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Eight Years to Go to Meet the SDG Targets: How Can Waste Management Enable and be Enabled?

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Abstract

Waste management has evolved from the earlier five step hierarchy to include many more R's: Reclaim, Repurpose, Remediate, Renovate, Replenish, Revere nature, being a few of them. Waste management can play a key role in the alleviation of, and the simultaneous adaptation to the repercussions of climate change. Waste valorisation, which is gradually entrenching itself, in both principle and practice, can go a long way in directly and indirectly enabling humankind to get closer to several SDG targets, and perhaps also overachieve in some respects. Value creation by adopting the R's wherever, however, whenever and by whosoever possible, is a sine qua non for achieving the SDGs by year 2030, and continuing in the same vein thereafter, when the world will have to grapple more perceptibly with the repercussions of climate change. It is clear that we cannot avert climate change now. We can, at best, alleviate the intensity of its repercussions, though unfortunately not uniformly all over the world. This commentary paper posits waste management in the scheme of things related to the Sustainable Development Goals (SDGs), as both enabler and enabled. The exposition introduces readers to the multi dimensionality of sustainable development, and thereby of efficient, value generating waste management.

Keywords: Circular bio economy • Recover • Recycle • Reduce • Remediate • Reuse • Sustainable Development Goals (SDGs) • Valorisation • Wastes • Waste management

Introduction

In a take make use dispose economy, one either disposes waste irresponsibly to the environmental media, or resorts to the so called end of pipe treatment. Awareness of resource scarcity (abiotic depletion) and the adverse impacts of anthropospheric activities on the environment that supports them gave birth to the popular waste management hierarchy Reduce, Reuse, Recycle, and Recover (energy) [1-5]. Landfilling was considered to be the last resort. The sought after gradual transition to a circular bio economy, a paradigm for the future, according to, has added more R's to the afore named set of waste management approaches (and ideals) Reclaim, Restore, Remediate, rainwater harvest, Renovate, Refuse, Replenish, Replace and Revere Nature. This author would like to add 'Repurpose' and 'Restrict' to the mix. This paper, which can be looked upon as a commentary, takes the form of a general discussion, positing waste management in the scheme of things related to the Sustainable Development Goals (SDGs). The references to published literature are by no means all encompassing, as this paper is not styled as a systematic review article [6-9]. While readers can be motivated by this discussion to model waste management strategies and policies, linked to the SDGs (and specific targets), no metrics/indicators or decision making approaches have been recommended by the author. This exposition introduces readers to the multi dimensionality of sustainable developme-nt, and thereby of efficient waste management as an enabler of the same [10-14].

Literature Review

Needless to state, there are complementarities and conflicts among the 17 SDGs, and the targets defined under each one of them. Trade-offs is indispensable to ensure that one does not upset the applecart, by missing the wood for the trees [15-18]. In other words, one can, at best, focus on optimising improvement across the swathe of targets. Further, different towns, cities, regions and countries will start from different initial states, on a continuous journey towards moving targets they set for themselves. Sustainable waste management approaches, while contributing to (enabling) some SDGs, are enabled by the progress made towards the attainment of others. The discussion is structured in order of the relevant SDGs. The official definitions of the SDGs have been truncated in length, for the sake of brevity of the sub headings [19-24].

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SDG 1 end to poverty in all its forms everywhere

The seven targets defined under SDG 1, can be combined together thus create sound policies, mobilise resources, build resilience and implement social protection systems to eradicate extreme poverty, provide access to the poor and the vulnerable to basic services, microfinance etc. Waste management, in a way, has been sustaining the livelihoods of the poor in the developing world, enabling many to stay afloat above the extreme poverty line, which is currently defined as USD 1.25 per day. The reference here is to the informal recycling sector which governments in the developing countries may be averse to dismantling completely [25-28]. Umair and colleagues posit the e waste recycling sector in Pakistan to be such an enabler. However, Ojha and co-authors, in a case study of the Mirzapur district of the state of Uttar Pradesh in north India, published in 2014, had reported that the average daily income for rag pickers in the district (people who make a living by collecting recyclables from dumping grounds or open landfills, and selling the same to middlemen who sell them forward to recycling units), was about INR 60. While this was the reported average, there were some who earned more than USD 1.25 per day (which in 2014 was equivalent to INR 88) [29-34]. Going by the mean value however (a metric which is commonly used to describe the situation, for decision makers), the average rag picker took home approximately 85 US cents per day. There are numerous people in developing world countries in South America, Africa and Asia, who make a living in this fashion. A difficult question to be answered here is if modernising the informal waste recycling sector is sustainable. Is not there a risk that many people who are barely managing to stay above the extreme poverty line, will sink to the depths of penury again? However, progressive thinking would entail policy making to create new jobs in circular bio economies of the future and help pull more and more individuals (and their families) out of extreme poverty. Social entrepreneurship however, supported by top down policy making, can show the way [35-39].

SDG 2 food security, improved nutrition, sustainable agriculture, end to hunger

The very first priority in the waste management hierarchy Reduce is evoked by the authors of, in an Irish case study, where they differentiate between avoidable food waste and unavoidable food residues along the food chain. Food waste reduction in households (as reported in, in Europe, one third of food waste along the value chain, happens in households), can be motivated by generating awareness and bringing about a change in consumer behaviour which is largely influenced by the prevailing social norms [40-45]. The question that is likely to be posed here is how can a decrease in food waste in European households solve the problem of hunger in the world? As most downstream food waste happens in the richer, developed countries of the world which also incidentally rely a lot on imported foodstuffs from the developing-world nations, a substantial reduction in food waste downstream, is likely to free up more food for domestic consumption in the exporting countries [46-49]. Additionally, the western world countries may also think of exporting any surplus of their locally cultivated fruits and vegetables for instance (a surplus that may come about when food wastage in households is considerably decreased), at reduced prices to countries striving to combat hunger and feeding their populations [50].

With time, the stress on arable land to continue feeding humankind (directly, and indirectly by feeding livestock) will be exacerbated. It can be alleviated by reducing food losses all along the value chain. There is another vital non substitutable resource phosphorus which may not be available as easily, affordably and abundantly in the future, as it has been heretofore [51-53]. While minimisation of phosphorus losses (waste reduction in other words) along the entire chain from phosphate mining to food/feed is recommended by, it has been noted by that phosphorus recovery from wastewater will become run of the mill in the future, and may be mandated legally by policymakers [54,55]. Mihelcic and fellow researchers are of the view that in 2050, 1.68 million tons of phosphorus (tantamount to 20% of the global phosphorus demand) can potentially be recovered form brown wastewater (yellow (urine) + black (faeces)), globally. There are numerous publications focusing on phosphorus recovery from wastewater upstream of (by separating urine at source), and in wastewater treatment plants (WWTPs), of which comprise a small sample. SDG 2 also refers to sustainable agriculture. Phosphorus apart, nitrogen can be extracted as urea from source separated yellow wastewater (putting coconut wastes to good use as adsorbents in, and alkaline dehydration [56-60]. Valorisation of bio wastes (from households, forests, fields, fisheries and industries) in bio refineries (ubiquitous entities in circular bio economies of the future, to yield resource inputs for the agricultural sector, can entrench a steady stream of biochar as soil amendment, and vermicomposting can be done by households with the intention of circularising their food waste as bio fertilisers to farmers. In regions experiencing water scarcity, reuse of adequately treated wastewater for irrigation purposes, will have to entrench itself firmly, as advised, in case studies centred on Italy, Spain, Greece, Tunisia, the Gaza Strip and Egypt [61-64].

SDG 3 healthy lives and well being for all at all ages

While e waste recycling enables the Pakistani workers to earn between USD 2-3 per day and that indeed may augur well for SDG 1, Umair and colleagues express concern about the health and safety aspects which go abegging. They have pointed out that the workers do not use any protective gear, suffer from breathing problems and skin disease, and endure improper ventilation in the recycling shops [65]. Child labour is common too and the blood lead levels of children are dangerously high, owing to the leakage of lead from the e waste into soil and water. Rag-pickers in the developing world are also exposed to a plethora of health and safety hazards when they foray for recyclables in garbage dumps. A recent publication which focuses on rag pickers in the city of Lucknow in the State of Uttar Pradesh in India (the authors of had chosen another city in the same State for their case study) lists respiratory, eye and skin problems, fever, cough and cold, dysentery and diarrhoea, road accidents, animal bites, and frost bite [66].

Citing from, at the ship breaking yards in Alang in the Western-Indian State of Gujarat, a yard owner brushed aside a question from this author concerning deaths of workers who were not provided gloves, helmets or masks while working at heights above the ground and blow torching the steel bodies of ships, some of which had been

delivered to the yard with inflammable oils inside. He said that if one worker dies, his jobless brother from a faraway state comes over to replace him and thereby the yard does not fall short of labour.' Recycling is indeed a good thing, be that e waste imported into the country, recyclables jettisoned in garbage dumps, or steel from ships that have reached the end of their lifetimes and have to be scrapped, if it contributes to SDG 1. However, the virtue of waste management should not be overshadowed/offset by the adverse impacts to the health and well being of the actual value creators the rag pickers and workers, in this case [67]. While recycling treated wastewater for irrigation is good for SDG 2, one must be wary of the presence of pharmaceuticals, alkyl phenols, polar pesticides, illicit drugs, oestrogens, pathogens and toxic heavy metals in it. These are often not completely removed during the treatment processes, and must not be recirculated back into the agricultural soils and thereby the food chain. (Therefore, the adjective adequately treated was used in sub section 2.2.) [68].

SDG 4 inclusive, equitable quality education and lifelong learning opportunities

People will not know about the R's of waste management unless they are made aware of the looming challenges facing humankind resource scarcity, environmental degradation, climate change and the like. Reverence for nature is easily imbibed by school going children. While it is necessary to ensure that all children the world over are able to go to school, it is also important to teach them about the R's referred to [69]. Academic researchers may be tasked with the responsibility of educating the unaware and sceptical sections of the population about the longterm benefits of a circular bio economy, in which what were hitherto wastes are rightly looked upon as valuable (valorizable) resources. Universities around the world must and will start offering new post graduate courses in bio based circular economy to jumpstart this paradigm shift, toeing China's line. Education pre primary, primary, technical, vocational and tertiary thus will continue to play a vital role in positing waste management as a value creator and an enabler of sustainable development [70].

SDG 5 gender equality and women empowerment

In the developing world, resource management and conservation (and thereby waste handling) in households are usually undertaken by women. This responsibility often extends to the community level, and in rural areas, encompasses agriculture, forestry and animal husbandry. Their experiences therefore are vital to policymaking for sustainable development. A study conducted in New Zealand which may very well apply to other parts of the world (both developed and developing) concluded that girls and women tend to be environment friendlier than men and have a lower Greenhouse-Gas (GHG) footprint *vis-a-vis* the males of the species [71]. This, the researchers attributed to traits of kindness, conscientiousness, honesty and emotionality. It follows that if women are empowered in society, industry and government, as leaders, experts, educators and innovators, the R's of waste management in a circular economy will be applied to a greater extent. In the western world though, women are already empowered, thanks to higher levels of education and gender parity, and play a crucial role as sustainable consumers, making most of the 'green' decisions for the households, optimising resource use and minimising waste generation [72].

Results and Discussion

SDG 6 availability and sustainable management of water and sanitation for all

Figure 1, in which it has been assumed that the source of raw water and the sink for treated wastewater are the same (which is often the case in many parts of the world) is at once illustrative of the role a well developed water and sanitation utility (SDG 6) servicing consumers who are also environmentally aware and cooperative, can play in uncovering sustainable and greener energy alternatives (SDG 7, refer sub section 2.7), contributing to the zero hunger goal (SDG 2) assisting in combating climate change (SDG 13), aiding sustainable consumption (SDG 12), and maintaining the carrying capacities of the water bodies in question (SDG 14). Envisaging the downstream of the water and sanitation system (Figure 1) as a 'multi output refinery' recovering value (bio energy, bio fertilisers and metals, non metals and chemicals when industrial wastewater streams are subjected to treatment at source) from wastewater, can even recast the water utilities as for profit enterprises. This incentivises investments made in developing the downstream (wastewater transport and wastewater transport) of the urban water cycle. The profits can be channelled back to progressive sustainable development (supporting research projects in academic circles), and/or lead to making the water and wastewater services increasingly more affordable for the consumers (applicable in the developing world countries). The words reduce reuse in a cascade and rainwater harvest have been added below the Consumer step in Figure 1. Rainwater which is not collected (harvested) can be looked upon as wasted water which wends its way through stormwater pipelines to the WWTPs. Likewise reduce leakage appears under the Water Distribution step. All these are waste minimisation approaches not just of water, but also of the resources consumed to provide these services. It is consumer demand that drives the utility in a way, and every effort made by the consumers to optimize their water usage (and thereby wastewater discharges), will go a long way to improve sustainability (SDG 12).

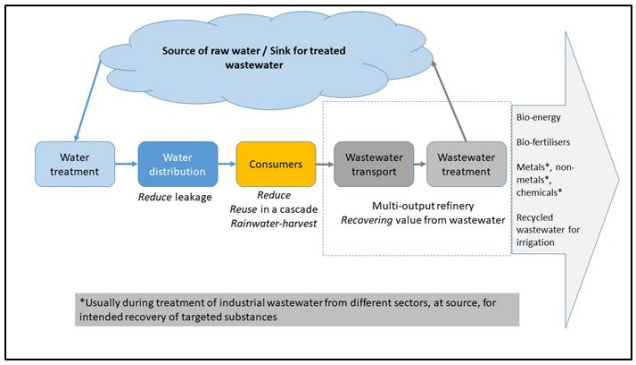

Figure 1. Achieving the sanitation targets in SDG 6 helps SDGs 2, 7, 12, 13 and 14 automatically.

SDG 7 access to affordable reliable sustainable and modern energy for all

Waste valorisation can contribute to SDG 7, by uncovering sustainable alternatives to fossil fuels. Biodiesel can be produced from, inter alia, activated sludge, waste cooking oil, spent coffee grounds and palm oil mill wastes. Hydrogen is heralded as the fuel for the future, and researchers have touted wastewater as a valorizable starting material for the production of bio hydrogen. Production of biogas/bio methane (ultra pure biogas in other words) by anaerobically digesting activated wastewater sludge, food waste, and other easily digestible biomass, is well entrenched in several parts of the world. However, the unharnessed potential is huge, at the time of writing. For instance, authors of are of the view that if all the bio solids in South African WWTPs could be valorised to biogas, bio hydrogen and bioethanol, about 7% of the country's electricity needs could be satisfied. In New Zealand, reportedly, energy recovery from wastewater (biogas being one of the recovered energy carriers) could easily be sextupled, according to, while authors of are of the view that maximising the biomethane output by anaerobically digesting all the human wastes in China, and using it to substitute coal for electricity generation, can potentially reduce Chinese GHG emissions by 142 kilotonnes daily. Pellets produced from biomass (wastes, wherever possible to be availed of), serve the dual purpose of ensuring energy security (both in developed and developing countries) and environmental sustainability. Crude palm oil effluent is one such valorizable waste, according to. Wastes like plastics and paper are combusted in Combined Heat and Power (CHP) plants in many countries of the world. While being affordable and reliable for sure, combusting plastics for energy generation is far from 'clean'. As noted by the authors in, CHPs in Sweden for instance are keen on decreasing the quanta of waste plastics in their respective input fuel mixes, and divert more of them thereby for recycling. As several researchers testify, the potential exists, and countries of the world must 'get down to brass tacks', to convert the reported estimates of biowaste derived energy generation to reality. While bio wastes (materials) can be valorised in bio refineries and WWTPs to solid, liquid and gaseous carriers of energy, (waste) heat can be recovered from the wastewater flowing to the WWTPs, using water source heat pumps, and utilised for purposes like district heating. In thermal power plants, cooling the spent steam in the condenser enables the power plant to maintain its net electricity output (some of the generation is for captive consumption by the pump that pressurises the condensed steam onward to the boiler). It is also a way of recovering useful heat energy which may be put to good use for district heating and for greenhouses in the horticultural sector, obviating the need for fossil fuels for these purposes and bringing about a net reduction in the GHG emissions. Waste heat recovery can also entail upgrading some of the high temperature heat to high exergy electricity (Figure 2).

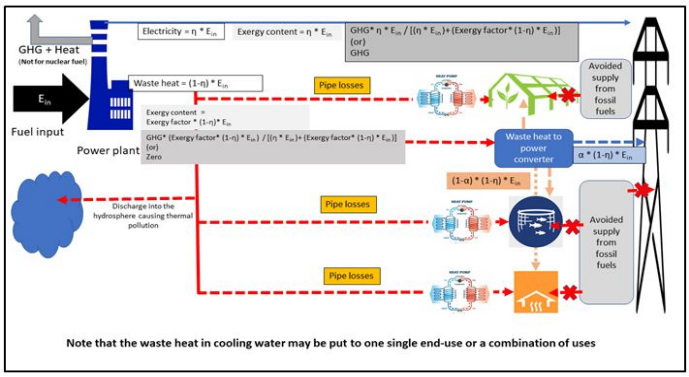

Figure 2. Utilisation of the waste heat in power plant cooling water streams for electricity generation, greenhouses, fish farms and district heating (top to bottom on the right hand side of the Figure). (α and η are conversion efficiencies; and the specific GWP-100 factors have been indicated for exergy based allocation and 100% allocation to the electricity output).

SDG 8 sustained, inclusive, economic growth, decent work, productive employment

While informal recycling in cities of the developing world does lift some families out of extreme poverty (sub section), and in a small but not insignificant way also contributes to economic growth by recycling value (abiotic materials like metals and plastics usually) back into the anthroposphere, one perhaps may not be able to label it as 'decent work' or 'productive employment' per se. This is because the actual 'value creators' in this case do not earn in proportion to the value they create, and the health risks they are exposed to. This is a hotspot in the value chains of several products, with operating nodes in the developing world, which needs to be highlighted and redressed by local governments. However, waste valorisation in general, must and will entrench itself in the circular economies of the future. As observed by, the Bio based Industries Joint Undertaking in the EU, is working towards facilitating private investment in new biorefineries. These, while valorising bio wastes and competing in the process, with non bio based products, will create several 'decent' and productive employment opportunities.

SDG 9 resilient infrastructure, sustainable industrialization and innovation

Waste collection, handling and valorisation ought to go hand in hand with industrialisation, if the latter needs to be labelled as sustainable. Here, the reference is both to wastes generated during industrial processes, at points of sale of products supplied by the industries and post consumption. Change being the only constant, innovation is key. This may be about doing different things (technological breakthroughs, product, and process related 'disruptive' innovations) or doing things differently ('creative destruction' of the conventional approaches). Innovations targeted at recovering resources from wastes take time to entrench themselves in economies, and deserve top down support. In sub section 2.6, the downstream of the water utility was identified as a 'multi output refinery'. While nutrients and bio energy are derived from the bio based wastes in the wastewater, researchers have proven that at source treatment of industrial wastewaters can be done with the purpose of recovering different metals, non metals and chemical

compounds silver, palladium, gallic acid, sodium, potassium and magnesium salts, copper, chromium, chlorine, zinc sulphide, gold, indium, caustic soda, aluminium, calcium fluoride, lead, uranium, cadmium and polyhydroxyalkanoates (bio plastics in other words). Necessity is the mother of invention. Technological breakthroughs which enable resource recovery, happen in R and D labs in industries, research institutes and universities, often serendipitously. Knowledge about them must be disseminated globally (of course without compromising the rights of the innovators to hold patents and avail of the advantages thereof), and once the desiderata of SDG 17 (subsection) are in place, the rewards of this knowledge sharing can be reaped on a larger scale.

SDG 10 reduction of inequality within and among countries

Waste management (with focus on valorisation), will aid in the reduction of inequality within and among countries, indirectly by contributing to the other SDGs.

- Sustaining the space for informal recyclers (SDG 1, sub section) to function (with some attention given to health and well being issues (refer sub section), and stay above the extreme poverty line and rise up gradually in the process. Creating more employment opportunities in a green economy focused on the collection, handling and valorisation of wastes (sub section)
- Aiding electrification of far flung areas in the developing world, by availing of waste derived energy options (bio waste as far as possible), and bringing electricity to the lives of people who have not experienced its benefits thus far (sub section).
- Spurring investments in sanitation in the developing world, motivated by the potential of WWTPs to be multi output refineries (sub section).
- Eliminating hunger (sub section) by way of reducing food waste, recovering nutrients from wastewater and producing bio fertilisers from bio wastes in bio refineries, and bridging the gap between the vast swathes of the human population who struggle to get three square meals a day, and the relatively smaller numbers who waste the surplus that they are able to afford.

SDG 11 inclusive safe resilient and sustainable cities and human settlements

The adjectives 'resilient' and 'sustainable' are relevant here from a waste management perspective. The targets include provision of basic services to all inhabitants, and access to sanitation facilities can be mentioned here. As mentioned in sub section 2.6, when the downstream of the water utility is envisaged as a 'multi output refinery' generating a lot of value from wastewater (Figure 1), city administrations are incentivised to expand sanitation services to the entire population in phases 'sustainably' and 'inclusively'. Another target is sustainable public transportation, and as discussed in sub section 2.7, biomethane (or biogas), biodiesel and bio hydrogen in the future all derived from bio wastes in biorefineries can become the fuels of choice, replacing slowly but surely, and eventually completely, fossil gasoline and fossil diesel (exemplified by Sweden, as discussed in. In this regard, authors of would like to point to the open burning of agro wastes in India which accounts for a sizable fraction of India's GHG emissions. The tremendous potential they hold for conversion to biogas which can be supplied as a sustainable transport fuel in the towns and cities of the country, must not be wasted. Resilience entails being able to uncover a host of alternatives to fall back on, to supply the essential needs of citizens, in the event of disruptions. Waste valorisation is a promising option which must be availed of, to adapt to the fallouts of climate change. Also targeted is a reduction in the per capita environmental impact, and all the R's of waste management working in tandem towards sustainable consumption (refer the next sub section) will speed up the process towards it.

SDG 12 sustainable consumption and production patterns

Sustainable production entails, in the context of waste management:

- Improving the efficiency of usage of resources (and thereby reducing waste generation).
- Recycling the in process wastes that are invariably generated.
- Increasing the recycled content in the products supplied.
- Designing products for recyclability, durability and energy efficiency in the use phase (to decrease energy losses also a form of waste to be avoided).
- Setting in place incentivised take back schemes to efficiently recycle materials back into the anthroposphere.
- Utilising waste derived energy (preferably bio waste derived) electricity, heat and solid/liquid/gaseous fuels in production processes wherever possible.
- Reusing wastewater in a cascade within the plants, to the greatest extent possible; and rainwater harvesting if possible.

Sustainable consumption, in the context of waste management entails, inter alia:

- Reducing/optimising one's material footprint and minimising waste of all kinds.
- Prioritizing bio based alternatives.
- Repurposing creatively, and extending the usable/functional lifetime of products.
- Cooperating with waste collection and valorisation initiatives undertaken by entrepreneurs.
- Supporting reuse by donating to second hand shops.
- Handling the end of life of products responsibly.
- Reusing water in a cascade at home, and rainwater harvesting if possible (sub section).

It follows that the entrenchment of the R's of waste management in production upstream and consumption downstream, will contribute significantly to Sustainable Development (SDG 12 in this case).

SDG 13 combating climate change and its repercussions

Climate change is attributed directly to the emission of Greenhouse Gases (GHGs) from anthropospheric activities. While circularising bio wastes from households, industries, points of sale,

WWTPs (sub section), fields/farms and forests and valorising them into forms of energy to supplant fossil fuels (sub section 2.7) is a sure fire strategy to have GHG emissions on a leash, bio materials and bio fertilisers produced in bio refineries will contribute by avoiding the production of conventional GHG emitting alternatives. In all these cases however, an environmental life cycle assessment needs to be carried out to determine if net GHG reductions are actually achieved by means of such replacements. Having more alternatives (courtesy the circularity paradigm and the realisation that 'waste' is a misnomer, the hidden value of which needs to be harnessed) to take recourse to, will impart resilience to societies and economies, as they try to adapt to any inevitable repercussions of climate change. As more and more changes are incorporated in the journey towards SDG 12 (12 of several strategies outlined in sub section), the targets of SDG 13 (and those of SDGs 14 and 15) will progressively seem nearer at hand.

SDG 14 conservation of oceans, seas and marine resources

In sub section 2.7, the author referred to waste heat recovery from the cooling water discharged from thermal power plants. In the absence of any heat recovery, the heat content of the cooling water is transferred to the hydrosphere into marine or freshwater ecosystems. This leads to thermal pollution, and habitat destruction, as the dissolved oxygen content in the water bodies decreases with rising water temperature and this tends to affect the aquatic biota. Thus, waste heat recovery, while aiding the journey towards SDG 7 and SDG 13, also contributes to SDG 14. While thermal pollution of water bodies (both freshwater and marine) is to be avoided, the issue which has been dominating headlines in the recent past and also currently, is marine pollution by waste plastics. A four fold approach is called for, to tackle this problem.

- Refusing and reducing the use of plastics and be willing to pay more for bio alternatives (SDG 12, and a part of sustainable consumption) and assuming the responsibility to deposit waste plastics in designated bins/containers.
- Replacing plastics with bio alternatives (SDG 12, sustainable production; SDG 9, industrial innovation)
- Restricting the use of plastics by bans and introducing fees (top down policy decisions, which may even be based on international agreements, encompassed by SDG 17)

Remediating the oceans by recovering the bio diversity destroying plastic wastes from the hydrosphere (necessary part of SDG), and subsequently harnessing energy from them, as recycling them will be quite challenging (SDG 7, though this energy cannot be deemed to be 'clean', as also mentioned earlier in sub section)

Remediating the oceans of the world necessitates global partnership (SDG 17; sub section) and innovative responsible initiatives undertaken by governments of countries which have coastlines and economies bolstered by proximity to the oceans/seas (South Korea for instance as gathered from) and by non governmental organizations.

SDG 15 conservation of terrestrial ecosystems, forests and biodiversity

Just as the atmosphere can be 'remediated' by capturing and utilising/sequestering carbon dioxide (as one of the strategies for SDG 13); and the oceans can be remediated by recovering waste-plastics therefrom (SDG 14; sub section), soils be they on arable land, in forests or on land in close proximity to industrial complexes and the groundwater beneath them, can be remediated by removing toxic (and other undesirable, though nontoxic) wastes therefrom. Soil and groundwater remediation is an advanced field of practical research which will serve the purpose, when it comes to SDG 15. Remediation technologies can restore soils and groundwater partially to their pre contaminated levels, restoring a good deal of their carrying capacities. Soil amendment and fertilisation in reclaimed forests and agricultural land can be sustainably done by utilising bio fertilisers and bio char from biorefineries, and sludge from WWTPs (SDG 2, sub section 2.2; SDG 6, sub section). It may read like a cliché, but the more consumers try to minimise their material footprints by reducing, reusing, recycling, repurposing and refusing (SDG 12; sub section), the degree of circularity in an economy can be gradually enhanced. While a developing bio economy may be characterised by a slightly greater dependence on arable land and forests, attempts made to circularise it will strike a good balance between economic development and conservation of terrestrial ecosystems (and thereby the biodiversity which they sustain).

SDG 17 revitalized global partnership for sustainable development

For waste valorisation to entrench itself in a significant way, and become pervasive, as observed by that cites from a host of publications from literature (not referred to here), the following are indispensable.

- Stronger private public partnerships.
- Collaborations among 'conventional and non conventional entities' in the economy.
- Robust institutional structures at local and regional levels.
- Strong governance to ensure transparency, decent work and productive employment (SDG 8; refer sub section).
- Effective policy mix of 'carrots and sticks' (penalties/fees and incentives/subsidies).
- Revamp of international quality standards to accommodate products valorised from wastes, and encourage and facilitate global trading of the same.
- Systemic level changes through the joint global efforts of researchers, technology centres, industries, the primary sector, new entrepreneurs, consumer, civil society and governments, and relentless innovation (SDG 9; sub section) are indispensable. This commentary has taken recourse to published literature, but as mentioned in section 1, they account for a very small sub set of extant waste management literature (Figure 3).

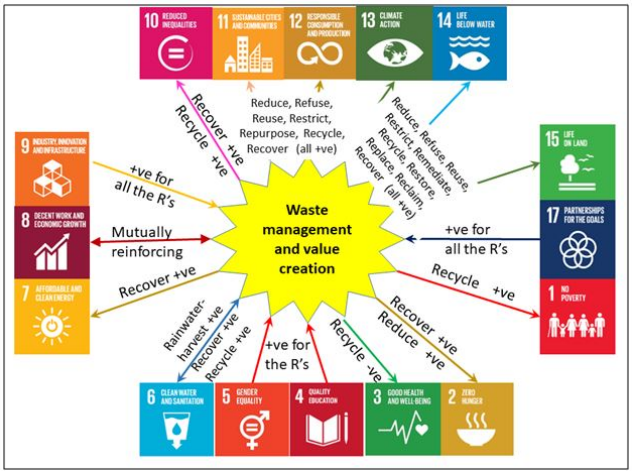

Figure 3. Summarising the discussion (the arrows are directed from 'enabler' to 'enabled').

Conclusion

Waste management, as discussed above, can play a key role in the alleviation of, and the simultaneous adaptation to the repercussions of climate change. Waste valorisation, which is gradually entrenching itself, in both principle and practice, can go a long way in directly and indirectly enabling humankind to get closer to several SDG targets, and perhaps also overachieve in some respects. As shown in Figure 3, waste management envisaged as value creation will enable SDGs 1,2,6,7,8, 10-15, while it will be enabled by SDGs 3,4, 9 and 17, and must be handled with care when it comes to SDG 2. SDG 8 can be considered to enable and be enabled, at the same time mutually reinforcing in other words. The author has excluded SDG 16 from the mix, considering it to be not so relevant in a waste management context. Waste not want not' is a popular slogan all readers may have heard or read before. However, what is inevitably wasted must be looked upon as a resource with 'hidden value' that has heretofore not been appreciated. Hereafter, a steady overhaul in thinking is indispensable. Value creation by adopting the R's wherever, however, whenever and by whosoever possible, is a sine qua non for achieving the SDGs by year 2030, and continuing in the same vein thereafter, when the world will have to grapple more perceptibly with the repercussions of climate change. It is clear that we cannot avert climate change now. We can, at best, alleviate the intensity of its repercussions, though unfortunately not uniformly all over the world.

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Conflicts of Interest

The author declares no conflicts of interest.

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