Green ICT and Sustainable Manufacturing: Economy of Saving and Saving of Environment

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Abstract: ***"The problem of climate change is so large that it can't be solved by voluntary individual responses. It requires an economy-wide solution that limits the total carbon intake of the economy." - Peter Barnes a sustainable business innovator. This quote epitomizes the imperative to embark upon climate change and environmental degradation caused by the consumption of our modern lives signifying necessity to set better environment for next generations. According to the World Meteorological Organization (WMO), last decade (2001-2010) was officially proclaimed as the warmest decade, measuring averaged sea level 20 cm higher and most active decade in terms of tropical cyclone activity alarming the issue of sustainability. Since the day information technologies have touched our life, generations are trying to reach and to process huge information leading in inventions, evolving technologies and advancements which are making systems more powerful but on the other hand causing larger size carbon footprints. This is a decisive time to make these carbon footprints smaller by taking precautionary measures to minimize Green House Gas (GHG) emission and hence defining of green Information and Communication Technologies (ICTs) by engineers, academicians and practitioners in order to meet objectives; practicing green approaches.***

ICT industry has two major challenges: to minimize its own footprint (2%) [1] and to minimize footprint (98%) caused by other industries. ICTs promises to tackle these challenges through Sustainable Manufacturing (SM) - by practicing green use (minimizing energy consumption), disposal (reuse, recycle and refurbish), design (energy efficient), and production (with non-hazardous chemicals) of products. ICT is contributing to agriculture sector too facilitating 'vision' to analyze soil fertility and provide crop maps allowing farmers to distribute inputs accurately. ICTs compromises of – end user devices (EUDs), telecommunication networks and data centers accounting for 25% (and growing) of global commercial energy consumption. EUDs has largest footprint with 59 percent of ICT emissions with Personal Computers (PCs) making 60 percent within it. SM represents saving opportunity at $20-$60/PC/year [2]. ICT application areas include – industrial process automation, transport optimization, smart buildings – grids – motors – logistics, and dematerialization (teleworking) suggesting total

savings of 7.82 $GtCO_2e$ in GHG emissions by 2020 [3]. How will ICT help reduce emissions? It comes back to saying – you can't manage what you don't measure.

Keywords: Information and Communication Technology (ICT), Sustainable Manufacturing (SM), Green House Gas (GHG), $GtCO_2e$: Giga tones of CO_2 equivalent

1. INTRODUCTION

The environment includes every living and non-living entities around us and ourselves. We use environmental resources to meet our needs. But in present era we have shown our undesirable appetite for these resources causing excessive exploitation of these resources ignoring its effects on environmental stability.

The environmental instability caused due to human activities like pollution, population growth, urbanization and industrialization is exceeding the carrying capacity of the environment to repair or replace itself, leading to severe environmental degradation. The environment is warning us by means of environmental factors like floods, droughts, famines, cyclones, scarcity of natural resources, extinction of some species (are we next?), by means of economical factors like inflation and recession and social factors like strikes and wars. The awareness about environmental issues appears increasing at all the levels ranging from governments - non government organizations, policy makers, practitioners, researchers, academicians and even at a laymen level. The SM and green ICT proved effective methodologies to tackle climate change and to address environmental problems posed to us by ourselves.

2. GREEN ICT

Electronic information processing, exchange and communication have turned out to be key necessities of modern life making ICT devices as integral part of our workplaces and homes. ICT has great potential to revolutionaries the focus of serving society and industry in an efficient and sustainable manner. ICT can reduce its own footprint (green of ICT) and footprint of others which are lingering for solutions (green by ICT). ICT devices include cellular and Public Switch Telephone Network (PSTN), data center/servers, internet and networking devices, infotainment systems, satellite television, mobile devices, PCs etc. As per predictions, energy consumption of ICT will be doubled by 2022 and tripled by 2030 compared to the level in 2010 [4].

In the terminology 'Green ICT' (fig. 1) green imply reduction in energy consumption, GHGs emissions, waste produced and materials used while ICT represents devices and technologies which are responsible for creation, processing, storage, transmission and/or presentation of information in any human or machine readable form.

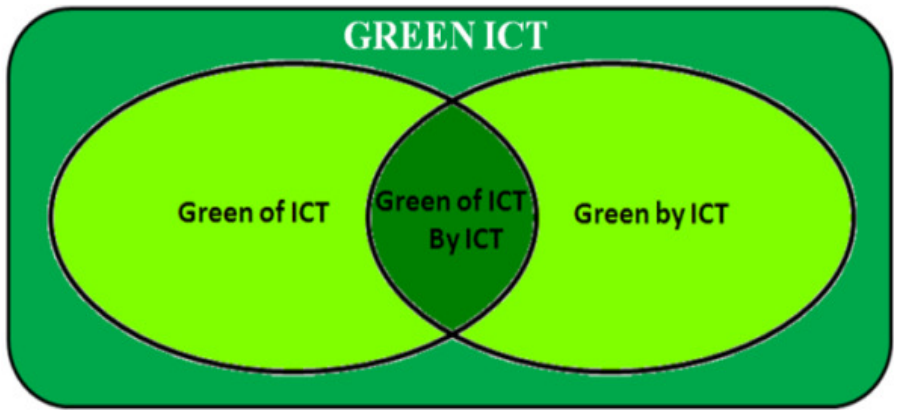

Fig. 1: **The components of green ICT**

2.1 GREEN OF ICT

ICT accounts for 25 % of commercial energy consumption for its operation excluding its manufacturing, transportation and disposal. It emphasizes the need of advancements in recent technologies to take up the challenge of greening of ICT and ICT devices (fig. 2).

2.1.1. Greening Data Center:

In order to measure efficiency of data center, two metrics are used viz. Power Usage Effectiveness (PUE) and Data Center Infrastructure Efficiency (DCIE) given by eq. 1

$$\text{PUE} = \frac{Total\ Facility\ Power}{ICT\ Equipment\ Power} = \frac{1}{DCIE},\ \text{DCIE} = \frac{1}{PUE} = \frac{ICT\ Equipment\ Power}{Total\ Facility\ Power} \quad \text{.... (Eq. 1)}$$

Ideal value of PUE and DCIE is 1 and this value can be approached by initiatives like - server virtualization that uses single server instead of application dedicated servers by masking of server resources and identity from users. Next best practice is data center outsourcing in which small part of server network is kept on-site and major part is maintained at a separate physical location generally by third party. Traffic to server is highly variable and in idle condition, servers can be operated in power saving mode. Use of Solid-state Drives (SSD) gives high I/O performance and energy efficiency as it does not have mechanical (moving) components. The finite storage capacity can be optimized and organized effectively by redundancy removal and data compression thereby reducing storage cost and files retrieval time. Some other methods include localized cooling, use of green energy, water - conservation, treatment, and reuse practiced by IT giants like Microsoft, Google and Facebook.

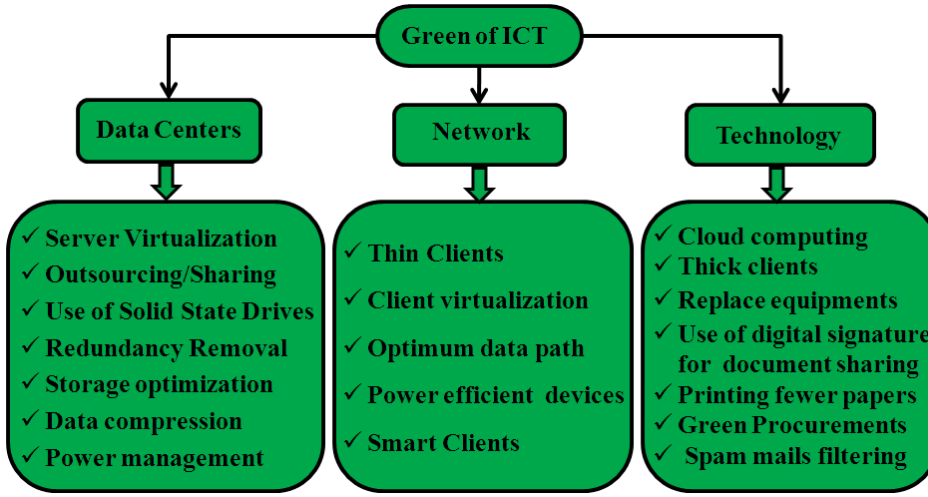

Fig. 2: **Showing the components of green of ICT**

2.1.2 Networks:

Network devices and network interfaces account for more than 10% of total ICT power usage [5]. This usage can be minimized by following techniques like use of thin client: a desktop terminal that has no hard drive and CPU and functionally depend on remote server, client virtualization: a centralization technique that simulates a user's desktop experience by separating it from the hardware and applications, use of optimum data path: includes use of power aware and fastest shortest routing algorithms and smart client : is a terminal that supports offline work saving cost of client server communication and delays. Energy Efficient Ethernet (EEE) provides a mechanism and a standard for reducing energy usage without affecting functionality of network interfaces. Cisco has introduced IEEE 802.3az for EEE. [5]

2.1.3 Technology:

ICT can be greener by use of evolving technologies like cloud computing: networked computers with distribute resources hosted on the Internet, thick clients: rely on a central server primarily for storage but not for processing. Next approach is replacement of equipments with energy efficient equipments like Quantum dot LED (QDLED) over LCD and LED display. Use of papers can be minimized by use of digital signature in document sharing and duplex printing (minimizing CO_2e emissions by 1,360 tons/year). Some behavioral steps towards greening include green procurements, spam mail filtering and minimizing search operations. Average email user is responsible for 28.82 kg with global estimate of 17 million metric tons of CO_2e emission of annually [6]. Google spends about 0.0003 kWh of energy translating to roughly 0.2g of CO_2 per search query resulting in 1677423 metric tons of CO_2e emission annually (2011) [7].

2.2 GREEN BY ICT

Success of use of ICT to green the organization depends on three factors viz. motivational factors: competitiveness, legitimation and social responsibility, organizational factors: support from senior management for environmentally sustainable initiatives and organization capability and technological constraints: limiting organization's ability to begin with Green ICT initiatives.

2.2.1 Network Optimization:

ICT can optimize all sorts of networks including transportation, power transmission, telecommunications, water, supply chain etc. by minimizing cost of structure and energy consumption and by maximizing the throughput. In agriculture sector [8], data collected at national level with ICTs is applicable to adjust policies, improving food safety and traceability, predicting food supplies, to strengthen marketing and to select appropriate cropping practices.

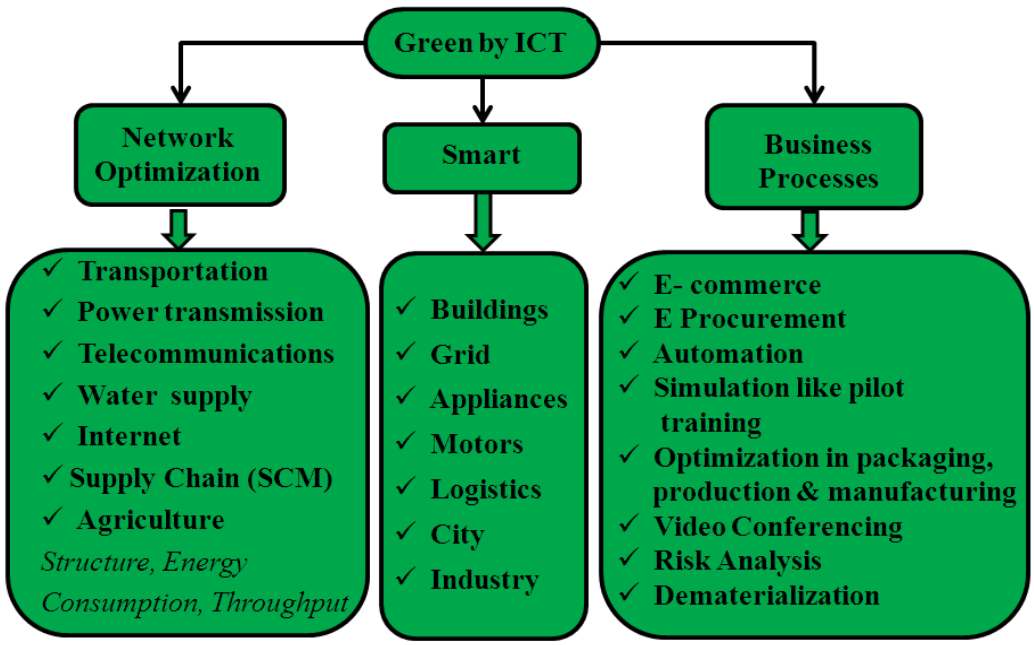

Fig. 3: **Showing the components of green by ICT**

2.2.2 SMART (Self-Monitoring, Analysis and Reporting Tool):

Intelligent tools enable better use of energy in buildings, transport, street lighting etc. It can also facilitate the integration of locally generated renewable energy into the main electricity grid [9]. Intelligence can also be used to improve performance of motors, appliances and logistics. These tools need to globally standardized and generate the need to secure concerns of collected data.

2.2.3 Business Processes:

As per eMarketers' forecast, Business-to-consumer (B2C) ecommerce is expected to increase by 20.1% this year to reach $1.500 trillion thereby saving movement of customers and reducing traffic load. Simulators designed using ICT for pilot training save valuable aviation fuel and make the pilot and the plane life risk zero. ICT tools benefit supply chain, manufacturing and packaging processes in minimizing waste produced and movement of material in production line.

3. SUSTAINABLE MANUFACTURING

Sustainability means the better quality of present and future life in community ensuring that dimensions of sustainability viz. environment, economy and society are healthy, productive and balanced. We need broad vision for understanding of the links (Fig. 4) between these dimensions as tackling problems in isolation can make another worsen.

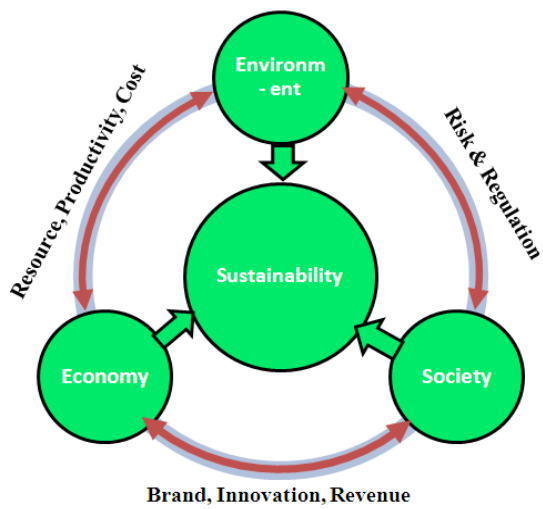

Fig. 4: **Three dimensions of SM and the relationship between these dimensions**

Many definitions of SM are available in literature given by practitioners, organizations like United Nations, Department of Commerce, etc. We try to define SM as "*Use of innovative engineering, technology, design solutions and rational approach that establish harmony and balance between environmental, social and economic practices and benefits ecosystem as a whole by meeting present needs of all in manner to retain the ability to meet future needs of all.*"

3.1 SM of ICT

SM and ICT are two sides of same coin having potential to improve each other in cyclic fashion (fig. 5). Four key factors with largest ICT impact are energy, carbon, e-waste and water [10].

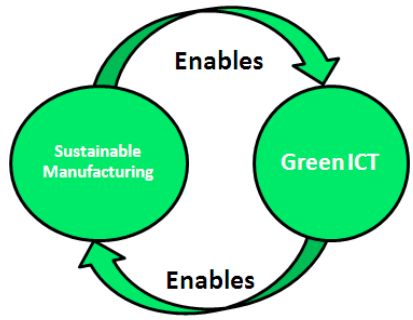

Fig. 5: **Cyclic relationship between SM and ICT**

Higher environmental impacts (80%) often occur before and after the use phase. Hence it is essential to understand complete ICT product life cycle (Fig. 6) to structure policies and programs. Toxic chemicals are often produced in mining of ores, extraction of metals and recycling of products. The first stage, R & D, must recycle and select material in way to minimize the impact of all stages. In PC and IC manufacturing industries, hundreds of hazardous chemicals are used causing death of thousands while others are dying, or diseased [11].

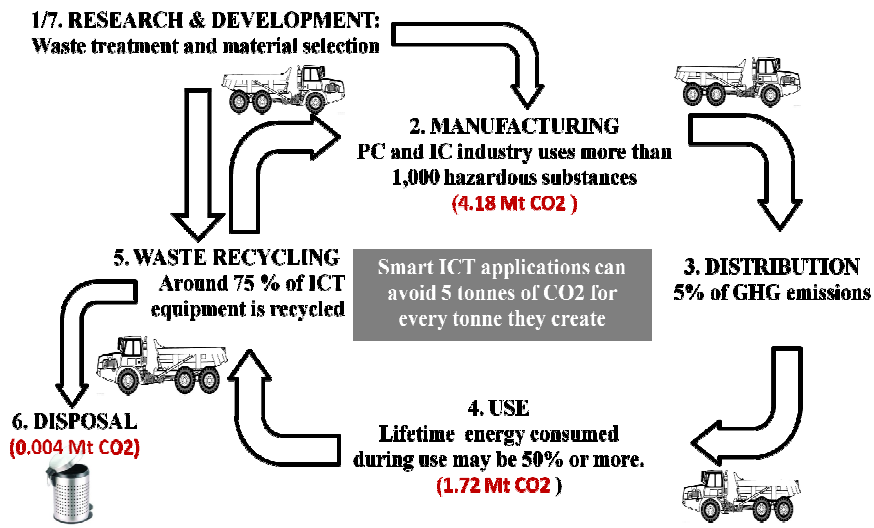

Fig. 6: **Simplified 6-stage model of an ICT product lifecycle**

Empirical research has shown that the production of each PC uses 22 kg of toxic chemicals, 240 kg of fossil fuels and 1,500 kg of water [12]. Shipping of products consumes fuel which is dependent on distance and mode of shipping. In use phase, product consumes energy its operation and maintenance. E-waste recycling produces many toxic substances and leaves unusable materials to landfill.

Some initiatives are discussed below which can contribute a lot to SM of ICT

- Reduce number and volume of toxic chemicals used in PC production like Cadmium in CRT, Mercury in highlighters and Indium in LCD.
- Mobile phone can contain over 40 elements including base metals - copper, tin, special metals - cobalt, indium, antimony, and precious metals - silver, gold, and palladium [13].
- Reduce number of different materials and volume of virgin materials.
- Increase use of reclaimed and recycled materials in PC production.
- Reduce energy consumption in PC production and distribution.
- Design PCs with up gradation and recycling in mind.

3.2 ICT IN SUSTAINABLE MANUFACTURING

Manufacturing is significant producer of GHGs at 14.8 $GtCO_2e$ making 31.4 % of global emission. ICTs that play a fundamental role in dynamic growth by enabling trade, global connectivity, productivity and value creation gives future hopes in betterment of manufacturing process. Research shows that with automation of industrial processes and optimization of variable speed motor systems abatement potential of ICT in manufacturing is 1.25 $GtCO_2e$ [2]. Some of the helpful technologies in SM are Computer Integrated Manufacturing (CIM), wireless monitoring, sensing and remote controlling, computer vision, data mining and data warehousing for predictive analysis and decision support system (like ERP) and simulation and modeling.

More often we encounter the old dictum: "3R's: Reduce, Reuse and Recycle." But we believe the need for extension of this 3R's model. We have proposed 7 R's model (fig.7) of which first 6 steps can directly be applied in manufacturing industry.

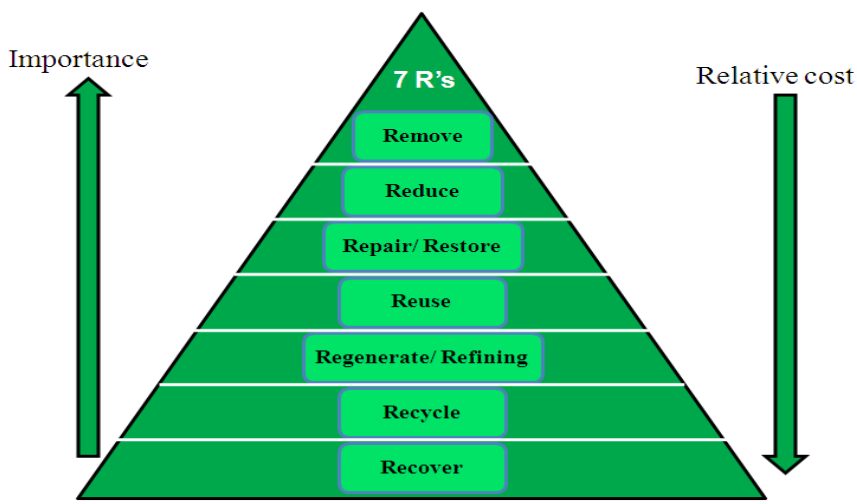

Fig. 7: **7 R's model**

These 7 R's described in general are:

1. **Remove:** Abolish the use of helpful but harmful chemicals and practices (DDT, CFC)
2. **Reduce:** Optimize the use of resources – use only if essential
3. **Repair/Restore:** Fix problems and broken items instead of throwing.
4. **Reuse:** Do not apply "use and throw" methodology directly. Try to find secondary applications of products and use those again.
5. **Regenerate/ Refining:** Best from the waste i.e. enhances the collected waste like waste oil.
6. **Recycle:** Extraction of core elements of waste products to use as raw materials to manufacture new goods.
7. **Recover:** Recover the environment to its original state by planting trees, harvesting rain water, protecting flora and fauna. Implicitly, this step also signifies the recovery of energy and toxic chemicals before and/or after disposal. For example, around 76% of waste sector emissions are caused by methane released from solid waste in landfills.

4. GLOBAL STATISTICS OF ICT: PRESENT AND FUTURE

Global statistics (table 1) about the use and growth of ICT [14][15][16] makes it obvious as why it has become essential to take precautionary measures in favor of environment. The answers to this 'why' is not widely known or appreciated but not are even hard to find. Following statistics is communicative of human activities impacts and environmental stability.

Table 1: **Comparing present and future of communication using ICT**

In 2013 (Present)	In 2017 (Future)
Mobile data traffic was nearly 18 times the size of the entire global Internet in 2000.	Annual global IP traffic will surpass the zettabyte threshold (1.4 ZBs)
Global mobile data traffic grew by 81 percent in 2013 to 2012 reaching 1.5 EBs.	Traffic from wireless and mobile devices will exceed traffic from wired devices.
Mobile video traffic exceeded 53 percent of global data traffic.	The global Internet networks will deliver 13.8 peta bytes every 5 minutes
Over 526 million mobile devices and connections were added	Nearly half of all IP traffic will originate with non-PC devices
4G made only 2.9 percent of mobile connections but accounted for 30 percent of mobile data traffic.	Overall, IP traffic will grow at a compound annual growth rate (CAGR) of 23 percent from 2012 to 2017.

** (1 Peta Bytes = 10^{15} bytes, 1 Zetta bytes = 10^{3} exa byte = 10^{6} peta bytes = 10^{21} bytes)*

5. CHALLENGES AND HOPES: CHALLENGING BUT FEASIBLE TARGETS

While the opportunities and hopes are abundant, yet we have to travel a challenging path to achieve the sustainability and path that has many obstacles and barriers. Some of the major technical challenges are inadequate ICT-based informed decision- making, low ICT and the least Green ICT awareness, lack of matured inter/multi-disciplinary software tools and issues related to availability and reliability of data. Some other challenges include too many conflicting standards, government apathy and lack of incentives for green practices. In order to achieve success on this path we need universal agreement on what sustainable means? Impact of ICT in mitigation of the climate change is estimated the reduction of 7.82 $GtCO_2e$ by the year 2020, equivalent to 5 times the ICT's and 15% of global footprint [2]. European commission proposed a 10 year 'Europe 2020' strategy with aims of minimum 20% reduction in GHGs emission and energy consumption while renewable energy making 20% share of total energy consumption [17]. Initiatives taken by mega industries (like Texas Instruments, HP, Fujitsu) towards sustainability are brightening the hopes towards achieving these green targets. Some of these green initiatives are 'Sustainability Map' by SAP, 'Smart Planet' by IBM, 'Environmental Vision' by Hitachi and 'Google Green'.

6. CONCLUSION

We wish to end our work with an optimistic note. We can firmly believe that (Green) ICT promises plenty of opportunities towards better world of tomorrow by enabling us to shrink our ever larger carbon footprint. Green ICT practices not only favor the environment but boost the economy and industries by means of automation and optimization. It is a matter of fortune that many governments and businesses view sustainability as a means to enhance competitiveness and human well-being by reducing costs and long-term risks. Looking at phenomenal growth of industries; we need to scale up existing innovative approaches and manufacturing models in order to enhance competitiveness and well being by minimizing cost and long term hazards. The contradictory economic, social and environmental requirements, constraints and criteria often lead to difficulties in optimal decision making in manufacturing process. In order to improve the effectiveness of this decision making; it needs to be formulized and standardized than being done heuristically. Global awareness about environmental issue, green economy practices and measures taken by few governments gives positive hope and present opportunities for accelerated eco-friendly progress leading economy of saving and saving of environment. We request everyone to play significant role in increasing awareness among society towards environmental issue and long term sustainability. In way to contribute at individual or at organizational level, we can apply 7 R's model in every possible micro to mega activity of our day to day life. Finally we conclude with quote by famous scientist, Albert Einstein, "*Problems cannot be solved at the same level of awareness that created them.*"

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