TECH FRONTIERS

Circular economy for productivity and sustainability

The overuse of resources the world over has led to an alarming state of the environment. Harnessing technology to promote the principles of circular economy of reduce, recycle, and reuse will go a long way in sustainable development of the world

NATIONAL PRODUCTIVITY COUNCIL

BY and large, today's manufacturing takes raw materials from the environment and turns them into new products, which are then disposed into the environment after use. It is a linear process with a beginning and an end. In this system, limited raw materials eventually run out. Waste accumulates, either incurring expenses related to disposal or else polluting – indeed. In a circular economy, however, products are designed for durability, reuse and recyclability, and materials for new products come from old products. As much as possible, everything is reused, remanufactured, recycled back into a raw material, used as a source of energy, or as a last resort, disposed of.

India has the opportunity to save money, make money and do good by adopting the principles of the circular economy. It has the opportunity to leapfrog other economies and establish a leadership position. Traditionally, the Indian economy has been one where reusing, re-purposing, and recycling have been second nature. In a world that is increasingly running out of natural resources, this thinking is an asset that must be leveraged by businesses, policymakers, and citizens in an organised manner and expanded to include other elements to make the economy truly circular.

Several building blocks of circularity are deeply ingrained in Indian habits, as exemplified by the high rates of utilisation and repair of vehicles and the distributed recovery and recycling of materials post-use. Often handled informally, these activities provide the only source of livelihoods to some of the poorest populations. By turning these existing trends into core development strategies, India could generate significant economic savings, while massively cutting down on carbon emissions.

Restorative and regenerative by design, a circular economy aims to keep products, components, and materials at their highest utility and value at all times. A circular economy is a continuous cycle that preserves and enhances natural capital, optimises resource yields, and minimises system risks by managing finite stocks and renewable flows. The concept of circular economy, a metaphor that neatly resonates with Mahatma Gandhi's ardent lifelong quest for efficiency in production, sufficiency in consumption, and what he could well have called 'conservancy' of resources and 'deficiency' in wastes, captures well the desirable characteristics of the future we will all have to live in – and how to get there.

The world's growing and the increasingly affluent population has caused an overuse of resources, higher price levels and increasing market volatility. An ambitious long-term vision of a circular economy, built on the current strengths of the Indian market and engaging business, policy, and education in its realisation, could, on the contrary, provide the basis for a regenerative development path towards long-term prosperity.

A circular economy reduces resource dependency and resource use, including energy, thereby reining in production costs, narrowing market exposure, and limiting costs stemming from resource extraction and generation. It additionally leads to the introduction of economically viable methods of reducing pollution, and separating harmful from reusable waste material.

THE PRINCIPLES OF CIRCULAR ECONOMY

Principle 1: Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows.

A circular economy enhances natural capital by encouraging flows of nutrients within the system and creating the conditions for regeneration of soil and other living systems. Whenever possible, utility is provided virtually or as a service rather than as a physical product. When resources are needed, the circular system favours technologies and processes that use renewable or better performing resources. The circular economy seeks to address several challenges to natural capital:

1. Threatened stock and variable quality of fresh water.
2. Soil degradation.
3. Loss of biodiversity
4. Depletion of fish stocks and degradation of marine ecosystems.

Principle 2: Optimise resource yields by circulating products, components, and materials at their highest utility at all times, in both technical and biological cycles.

This entails designing for refurbishing, remanufacturing, and recycling to keep products, components, and materials circulating and contributing to the economy.

As in a linear system, increasing yields is useful and requires ongoing system improvements. But unlike a linear system, a circular system would not compromise effectiveness – which requires a fine balance between efficiency and long-term resilience. The circular economy seeks to address several resource challenges.

1. Materials consumption: If India maintains the economic development pace of the past few decades, it stands to more than triple its demand for resources by 2030. This process could be effectively contained by adopting the circular economy principles.

2. Nutrient loss: The deterioration of soil due to loss of nutrients is a significant trend in India and this could be reduced for effective gains.

Principle 3: Foster system effectiveness by revealing and designing out negative externalities.

The negative externalities of economic activity include land degradation; air, water, and noise pollution; release of toxic substances; and GHG emissions. A circular economy would reveal the cost of these externalities – in other words, outline their risks and potential economic impact.

TOWARDS CIRCULAR ECONOMY BY 3R PRINCIPLE

CIRCULAR consumption is an indispensible part of a circular economic system for sustaining economic growth and mitigating environmental degradation and resource depletion. The challenge to put circular consumption into practice can be addressed by the 3R Principle that is based on Reduce, Recycle, and Reuse. The principle reflects on the scope for converting wastes into valuable products and making the Mission Zero Waste a reality. This

Mission emphasises 100 percent scientific waste management in 400 targeted cities of the country.

Solid waste management

In respect of the Indian solid waste management scenario, it is indicative that MSW generation is estimated to be 1.43 lakh tonnes per day. Of this MSW processed/treated is about 35,602 tonnes per day (24.8 percent). Further, the number of wards with 100 percent D2D (door-to-door) collection being achieved has been in 61,846 (73 percent of wards) and that the number of wards with 100 percent source segregation are 30,749 (36 percent of wards).

The Government of India Policy Interventions to encourage conversion of Waste to Wealth and various Ministries and Departments are engaged in the implementation process. In this regard 35 percent funding is being provided as viability gap funding/grant by the Government of India for all solid waste management projects such as:

a. Waste to Compost
b. Waste to Energy
c. Plastics in Road Construction
d. Construction and Demolition Waste Management

In addition are the development and notification of six Waste Management Rules, 2016 and capacity-building initiatives in cities for various stakeholders. These rules are concerning Solid Waste Management, Plastic Waste Management, Construction and Demolition Waste, Hazardous Wastes, Bio-Medical Wastes, and Electronic Wastes Management.
Further, is the initiative in India on Swachh Survekshan (i.e. Cleanliness Survey) for cities, and development of the star rating system to achieve garbage-free cities.

Many countries have started practising circular economy and lessons can be learnt on futuristic approaches, like clustering ULBs of South Australia for effective integrated solid waste management, where larger ULBs could lead the action, is worth emulating.

In Ambikapur, administrative reforms like habitation clusters, contract management, partnerships, open technology sourcing, renewable obligations, and awareness campaigns, etc. can result in novel and customised solutions to the waste problems towards a closed loop waste cycle.

Perspectives on industry initiatives on 3R also are reflected upon and highlighted in **Figure1**.

Table1: Typical composition of municipal solid waste in India

Type	Total (metric tonnes)	%
Biodegradable	62,510	47
Paper	10,640	8
Rubber	11,970	9
Metal	1,330	1
Glass	1,330	1
Rags	6,650	5
Others	5,320	4
Inert	33,250	25

In essence, it is to be highlighted that the behavioural change in society are pivotal to be achieved by various interventions including infrastructural, financial, and technological initiatives which could help progress towards a zero-waste society within the framework of the circular economy.

Reducing water pollution

The significance of water security is linked to various sustainable develop-

Figure1: A pictorial feature of industry initiatives to promote 3R

DRIP/c

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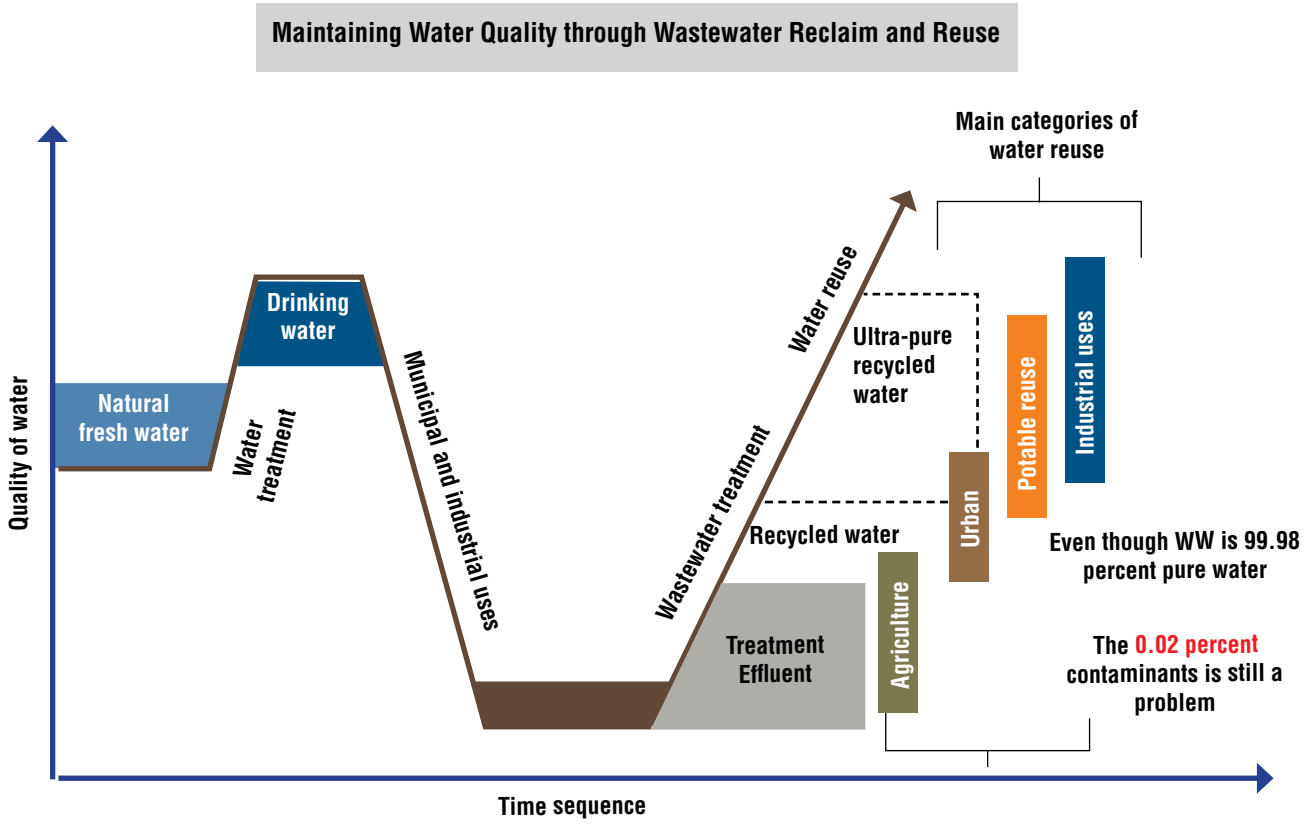
Figure2: Waste water treatment and reclamation perspective



C Visvanathan/Asian Institute of Technology, Thailand — Water quality and security in Asia Pacific: What 3R and Circular Economy can Offer?

ment goals. Water is critical for socio-economic development, healthy ecosystems, and for human survival itself. The pressure on global water resources (both surface and ground water) is increasing due to growing gap between water supply and demand, anthropogenic water pollution, and climate change impacts. Urban centres in the Asia Pacific regions are highly vulnerable to water security issues and urban resilience is a concern internationally. The concern regarding water sharing disputes (domestic and international) is also an issue to be tackled. On the domestic water consumption side, focus should be on development of innovative water saving appliances. Rainwater harvesting will be the cornerstone of the urban circular water economy development.

Advancing 3Rs and circular economy encourage the use of treated water and sustainable use of water resources to achieve a number of benefits such as safe drinking water and effective sanitation system, among others. As regards wastewater reuse applications the key is innovations in wastewater treatment and recycling technologies. A perspective on this is outlined in **Figure2**.

To achieve the circular water economy option, there is a need to revisit the conventional centralised water and wastewater treatment to decentralised system which promotes better water reuse applications.

There are other innovative solutions like Phyco-remediation that refers to the use of algae for treating wastewater. Algae are green, microscopic plants that survived extremely harsh, prehistoric environmental conditions and helped produce oxygen on earth and bring down the earth's temperatures. Nature also uses algae to treat rivers and lakes. Since millennia, our civilisations have spawned near rivers, but pollution had never been a problem because of the remediation work carried out by algae. However, because of the surge in population growth, construction of dams and

barrages, and especially because of the addition of industrial effluents, the pollution loads in rivers have shot up significantly. The experimental outcomes were encouraging when micro-algae-based water treatment technology was used on a 10-km stretch of river Mausam at Malegaon and 0.4 acres Lakshmi Tal at Jhansi on sample basis.

Preventing land pollution

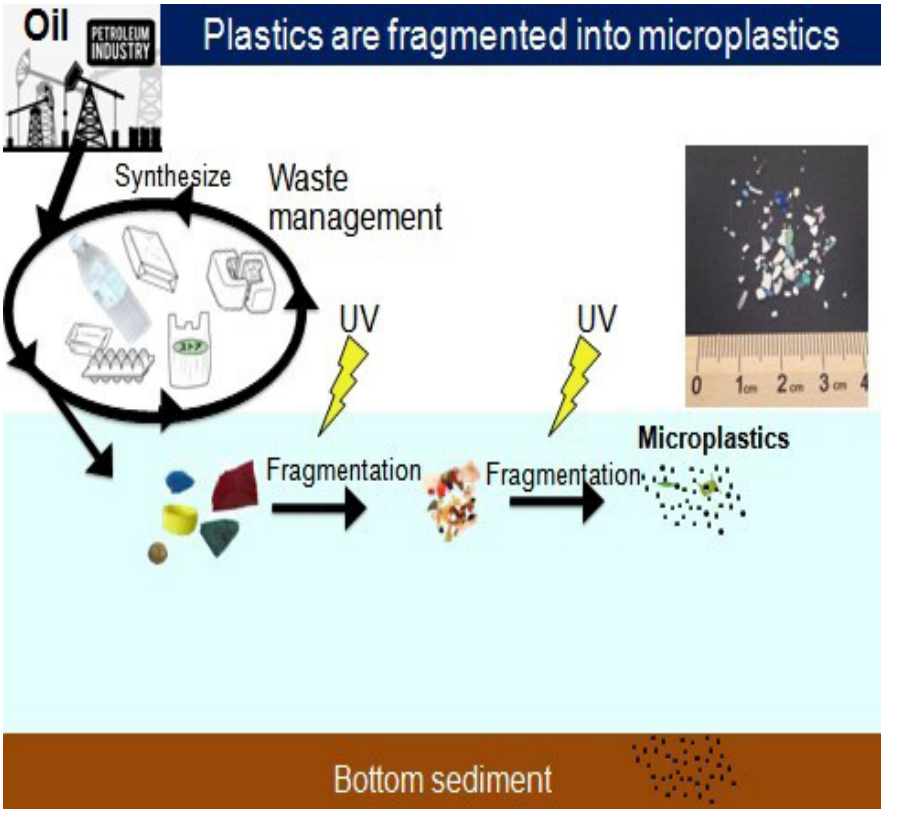
The problem of land degradation is due to open dumping, open burning, spillages of oil and other contaminants etc, and other causes such as deforestation, overgrazing, agricultural activities, industrialisation, overexploitation for fuel wood, etc.

Land pollution has a number of adverse effects on the physical, chemical, and biological properties of the land that reduces its productivity. Further, the land becomes the breeding ground for disease-causing insects and vectors. Open burning and illegal dumping also allow the percolation of harmful substances in the food chain.

It has also been seen from the records that more than 35 percent of the 50 biggest landfill sites are located in the Asia and the Pacific.

There is huge potential for implementing 3R and circular economic development strategies to prevent physical and chemical degradation of land as well as effective utilisation of organic waste and biomass for sustainable farming and energy. Remediation of already polluted land, rehabilitation of deserted lands, landfill mining, utilisation of organic waste and biomass for sustainable farming, continuous mass campaign to prevent open burning, waste recovery through composting, and enforcing appropriate legislation encouraging earning from the waste recovered materials, are some of the solutions. It is required to have a national target for respective states, national and state level strategies and policy development, robust supply chain, and technological support to prevent the land degradation for realising circular economy.

Figure3: Plastics in oceans and water bodies – impacts and pathway to food chain



Prevention of air pollution

Air pollution is an intensifying environmental challenge in Asia and the Pacific, where uncontrolled, unmonitored and unregulated biomass burning and open burning from open dump sites is still inevitable. Air pollutants like particulate matter, black carbon, methane, etc are released to the atmosphere, essentially interrelated to short-lived climate pollutants (SLCP) or greenhouse gas emissions with significant impacts on human health, agriculture, forests, and habitats. Air pollution affects environmental health, social, and economic aspects. Exposure to air pollution outdoors and indoors costs $5.11 trillion per year and has consequential health impact in terms of non-communicable diseases, i.e. stroke, heart disease, respiratory disease, and lung cancer.

In terms of trans-state air pollution from biomass burning creating haze requires green agriculture system for utilisation of biomass residue. Sustainable management of air emissions and air quality management strategies are key to achieve circular economy.

Protection of coastal and marine ecosystem

The impact on coastal and marine ecosystems due to poor waste disposal practices, in particular plastics waste, is a major concern. Scientific studies say more than 5 trillions of plastics are

floating in the ocean, whereas much more are deposited and accumulated in bottom sediments. They bring toxic chemicals to organisms such as fish and shellfish, causing concern about food security. Disposal of micro-plastics to the ocean has major impacts on the marine ecosystem as these materials are ingested by marine organisms causing severe food security issues.

There is a need to consider a wide spectrum of 3R options as part of circular economy to reduce the generation of plastic wastes. Among them, reduction of production of unnecessary single-use plastics could be helpful, considering long-term environmental impacts.

Indian stakeholders can learn from global initiatives such as Clean Seas Campaign and North West Plastic Action Plan (NOWPAP) for solving the issue. In this context strengthening the policies related to marine pollution, capacity building of local and national bodies, development of marine research and development activities, and raising awareness can be critical.

Greening of small manufacturing enterprises (SMEs)

Greening of SMEs is important to achieve decoupling economic progress vis-à-vis resource consumption, leading to circular economy. It is indicated that SMEs are the major contributors worldwide to industrial activity as part of supply chains and that significant pollution is also generated by SMEs. A perspective on resource efficient cleaner production (RECP) initiative and the challenges faced in effecting behavioural change in SMEs and obtaining responsiveness towards modernisation needs to be reflected upon, with recognition that technology costs can be a deterrent, and that governmental initiatives and support can enable and assist SMEs towards green industrial development.

In order to green SMEs, a concept of GLEAN (Green Lean) which is a combination of Material Flow Cost Accounting (MFCA) and LEAN management, developed by NPC could be put into practice. The application of MFCA in production has been demonstrated in SMEs and the implication of adopting MFCA with LEAN is that it clearly leads to higher process efficiency and reduction/elimination of waste. The fundamental strategy behind implementing MFCA with LEAN is the evaluation of the operations and activities in terms of efficiencies. Since MFCA is a management accounting method, it does not automatically resolve this loss. In fact, it is necessary to clarify the cause of the loss occurring in each process and change the design, materials/parts, manufacturing method, processing, equipment, etc, and to eliminate the cause, for which PDCA (Plan, Do, Check, and Act) approach of LEAN principles when clubbed with MFCA fits well in the framework and delivers sustainable outcomes to help SMEs to achieve resource efficiency.

THERE IS A NEED TO CONSIDER A WIDE SPECTRUM OF 3R OPTIONS AS PART OF CIRCULAR ECONOMY TO REDUCE THE GENERATION OF PLASTIC WASTES. AMONG THEM, REDUCTION OF PRODUCTION OF UNNECESSARY SINGLE-USE PLASTICS COULD BE HELPFUL, CONSIDERING LONG-TERM ENVIRONMENTAL IMPACTS

CAPTURING THE BENEFITS OF CIRCULAR ECONOMY

THE circular economy is a new way of creating value, and ultimately prosperity. It works by extending product lifespan through improved design and servicing, and relocating waste from the end of the supply chain to the beginning – in effect, using resources more efficiently by using them over and over and only once.

Indian businesses are well placed to lead the way in the transition. Businesses stand to realise substantial profit from the circular economy opportunities. Five recommendations could guide companies seeking to capture this value.

- Build circular economy knowledge and capacity.
- Innovate to create new products and business models and demonstrate their success.
- Integrate circular economy principles into strategy and processes.
- Collaborate with other businesses, policymakers, and the informal economy.
- Invest in circular economy opportunities.

Profit opportunities for businesses through increasing innovation and demand for new business services: By applying circular economy principles, businesses could generate new ideas and explore new ways of working, especially in digital technology. Indian innovation hubs could

help businesses implement new approaches and capture new profit opportunities.

Material cost savings and reduced exposure to resource price volatility: A circular economy would significantly lower costs for businesses related to the use of virgin materials. Less material use would also reduce their exposure to volatile raw materials prices and strengthen resilience.

Economic growth: As mentioned earlier, circular economy practices are making more productive use of material inputs (including looping of products, components, and materials) and increasing revenue from emerging circular activities. While some sectors (e.g. the material extraction industry) would expect reduced activities, overall more activity would happen across the economy, boosting economic growth.

Benefits for citizens

1. Lower cost for products and services. In the circular economy scenario, cash-out cost in the three focus areas would be Rs14 lakh crore ($218 billion, 11 percent of India's GDP) lower in 2030 and Rs40 lakh crore ($624 billion, 30 percent of India's GDP) lower in 2050, compared with the current scenario.

2. Greater utility and choice. The additional choice or quality that circular models provide would enhance the utility, or benefit experienced by customers. Choice increases as producers provide systems that enable tailoring products or services to better meet customer needs. For example, applying circular economy principles in mobility would give customers more vehicle options, without increasing the number of vehicles on the road.

3. Reduced negative externalities, e.g. congestion, pollution. The analysis suggested beneficial impact from applying circular economy approaches to address issues like congestion, pollution, and ill-health.

CIRCULAR ECONOMY'S OPPORTUNITIES IN INDIA

1. Cities and construction

As India invests in long-term infrastructure to improve citizens' quality of life, for example, through the Smart Cities Mission, it could incorporate circular economy principles into the design of the infrastructure needed to provide water, sanitation, and waste services at scale, creating effective urban nutrient and material cycles. More systemic planning of city spaces, integrated with circular mobility solutions, can contribute to higher air quality, lower congestion, and reduced urban sprawl. Flexible use of buildings and urban spaces, enabled by digital applications, can increase utilisations rates, getting more value out of the same assets. Higher efficiency and lower overall building and infrastructure costs could also help meet the housing needs of the urban poor without compromising safety and quality.

Circular economy principles can contribute to this construction activity in ways that create economic value and decouple development from the use of virgin, non-renewable resources. Renewable and recycled materials and modular construction methods can minimise waste and reduce construction costs. Buildings can be designed to be adaptable to changing needs and contribute to the regenerative urban ecosystem during their use phase (energy generation, connection to nutrient cycling systems, etc.).

2. Food and agriculture

India can adopt a regenerative, restorative agricultural system that combines modern technology with traditional practices to meet India's growing food demand. There is an urgent need for an agricultural system framework which retains natural capital, boosts economic and ecological resilience, and delivers a stable supply of fresh, healthy, and diverse food to India's growing population besides closing the gap in nutrient loops. Leveraging the current small-farm structure, India could create large-scale networks of farmers, interconnected and symbiotic in their practices and committed to regenerative approaches. Combining local knowledge and traditional methods (like working with a large variety of species) with modern technology (like precision farming and digitally-enabled asset and knowledge-sharing systems) could increase yield while significantly decreasing requirements for resources such as water, synthetic fertilisers and pesticides.

Reducing food waste across the supply chain could make the Indian food system even more effective. This would require optimising production and digitising food supply chains to match supply and demand more easily. Urban and peri-urban farming can bring food production closer to consumption, reducing food waste and transportation requirements. Composting and an aerobically digesting food waste with no other valuable use and post-consumption nutrients (those contained in human excreta) allows restoration of nutrients to the soil and production of energy.

3. Mobility and vehicle manufacturing

Circular economy principles can contribute to a mobility system that would meet the growing needs of the Indian population, especially in cities, while limiting negative externalities, such as

GHG emissions, congestion, and pollution.

Taking reparability, remanufacturing, and recycling into account in vehicle design and creating the appropriate reverse cycle infrastructure can reduce the need for virgin, non-renewable resources and energy. Building vehicles that rely on zero-emission propulsion technology could reduce negative externalities like GHG emissions, pollution, and dependence on imported fossil fuels. As car ownership is currently low, adoption could be rapid as ownership expands.

A multimodal, door-to-door, on-demand mobility system, embracing vehicle-sharing trends and leveraging digital innovation, could provide efficient and effective transportation with high vehicle usage and occupancy rates. Mass transit as the backbone combined with other forms of transport – including vehicle as a service – for convenient last-mile connectivity can create convenient door-to-door journeys. Technological innovation can help plan these journeys and make travelling safer and faster.

POLICY INITIATIVES

The Government of India has done substantial work towards policy interventions and formulation such as

1. Notification of National Ambient Air Quality Standards
2. Formulation of environmental regulations/statutes
3. Setting up of monitoring network for assessment of ambient air quality
4. Introduction of cleaner/alternate fuels like gaseous fuel (CNG, LPG, etc), ethanol blend etc
5. Promotion of cleaner production processes
6. Launching of National Air Quality index by the Prime Minister in April 2015
7. Implementation of Bharat Stage IV (BS-IV) norms in 63 selected cities and universalisation of BS-IV by 2017
8. Decision taken to leapfrog directly from BS-IV to BS-VI fuel standards by 1 April 2020
9. Taxing polluting vehicles and incentivising hybrid and electric vehicles
10. Comprehensive amendments to various Waste Management Rules including Municipal Solid Waste, Plastic Waste, Hazardous Waste, Bio-medical Waste and Electronic Waste notified
11. Notification of Construction and Demolition Waste Management Rules;12. Ban on burning of leaves, biomass, municipal solid waste
13. Promotion of public transport network of metro, buses, e-rickshaws and promotion of car pooling, Pollution Under Control, lane discipline, vehicle maintenance
14. Revision of existing environmental standards and formulation of new standards for prevention and control of pollution from industries
15. Regular coordination meetings at official and ministerial level with Delhi and other State Governments within the NCR
16. Issuance of directions under Section 5 of Environment (Protection) Act, 1986 and under Section 18(1)(b) of Water (Prevention and Control of Pollution) Act, 1974 and Air (Prevention and Control of Pollution) Act, 1981
17. Installation of online continuous (24x7) monitoring devices by major industries
18. Preparation of action plan for sewage management and restoration of water quality in aquatic resources by State Governments
19. Implementation of National River Conservation Plan for abatement of pollution in identified stretches of various rivers and undertaking conservation activities which inter-alia include interception and diversion of raw sewage, construction of sewerage systems, setting up of sewage treatment plants, low-cost sanitation facilities, education and awareness creation, community participation, electric/improved wood crematoria, and riverfront development
20. India's National Manufacturing Policy focuses on promotion and adoption of Green technologies and Green manufacturing especially with its MSMEs
21. Government of India has embarked upon an initiative of creating 100 smart cities across the country and waste management and resource conservation are significant part of this important initiative
22. Government of India is in process of finalising national goals under UN's sustainable development goals
23. Government of India has promoted the concept of Zero Effect Zero Defect Effect in order to achieve Green economic growth
24. Government of India has emphasised focused on Development of MSMEs and making them competitive and sustainable in order to achieve increased economic growth in manufacturing sector.

The following actions are required to lead the way to the transition to circular economy:

1. Set direction and show commitment.
2. Create enabling regulatory frameworks and remove policy barriers.
3. Represent the interests of groups like the informal sector, or facilitate collaborative initiatives among businesses, the public sector, and other stakeholders
4. Support circular models through public procurement and infrastructure.
5. Embed circular economy principles into education.
6. Conduct research and pilot projects to create a knowledge base and establish proof points.