1.2 Carbon Footprint

What is Carbon Footprint?

- The total amount of Greenhouse Gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO_2).
- Sum of all emission of carbon dioxide for a given time frame is referred as Carbon footprint.
- Carbon foot print is also referred as total set of Green House Gas emission caused by an organization, event, product or person.
- It is an extension of "Ecological Footprints".
- The carbon footprint is a very powerful tool to understand the impact of personal behaviour on global warming. Since Carbon dioxide is called greenhouse gas causing global warming.

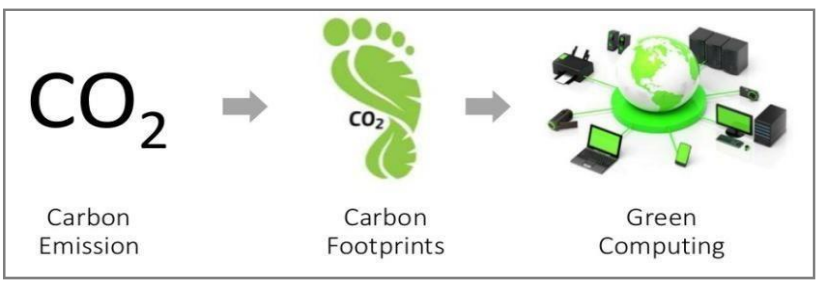

Figure 1.6 – Relation between carbon emission and green computing

- Every time a computer is powered it draws electricity from the power source which is powered by coal, oil or natural gas which releases carbon dioxide.

Energy	Leaving Computers on when not in use
Printing	Unnecessary printing of emails, agendas, drafts etc.
Pollution	Manufacturing techniques, packing etc
Toxicity	Chemical Usage like mercury, lead and cadmium

Table 1 – shows different forms of natural resources wasted

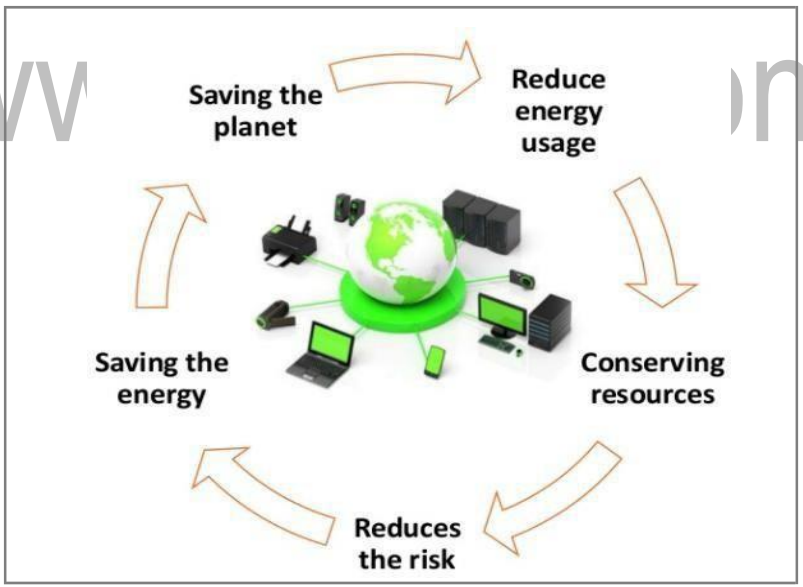

Figure 1.7 –Depicts the relationship between conversing energy and health of planet

- Energy Consumption

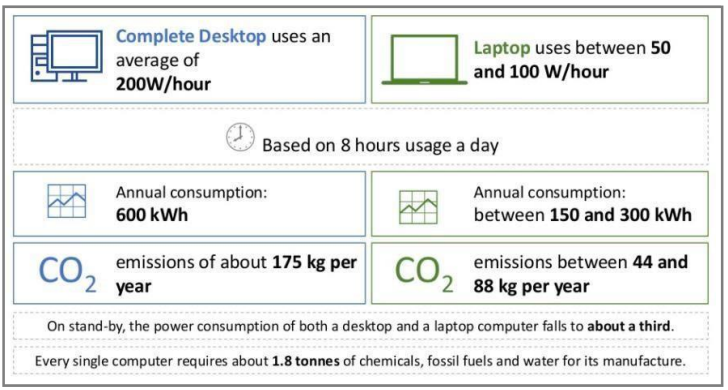

Figure 1.8 – Energy consumption comaprison between desktop and laptop

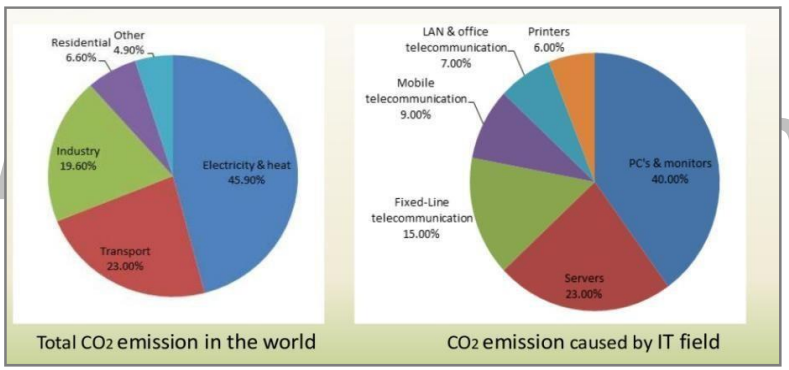

Figure 1.9 – CO_2 emission – world and IT field

Green Manufacturing

Bamboo is becoming increasingly popular in manufacturing casings for computers and peripherals.

Reusable plastic is used in place of non – recyclable plastic.

Flame retardant compounds that are eco-friendly and non-toxic materials are widely used to support implementationof Green IT.

Process of monitoring reduction in the quality of raw material and hazardous materials used in manufacturing consumables.

Segregation of hazardous and non-hazardous materials from disposed components will improve the environment to great extent.

Figure 1.10 – Bamboo Products

Figure 1.11 – Bamboo based computer components

1.5 Green IT - Four Dimensions

Green IT practice translates the green IT strategies, plans, and policies in the day-to-day workings of the organization by using its transformational and operational capabilities. Green IT in practice is based on four distinct yet interrelated dimensions of business: economy (why), technology(what), process (how), and people (who).

1. Economy (Why)

The economic dimension deals with the financial justification for green enterprise transformation. The key practice in this dimension revolves around metrics that enable justification of the investment in green IT initiatives. Following are some of the economic factors appearing in green IT practice:

- **Green ROI metrics justify the business decision to invest in carbon reduction.**

  These are measures that reflect the business value emanating from the costs, effort, and risks in undertaking a green enterprise program. For example, the replacement costs of electronic devices is matched against the power and costs saved over the lifetime of those devices.

- **Metrics that demonstrate the net present value (NPV) of the carbon initiative over a three- to five-year period.**

  In this period, the carbon economy can be expected to be in full swing, and the carbon reduction investments made today will affect the worth of organizations on the stock exchange then (around 2013-15).

- **Incorporation of intangible and/or otherwise non carbon measures, such as organizational image,subtle marketing, and motivated HR, in the overall justification for green IT.**

  For example, the image of an organization as perceived by its customers (or employees) can be measured through a survey and, then, the same image measured again after the green transformation has taken place. The difference in the two views of the organization by its customers can be made to count toward the economic benefits resulting from green initiatives.

- **The comparison of carbon performance across multiple organizations and industry sectors, especially when businesses are geographically dispersed.**

  This comparison facilitates understanding of the economic advantage of green initiatives among competing organizations.

- **The formulation of KPIs (key performance indicators) that provide financial benchmarks indexed to carbon benchmarks.**

  For example, a KPI can be “reduction in scope 2 carbon emissions by 10% per year over the next three years” and can be extended and mapped to “reduction in cost of production by three to five percent per year for the next three years.” KPIs not only measure progress in carbon efficiency but also provide an indication of what needs to change.

- **Carbon trading based on the recording and reporting of emissions.**

  This trade in carbon in a carbon economy on carbon stock exchanges will make use of CEMS, enabling it to mature into systems-based automated trades monitored and enforced by law.

2. **Technology (What)**

The practice of green IT in the technology dimension deals with reduction of emissions from IT equipment, such as monitors, computers, data servers, and network equipments. Examples of the technological dimension of green IT practice include:

- **Sophistication in managing desktops, laptops, and other individual computing devices when not in use.** This includes switching them off when not in use, using a blank screen saver, centralized power management, and use of smart operating systems.

- **Use of smart metering devices** that measure and display emissions in real time and provide feedback andcorrection to the equipment.

- **Printer use in an efficient way** through default duplex printing, default page cap per user, double-sided printing, distance printing (i.e., not have a printer by the side of the desktop), and recycling of ink cartridges.

- **Virtualization and optimization of data servers and desktop machines.**

- **Use of low-carbon-emitting green monitors and computers instead of the aging and high-power-consuming computers.**
- **Implementing basic to advanced carbon emissions management software**[2] for collection and dissemination of standardized carbon data.
- **Preferential use of renewal sources of energy such as solar, wind, and nuclear.** This would be based on increased ease in selecting the source of energy and greater transparency in viewing the effect of the choices through sophistication in carbon reporting systems.
- **Environmental intelligence (EI) comprises technologies like data warehouses, analytical tools, and reporting tools.** This EI will combine existing business intelligence systems and organizational processes with the tacit green knowledge people carry.

3. Process (How)

The process dimension of green IT practice deals with the use of IT systems in improving business processes (e.g., supply chains) and use of standards (e.g., ISO14001). The process dimension in the practice of green IT is affected as follows:

- Business optimization processes such as lean or Six Sigma would be also responsible for carbon reduction.
- Modeling and implementation of new green processes.
- Embedding green organizational policies within the systems that support business processes.

- Collaborative green business processes
- Processes associated with reuse and recycling of equipment that balance the longevity of the equipment and its ongoing power consumption.
- Collaborative business processes, based on Web services that enable support and sharing of carbon reduction across multiple organizations.

4. People (Who)

The people dimension of green IT practice deals with the soft, sociological aspects of changes to the organization. Following are some of the areas associated with people that undergo change in a green IT initiative:

- **Changing customer preferences** with respect to favoring green products and services needs to be considered and incorporated in product and service design, development, and production.
- **Basic training and creation of awareness of environmental sustainability and green IT** among various groups of people, including employees, customer groups, and suppliers.
- **Use of social media networks** that generate public opinion, provide carbon-related information, publicize green standards, as well as facilitate "crowd-sourcing" (e.g., a member of the crowd reporting a wastage such as street lights on during the day, an oil spill in the neighborhood, or unethical dumping of batteries or mobile phones).

1.6 Green IT Goals

The **goal of green computing** is to attain economic viability and improve the way computing devices are used. Green computing practices include the development of environmentally sustainable production practices, energy efficient computers and improved disposal and recycling procedures. There are other goals of green information technology, most notably at the design and manufacturing stages.

In all cases, four main aims are:

- to cut down to as little as possible the amount of energy used.
- to minimize the inclusion of harmful materials.
- to use as many biodegradable materials as possible.
- to extend as far as possible the life of the equipment.

1.6 **Environmentally responsible business policies practices and metrics**

- Sustainable business practices are characterized by environmentally-friendly practices initiated by a company for the purposes of becoming a more sustainable organization.
- These companies aim to reduce their environmental footprint through initiatives that cut down on waste, poor

environmental stewardship and unethical environmental practices that offer a reduced level of sustainability within company practices.

- Sustainable business practices differ among industriesand are often specific to the company type and the product or service it produces.

The **definition of sustainability** is:

"The quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance."

1.7 Sustainable Business Practices

1. Be Intentional About Sustainability

- Sustainability needs to be incorporated into corporate strategies and reflected in **organizational business goals**.
- This means making this a priority in every aspect of organizational operations.
- As with any other business initiative, you need to make a plan of action and assign accountability. Hold people accountable and measure the results

2. Partner with Employees

- Invest the time in **training employees** on the importance of sustaining the environment and share what the organization is doing to help conserve resources.
- Solicit additional ideas from employees for resource conservation.

- ❖ Get an idea about what employees are experiencing and can offer ideas to reduce waste and improve their work environment.

3. **Water and Electric Conservation**

- ❖ Conserving water is something where everyoneparticipate in by reducing the opportunities for wasting this valuable resource.
- ❖ For example, converting to energy-efficient faucets, toilets, and lighting can be a great way to save water, energy, and budget dollars.

4. **Supply Chains**

Statistics show that **customers prefer working with sustainable companies** that are environmentally friendly. Maintain a list of sustainable friendly vendors and make it a priority to only use organizations that embrace sustainable business practices. **Negotiate contracts** with this expectation made clear.

5. **Develop a Recycling Program**

Develop an in-house program for recyclable products like:

- ➢ fluorescent light-bulbs
- ➢ electronics
- ➢ computers and monitors
- ➢ paper products
- ➢ supplies

Use of waste management vendor to help create a process for this.

6. Chemical Management

Chemical impact on environment is been plundered in recent times. Strive to use green cleaning products and non-chemical products for pest control and weed management. Use chemical vendors to help train employees on the proper use and disposal of chemicals.

7. Purchase Only Energy Efficient Products

Use of energy-efficient electronic products and use environmentally friendly settings on office equipment. Choose computer, electronic, and IT acquisition productsthat are **EPEAT** registered to ensure the highest levels of efficiency.

8. Develop Sustainability Work Policies

Develop sustainability **policies and procedures** to reinforce the efforts. Things like, power down equipment at the end of the day and enable energy savings settings on all computers and desktops, are examples of policies that can support the cause. The challenge to sustain the environment can be overwhelming, but if each of the organizations, large or small, does its part, everyone can contribute to conserving this great planet that is home for all living things.

1.8 Metrics used for measuring power consumption in data centres.

a) (TDE) Thermal Design Power

It is the measurement of maximum amount of power required by cooling of computer system to dissipate. It is the maximum amount of power which a computer chip can take when running a real application.

b) (PUE) Power Usage Effectiveness

It is used for comparison of energy used bycomputing application and infrastructure Equipment and the energy wasted in overhead. The PUE can be described as theratio of overall electricity consumed by the facility of a data centre to the overall electricity consumed by IT equipment's (network peripherals, servers, storage, routers, etc.). Value of PUE depends on the location of datacentres and construction done for that Datacentre. Thus it is different for all datacentres.

$$PUE = \frac{\text{Total Facility Energy}}{\text{IT equipment energy}}$$

c) (DCiE) Data centre Infrastructure Efficiency

It is the reciprocal of PUE. PUE and DCiE are most commonly used metrics that were designed for the comparison of efficiency of datacentres.IT Equipment Power can be described as the power that data centre has taken for the management of IT equipment's, processing of IT equipment's and storing the data in disk drives or routing the data within the datacentre. Total Facility Power is IT equipment power plus power needed by uninterrupted power supply (UPS), generators (needed to provide power in case of power failure),Batteries, cooling system components such as chillers, CRACs, DX air handler pumps, units, and cooling towers.

$$DCiE = \frac{1}{\text{PUE}}$$

d) (CPE) Compute Power Efficiency

It is a measure of the computing efficiency of a datacentre. As each watt consumed by server or cluster did not draw fruitful work all the time, some facility consumed power even in idle state and some consumed power for computing. Although 100% of facility capacity will never be used, but the need for maximum output from the electrical power which datacentre has taken. CPE is defined as

$$CPE = \frac{\text{IT equipment utilization}}{\text{PUE}}$$

e) (GEC) Green Energy Coefficient

It is a measure of green energy (energy that comes from renewable sources) that is used by the facility of a datacentre. For evaluating the environment friendly nature of a data centre this metric is used. It is selected as a PUE metric by green grid organization in November 2012.
Energy consumed is measured in kWh. It is defined as

$$GEC = \frac{\text{Green Energy Consumed}}{\text{Total Energy Consumed}}$$

f) (ERF) Energy Reuse Factor

It is a measure of reusable energy (energy that is reused outside of datacentre) that is used by datacentre. For making cloud, environment friendly data centre should use renewable energy such as electricity generated by wind power, hydro power etc. ERF is selected as PUE metric by green grid organization in November 2012. It is defined as

$$ERF = \frac{\text{Reused energy used}}{\text{Total Energy Consumed}}$$

g) (CUE) Carbon Usage Effectiveness

It is a measure of carbon dioxide emission in environment by the data centre. It is selected as a PUEmetric by green grid organization in November 2012. WhereECO2: Total carbon dioxide emission from total energy absorbed by the facility of a data EIT: Total energy consumed by IT equipment's. ECO2 includes all greenhouse gases (GHGs) such as CO2 and methane (CH4) that are emitted in atmosphere. This value is taken for whole year analysis.

$$CUE = \frac{E_{CO2}}{E_{IT}}$$

h) (WUE) Water Usage Effectiveness

It is a measure of required water by a data centre annually. Water is needed - a) For cooling the facility of a data centre. b) For humiliation. c) For apparatus associated power generating d) For production of energy.

$$WUE = \frac{\text{Water Used Annually}}{E_{IT}}$$

Advantages of Green Computing

- Green computing can save energy
- Green computing can save money in the long run

- More sophisticated recycling processes
- Waste reduction
- Reduction of the resource depletion problem
- Less pollution
- Less greenhouse gas emissions
- More efficient hardware use
- Sustainable IT practice
- Increases pressure to go green in the IT industry
- Reduction of health risks for customers
- Better working conditions
- Teleworking may improve flexibility
- Green computing may strengthen the brand of companies
- Positive impact on our flora and fauna

Disadvantages of Green IT

- Significant upfront costs
- Plenty of knowledge may be required
- Green IT may conflict with profit maximization goals
- May slow down computer networks
- Technological change may make older IT-systems obsolete

- Acceptance inside companies may be rather low
- Lacking awareness of the general public
- Green IT may be vulnerable to safety issues
- May not be manageable for small businesses
- Reliance Maintenance may be difficult
- Many technologies aren't actually that green

PREFACE

UNIT I - FUNDAMENTALS

This unit introduces the notion of Green Computing with its motivation. This also speaks about the necessity of Green IT in imparting sustainable environment. The unit mainly focus on changing the perspective of the industries by including Green IT asone of their business strategic policy. A briefing about the metrics to quantify the intensity of greening is also discussed here.

UNIT II - GREEN ASSETS AND MODELING

This unit briefs about the assets of Green IT. The transformation process from conventional IT to Green IT at various operational levels are discussed elaborately in this unit. Green architecture, design and development of models for implementing greenness and external factors like supply chain management are also focused.

UNIT III - GRID FRAMEWORK

This unit speaks about the benefits of virtualization and its impact on Green IT. A brief discussion on the utilities, communication and other amenities in an industry which tends to contribute to carbon emissions are explained here. Green data centre and the Green Grid framework and best practices to achieve Green IT are explained in this unit.

UNIT IV - GREEN COMPLIANCE

This unit deals about the public perception of Green IT, various compliance standards, protocols etc. The Green IT's audit process is given a special mention. The later part of the unit discuss the technologies and the future roadmap to achieve Green IT.

UNIT V - CASE STUDIES

This unit starts with Environmentally Responsible Business Strategies. Various case studies and a detailed description about each scenario such as hospital, packaging industry and telecom industry is given in this unit.

SYLLABUS

CS8078-GREEN COMPUTING

UNIT I - FUNDAMENTALS 9

Green IT Fundamentals: Business, IT, and the Environment – Green computing: carbon foot print, scoop on power – Green IT Strategies: Drivers, Dimensions, and Goals – Environmentally Responsible Business: Policies, Practices, and Metrics.

UNIT II - GREEN ASSETS AND MODELING 9

Green Assets: Buildings, Data Centres, Networks, and Devices – Green Business Process Management: Modeling, Optimization, and Collaboration – Green Enterprise Architecture – Environmental Intelligence – Green Supply Chains – Green Information Systems: Design and Development Models.

UNIT III - GRID FRAMEWORK 9

Virtualization of IT systems – Role of electric utilities, Telecommuting, teleconferencing and teleporting – Materials recycling – Best ways for Green PC – Green Data centre – Green Grid framework.

UNIT IV - GREEN COMPLIANCE 9

Socio-cultural aspects of Green IT – Green Enterprise Transformation Roadmap – Green Compliance: Protocols, Standards, and Audits – Emergent Carbon Issues: Technologies and Future.

UNIT V - CASE STUDIES 9

The Environmentally Responsible Business Strategies (ERBS) – Case Study Scenarios for Trial Runs – Case Studies – Applying Green IT Strategies and Applications to a Home, Hospital, Packaging Industry and Telecom Sector.

TOTAL : 45 PERIODS

TEXT BOOKS:

1. Bhuvan Unhelkar, ―Green IT Strategies and Applications-Using Environmental Intelligence, CRC Press, June 2014.
2. Woody Leonhard, Katherine Murray, ―Green Home computing for dummies, August 2012.

REFERENCES:

1. Alin Gales, Michael Schaefer, Mike Ebbers, ―GreenData Centre: steps for the Journey, Shroff/IBM rebook, 2011.
2. John Lamb, ―The Greening of IT, Pearson Education, 2009.
3. Jason Harris, ―Green Computing and Green IT- Best Practices on regulations & industry, Lulu.com, 2008
4. Carl speshocky, ―Empowering Green Initiatives with IT, John Wiley & Sons, 2010.
5. Wu Chun Feng (editor), ―Green computing: Large Scale energy efficiency, CRC Press

CONTENTS

Unit-1

FUNDAMENTALS

1.1 GREEN IT FUNDAMENTALS: BUSINESS, IT, AND THE ENVIRONMENT

What is Green IT?

Green IT is learning and preparation of manufacturing, designing, consuming and ordering of computers, servers, storage devices and other peripheral devices commendably and competently with minimal or no impact on environment. In other words Green IT is the branch of study that aims at using computers and its associated resources effectively.

Green IT is composed of dimensions of environmental support, the economics of energy efficiency and the total cost of disposal and recycling of the same.

History of Green Computing/ Green IT

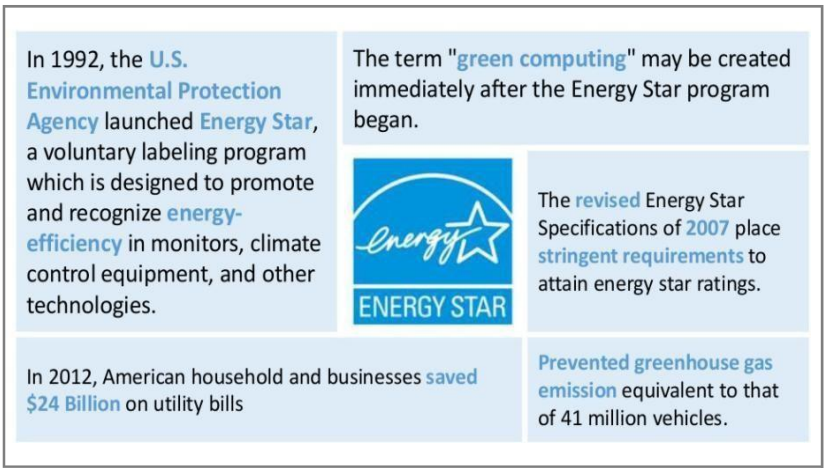

Figure 1.1 – History of Green IT

A brief history of Green IT is provided in the Figure 1 shown above.

How Computing Harm Environment

- Cost of Spam
  - Trillions of spam messages since 2014
  - 0.3 grams of carbon dioxide per message
  - Annual spam energy usage accounts to tera watts which is equivalent to the electricity usage in 2.4 million homes per year.
- Carbon dioxide emitted by device in sleep mode is equal to $1/7^{th}$ of the CO_2 emitted by an automobile.
- Increase in power, cooling and space for storage of data in data centre

- Hazardous materials inside computers like cadmium – damage kidneys, Mercury – neurological damage, Lead – disrupt brain neurotransmitters.

Need of Green IT

- Carbon efficiency is considered one of the major reasons behind efficiency and effectiveness of any organization.
- Reducing carbon consumption reduces the cost is the promising condition for achieving the mantra of Lean Organization is the one that looks for increasing value by reducing cost.
- Green IT aims at attaining the goal of reduced cost by adapting right individual attitude and working life style, thus reframing the rules and regulations of business.

- The need to Green and sustainable ICT is required to collaborate technologists, developers, politicians, researchers and consumers.
- The focus on climate change is also a reason for the development of Green IT.
- The need for an environmentally-efficient business.
- The rising cost over the past year in manufacturing/ production house and in consumer end in case of computers.
- Greenhouse gases and increase in legislation surrounding energy efficiency as well as toxic materials

Green IT Vision

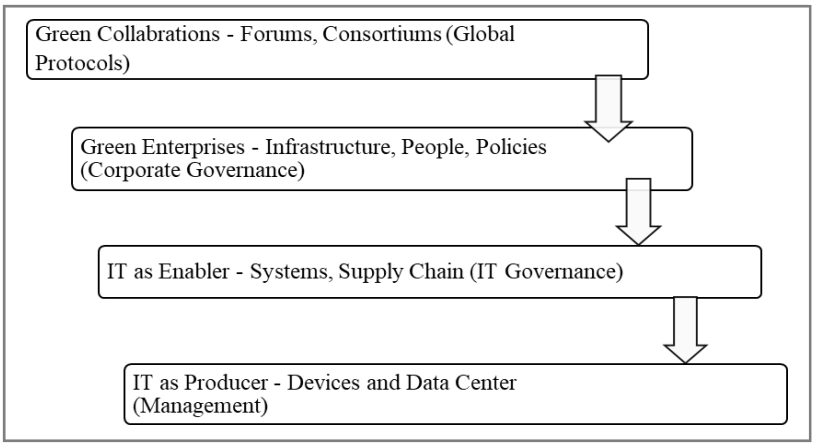

Figure 1.2 – Green Enterprises a vision beyond Green IT

The above figure shows the four stages of a complete Green It vision of an enterprises. They are as follows:

- **IT as a producer** – This addresses the emission produced by the gadgets, it is based on end user as well as from data centres.
- **IT as an Enabler** – Reduction of carbon emission in all areas of the enterprises, the IT governance also plays a major role in controlling the purchase and disposal of the equipment.
- **Green Enterprise** – Deals with infrastructure and buildings, people and their attitude, legal and standards as well as manufacture and sales.
- **Green Collaboration** – Collaboration of all enterprises that belong to a single market vertical.

The major aim of Green Computing is

- To reduce the use of hazardous materials so as to improve the climate change and help preserve nature.
- Maximize energy efficiency during the product's lifetime.
- Promote the recyclability or biodegradability of defunct products and factory waste.
- Computing cost reduction
- Reliability of power – energy efficient systems are in high demand to meet the energy demand as well preserve healthy power supply.
- Save amount spent on power, components and devices.

Approaches to Green Computing

In order to gain the environmental sustainability and efficient use of energy through computing there are four main paths to be taken.

Green Use – Using the computers and other related products in an efficient manner where the energy consumption is minimized.

Green Disposal – Reusing old computers, properly disposing and recycling other unwanted products.

Green Design – Designing energy efficient and environmentally friendly computers and accessories.

Green Manufacturing – Manufacturing computers and other related equipment in a way that they have a minimal effect to the environment.

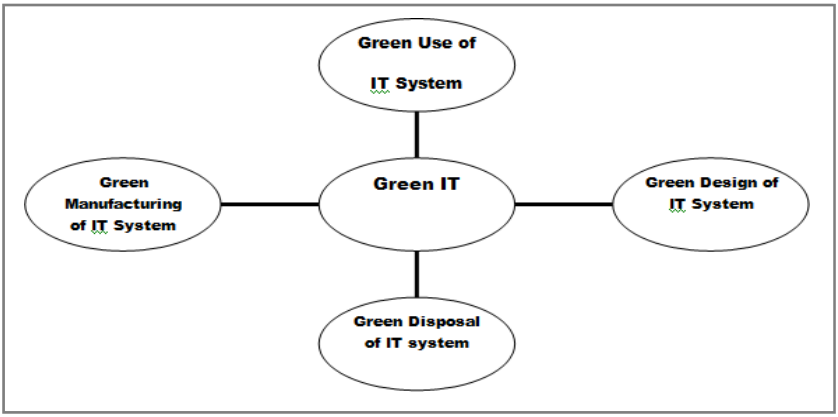

Figure 1.3 – Path way to Green IT

How to apply Green IT in any Organization

Green IT isn't just about energy efficiencies but also about operational efficiencies that can improve the organization. In most of the organizations, Green IT is practiced because of the explicit business drivers such as cost and the availability of the energy, cost of the equipments, cost of the data centres, business process optimization and performance and efficiency. When focusing on business optimization, few areas can be targeted which energy demand can be reduced and growth can be increased with the help of IT.

- Reducing environmental waste
- Improving energy efficiency
- Green IT purchasing

Reducing Environmental Waste

- By reducing office waste in the form electronic components and how to dispose them.

- The old desktop or laptops in office could be used to replace parts needed for hardware repairs or could be donated to families who can use them thus keep them out of landfills.

Improving Energy Efficiency

- This could be achieved in any IT sector by encouraging energy consumption thus company money is also saved to large extent
- The computers which are left turned on in any IT sector for a year, emits carbon which equal emission produced by over 2,000 cars a day.
- The use of standby mode or hibernate mode could also enhance energy consumption.

Green IT Purchasing

- By controlling purchase of new equipment.
- By choosing LCD monitors which uses less energy.
- By choosing Laptop or tablets over desktop which consumes more power.
- By purchasing devices which goes to standby or hibernation mode when not in use.
- Paperless system.

The execution of Green IT approaches in any business environment is based on various stages of complexity with in department and user clusters. The entire business organization is divided into many small chunks and then the approaches are applied. Green IT is not for a specific department or level or complexity rather it is for entire organization. An individual

chuck can become Green by applying its own strategy to attain that state.

Ways to Adopt Green IT

How are some companies addressing green IT?

Printing: this is a movement which involves the use of low- VOC inks, recycled paper, energy-efficient printers, re manufactured toner cartridges & ink cartridges, paperless data distribution, and implementing a pull printing system.

Supply Chains: Companies are altering their supply chain and cutting ties with companies that do not adopt the same green IT goals and practices as them

Data Centres: Data centres are using massive amounts of electricity generated using fossil fuels. Companies recognizethis are looking for renewable energy sources to power data centres and maximize efficiency.

IT Department: The IT department is integral to the success of green IT due to their energy consumption, device management, and data collection.

Green Information Strategy

Under Green Information Strategy, the ways of managing and retaining information has been defined. The ways of collecting, classifying and archiving information are introduced in Green Information Strategy.

It involves several key steps:

- Understanding the requirements for information retention and availability.
- Determining infrastructure requirements.

- ❖ Conducting continual strategic planning to meet economic and business conditions and demand.
- ❖ Measuring progress and adjusting the strategies.

Information Lifecycle Management is a set of concepts which helps organizations to build processes and implement best practices for creating, storing, archiving, and dispose data. A variety of technologies and methodologies can be used in order to optimize the storage utilization. Then the amount of storage required and the energy used to power will be reduced.

Green Computing Strategies Points

- Minimizing energy Consumption
- Purchasing green energy
- Reducing the paper and other consumables used
- Minimizing equipment disposal requirements
- Reducing travel requirements for employees/customers

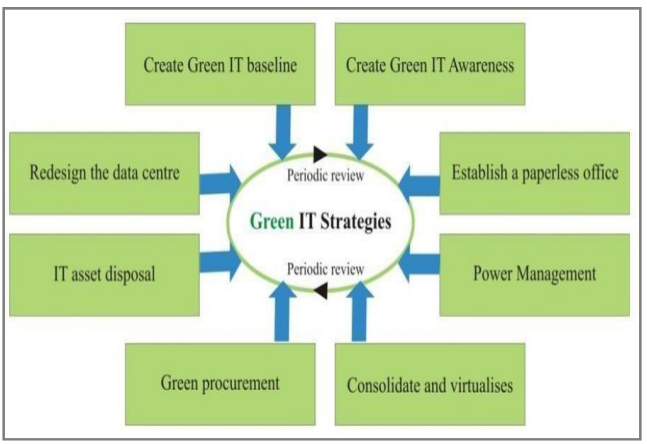

Figure 1.4 Green IT strategies to reduce the carbon emission in IT sectors

Green Value

- Green value is the overall value consumer's gain by using green products and services.
- Green value is the sum of the financial, environmental, social, information and functional benefits thata green product or service can provide to the consumers.
- Consumers evaluate offerings based on these benefitsand form positive or negative attitudes.
- Cost savings is one of the major reasons why green IT has taken off among large organizations.
- Spending reductions on equipment, energy, and even tax breaks and other financial incentives make green computing that much more practical and attractive for companies to adopt.

- Regulations established to address climate change have forced businesses to change their ways and become environmentally friendly.
- As a result, new economic opportunities exist.Companies can enter the market and grow revenue and job growth by supplying or servicing energy efficient equipment, or developing green technology, just as a fewexamples.
- In addition, it's no surprise that green IT is just good PR for companies. Customers and stakeholders care about the environment and the effects of global warming, so companies that are demonstrating good initiative in this area are showing they are responsive and taking action.

Green IT: An Opportunity

- The opportunities presented by Green IT are to reduce carbon emissions, for example in the transportation area.
- The use of smart automation and driving, real-time traffic alerts, and the Green IT-enabled logistics systems,helps to decrease total mileage and the amount of fuel essential to transport people and goods.
- Online maps available in mobile with real-time traffic data enables to optimize routing decisions, reduce fuel consumption, and lower emissions.
- The adoption of telecommuting and video conferencing eliminates transportation requirements.
- All of these subsidise to discounts in energy use and, reductions in GHG (Green House Gas) emissions while offering convenience and other benefits.

- A universal and neutral valuation reveals that even if one feels burdened with 'go green' initiatives and demands, it is better to adopt them in the interest of several opportunities and benefits it offers to the businesses, the society and to the planet.
- Smart companies are adopting an environmental strategy to innovate, create value and build a competitive advantage.
- Greening of – and by – IT will soon be necessities – not options.
- Green initiatives are becoming a key agenda for many enterprises, and enterprises need to develop and

implement the green IT strategy that is aligned with their business strategy and goals.

Roadblocks to adopting green IT

- Resistance to change, apathy, and competing priorities are universal problems. However, they can be overcome through education and leadership.
- The data needed to make informed decisions around green IT initiatives is often fragmented and must be collected and analyzed from a holistic point of view.
- Manual data collection makes it difficult to piece together a complete picture of a business's carbon footprint.
- Lack of robust metrics and measurements across all dimensions of an organizations.
- Lack of availabilities of substantial support in usage of Green IT.
- Uncertainty in terms of the scopes of the emissions to be included in the calculations.
- Technologies like virtualizations, thin clients and cloud computing are implemented in organizations, but not for improving its environmental performances.
- Non recognition of inefficient businesses processes and lack of corresponding business process management.
- Disposal of Electronic wastes.
- Equipment Life Cycle management – Cradle of Grave.

Practical Applications of Green IT

- Product Longevity – reuse part of the disposed devices.
- Algorithmic Efficiency – Reduces computer resources for computing function
- Resource Allocation - by reducing routing traffic and moving data to centralized location for easy access latter from anywhere.
- Virtualization – virtual machine are powerful system, which reduces power consumption.

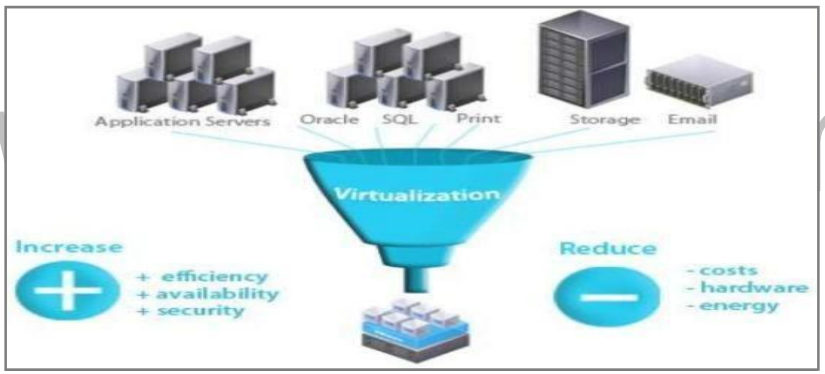

Figure 1.5 –Depicts Virtualization

- Terminal Servers – end users make all computation in central servers thus cutting down cost through computation
- Power Management – by using advanced power management techniques like ACPI allows operating system to directly control the power saving aspects of underlying hardware.

- Power supply – by purchasing and using products with energy star certificate.
- Data Centre – by improving inefficient cooling systems in data centres.
- Video Card – Use of shared terminal or desktop forsharing software when display required, Usemotherboard video output for reducing power consumption and by reusing older video card that uses less power.

Recent and Future Implementation of Green Computing

Recyclable paper laptop - One of the most environment friendly computers are Recyclable Paper Laptop. These laptop is manufactured using paper pulp or recycled materials packed in layers.

IMEC Laptop – These are powered by solar energy.

Life book Leaf multipurpose laptop – These gadgets uses OLED touch screen which could be folded like a laptop, whose exterior are carved out of polycarbonate a sensitive and shatterproof.

LOOP and EVO PC concept – These are devices that uses less carbon foot print.

Zonbu Computer – Consumes 1/3rd of power of light bulb with Linux OS.

Fit – PC draws only 5 watts which is typically less than the traditional PC consumes.

1.3 Scoop on Power

In the past decade, a lot of research has been carried out aiming at providing better battery life to the mobile devices like PDAs, mobile phones and Laptops. However with the advent of data centres, Greening of Computing also deals with energy efficient designs for servers and to lower costs and carbon emissions produced by Data centres. A recent survey shows that quite a lot of power used in office buildings and colleges are spent on Computing. The scope of optimizing the usage of power are as follows:

- Input and Output devices – Black CRT utilizes less power than White CRT

Brightness	White CRT	Grey CRT	Black CRT
100	85	74	63
50	84	67.5	60.5
0	77.7	65	60.0

Table 2 – Comparison of Brightness in various CRT models

Power Consumption Parameter	CRT Monitor	LCD Monitor
Avg. consumption	76 W	20 W
Screen color sensitivity	Extremely sensitive. Consumes lot more power (43% more) when displaying white on screen.	Completely insensitive. Consumes same power for all colors on screen.
Brightness setting sensitivity	Moderately sensitive. Consumes more power at higher brightness.	Sensitive. Consumes higher power for higher brightness
Contrast setting sensitivity	Less sensitive. (Almost insensitive when brightness setting is low.)	Completely insensitive. Consumes same power for all contrast
Consumption when turned off from computer power settings	2W	0 W

Table 3 – Comparison between CRT and LCD monitor

- Storage Units
- Processors
- Operating Systems

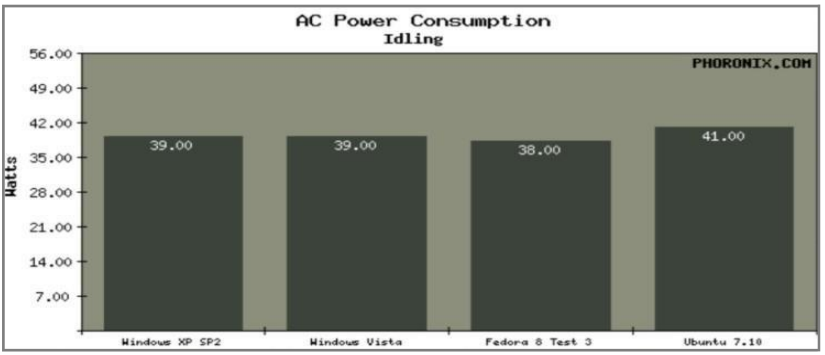

Figure 1.12 – Power Consumption of various Operatiing Systems

- Frequency of operation in any Computing Devices.

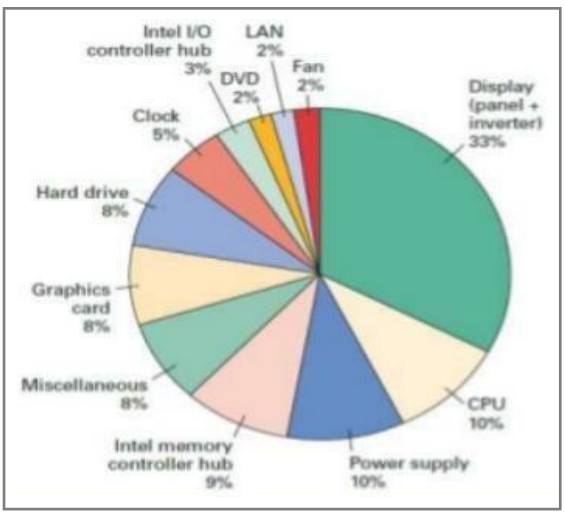

Figure 1.13- Power consumption in an average Laptop

Data Centres

- A Data Centre is a facility housing a large number of servers and data storage.
- In reality the electricity bill for a data centre is close to 6 million a month with about 20 percent of the powerspent on cooling the data centres.
- The average amount of money spent on buying the servers amortized over a period of three years is almost equal to the cost of powering the servers.
- This shows that it is necessary to effectively utilize the electricity used by the Data centres.

Power Usage Effectiveness

- Power Usage Effectiveness = Total Facility Power/IT Equipment Power
- The PUE is a ratio of the input power to theactualamount of power required by the servers at a Data Centre.
- If the amount of power required to cool the system is 100 percent , then the PUE grows to 2 which is undesirable.

Low PUE Design

Better Power Infrastructure

- If there are multiple data centres in different locations then one way of making using of power infrastructure is to shift the load to the data centre that has a low-price period.

- The power generally undergoes a conversion from AC-DC a number of times before it reaches the server, by reducing the number of conversion the conversion loss can be avoided.
- Multi-phase power (use of a 3 phase AC) can help provide efficient power usage.

Better air conditioning

- Cold air is allowed to pass through the servers.
- On passing through the servers the cold air turns hot and this is cooled and then reused.
- Balancing load across the data centre helps eliminating hot spots Another means of cooling is to use the outside air to cool the machines.
- Iceland being a cold country and being a good source of Geo-thermal energy hosts a few data centres.
- Microsoft conducted an experiment by placing the servers outside and using the outside air to cool the systems. The servers worked fine even with temperatures in the late 90s.
- However they faced issues with filtering the outside air which contained leaves and other dust particles.

Better server and IT equipment

- It is observed that the servers consume 65% of the power.
- A server is not to be energy proportional if the power usage scales linearly with the workload intensity.

- However in practice, servers are not energy proportional and consume close to half the power even when they are in the idle state. This is attributed to various components like Disk , RAM, motherboard and network card which consume power even in the idle state.
- In practice it is observed that the servers are around 10-30% utilized all the time.
- The amount of work done by the server for each joule of energy used is defined as the efficiency. The servers are not efficient either. This is due to the unused CPU features like the large caches, complex architecture.
- If the CPU is not the bottleneck for the application then the use of a CPU with limited features can solve the problem and also make the server more efficient.

- The server is most efficient when its utilization is 100%. The efficiency of a server is also linked with the software flexibility.
- By using Virtualization, the CPU/memory usage can be controlled.
- Migrating virtual machines to a subset of the physical machines and switching the other machines off also helps in efficient usage.

Common Approaches

- One common approach is to make the Ensembles energy proportional.

- This is achieved by distributing the workload and with the decrease in utilization the components are turned off and the word-load is migrated to active components.
- If there is an increase in the utilization the components are turned on and the load is migrated to the newly active components.
- However, this method does have problems. Moving the workload might take a long time and turning on/off of the components takes a long time.
- It also does not work if the workload intensity changes faster than the data transfer and if the workload is not distributed.
- Some of the other IT components like the switches and the routers are much inefficient when compared to the servers. They are at 100% Utilization all the time.
- Turning off RAM memory banks is rarely done. Mechanical disks are not energy proportional. Flash disk use no energy but they are expensive

Renewables

- The Main reasons behind using renewables is due to the Bad press for using many fossil fuels, electricity costs and also to reduce carbon emissions.
- However with renewables the word-load and the available power are now changing and there is a need to match supply and demand since storage of power brings in additional overhead.

Information technology can be used to make the building more green using sensors, smart software, smart appliances and smart meters

Smart Buildings

- In order to make the building smart, there is a need to monitor the energy usage.
- The user must be able to control electricity usage by automatically turning devices on and off.
- Green Computing comes up with means to satisfy these needs cheaply and reliably.
- The Building Management Systems are existing systems that monitor the energy usage but lacks load balancing methods.

Monitoring Energy Usage

- Energy usage can be monitored at multiple levels of the wiring right from the electricity incoming level to the outgoing level. But this is not same with data transfer, which a tedious process is done using wireless networking techniques like Zigbee and Wifi.
- The most Challenging task to place sensors at every load since it's expensive, it may not look good and it's unreliable due to the bandwidth constraints.
- Some Alternatives include collecting high bandwidth data at the source, disaggregating data into multiple chucks or loads by using well placed sensors.

Controlling Energy Usage

- Programming load control switches are needed to control the energy usage.
- Generally the control involves switching a device on/off. The switching mechanism may be external or internal.
- An example of a Wi-Fi enabled washer and dryer has been provided. The control is provided by means of a mobile application.

Environment Monitoring

- It has similar issues as energy monitoring which monitoring weather, thermostats, and doors as well tracking motion.
- Energy usage can be implemented using recommendations via smart phones, enabling remote but manual control, automated scheduling policies.
- The main aim of the computing for greening is to optimize for lower costs, lower energy usage, lower peaks and aligning consumption with renewable generation.

1.4 Green IT Strategies: Driver's, Dimensions and Goals

Green IT Strategies

- Each enterprises must develop a holistic, comprehensive green IT strategy and policies that outline aims, objectives, goals, plan of action and schedules.

- A Large enterprise must appoint an environmental sustainability officer to implement their green policy and to monitor the progress and achievements.

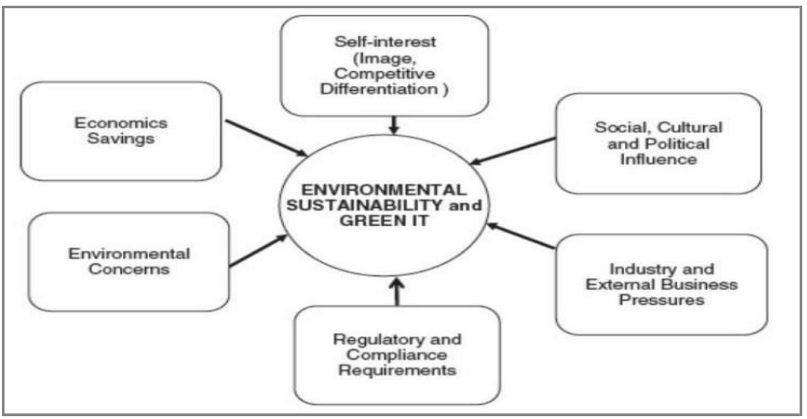

Figure 1.14 – Various factors responsible for Environemental Sustainability

- Every enterprise must have a tactical incremental approach with green goal such as reducing energy consumption.
- It must also have measures adopting policies and practices namely power management, switching off computers when not in use.
- Enterprises must conduct audit of its IT infrastructure and its use from an environmental perspective.
- Enterprises also adopts additional measures such as implementing a carbon offset policy to neutralize GHG emissions – including planting trees, buying carbon credits from one of many carbon exchanges or using green power generated from solar or wind energy.