to replicate technology and practices?
ii. How can the replication be facilitated by the developed cities?

iii. How can emerging cities finance such technology lead transformation?
iv. How can Technology Facilitation Mechanism (TFM), an initiative to widen science, technology, and innovation to advance progress toward the SDGs, facilitate government and industries?

4. Mapping of Resources and Integration of Resource Efficiency

In order to increase the resource reuse and recycling, the information on the waste produced is needed. For this purpose, there must be a proper flow of information regarding the availability of resources and waste. These data can further help cities to set future targets. Key issues regarding resource mapping to be addressed are:

i. Is it possible to geographically map the waste produced so that new businesses can emerge?
ii. Will the transparency of the waste produced be capitalized through the development of networked material flow within industries?

In addition to this resource mapping, the urban sector needs to develop the integrated resources efficiency policies and strategies. Some of the key discussion points could be:

i. How to move from the conventional silo approach of resources (energy, transport, water, waste, industry, etc.) to holistic urban resources management?
ii. Innovative financing mechanisms for the development of resource efficient infrastructures such as eco-towns or green cities.

5. Supporting the Role of Private Sectors

The private sectors' willingness to pay must be high. Planning push and pull factors that widen the 3R practice through the active participation of private sectors, is challenging. The policies to support the role of private sector in building resilience in cities is needed. The key issues here to be addressed are:

i. How can private sector be motivated by the city administration to adopt practices that can increase the resilience?
ii. What kind of incentives is needed?
iii. How can private sector be financially supported?

Role of the 3R Forum in Asia and Pacific in developing resilient cities under the principles of resource efficiency and 3R

The Asia and Pacific region also need to keep a track on the progress of the Hanoi and Surabaya Declaration on integrating "3R Concept" in relevant policies and programs for transitioning to a resource efficient city. Successful implementation of Hanoi and Surabaya Declaration can also help to achieve the SDG targets in the Asia and Pacific region. As the cities in the Asia and Pacific are emerging and there lies a greater opportunity for cities to plan for long-term resilience with 3R principles, a push factor is needed to plan for more resilient plans and policies.

Adelaide 3R Declaration also put forth a declaration that can help to build resilience in the cities. It emphasizes on the several aspects like reducing import dependency, pursuing sustainable business, exploring the circular businesses, building or renovating resource efficient green buildings, adopting sustainable transportation, reusing waste water, benefiting from waste by exploring ways to generate revenue from it, etc through the usage of 3R principles. Additionally, it also elaborates the role of 3R

practice in the reduction of GHG emission from cities. 3R and resource efficiency can thus serve as a mean for the Intended Nationally Determined Contribution (INDCs). It also highlights the need for integration of 3R practices into the macroeconomics as well.

Adelaide Declaration thus looks forward to the commitments from its member nations to realize the potential of circular economy, explore 3R into their policies and programs, ensure extended producer responsibility, plan for environment friendly and low emission technological integration where ever possible, discourage the end-of-pipe waste disposal, support policy supported by science and technology, support the research and development related to 3R, and develop institutional capacity to absorb the concept of green governance. If implemented or initiated by the member nations, these changes will surely help the cities to grow sustainably. Resilience planning often needs to consider long-term payback, which is often unattractive for a government which needs immediate benefits.

Cities surely will need technology to leapfrog from the conventional city models to resilient cities. Technology related to resource optimization, reuse of materials, remanufacturing technology, sustainable transportation technology, etc. will be essential for the nations to develop resilience. Adelaide Declaration also emphasizes the role of Technology Facilitation Mechanism (TFM) (led by UN system) for cities as a source of information for cities.

Adelaide Declaration will surely help the assurance of SDG 11, 12 and 8 if properly executed by the member nations as it put forward the importance of 3R and resource efficiency.