Nat. Volatiles & Essent. Oils, 2021; 8(4): 12823-12851

Major Applications Of Green Nanotechnology In Sustainable Development And Its Impact On Global Environment: A Revi ew

Ms. Gargi Gurtu[1] , Dr. Mukesh Sharma[2]

[1,2]Department of Biochemistry Maharaj Vinayak Global University

Abstract – The main applications of green nanotechnology (GN) in sustainable development (SD) as well as their implications for the global environment are examined in this paper. Nanotechnology (NT) presently holds great potential for addressing sustainability challenges, but the deleterious implicationsof nanomaterials on environmental and human health (EHH) must not be overlooked. Despite nano-remediation technology improved performance as well as reduced cost, more research is needed to know and avoid possible negative environmental effects. The study analyze an exploratory research design focused on postulate development. The information and data were gathered from a variety of associated academic works that were accessed using the appropriate keywords. The current paper discusses the fundamental principles of green chemistry (GC) that affect the entire life cycle (LC) of nano-products, from layout to disposal. In the context of the principles of GC for sustainable development, the different applications as well as constraints of GN have been mentioned. The implementation of advanced technology under the Sustainable Development Goals (SDG), inspiration to adopt GN industries globally, and prospective viewpoints were also presented in this paper. This article indicates that implementing life-cycle thinking to notify design of the product, integrating life-cycle as well as risk evaluation, implementing sustainable manufacturing practices, and utilizing GC options are all alternative options for the global ecosystem. In this article, NT applications are used to fix environmental concerns, including the potential to reduce overall consumption of energy during the synthesis as well as production processes, the ability to reuse goods after using them, and the development and use of eco-friendly components. Additionally, this article suggests that nations should promote NT experiments through increasing insight into potential applications, enhancing NT training and education at the elementary and secondary school levels through the creation of NT increasing popularity initiatives, and inspiring companies from various enterprises to conduct manufacturing studies that use their financial gains and CSR funds, while also offering some tax incentive practices.

KEYWORDS: Green Chemistry, Nanotechnology, Sustainable Development, Global, Environment, Sustainable Development Goals (SDG)

I. Introduction

NT is now regarded as an all-pervasive facilitating technology [Fleischer 2008] which cuts across industry boundaries and actually results in new nanomaterial applications which assure drastic advancements in a variety of areas. Nanoengineered batteries, for example, are paper-thin and high-energy. Such sheets of nanocomposite paper, which can be rolled up as well as cut like paper and therefore are instilled with carbon nanotubes, represent ultra-thin, adaptable batteries & energy storage systems for next-generation devices and implantable medical devices [Mullaney 2007]. Nano-enabled miniaturized diagnostic equipment can be placed in the bodies of human beings for early disease detection, and NT for in-vivo delivery of drugs as well as imaging equipment is constantly emerging [Koo 2005]. Nano-based adhesives can improve implant biocompatibility and bioactivity [Commission Communication 2004], and nanocoatings are used in water and dirt repellency, corrosion resistance, heat resistance, and anti-microbial tools.Applications of NT which actively improve the environment include site remedial action and treatment of wastewater [Watlington 2005], solar cells based on nanomaterials for energy efficiency improvements, usage of nanocatalysts for cleaner air [Sinha 2007], as well as nanostructured filtration or nanoreactive membranes for purifying water [Theron 2008].

Despite the obvious benefits of NT, there may be unanticipated human health and environmental issues associated with the widespread use of nanomaterials which have yet to be fully understood. There is a necessity for using a life-cycle systematic model, presumably in conjunction with risk analysis, as mentioned in the preceding sections. To attain an understanding of the potential challenges and to applying green nanomanufacturing methods that are less harmful to the environment and to people's health. The purpose of this article is to illustrate significant applications of GN in SD and their effects on the global environment, which are discussed in the following subsections:

A. Concept of Green Nanotechnology (GN)

GN is described as the technology which is used to create sustainable methods so as to minimize people's health as well as possible environmental dangers. It has to do with NT goods as well as the production methods. GN promotes the use of current products in the establishment of innovative nanoproducts. The innovation of modern nanoproducts benefits the environment. (Smith, 2011). The introduction of innovative nanoproducts benefits the environment [Smith 2011]. The word "technology" refers to the pragmatic application of knowledge. GN incorporates a continually changing series of techniques as well as components, ranging from energy generation strategies to non-toxic cleaning agents [Fleischer, & Grunwald, 2008]. The current assumption is that this domain will generate about similar levels of innovation and creativity in everyday lives as the 'information technology' boom during the last 2 decades [Karn 2008]. It is hard to anticipate what 'green nanotechnology' will ultimately include in this preliminary phase [Palak 2018].

B. Main Objective of GN

In contrast to current manufacturing techniques, the main objective of GN is to develop technologies that enable the manufacturing of nano-pigments in substantially more environmentally friendly manner by applying significantly more eco - friendly materials.GN must seek to attain the following objectives so as to attain the following goals:

- Nano-pigment preparation depending on using nanoclays as well as preferred natural as well as synthetic colorants [Clarke, & Anliker, 1980];
- Techniques for improving the light-fastness, temperature resistance, fatigue process, as well as dispersibility of hued nanoclays;
- Surface treatment techniques for nanoclays for better colorants compound fixation;
- The use of green and sustainable nano-pigments throughout photovoltaic equipment;
- Green and sustainable nano-pigments' use in colorants, paints, as well as adhesives [Bamfield, & Hutchings, 2010];
- Impact on the environment of greener nano-pigments is being assessed;
- Commercialization and spread of greener nano-pigments.

C. Green Chemistry (GC)Principles

The mentioned list, established by Paul Anastas & John Warner, explains an initial notion as to what would create a green and sustainable compound, procedure, or commodity [Anastas, & Warner, 1998].

1. It is preferable to minimize waste rather than clean up or treat wastes that has already occurred.
2. Synthetic techniques must be developed by integrating all components used throughout the procedure as much as possible into the finished product.
3. Wherever possible, synthetic techniques must be crafted to apply as well as produce compounds which are safe for human health and environment.
4. Chemical components must be crafted to perform their intended function while being as non-toxic as possible.
5. The utilization of auxiliary materials (for example, solvents, separation agents, and so on.) must be avoided whenever possible and produced innocuous when appropriate.

6. Chemical procedure energy demands must be recognized for their economic & environmental implications and must be minimized. If at all feasible, synthetic techniques must be carried out at room temperature as well as pressure.
7. Once economically & technically feasible, a feedstock or raw materials must be renewable instead of depleting.
8. If possible, useless derivatization (usage of blocking clusters, protection or deprotection, transitory alteration of the process of physical or chemical) must be reduced or avoided, as these procedures need more solvents and therefore can produce waste.
9. Catalytic reagents that are as selective as possible outperform stoichiometric reagents.
10. Chemical goods must be planned in such a manner that they degrade into harmless degradation goods and so don't continue to exist in the environment after they have served their purpose.
11. Analytical techniques must be improved to enable real-time, in-process control and monitoring leading to the advent of toxic chemicals.
12. In the process of chemical, compounds and their forms must be selected to reduce the risk of chemical collisions, such as discharges, explosions, as well as fires.

D. Environmental Issues & Nanomanufacturing Techniques

One of two strategies to nanoscale production exists: top-down or bottom-up.The top-down process begins with microsystems as well as miniaturizes them using carving or grinding techniques like etching, lithography, as well as milling.Bottom-up methods imitate nature by beginning at the molecular or atomic level and progressing via precipitates and/or development from solid, liquid, and gas precursors via chemical reactions as well as physical methods.Epitaxy and sol-gel are two instances of methods [Communication from the Commission 2004, Sengul 2008].It is commonly known that top-down approaches certainly make more wastes.However the bottom-up method is still in its initial phases of development, it seeks to revolutionize existing manufacturing techniques.

One-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) nanostructured materials exist (3D).Thin films & coatings are instances of 1-D nanoproducts, whereas nanorods &nanotubes are illustrations of 2-D nanoproducts, while fullerenes & nanoparticles are instances of 3-D nanoproducts.In general, the manufacturing of 2-D & 3-D nanoproducts has stringent authenticity prerequisites. Several of the materials used to create them have lower processing yields and, as a matter of fact, reduced material efficiencies, leading to increased waste.Furthermore, such procedures typically consume massive amounts of water, energy, as well as solvents. Aside from being energy as well as resource-intensive, a few of these procedures have the possibility of triggering unplanned acute and long-term human health effects as a result of inadvertent exposure of nanomaterial. The article "Towards sustainable nanoproducts: An overview of nanomanufacturing methods" by Sengul et al. [2008] looked into the problems involving nanomanufacturing techniques for one-dimensional, two-dimensional, as well as three-dimensional (3D) nanostructured substances in detail. As nanomaterials are becoming more commonly accessible and proceed to replace conventional elements in goods, their production is expected to increase.As presented in the following research study, the starting substances used during production methods are typically infrequent and require resource intensive retrieval or processing, putting extra pressure on natural resources as well as greatly increasing the LC environmental effect of the product they are eventually used in. This brings up the question of creating appropriate starting components for nanomanufacturing processes.

D. Applications of NT and its Environmental Impact

Nanotechnology's wide-ranging applications have the possibility to hinder human health and environment through a variety of nanoparticle route of exposure [Curran 2007], comprising occupational exposure [Boccuni 2008]. Despite initial calls to take steps to make sure the long-term viability of nanotechnology, very little can be done so far in the never-ending search to implement ever more new nano-applications [Allenby and Rejeski 2008]. The Life-Cycle Assessment (LCA) refers to a useful instrument for evaluating the environmental issues linked to a product's entire life cycle. In reality, making assertions about the environmental advantages of a product or production process before even contemplating its environmental implications in the context of its LC would be premature.

An LCA generally entails the following stages:

(1) Describing the assessment's applicability and purpose.

(2) Measuring the input of energy and materials, and the environmental outputs, for every unit operation included in the evaluation. Also, called Life-Cycle Inventory (LCI).

(3) Assessing the prospective health of humans as well as environmental consequences of the inputs & outputs indicated during the LCI data gathering phase.

(4) Defining the findings, emphasizing critical points, making judgments, and providing suggestions [National Risk Management Research Laboratory 2006].

Extraction of materials, Preparation, Production, Usage, Transportation, as well as End-of-Life (Recycling or Discarding) are the phases of the LC that are generally regarded.

Implementing a LCA of traditional products is a difficult task in and of itself, with boundaries frequently drawn to restrict the assessment scope so as to complete it in a timely manner with limited resources.The following are some of the approaches to reduce the assessment scope (also called LCA streamlining):

(i) Limiting it to specific LC phases of interest, like the Use phase.

(ii) Defining important environmental evaluation metrics, like Global Warming.

(iii) Simply comparing two distinct production procedures which result in the development of otherwise similar items.

Since there is a lack of inventory information on nanomaterials, implementing LCA becomes even more challenging [Meyer 2009]. This is due to the absence of accessible inventory information on such materials, as well as the fact that their production methods are innovative and quite often subject to secrecy restrictions. Another possible explanation for not being able to use inventory relevant information in a relatively similar manner to traditional techniques is that mass-based cutoffs for nanoparticles are ineffective [Curran 2007]. Furthermore, because the human health and environmental consequences of nanomaterials are still not completely understood, prevailing impact analysis techniques don't include formulas for calculating them. Furthermore, production methods for nanomaterials aren't yet standardized, but are in a stage of evolution, adjusting on a regular basis. As a result, the environmental effects related to production process A may differ significantly from those related to production process B for a specific product. In the particular instance of new innovations in the development stage, like these, it may be useful to perform situation assessments while conducting LCAs to discuss uncertainty and risk in prospective outcomes.

Despite the difficulties in performing LCAs of nanomaterials [Khanna 2007; Krishnan 2008; Lloyd 2003; 2005; Osterwalder 2006; Roes 2007], a majority of LCAs have been repeatedly tried. It's necessary to keep in mind a life-cycle approach to new technologies like these in order to uncover any problems or questions which may be hidden at first in any of the upstream or downstream phases. This thinking approach should be used at the beginning of the development process of the product so as to understand better the environmental impact of emerging technologies and make intelligent choices about the advantages and disadvantages of one option over the other. Multiple proposals have been made to implement the thinking approach of the LC to the development of NT [Curran 2007, von Gleich 2008; Bauer 2008; Köhler 2008].

E. Green Nanotechnology's Prospects for Solving Problems

Given that the manufacturing of nanomaterials may be environmentally harmful as well as the possibilities for health and safety issues, it is critical that we investigate the tradeoffs by evaluating the positive aspects of nano-based goods against their undesirable consequences. The concern is exacerbated by the fact that current policies only apply to traditional chemical compounds, and manufacturers are not required to define nanomaterials in their goods [Som 2010]. Green and sustainable nanosynthesis techniques, referred to as "Green Alternatives," and assessment paradigms that integraterisk assessment (RA)&LC such as Life Cycle Risk Assessment (LCRA) and Comprehensive Environmental Assessment (CEA), are two possible alternatives.

The following recommendations of GC, as highlighted by the US Environmental Protection Agency (EPA) on their GC webpage can be applied to nanomanufacturing procedures, according to Michael Berger of Nanowerk LLC [2010].

- Create waste-free chemical syntheses.
- Make chemicals as well as products that are more environmentally friendly.
- Create less dangerous chemical syntheses.
- Utilize renewable raw materials as well as feedstocks.
- Utilize catalytic reactions to reduce waste.
- Chemical compounds should be avoided.
- Increase the atom economy as much as possible.
- Safe solvents as well as reaction conditions should be used.
- Improve your energy effectiveness.
- Create chemicals as well as products that are biodegradable after using it.
- Real-time analysis is required to pollution problems.
- Reduce the likelihood of mishaps.

It is only possible to apply and recognize these techniques in production when all interested parties are engaged in the process of decision-making.These process measurements as well as GC metrics are used to assess the merits and disadvantages of production alternatives [Naidu 2008].James Hutchison, director of the world's largest GN project, the Safer Nanomaterials and Nanomanufacturing Initiative (SNNI), suggests a three-phased approach to NT Environmental Health and Safety (EHS) studies [Hutchison 2008].

- Phase 1:Research on the effects of Nanomaterial
- Phase 2: Coordinated applications &repercussionsstudy.
- Phase 3: Amethod focusing on green nanoscience to process &material design to removerisksduringLC of the materials.

While investigation is presently being conducted in each of the 3 phases listed above, the majority of the studies nowadays being conducted is transforming from Phase 1 to Phase 2, with tasks in Phases

2 and 3 just getting started.Concentrating on Phase 3 development, which is a much more proactive strategy that targets the root cause of the problem, will yield the greatest benefit.Since most nanomaterials syntheses start with famous dangerous chemicals as solvents or raw materials, which inflict extra environment effects linked to nanomaterials as well as nanoenabled goods, it thus leads to reduce EHH implications from the procedure of production itself or assist us concentrate on the environmental consequences of nanomaterials as well as nanoenabled goods.If managing components used throughout the manufacturing of nanomaterials causes health and/or safety issues, we must investigate the tradeoffs and see whether appropriate manufacturing techniques can be applied.Green chemistry-based procedures include the following [Dahl 2007]:

1. Electrochemical techniques as well as Microcapillary & Integrated Microchannel reactors which use the least amount of reactants,solvents, as well as processing times.
2. Microwave as well as sonochemistry-based methods as energy sources that reduce processing times as well as energy usage.
3. Eco friendly solvents such as Ionic Liquids, Supercritical Fluids (SCF), and mixtures of organic solvents &SCF.
4. The usage of microorganisms to expand nanomaterials in a biomimetic or biosynthetic manner.

Even if attempts at making nanomanufacturing procedures more environmentally friendly are currently ongoing, they must be aligned with the initiatives of LCA professionals as well as product developers who are examining the repercussions of such substances in nano-enabled goods.

F. Relation of LCRA&its Environmental Effect

There is unquestionably a need to properly address the human health effects of nanomaterial use. Moreover, as previously stated, existing LCA technique has its drawbacks.For example, existing LCA technique makes no distinction between nanoparticles and composite materials. Furthermore, environmental levels are used to characterize the impacts on human health and environment in Step 3 of the LCA methods (Impact Assessment).To put it another way, EHH effects are measured throughmetrics depends on the quantity of toxins released into the water,air, as well as land.This means that LCA can only reach the conclusion that less is preferable while tradeoffs are concerned [Matthews 2002], or not if one specific consequence is more considerable than the other.[US EPA 2010] RA aids in comprehending the significance and potential negative health effects of toxic substance and other toxin exposure.Through multiple exposure routes, RA progresses from the quantity of toxins released to analyze their consequences under atmospheric temperatures.An method which integrates LCA as well as RA is inclined to work well during the situation of nanomaterials, where, in particular with respect to amount, extra variables like particulate size as well as surface area play an important role in impacting people's health; because although they confront similar difficulties in terms of information discrepancies for nanomaterials, they supplement one another [Savolainen 2010; Olsen 2001].The ten-step framework of Nano LCRA for nanomaterials, an initial phase which includes the following, is however one method that integrates LCA as well as RA [Shatkin, Rajive Dhingra].

1. Define the product's life cycle.
2. Recognize the components and evaluate possible dangers during every stage of the life cycle.
3. Perform a qualitative risk assessments for materials during every stage of their life cycle.
4. Decide at what point in the LC exposure is likely to happen.
5. Identify possible human as well as non-human toxic effects at important aspects in the product's LC.
6. Evaluate risk prospects for identified LC stages.
7. Highlight relevant complexities and incomplete data.

Comprehensive Risk Assessment (CRA) is another method which integrates the impact on the environment concentrate on LCA with the exposure emphasis of RA and contains acute toxicity of nanomaterials.Davis [2007] proposes a general premise to summarize the CRA approach.It starts with a qualitative explanation of the product's life cycle, laying the groundwork for thoroughly characterizing the prospective multimedia effects of nanomaterials.The exposure routes of primary as well as secondary pollutants would then be recognized. An assessment of the impact on human beings and ecosystems is the final step in the procedure.None of the aforementioned consolidated approach conceptual model studies were found to have been carried out. This is due to the fact that nanomaterials don't yet have sufficient inventory data and effect as well as risk characterization techniques haven't been formed.Using a consolidated LCA-RA method to evaluate the EHH repercussions of nanomaterials in the long term would be extremely beneficial.LCA as well as RA professionals can help improve overall if they work together more intently in the coming years, particularly in the aspect of nanomaterials.

G. Implementation of Appropriate Technology in the Context of SDGs

Implementation of appropriate technology as well as strategic management of it to fix global problems in society is urgently required. The United Nations, which has a multi-country membership, declared seventeen SDGs in 2015, with the motto "Action to End Poverty, Protect the Planet, and Ensure Peace and Prosperity by 2030."Nanotechnology, which is regarded a 21st-century technology, is said to be capable of achieving 13 of the seventeen SDGs by 2030[Colglazier, 2015; Aithal, & Aithal, 2019].The following are among the thirteen SDGs: Reduce the number of people living in poverty, Minimize Hunger, Wellness & good health of the people, Sanitary facilities & Safe Drinking water, Affordable renewable energy, Industrialization with a Long-Term Perspective, Ensure Long-Term Production and Consumption, Climate Change Defense, ProtectMarine Resources & Ocean, as well asProtect land-based life [Shubhrajyotsna Aithal & Aithal, 2021].

Table 1: Technology generations and their applications [Aithal, & Aithal, 2016a]

Technology Generation with Time period	Name & Characteristics
First Generation (4,000-2,800 BC)	Mechanization: Characteristics – Tools, Weapons, and Printing (Knowledge Era)
Second Generation (18thC)	Steam Engine Technology: Characteristics – Industrial Revolution (Industrial era)
Third Generation (19thC)	Electricity Technology: Characteristics - Power generation & Usage
Fourth Generation (20thC)	Automobile Technology: Characteristics - Long distance commuting & transportation
Fifth Generation (20thC)	Airplane & space Technology: Characteristics – International Travel & Transportation
Sixth Generation (20thC)	Telephone Technology: Characteristics – Distance communication
Seventh Generation (20thC)	Television Technology: Characteristics – Video communication
Eighth Generation (20thC)	Computer Technology: Characteristics - Data Processing
Ninth Generation (20thC)	Internet Technology: Characteristics - Data & Information Communication, E-business
Tenth Generation (20thC)	Mobile Communication & Biotechnology: Characteristics - Ubiquitous communication & Bio-engineering, Gene Therapy
Eleventh Generation (21stC)	ICCT underlying Technologies: Characteristics – Ubiquitous computing & Communication, and Total Automation

Twelfth Generation (21^{st}C)	Nanotechnology: Characteristics - Solutions to nutritious food, drinking water, renewable energy, Nanomedicine & Therapy

Numerous technologies found applications in specific fields or industries, and thus were dubbed General-Purpose Technologies (GPTs) [Aithal, & Aithal, 2018a;2020;2021]. Table 1 demonstrates the effects of multiple technology generations as well as the time frame during which they were efficacious. Implementation of appropriate technology and strategic management of it to fix global social problems is a must [Aithal, & Aithal 2019a,b].Information Communication & Computation Technology (ICCT) as well as Nanotechnology(NT) are the $11^{th}$and 12^{th}technology generations of the 21^{st}century.ICCT is able of providing optimal solutions in firms that depend on service [Aithal, & Aithal 2019c-g, Ganesh. & Aithal, 2020; Aithal, 2018b] as well asNanotechnology has the potential to provide the best solutions for the industrial sector [Aithal, & Aithal 2016b-e; 2018d-e]. Additionally, NT provides support to

1.	Essential requirement-based issues	(i) Enhancing natural as well as artificial agricultural production to provide nutritional meals to all. (ii) Providing access to clean drinking water & irrigation water. (iii) Energy generated from renewable sources that can be used in everyday life. (iv) Safety shelters (v) Health care facilities that can be afforded.
2.	Amenities designed to meet specific needs in order to have a comfortable environment for pleasure	(i) Communication (ii) Transportation (iii) Entertainment (iv) Computation (v) Smart homes (vi) Education (vii) Healthcare facilities that are comfortable
3.	Desires which are dreamy	(i) Chameleon chips (ii) Embedded intelligence

		(iii) Optical computation (iv) Travel to Space (v) Super intelligent devices (vi) Regeneration of Organs (vii) Projected immortality

GN practices reduce the risk of negative health and environmental consequences, ensuring that life on Earth will continue to exist.Such environmentally friendly technologies will not leave a trace of any chemical methods that were used [Aithal & Shubhrajyotsna Aithal 2021]. This also diminishes the yield of greenhouse gases during production methods, encourages the use of organically grown resources, and does not add to the universe entropy.Each method which does not necessitate human involvement can be automated using green technologies.

H. Green Technology (GT) in the Twenty-First Century: Opportunities and Challenges

Key problems of NT, their strategic management, and a design as to how green as well as efficient and environmentally NT can be applied in numerous businesses to achieve these 13 out of 17 SDGs and remove the risk of technification of development efforts were formed.Shubhrajyotsna Aithal & Aithal, (2021) went into great detail about the beneficial properties of systematic management of green as well as efficient and environmentally NT in the context of attaining personal sustainability targets.It is also examined how the notion of attaining global SDGs utilizing efficient and environmentally GN can be evaluated using exploratory study methodology's forecasting analytical framework.Aithal et al. (2021) investigate the present situation in the field of GN.The advantages and disadvantages of applying NT as a green and environmentally friendly technology are described and analyzed in light of the assessment and comprehension of multiple environmental destruction problems.Additionally, the Opportunities and Challenges for GT in the Twenty-First Century are examined through a comprehensive study [Aithal, & Aithal, 2016].If the United Nations encourages NT experiments through increasing youth knowledge as well as sufficiently financing research in various fields pertaining to SDGs, the objectives can be met by 2030.The parts of NT include the following:

Nanomaterials Design Technology	Nanomaterial fabrication
Nanomechanics technology	Nanomaterials

	characterization
Nanoelectronics Technology	Nanophotonics Technology
Nanomedicine	Nanobiotechnology

All of these are predicted to change the conditions of development games in all member nations by 2030in a variety of ways [Aithal, 2021b]:

- Agriculture & food industry
- Systems of water supply [Aithal & Aithal, 2018f]
- Automobiles that are fuel-efficient [Aithal, & Shubrajyotsna Aithal, 2021]
- Renewable energy systems [Aithal, & Shubrajyotsna Aithal, 2021a; 2018g]
- Space vehicles
- Optical computers with great velocity
- Low-cost, long-lasting shelters
- Embedded intelligence
- Solutions to healthcare & Medical [Architha Aithal & Aithal,. 2018i; Aithal, 2021c]

This will enable humans in becoming ubiquitous and will offer people with fully automated goods and services, thereby serving as a cornerstone of social, technological, as well as economic evolution [Shubhrajyotsna Aithal & Aithal, 2021a]. For example there are some initiations towards futuristic sustainable approach:

1.Evaluation of photodetection properties

Keng-Te Lin, Han Lin and Baohua Jia (2020) provided guidance towards integration of plasmonic nanostructures for functional devices for both academic researchers and engineers in the fields of silicon photonics, photodetection, sensing, and energy harvesting. Three main characteristics of plasmonic nanostructures, including the enhancement of electric field around antennas, the generation of hot electrons in a metal film, and thermoplasmonic effects occurring when the incident light propagates through the plasmonic nanostructures. Such attractive properties of plasmonic nanostructures suggested that they have a great potential for use in the fields of photodetection, sensing, and energy harvesting

2.Nitroaniline concentration of Ag nanoparticles for Detecting Melamine level in Milk

Silver nanoparticles were prepared by reduction of $AgNO_3$ in dilute aqueous solutions of 4-nitroaniline. The effect of 4-nitroaniline concentration on Ag nanoparticles was investigated, and the sensitivity and selectivity of the prepared Ag nanoparticles solution on the presence of melamine in milk were studied. A color change from yellow to blue was observed with increasing melamine concentration. The characterization methods used were transmission electron microscopy (TEM) and ultraviolet-visible (UV-Vis) spectroscopy. The TEM images indicated that the silver nanoparticles solution consisted of well-dispersed agglomerates of spherical-shaped Ag nanoparticles with an average size of about 32 nm. The plasmon absorption peak of the silver nanoparticles was found at 397 nm. In addition, it was revealed that a sensitive nonlinear correlation existed between the absorbance and the logarithm of melamine concentrations ranging from 50 to 10 ppm(Rana Bagheri, 2012).

3.Hydrogen fuel

There is a rapid increase in the pollution level as the global demand for fossil fuels increases. Burning fossil fuels leads to the release of greenhouse gas and other toxic pollutants into the environment, and that level has reached the limit. For the last few decades, scientists worldwide have been looking for a safe, eco-friendly alternative energy source. One of the prime alternative forms of energy is green hydrogen. The application of nanotechnology in green hydrogen fuel production has increased the possibility of substituting fossil fuels with this sustainable form of energy. Green hydrogen fuel can supply clean power for transportation, manufacturing units, and many other energy-dependent units. Another significant advantage of the production of green hydrogen is that the byproduct of the process is oxygen.

The Future of Green Hydrogen

According to Goldman Sachs, green hydrogen could supply up to 25% of the world's energy needs by 2050. Scientists are working to reduce the cost of green hydrogen fuel production. A current analysis revealed that if the cost of green hydrogen and its derivatives can be lowered to $2/kg, it will be readily used by multiple sectors such as power generation and steel and fertilizer production. Another form of green hydrogen is green ammonia, a potential replacement for fossil fuels in thermal power generation. Green ammonia can significantly decrease greenhouse gasses and other toxic emissions. Scientists believe that increasing the production and utilization of green hydrogen will help achieve net-zero emissions by 2050 and dampen the rise in the world's temperature. Currently, many countries such as Australia, Japan, Germany, and Portugal are involved in developing green hydrogen to minimize the use of fossil fuels(https://www.azonano.com/article.aspx?ArticleID=5654).

Samuel S.Mao (2012) overviewed on nanomaterial designs for selected technologies of renewable energy conversion and utilization, based on the research activities of the Clean Energy Engineering Laboratory in the University of California at Berkeley. The topics include (1) photoelectrochemical

(PEC) water splitting, (2) photocatalytic hydrogen production, (3) solid-state hydrogen storage, and (4) proton exchange membrane fuel cells (PEMFCs). We hope that these concepts of nanomaterial designs will offer a new paradigm for realizing a renewable energy based economy in the not so distant future.

Future of Fuel Cells

Fuel cells are a technology for transforming the chemical energy of a fuel into electricity using redox reactions (usually combining hydrogen fuel with oxygen from the air). They are different from most batteries, because they require a constant source of oxygen and fuel to sustain the chemical reaction. In batteries, the energy comes from metals and their oxides or ions that are already stored inside the battery; when those materials run out, the battery dies. As long as a fuel cell has a supply of oxygen and fuel, it can keep producing power continuously Posted by gileskirkland (https://sustainable-nano.com/2020/03/30/nanotechnology-and-the-future-of-fuel-cells/).

4 Nanobiology/ nanomedicine

Nanoparticles (NPs) are key components of nanomedicine, and currently, a large variety of nanoparticle types exist. However, no standardized nomenclature exists in the literature; therefore, terms such as engineered nanomaterials, nonbiological complex drugs (NBCDs), nanomedicals/nanomedicines, etc. are used freely. Many nanomaterials can replicate some functions of globular biological macromolecules. Examples are lipid micelles, different polymeric nanostructures, protein constructs, ribonucleic acid (RNA) NPs (RNPs), carbon dots (C-dots), nanodiamonds (NDs), carbon nanotubes (CNTs), graphene, as well as inorganic materials such as mesoporous silica NPs (MSNP), superparamagnetic iron oxide NPs (SPIONs), quantum dots (QDs), plasmonic NPs, gold nanoclusters (GNCS), upconverting NPs (UCNPs),etc. Research in nanomedicine spans a multitude of areas, including drug delivery, vaccine development, antibacterial, diagnosis and imaging tools, wearable devices, implants, high-throughput screening platforms, etc. using biological, nonbiological, biomimetic, or hybrid materials. Many of these developments are starting to be translated into viable clinical products. Here, Beatriz Pelaz et al., (2017) provided an overview of recent developments in nanomedicine and highlight the current challenges and upcoming opportunities for the field and translation to the clinic..

I. Global motivation to create GN industries and their current situation

GN in industries:The possibilities for commercializing NT for green innovation has gained considerable attention in current years as NT research begins to be applied in a variety of concrete applications.As a consequence of elevated energy shortfall as well as global climate change, nations are charging much greater focus to energy efficient technologies including the use of GT in the industry [Ahuja 2009].Whenever green synthesis nanomaterials supplanted current constituents in goods, innovative foods were crafted through green engineering principles, and cleaner nano-based production methods were implemented, a new industrial ecosystems could appear in the long-term [Weisner 2005].

Large businesses adopting GT in India:Numerous developed nations around the globe, as illustrated in Table 2, are now empowering the use of GT in industry. Billions of dollars are now started investing in ecofriendly wind as well as biomass initiatives. GT is being developed by both state-owned as well as private-sector ventures [Golub 2011]. Some of them are: Reliance Industries, Wipro Technologies,Idea Cellular,PNB, ITC Limited,ONGC,Hero Honda Motors and Suzlon Energy,Tamil Nadu News Print and Papers Limited,Tata Metallics Limited (TML),IndusInd Bank, HCL technologies, and so on. Furthermore, some global companies areDell, Nokia, Cisco, Intel, and so on.

Table 1: Situation of Businesses Using GT

Industry	**Number of businesses using minimum one GT or practice**
Total, all industries	4,933,500
Agriculture, Forestry, Fishing and hunting	64,600
Mining, quarrying, oil and gas extraction	13,400
Utilities	16,900
Construction	4,03,200
Manufacturing	2,21,700
Wholesale trade	302,400
Retail Trade	712,900
Transportation and warehousing	120,800
Information	94,600
Finance and Insurance	2,94,600
Real estate, Rental or leasing	2,06,700
Professional, scientific and Technical Services	5,40,200
Management of companies and Enterprises	29,500
Administrative and waste services	252,100

Educational Services	114,300
Healthcare and Social services	560,800
Arts and Entertainment	80,200

Source: GT for Sustainable Development, Prem Kumar

Green nanomanufacturing:There is a strong emphasis placed on producing nanomaterials that have minimal or no environmental impact or people's health.Electro spinning could produce starch and protein “nano fibers”. Substantial quantities of biopolymer wastes from the chemical as well as pharmaceutical industrial sectors could be recycled into beneficial biodegradable nanofibres [Zhonghua 2012].

Green synthesis of nanomaterials:The use of water-soluble carbon nanotubes in electronics, thin films, composite materials as well as drug release is green.Biological synthesis is recommended since it can make a lot of nano particles which are free from chemicals and also have a specified morphology and size.We can create green nanoparticles through proteins,microorganisms, viruses,plants, as well as lipids [OECD 2013].

Green nanotechnology in automobiles:Automotive manufacturing companies are concerning NT as a requirement to meet stringent emission standards established by regulators.Nanomaterials-based materials have the ability to reinterpret materials and energy applications due to their accurate constructing as well as outstanding mechanical and physical characteristics.“Their ability to replace expensive platinum in fuel cells that are more environment-friendly than regular gasoline cars, are expected to act in their favor,” said a study from Frost and Sullivan. Consider NanoLub, a lubricant relying on substances found at Israel's Weizmann Institute of Science, which contained inorganic nanotubes as well as nanospheres.[Nano Technology for Green Vehicles] The particles have a particular characteristic of nested realms which lubricate by a special mechanism, significantly reducing wear and friction. Green vehicles, such as hybrids as well as hydrogen cars, will benefit much more. Engineers are now working on hydrogen-storage and reactivity-increasing fuel cells with carbon nanotubes.Green cars, for instance, are complicated goods that integrate GT in a variety of ways, such as in the chassis,tyres, as well as windscreen.It also allows elements of the green car as well as its creation to minimize energy wastages, for instance, by using to observe and minimize energy wastes [OECD 2013].

Nano-enhanced green technologies:Electronic equipment was not previously thought to be main energy consumers when contrasted to heating systems or engines or.Low-power electronics that use energy extractors to transform ambient energy into electrical energy are now being created as innovative zero-power systems (thermic, piezoelectronics,photovoltaics, and so on).

Nano-enhanced cleanup technologies:This includes cleaning as well as remediation of the environment (purification of air &water, treatment of sewage, waste management, as well as environmental remediation). Presently, various GT wastewater treatment techniques are being evaluated and then used, either alone or in combination with other conventional ways.Biofiltration,bioreactors, electro winning, nanobioremediation, as well as electro coagulation are just a few of them [Alex Barshai 2017].

Green nano electronics:The utmost objectives of this paper is to pave the way for the development of human- and eco-friendly electronics, as well as the inclusion of these circuits with living tissue.By categorizing green materials as well as "green" technologies, methods to attain the aspirational sustainability objectives in the electronics sector are being crafted.

(i) Synthetic paths which are both economically viable as well as high throughput while avoiding the use of harmful materials in the manufacturing of digital quality material and therefore don't create hazardous sludge which requires costly processing and disposal.

(ii) In practical systems, low cost routes of processing exist.

(iii) As a device for interconnecting electronics with numerous life forms, make electronics which highlight biodegradability in slight degradation situations at the end of its LC and/or electronics which are appropriate for handling multiple biological features (for example event triggering, transduction, recognition, detecting, etc.)[Mihai Irimia vladu 2014].

Green investments: "Green investments" are tasks that, taken to their broadest interpretation, can benefit the environment directly or indirectly in certain manner.If investors care about the environment and want to support eco-friendly businesses, green investing can be an appealing way of putting their resources to work. Bonds, securities, ETFs, and mutual funds are amongst the alternatives available to investors planning to develop a portfolio.Following are the green mutual funds which are accessible: Social Charity Equality Fund and TIAA-CREF. Governments may issue green bonds to create income for businesses or projects, and all these bonds are often free from tax [Green Investing, Rani and Sridevi 2017].

Some of the difficulties in GT is that the regulatory policy, testing,science, and perhaps even commercial manufacturing processes are all being designed and implemented at the same time [Kira 2011].

J. Obstacles to GN development and commercialization [Kira, 2011]:

- Investigators in the early stages of green nanoscience exploration have no clear defined rules to follow.

- Several green nanomaterials necessitate new commercial manufacturing methods, necessitating more fundamental research, engineering research, and collaboration between the academic and industry groups.
- A scarcity of researchers and technologists with expertise in GN development.
- Toxicology as well as assessment procedures must be established and reviewed on a regular basis to keep up with scientific advances.
- Regulatory unpredictability persists, as well as green technologies frequently face more stringent regulations than current or traditional substances.
- End-market demand is unknown, particularly because there are only a few commercial goods which can be contrasted to traditional components in terms of effectiveness.

K. Benefits and Drawbacksof GN

We looked at 7 NT applications which are relevant to green sustainability and growth after identifying the approaches of NT as well as green sustainable development.Market projections, green advantages, as well as possible problems and drawbacks are used to evaluate such application aspects in order of their scope and scale [Rani and Sridevi 2017].

Benefits

- It makes use of renewable resources which will never run out in nature. As a result, future generations will be able to benefit from them without causing damage to the environment.
- Waste production management, as a result, provides recycling as well as waste disposal options.
- By decreasing carbon dioxide emission levels, it is possible to mitigate the effects of global warming.
- Contribute to the economic well-being of some aspects (Farming).
- A rise in output as well as productivity.

Drawbacks

As the technology advances, more attempt is being put into determining how to evaluate or monitor the implications of NT on particular policy goals like green growth. This is an extremely difficult task.The cost of human as well as environment of not resolving critical international problems should be evaluated against the repercussions of using innovative GN [Miguel de la Guardia 2014]. A few of them include:

- Higher cost in Implementing.

- Absence of Information (There is no clear information on the extent to which research organisations, universities, and businesses are working on this).
- There are no known substitute chemicals or raw materials.
- Ambiguity about the effects on performance.
- A scarcity of human resources as well as expertise

L. Conclusions and Future OutlooksGN innovations to support sustainable developments

Following a review of the literature, we discovered that GN innovations help to reduce poverty by addressing basic needs of citizens in developing nations.GN innovations help to reduce hunger and thirst by increasing food grain production efficiency, either natural or man - made, for all.It also aids in the provision of high-quality health and well-being to everyone around the world by identifying simple and effective medicines for all diseases.GN enables the desalination of seawater through renewable energy and the movement of clouds to preferred places to continue providing safe drinking water for everybody, such as plants, for long-term survival.GN benefits everyone by allowing for more effective processing and storage of renewable energy sources such as solar and wind.GN helps nations increase employment through conducting research and development on a variety of new as well as innovative goods and services in aspects such as basic needs, advanced needs, and dreamy desires, resulting in more employment options.For long-term economic growth, GN promotes sustainable industrial growth in primary, secondary, tertiary, as well as quaternary industries in each and every nation.It promotes economic development in all nations, reducing inequalities between them.By reducing water, air, as well as other pollution of the environment, GN aids in the development of environmentally friendly, clean, as well as safe city areas. GN helps to make sure sustainable production through encouraging the usage of renewable energy & smart materials to make sure that goods and services last as long as possible.It also aids in the reduction of environmental degradation and the combat of global climate change.It contributes to the conservation of ocean as well as marine resources through reducing harmful emissions and toxic effects in the ocean via solar light & temperature-controlled reactions involving appropriate nanomaterials.It helps in protecting life on land by reducing environmental degradation and allowing for large-scale, long-term cleaning of already polluted water and air.It will also regulate greenhouse gas emissions and hazardous chemical generation, safeguarding all forms of life [Shubhrajyotsna Aithal & Aithal, 2021a].

II. CONCLUSION

The topic of this article is GN for long-term development. The advancement of pollution-free techniques for removal of pollutants as well as clean energy equipment is critical for the long-term viability of humankind.New technologies based on NT have the potential to substantially lead to the growth of healthier and more environmentally friendly products and processes.GN applications are being investigated for their possibility give ways to resolve, reduce, and clean up air, water, as well as land contamination, and also to boost the effectiveness of traditional environmental clean-up technologies by 2030, as part of the SDGs.GN is a subset of NT which focuses on long-term sustainable development in a variety of applications.GC principles should be applied to nanomanufacturing techniques, GC metrics should be used to evaluate the sustainability level of nanomaterials as well as nanomanufacturing procedures, as well as accepting a more practical approach while planning new nano-based goods are amongst the suggested methods to keep in mind that nanomaterials have a favourable impact on future areas of application.The potential benefits of NT including efficient production techniques, better environment & water purification mechanisms, effectivesystems of renewable energy, Improvements to the characteristics and properties of physical processes, improvement in health-relateddifficultiesby nanomedicine, improved food processing techniques and improved food nutrition, infrastructure auto-fabrication on a large scale using self-replicating devices, etc.However, if not properly managed with clear knowledge and precautionary measures, it may have possible negative consequences in terms of dangers to health of human beings, the environment, social activities, and the economies of nations.Sustainability as well as long term prospects results of this study may have different timeframes depending on the context of the stakeholders involved.Futures thinking necessitates planning on a hundreds of year time scale, while environmental study may only consider a few centuries at most. The long-term effectiveness of new technology, whether it's genetically modified foods, stem cell investigations, or nanotechnology, is a significant issue these days.

III. SUGGESTIONS

- Developing NT popularization programs to promote NT training and education at the school level.
- Boosting industries from different sectors to begin industrial studies with profits and CSR funds, and also giving tax incentives.
- Increasing the number of patents granted in NT fields through providing extra benefits and shortening the timelines.
- Nation governments must prioritize GN research through establishing distinct NT mission programs and nanoscience &NT Centers of Excellence in all universities & associated research institutions.
- Implementing a single-window model to facilitate national policies on the commercialization of NT goods in various businesses.

REFERENCES

1. Ahuja D, Tatsutani M. (2009) Sustainable energy for developing countries; Sapiens(Surveys and Perspectives Integrating Environmentand society.
2. Aithal P. S. & Shubhrajyotsna Aithal (2016)e. Business Strategy for Nanotechnology based Products & Services. International Journal of Management Sciences and Business Research (IJMSBR), 5(4), 139-149,
3. Aithal P. S., & Shubhrajyotsna Aithal, (2021) Nanotechnology Innovations and Commercialization – Opportunities, Challenges & Reasons for Delay. Proceedings of National Conference on Changing Perspectives of Management, IT, and Social Sciences in Contemporary Environment, 14, 1-12, ISBN 978-93-5265-6523.
4. Aithal, P. S. & Shubhrajyotsna Aithal (2016)f. A New Model for Commercialization of Nanotechnology Products and Services. International Journal of Computational Research and Development, 1(1), 84-93.
5. Aithal, P. S. & Shubhrajyotsna Aithal (2018)c. The Concept & Characteristics of Ideal Energy System and its Realization Constraints. International Journal of Applied Engineering and Management Letters (IJAEML), 2(2), 127-137.
6. Aithal, P. S. & Shubhrajyotsna Aithal, (2016)d. Nanotechnology Innovations & Business Opportunities in Renewable Energy Sector. International Journal of Engineering Research and Modern Education (IJERME), 1(1), 674- 692.
7. Aithal, P. S. & Shubrajyotsna Aithal, (2016)c. Nanotechnological Innovations & Business Environment for Indian Automobile Sector : A Futuristic Approach. International Journal of Scientific Research and Modern Education (IJSRME), 1(1), 296-307.
8. Aithal, P. S. (2018)b. Emerging Trends in ICCT as Universal Technology for Survival, Sustainability, Differentiation, Monopoly and Development. In Proceedings of National Conference on Advances in Information Technology, Management, Social Sciences and Education,(2018), 130-141.
9. Aithal, P. S. (2019)c. Information Communication & Computation Technology (ICCT) as a Strategic Tool for Industry Sectors. International Journal of Applied Engineering and Management Letters (IJAEML), 3(2), 65-80.
10. Aithal, P. S. (2019)g, October)g. Industrial Applications of Information Communication & Computation Technology (ICCT)–An Overview. In Proceedings of National Conference on Recent Advances in Technological Innovations in IT, Management, Education & Social Sciences ISBN (No. 978-81, 941751-6).

11. Aithal, P. S. (2021). Introduction to General Purpose Technologies & Systems. Chapter, 1, 1-24.
12. Aithal, P. S. (2021)b. Ideal Technology & Its Realization Opportunity. Ideal Systems, Ideal Technology, and their Realization Opportunities using ICCT & Nanotechnology, Srinivas Publication, India, (April 2021). ISBN: 978-81-949961-3-2, 83-216.
13. Aithal, P. S. (2021)c. Marching towards technological immortality. Ideal Systems, Ideal Technology, and their Realization Opportunities using ICCT & Nanotechnology, Srinivas Publication, India, (April 2021). ISBN: 978-81-949961-3-2, pp. 386-405.
14. Aithal, P. S. (January 2016)b. Nanotechnology Innovations & Business Opportunities : A Review. International Journal of Management, IT and Engineering (IJMIE), 6(1), 182-204.
15. Aithal, P. S. and Shubrajyotsna Aithal (2016)e. Nanotechnology Innovations and Commercialization – Opportunities, Challenges & Reasons for Delay. International Journal of Engineering and Manufacturing (IJEM), 6(6), 15-25,
16. Aithal, P. S., & Aithal, S. (2016)a. Opportunities & Challenges for Green Technology in 21st Century. International Journal of Current Research and Modern Education (IJCRME), 1(1), 818- 828.
17. Aithal, P. S., & Aithal, S. (2018)a. Study of various general-purpose technologies and their comparison towards developing sustainable society. International Journal of Management, Technology, and Social Sciences (IJMTS), (2018), 3(2), 16-33.
18. Aithal, P. S., & Aithal, S. (2019). Analysis of Higher Education in Indian National Education Policy Proposal 2019 and its Implementation Challenges. International Journal of Applied Engineering and Management Letters (IJAEML), 3(2), 1-35.
19. Aithal, P. S., & Aithal, S. (2019)a. Strategic Management of Universal Technologies for Redefining Productivity & Performance. International Journal of Applied Engineering and Management Letters (IJAEML), 3(2), 81-95.
20. Aithal, P. S., & Aithal, S. (2019)b. Management of Universal Technologies & their Industry Implications. In Proceedings of International Conference on Emerging Trends in Management, IT and Education (Vol. 1, No. 2, pp. 318-328).
21. Aithal, P. S., & Aithal, S. (2019)d. Management of ICCT underlying technologies used for digital service innovation. International Journal of Management, Technology, and Social Sciences (IJMTS), 4(2), 110-136.
22. Aithal, P. S., & Aithal, S. (2019, October)f. Digital service innovation using ICCT underlying technologies. In Proceedings of International Conference on Emerging Trends in Management, IT and Education (Vol. 1, No. 1, pp. 33-63).

23. Aithal, P. S., & Aithal, S. (2020). Conceptual Analysis on Higher Education Strategies for various Tech-Generations. International Journal of Management, Technology, and Social Sciences (IJMTS), 5(1), 335-351.
24. Alex Barshai. Advanced Green Technologies for Wastewater Treatment. (2017).
25. Allenby, B.R.; Rejeski, D. The industrial ecology of emerging technologies. J. Ind. Ecol. 2008, 12, 267-269.
26. Anastas, P. T., & Warner, J. C. (1998). Principles of green chemistry. Green chemistry: Theory and practice, 29-56.
27. Architha Aithal & Aithal, P.S. (2018)e. The concept of Ideal Drug & Its Realization Opportunity using present Pharmaceutical Sciences Scenario. International Journal of Health Sciences and Pharmacy (IJHSP), 2(2), 11-26.
28. Bamfield, P., & Hutchings, M. G. (2010). Chromic phenomena: technological applications of colour chemistry. Royal Society of Chemistry.
29. Bauer, C.; Buchgeister, J.; Hischier, R.; Poganietz, W.R.; Schebek, L.; Warsen, J. Towards a framework for life cycle thinking in the assessment of nanotechnology. J. Clean. Prod. 2008, 16, 910-926.
30. Beatriz Pelaz, Christoph Alexiou, Ramon A. Alvarez-Puebla, Frauke Alves, Anne M. Andrews, Sumaira Ashraf, Lajos P. Balogh, Laura Ballerini,△ Alessandra Bestetti, Cornelia Brendel, Susanna Bosi, Monica Carril, Warren C. W. Chan,$ Chunying Chen, Xiaodong Chen, Xiaoyuan Chen, Zhen Cheng,‡ Daxiang Cui, Jianzhong Du,Christian Dullin, Alberto Escudero, Neus Feliu, Mingyuan Gao, Michael George, Yury Gogotsi, Arnold Grünweller, Zhongwei Gu,& Naomi J. Halas,¤ Norbert Hampp, Roland K. Hartmann, Mark C. Hersam, Patrick Hunziker,Ji Jian, Xingyu Jiang, Philipp Jungebluth, Pranav Kadhiresan, Kazunori Kataoka, Ali Khademhosseini, Jindřich Kopeček, Nicholas A. Kotov, Harald F. Krug Dong Soo Lee, Claus-Michael Lehr, Kam W. Leong, Xing-Jie Liang, Mei Ling Lim,ð Luis M. Liz-Marzán, Xiaowei Ma, Paolo Macchiarini, Huan Meng, Helmuth Möhwald, Paul Mulvaney, Andre E. Nel, Shuming Nie Peter Nordlander,¤Teruo Okano, Jose Oliveira, Tai Hyun Park, Reginald M. Penner, Maurizio Prato, Victor Puntes, Vincent M. Rotello, Amila Samarakoon, Raymond E. Schaak,∀∀ Youqing Shen, Sebastian Sjöqvist, Andre G. Skirtach,ðð Mahmoud G. Soliman, Molly M. Stevens, Hsing-Wen Sung, Ben Zhong Tang, Rainer Tietze,‡ Buddhisha N. Udugama, J. Scott VanEpps Tanja Weil, Paul S. Weiss, Itamar Willner, Yuzhou Wu Lily Yang, Zhao Yue, Qian Zhang, Qiang Zhang, Xian-En Zhang, Yuliang Zhao, Xin Zhou, and Wolfgang J. Parak, Diverse Applications of Nanomedicine, ACS Nano 2017, 11, 2313−2381

31. Berger, M. Nanotechnology—Not that Green? Nanowerk LLC: Berlin, Germany, 2008; Available online: http://www.nanowerk.com/spotlight/spotid=7853.php (accessed on 16 June 2010).
32. Boccuni, F.; Rondinone, B.; Petyx, C.; Iavicoli, S. Potential occupational exposure to manufactured nanoparticles in Italy. J. Clean. Prod. 2008, 16, 949-956.
33. Clarke, E. A., & Anliker, R. (1980). Organic dyes and pigments. In Anthropogenic compounds (pp. 181- 215). Springer Berlin Heidelberg.
34. Colglazier, W. (2015). Sustainable development agenda: 2030. Science, 349(6252), 1048-1050.
35. Communication from the Commission— Towards a European Strategy for Nanotechnology; European Communities: Brussels, Belgium, (2004).
36. Curran, M.A.; Frankl, P.; Heijungs, R.; Kohler, A.; Olsen, S.I. Nanotechnology and Life Cycle Assesment—A Systems Approach to Nanotechnology and the Environment; Woodrow Wilson Center for Scholars: Washington, DC, USA, (2007).
37. Dahl, J.A.; Maddux, B.L.S.; Hutchison, J.E. Toward greener nanosynthesis. Chem. Rev. 2007, 107, 2228-2269
38. Davis, J.M. How to assess the risks of nanotechnology: Learning from past experience. J. Nanosci. Nanotechnol. (2007), 7, 402-409.
39. Fleischer, T., & Grunwald, A. (2008). Making nanotechnology developments sustainable. A role for technology assessment. Journal of Cleaner Production, 16(8), 889-898.
40. Fleischer, T.; Grunwald, A. Making nanotechnology developments sustainable. A role for technology assessment? J. Clean. Prod. (2008), 16, 889-898.
41. Future of Fuel Cells, Posted by gileskirkland, https://sustainable-nano.com/2020/03/30/nanotechnology-and-the-future-of-fuel-cells/).
42. Ganesh H. R. & Aithal, P. S. (2020). Inappropriate Adaptation of Information Communication and Computation Technologies (ICCT) by Indian Brick-and-Mortar Lifestyle Retailers–Insights from an Experiment. Information, Communications and Computation Technology (ICCT) The Pillar for Transformation" edited by PK Paul et al. published by New Delhi Publishers, New Delhi, India, 29-44.
43. Golub, SS, C Kauffmann, P Yeres. Defining and Measuring Green FDI: AnExploratory Review of Existing Work and Evidence.OECD Working Paperson International Investment, (2011).
44. Green Investing. Rani K and Sridevi V, An Overview on Role of Nanotechnology in Green and Clean Technology, Austin Environ Sci. (2017); 2(3): 1026.

45. Hutchison, J.E. Greener nanoscience: A proactive approach to advancing applications and reducing implications of nanotechnology. ACS Nano (2008), 2, 395-402.
46. Karn, B. (2008). The road to green nanotechnology. Journal of Industrial Ecology, 12(3), 263-266.
47. Keng-Te Lin, Han Lin and Baohua Jia, Plasmonic nanostructures in photodetection, energy conversion and beyond, Nanophotonics 2020; 9(10): 3135–3163.
48. Khanna, V.; Bhavik, B.; Lee, L.J. Life Cycle Energy Analysis and Environmental Life Cycle Assesment of Carbon Nanofibers Production; IEEE International Symposium on Electronics & the Environment: Orlando, FL, USA, (2007); pp. 128-133.
49. Kira JM Matus, James E Hutchison, Robert Peoples, Skip Rung, Robert LTanguy. Green Nanotechnology Challenges andOpportunities. ACS GreenChemistry. (2011).
50. Köhler, A.R.; Som, C.; Helland, A.; Gottschalk, F. Studying the potential release of carbon nanotubes throughout the application life cycle. J. Clean. Prod. (2008), 16, 927-937.
51. Koo, O.M.; Rubinstein, I.; Onyuksel, H. Role of nanotechnology in targeted drug delivery and imaging: A concise review. Nanomedicine (2005), 1, 193-212.
52. Krishnan, N.; Boyd, S.; Somani, A.; Raoux, S.; Clark, D.; Dornfeld, D. A Hybrid Life Cycle Inventory of Nano-Scale Semiconductor Manufacturing. Environ. Sci. Technol. (2008), 42, 3069-3075.
53. Lloyd, S.M.; Lave, L.B. Life cycle economic and environmental implications of using nanocomposites in automobiles. Environ. Sci. Technol. (2003), 37, 3458-3466.
54. Lloyd, S.M.; Lave, L.B.; Matthews, H.S. Life cycle benefits of using nanotechnology to stabilize platinum-group metal particles in automotive catalysts. Environ. Sci. Technol. (2005), 39, 1384-1392.
55. Matthews, H.S.; Lave, L.; MacLean, H. Life cycle impact assessment: A challenge for risk analysts. Risk Anal. (2002), 22, 853-860.
56. Meyer, D.E.; Curran, M.A.; Gonzalez, M.A. An examination of existing data for the industrial manufacture and use of nanocomponents and their role in the life cycle impact of nanoproducts. Environ. Sci. Technol. (2009), 43, 1256-1263.
57. Miguel de la Guardia. The challenges of green nanotechnology. BioImpacts,2014; 4: 1-2.
58. Mihai Irimia vladu. Green electronics: biodegradable and biocompatiblematerials and devices for sustainable future. RoyalSociety of Chemistry.(2014); 489-736.
59. Mullaney, M. Beyond Batteries: Storing Power in a Sheet of Paper; Rensselaer Polytechnic Institute: Troy, NY, USA, 2007; Available online: http://www.eurekalert.org/pub_releases/2007-08/rpi-bbs080907.php (accessed on 16 June 2010).

60. Naidu, S.; Sawhney, R.; Li, X.P. A methodology for evaluation and selection of nanoparticle manufacturing processes based on sustainability metrics. Environ. Sci. Technol. (2008), 42, 6697-6702.
61. Nano Technology For Green Vehicles.Rani K and Sridevi V, An Overview on Role of Nanotechnology in Green and Clean Technology, Austin Environ Sci. (2017); 2(3): 1026.
62. National Risk Management Research Laboratory. Life Cycle Assessment: Principles and Practice; US EPA: Cincinnati, OH, USA, (2006); EPA/600/R-06/060.
63. OECD Science, Technology and Industry Policy Papers. (2013).
64. Olsen, S.I.; Christensen, F.M.; Hauschild, M.; Pedersen, F.; Larsen, H.F.; Tørsløv, J. Life cycle impact assessment and risk assessment of chemicals—A methodological comparison. Environ. Impact Assess. Rev. (2001), 21, 385-404.
65. Osterwalder, N.; Capello, C.; Hungerbühler, K.; Stark, W. Energy consumption during nanoparticle production: How economic is dry synthesis? J. Nanopart. Res. (2006), 8, 1-9.
66. Palak K. Lakhani, Neelam Jai, Nanotechnology and Green Nanotechnology: A Road Map for Sustainable Development, Cleaner Energy , and Greener World, International Journal of Innovative Science and Research Technology, 3, Issue 1, January – (2018)
67. Rajive Dhingra, Sasikumar Naidu, Girish Upreti and Rapinder Sawhney, Sustainable Nanotechnology: Through Green Methods and Life-Cycle Thinking, Sustainability (2010), 2, 3323-3338;
68. Rana Bagheri,Ahmad Kompany,Nasser Shahtahmassebi, The Effect of 4-Nitroaniline Concentration on Ag Nanoparticles for Detecting the Melamine Level in Milk, October 2012, International Journal of Green Nanotechnology 4(4) DOI: 10.1080/19430892.2012.738579
69. Revathi, R., & Aithal, P. S. (2019)e. A Review on Impact of Information Communication & Computation Technology (ICCT) on Selected Primary, Secondary, and Tertiary Industrial Sectors. Saudi Journal of Business and Management Studies, 4(1), 106-127.
70. Roes, A.; Marsili, E.; Nieuwlaar, E.; Patel, M. Environmental and cost assessment of a polypropylene nanocomposite. J. Polym. Environ. (2007), 15, 212-226.
71. Samuel S.Mao, Shaohua Shen, Liejin Guo, Nanomaterials for renewable hydrogen production, storage and utilization, Progress in Natural Science: Materials International, Volume 22, Issue 6, December 2012, Pages 522-534
72. Savolainen, K.; Alenius, H.; Norppa, H.; Pylkkänen, L.; Tuomi, T.; Kasper, G. Risk assessment of engineered nanomaterials and nanotechnologies—A review. Toxicology (2010), 269, 92-104.

73. Sengul, H.; Theis, T.L.; Ghosh, S. Toward sustainable nanoproducts: An overview of nanomanufacturing methods. J. Ind. Ecol. (2008), 12, 329-359.
74. Shatkin, J.A. Nanotechnology: Health and Environmental Risks; CRC Press/Taylor & Francis Group: Boca Raton, FL, USA, (2008); p. 167.
75. Shubhrajyotsna Aithal & Aithal, P. S. (2018)d. The Realization Opportunity of Ideal Energy System using Nanotechnology Based Research and Innovations. International Journal of Advanced Trends in Engineering and Technology, 3(2), 1-15.
76. Shubhrajyotsna Aithal & Aithal, P. S. (2018)g. The Realization Opportunity of Ideal Energy System using Nanotechnology Based Research and Innovations. International Journal of Advanced Trends in Engineering and Technology, 3(2), 1-15.
77. Shubhrajyotsna Aithal & P. S. Aithal, (2021)a Green Nanotechnology Innovations to Realize UN Sustainable Development Goals 2030, International Journal of Applied Engineering and Management Letters (IJAEML), 5(2), 96-105.
78. Shubrajyotsna Aithal & Aithal, P. S. (2018)f. Concept of Ideal Water Purifier System to Produce Potable Water and its Realization Opportunities using Nanotechnology. International Journal of Applied Engineering and Management Letters (IJAEML), 2(2), 8-26.
79. Sinha, A.K.; Suzuki, K.; Takahara, M.; Azuma, H.; Nonaka, T.; Fukumoto, K. Mesostructured manganese oxide/gold nanoparticle composites for extensive air purification. Angew. Chem. Int. Ed. 2007, 46, 2891-2894.
80. Smith, G. B. (2011). Green nanotechnology. In SPIE NanoScience+ Engineering (pp. 810402-810402). International Society for Optics and Photonics.
81. Som, C.; Berges, M.; Chaudhry, Q.; Dusinska, M.; Fernandes, T.F.; Olsen, S.I.; Nowack, B. The importance of life cycle concepts for the development of safe nanoproducts. Toxicology (2010), 269, 160-169.
82. The Main Features and Benefits of Green Technology. (2015).
83. Theron, J.; Walker, J.A.; Cloete, T.E. Nanotechnology and water treatment: Applications and emerging opportunities. Crit. Rev. Microbiol. (2008), 34, 43-69.
84. US EPA. Risk Assessment Portal: Human Health Risk Assessment; Available online: http://www.epa.gov/riskassessment/health-risk.htm (accessed on 16 June 2010).
85. von Gleich, A.; Steinfeldt, M.; Petschow, U. A suggested three-tiered approach to assessing the implications of nanotechnology and influencing its development. J. Clean. Prod. (2008), 16, 899-909.
86. Watlington, K. Emerging Nanotechnologies for Site Remediation and Wastewater Treatment; US EPA: Washington, DC, USA, (2005).

87. Weisner Mark. R Vicki. L.Colvin. Environmental Implications of emergingnanotechnology, Environmentalism and thetechnologies of tomorrow:Shaping the next industrial revolution. Washington: Island press. (2005); 41-52.

88. Zhonghua Xu, Scott Lenaghan, David Gilmore, Lijin Xia, Mingjun Zhang.Automated High Throughput Scalable GreenNanomanufacturing forNaturally Occurring Nanoparticles using English Ivy. (2012).