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Please read this disclaimer before proceeding:

CS8078
GREEN COMPUTING

Computer Science and Engineering

2023 – 2024 / IV Year

Created by:

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RMKCET

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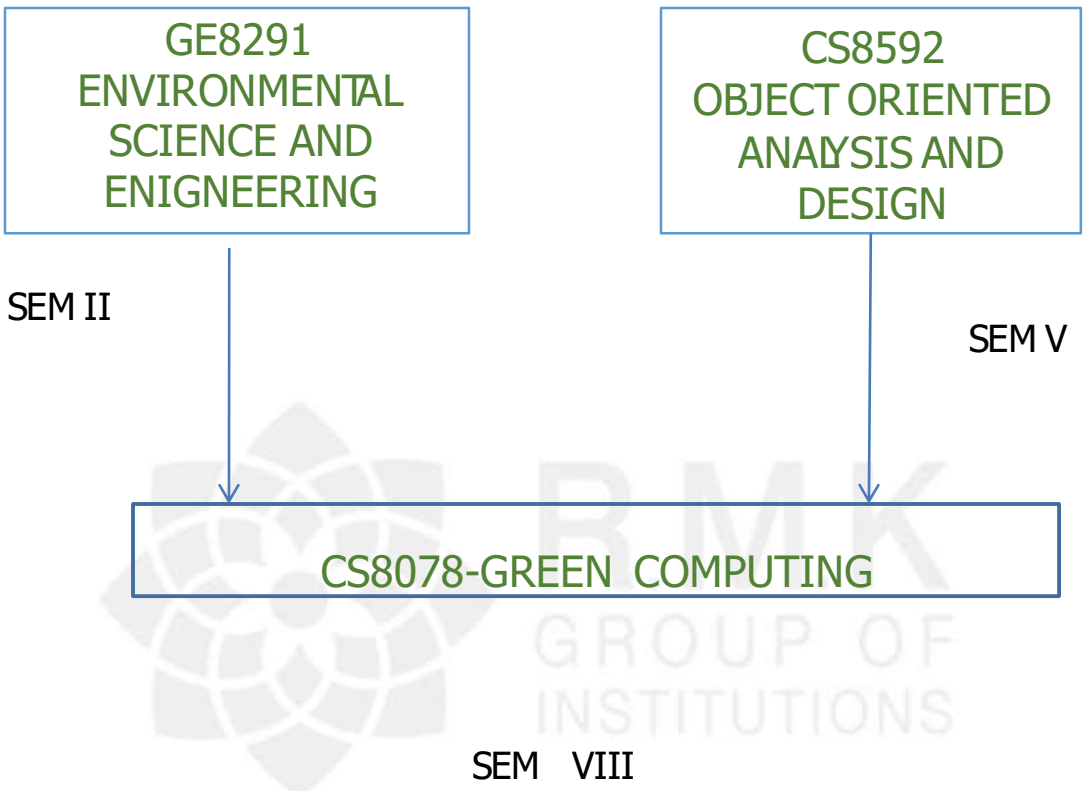
Table of Contents

Course Objectives

- To learn the fundamentals of Green Computing.
- To analyze the Green computing Grid Framework.
- To understand the issues related with Green compliance.
- To study and develop various case Studies.
- To explain the Strategies of Environmental Intelligence to Green Organization.

Pre Requisites



SYLLABUS

CS8078 GREEN COMPUTING

L T P C
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UNIT I FUNDAMENTALS

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

Green Assets: Buildings, Data Centers, 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

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

UNIT IV GREEN COMPLIANCE

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

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..

Course Outcomes

At the end of the course, the student should be able to:

S.No	Description	CO	HKL
1	Acquire knowledge to adopt green computing practices to minimize negative impacts on the environment	CO1	K2
2	Enhance the skill in energy saving practices in their use of hardware.	CO2	K3
3	Evaluate technology tools that can reduce paper waste and carbon footprint by the stakeholders	CO3	K3
4	Understand the ways to minimize equipment disposal requirements	CO4	K2
5	Explain the Strategies of Environmental Intelligence to Green Organization	CO5	K2
6	Summarize the controlling methods and tools to increase Green productivity of the Organization	CO6	K3

*HKL - Highest Knowledge Level

6. CO - PO / PSO MAPPING

CO	HKL	PROGRAM OUTCOMES												PSO		
		K3	K4	K5	K5	K3, K4, K5	A3	A2	A3	A3	A3	A3	A2	PSO 1	PSO 2	PSO 3
		PO -1	PO -2	PO -3	PO -4	PO -5	PO -6	PO -7	PO -8	PO -9	PO -10	PO -11	PO -12			
C203.1	K2	2	1	-	-	-	-	-	-	-	-	-	-	2	2	1
C203.2	K3	3	2	1	-	3	-	-	-	-	-	-	-	2	2	-
C203.3	K3	3	2	1	-	2	-	-	-	-	-	-	-	2	1	-
C203.4	K2	3	2	1	1	2	-	-	-	-	-	-	-	-	-	-
C203.5	K2	3	2	1	1	2	-	-	-	-	-	-	-	-	-	-
C203.6	K3	2	1	-	-	1	-	-	-	-	-	-	-	-	-	-

- **Correlation Level - 1. Slight (Low) 2. Moderate (Medium) 3.Substantial (High) , If there is no correlation, put "-".**

LECTURE PLAN

UNIT 2 GREEN ASSETS AND MODELING

S. No	Proposed Lecture Date	Topic	Actual Lecture Date	CO	Highest Cognitive Level	Mode of Delivery	Delivery Resources	LU Outcomes	Remark
1	26.8.23	Green Assets-Introduction	26.8.23	CO2	K2	MD1 & MD5	T1	Understand the purpose of Green Assets Introduction	-
2	27.8.23	Buildings, Data Centers, Networks, and Devices	27.8.23		K2	MD1 & MD5	T1	Learn the different types of Buildings & data center	-
3	01.9.23	Green Business Process Management Policies	01.9.23		K2	MD1 & MD5	T1	Understand the concept of Green Business process management	-
4	02.9.23	Modeling, Optimization, and Collaboration	02.9.23		K2	MD1 & MD5	T1	Know about the Modeling, optimization and collaboration	-
5	03.9.23	Green Enterprise Architecture	03.9.23		K2	MD1 & MD5	T1	Learn the concept of Green Enterprise Architecture	-
6	05.9.23	Environmental Intelligence	05.9.23		K2	MD1 & MD5	T1	Understand the strategies in Environment	-
7	07.9.23	Green Supply Chains	07.9.23		K3	MD1 & MD5	T1	Learn the different planning Strategies used	-
8	08.9.23	Green Information Systems	08.9.23		K3	MD1 & MD5	T1	Understand the decision making steps and its processes	-
9	09.9.23	Design and Development Models	09.9.23		K2	MD1 & MD5	T1	Understand the decision Making steps and its processes	-

ASSESMENT COMPONENTS

AC 1. Unit Test
AC 2. Assignment
AC 3. Course
AC 4. Course Quiz
AC 5. Case
AC 6. Record Work
AC 7. Lab / Mini Project
AC 8. Lab Model Exam
AC 9. Project Review

MODE OF DELIVERY

MD1. Oral Presentation
MD2. Tutorial
MD3. Seminar
MS4. Hands On
MD5. Videos
MD6. Field Visit

Activity Based Learning

Activity Zone

Unit – II :

- List out the different types of Renewable Energy resources and their impact to the Environment.

Class Notes

- UNIT II
- 2.1.Green Assets: Buildings, Data Centers, Networks, and Devices
- Introduction
- •While these assets have been grouped from an accounting perspective in tangible and intangible assets, it is worth grouping them into two groups from a carbon perspective: the static, infrastructural assets (e.g., the data center) and the nonstatic assets (which are mobile, such as a laptop computer) of the organization,
- •These assets impact the carbon footprint of the organization right from their procurement and installation through to their disposal. Eventually, a stute carbon management of these assets results in reduced carbon footprints that can be exchanged, traded, and used to increase the value of the organization, its products, and services.
- •In the context of these electronic assets, the strategies and policies of a green organization discussed in the previous two chapters need to be translated into practice of the way it procures, uses, and then disposes these various assets.

Green Assets

- The three major phases or activities associated with the lifecycle of these assets is depicted: the way they are established or procured, the manner in which they are operated or run, and eventually the strategies for their disposal or demolishment.

- *Establish (Procure)* deals with the green credentials of the asset in terms of its design and development. This is a one-off decision-making process that decides on the carbon efficiency of that assets design

- *2.Operate (Run):* The manner of operation of the asset has a bearing on the total carbon contribution of the organization. Length of operation of the asset, such as operating a vehicle for 10 years or a mobile phone for 2 years will impact the overall emissions of that asset over its lifetime. The user of the asset is responsible for operating (using) it in such a way as to reduce its carbon impact.
- *3.Dispose (Demolish):* This is the eventual phase of an asset and it also impacts the overall carbon footprint of an organization. This impact is through the organization's approach to disposing or demolishing the asset. This is also a one time decision-making process with long-term effect on the environment.

- Therefore, counting the total carbon costs over the lifetime of an asset including its carbon content in production, the carbon generated during its operation over its lifetime and the carbon produced in its disposal, is vital.
- However, when the TCCO calculations are made, it becomes important to incorporate the carbon that is generated along with the calculations of costs associated with equipment's. TCCO can be improved with smart metering capabilities, carbon calculations throughout the life of the equipment and its disposal. Since the power consumption of data centers is rising, so is the heat generated by data center processors.

Table 4.1 Types of Assets (Categories) and Their Impact on the Environment

Type of assets	Impact on environment
Building and facilities(e.g.., offices, meeting, rooms, training, centers, social rooms, sports facilities)	Long-term impact as major environmental considerations should be during architecture and construction. Purpose of buildings, people movements, geographical locations (weather), and durability of the building impact their overall carbon contribution. Examples of one-off decision making in design include the materials used in the construction, the extent to which the building is facing the sun, the wind directions, and the way in which these natural light and natural cooling are put together to reduce energy consumption.
Data Center (as separate, dedicated buildings to house servers)	This is a special purpose building to house data servers. In addition to the standard building considerations, the ratio between power usage by the servers versus the rest of the power is a popular environmental consideration. CRAC (Computer Room Air Conditioning) is a discipline in its own right that separates the cooling of the servers from the air conditioning required in rest of the building. Thus, building technologies together with data server technologies are put to use here to reduce carbon.
Devices (e.g., laptop, mobiles)	Design, development, procurement, operation, and usage of devices is considered here. Example of this includes low-power consuming design for laptops and mobile devices, efficient batteries for them, carbon-conscious electronic chip design, biodegradability of materials used, and so on. Apart from the operational carbon generated by these devices, their disposal itself is an important issue.
Vehicles (e.g., cars, trucks, corporate vans, and buses)	Direct fuel emissions, pollution level of the type of fuel, design of the engines, and so on. Procurement, operations and disposal activities apply to vehicles used by the organization. These vehicles produce the Scope 1 emissions. Fleet maintenance systems need to be updated with carbon calculations. The kind of vehicle, its design, how long it will be operated, and the method of its disposal has to be considered. Vehicle emission consideration is vital when considering the entire organization. This table lists vehicles as an important reminder. However, detailed discussion on vehicle emissions is out of scope for this chapter.

Building and Facility Management

- This carbon generation from buildings, as depends on the material of the building itself, its air conditioning, and related operational features such as lighting and ventilation.
- The focus of Green IT has been on the operational aspect of these facilities, the architecture and design offices, factories, and also related facilities (such as, a sporting complex or a community room) have a strategic role to play in the organization’s carbon footprint. For example, the location of an operational room, where staff is ideally located, should have natural and sufficient sunlight during day time that would reduce electricity usage. Use of translucent materials for dividers, focus on solar charging, and use of solar equipment's and cells are all examples of strategic aspects of environmental asset management.

Green IT Hardware

The hardware aspect of Green IT deals with the architecture and design of IT hardware, the manner in which it is procured and operated.

Table 4.2 Rating Building Features to Environmental Factors

Building Features	Environmental Relevance	Comments and Actions
Location	Use of geographically specific natural resources such as cool weather, natural sunlight.	Locating a data center in Iceland can reduce the cooling costs, effort and corresponding carbon.
Architecture and design	To maximize the use of available natural resources for the building.	Windows facing sunlight; cross-ventilation; air and water cooling of data centers.
Construction	Use of material (concrete, carpets, terracotta) to compliment the location and design to ensure that the material reduces wastage and maximizes natural resources.	Use terracotta roof instead of concrete.
Livability (occupancy)	People friendliness of the building/ facility that has health as well as aesthetic benefits.	Optimizes the way in which people use the facilities. A naturally lit, cheerful building will need less power.
Visibility	Promoting the physical building as a place of attraction adds marketing value, as also improved asset value.	Ivy's climbing on the walls. Terrace gardens.

Data servers—deals with the physical machines and the specific buildings in which they are housed.

These servers also have both wired and wireless networks and corresponding communications equipment associated with them that are directly emitting carbon.

End-user computers—laptops, desktops, their capacities, operational efficiencies, and their disposal (especially as the lifecycle of a computer is getting shorter by the day) need to be discussed from their P-O-D viewpoint.

Mobile devices—the mobile de vices and associated hardware (e.g., extension leads), their batteries including the recharging mechanism and disposal of the batteries and the policies and actions when the devices become outdated (quickly).

The mobile devices P-O-D is affected heavily by the corresponding attitude of their users. For example, a perfectly working mobile phone may be discarded by a young user if it goes out of fashion. Thus , a sociocultural issue is an important contributor to the carbon behavior of these devices.

Peripherals—printers, photocopiers, and so on.

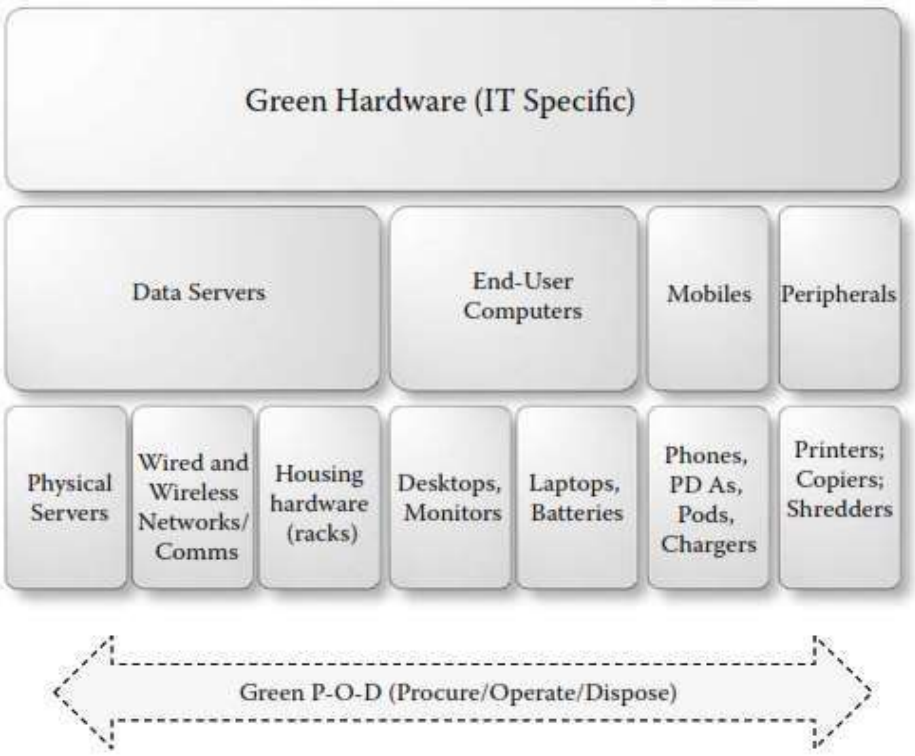


Figure 4.3 Range of Green IT hardware generating carbon.

The carbon emissions from each of these Green IT hardware group mentioned above is affected by its procurement, operations, and disposal (Green P-O-D) phases in its lifecycle.

1 **Procurement** focuses on well-designed, low-carbon emitting data servers or monitors, buying it from a green supplier and using the most efficient means of packaging and transporting the equipment.

2 **Operation** is the ongoing use of hardware in an efficient and effective manner

3 **Disposal** the building and facilities management department can focus on recycling, reuse, and "buy-back" policies to improve its disposal function

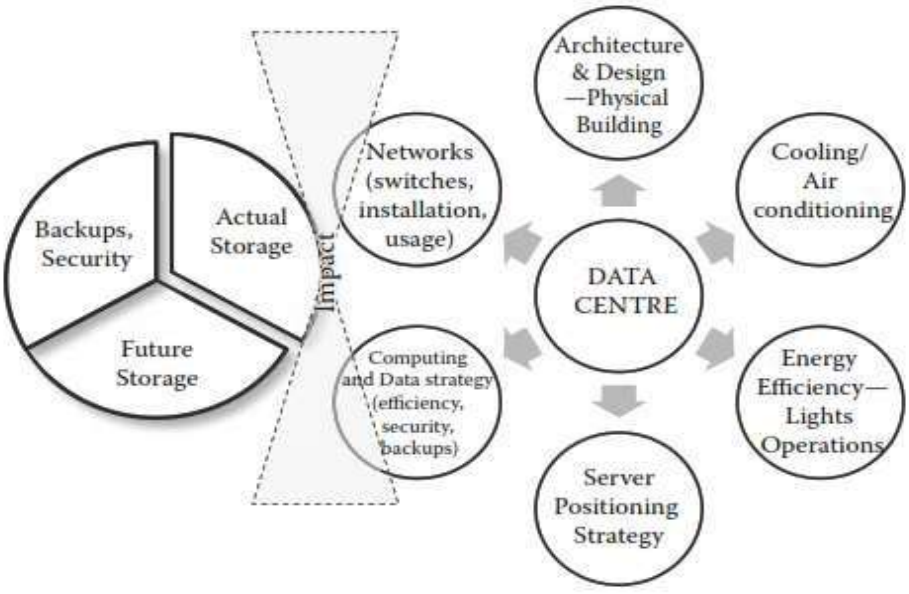
Green Data Centers

•Data servers, in practical terms, can be seen as powerful computers that have the capacity to store as well as process vast amount of multiformatted data.

•This growth in demand for vast amount of data storage coupled with corresponding demand for increasingly fast processing resulting in carbon emissions.

•Costs and carbon emissions are also closely tied together in case of data centers.

•Green data centers also include the architecture, design, development, production, procurement, installation, operation, and disposal of the data server machines and their associated paraphernalia—such as monitors, printers, storage devices, and networking and communications systems.



Green data center influencing factors.

Data center design, layout, and location—the location of the server rooms within the data center can play a role in carbon reduction.

For example, if the room to house the server exactly fits the server size, cooling effect will be maximized. These purpose-built data center buildings are a major influence in an organization's green endeavor.

Cooling, air conditioning, power source and power consumption —This includes the cooling strategies of the servers; and the air conditioning relating to the actual building.

Power management—lights and operational aspect—. Number of people working, opening and closing of doors. This would include procurement and installation of green products (such as LED light bulbs) and use of green services.

Servers—their n umbers, their positioning and corresponding energy-efficient computing— Physical location of the racks, their positioning (hot isle/cold isle).

Data strategy—including security and backup—Adopting virtualization strategies and creating ground-up virtualization architectures will enable data center energy efficiencies. Virtualization software such as VMware and SWsoft, coupled with consolidation analysis software such as CiRBA, can enable people to maximize server production.

Networks and communications equipment—Land-based as well as wireless communications such as switchgears, routers, and modems. The numbers and capacities of these equipments in the data center contribute to its carbon footprint.

Data center factors need to be discussed a longside their financial impact, their attitude impact, and the Total Cost of Carbon Ownership (TCCO). The usual linear relationship between cost and energy may not be sufficient to bring about behavioral change.

Data center carbon costs need to match its data storage and data usage. The actual data storage requirements are usually coupled with additional backup storage as well as future storage requirements.

2.1.6 Data Center Building—Design, Layout, and Location

•The challenges in handling data centers from carbon perspectives arises from the fact that the data center buildings themselves are based on a ROI over 15–20 years, whereas the internal equipment, the data servers and other computing equipments themselves are usually upgraded every 3 –5 years.

•Therefore, the data center building, together with the data center's non-ICT infrastructure, can quite easily (and most often does) consume more power than the ICT equipment within it.

•As a result there is a mismatch between the operational efficiency of the data center over its lifetime as compared with the cooling strategies of the data server. The older data centers may thus not be equipped to power and cool the newer IT equipment (servers) in an energy-efficient manner.

There will usually be a need to upgrade the data center building in order to handle its carbon efficiency requirements.

The specific design, layout, and location consideration for data centers are,

➢**Physical (geographical) location of the building**: This includes the weather patterns of the geographical region.

➢**The building that houses the data center**: This may be a dedicated stand-alone facility, or it may be purpose-built within a larger facility, or it may be retrofitted into existing premises.

➢**The power supply:** Data centers can also generate their own power, and backup power supplies are common for business continuity.

➢**Cooling and lighting**: Modern ICT equipment typically demands significant a mounts of cooling, either air cooling or water cooling.

➢**Server and storage virtualization:** the power consumption of data centers can rise as the virtualized servers may be more powerful and may use greater electricity.

➢**Facilitation of new and emerging technologies:** The building of the data center should be conducive to wireless communication, Cloud computing-related communication.

2.1.7 Data Center ICT Equipment—Server Strategies

•They are housed within the green data center and require specific strategies for positioning, cooling, and usage. Increasing demand for more powerful servers with increased storage and processing facilities.

•While desktops are predominantly individual machines, servers belong to the data center manager who is responsible for providing a service to the rest of the organization rather than using it directly themselves.

•This philosophical difference between a desktop and a server requires different server-side strategies for carbon control. The users of the data application are usually removed from the physical data center.

The list of green server strategy:

- Power consumption bill in real time—mapped to carbon generation, that provides operational feedback to the entire organization.
- Pue, DCiE—these popular metrics providing comparative data over a length of time, as also across the industry.
- Mirroring backup strategies that are balanced by the "acceptable risks" of the data center director.
- Data capacity forecasting. Server capacities need to be estimated on a continuous basis as the business changes.
- Carbon-cost visibility. Lack of visibility of server costs.
- Efficient decommissioning. Once the purpose of a server is consummated, there is a need for a formal yet quick way of decommissioning the server.
- Enhanced server distribution. Also enable server sharing between operational development and test environments.
- Incorporate Cloud computing and server virtualization.

2.1.8 Data Strategy and the Carbon Emitting Bit

Closely associated with the data server strategy is the data strategy itself. This data strategy encompasses the use, storage, mirroring, security, backups, clean ups, and architectures for data.

Data efficiency is in relational database management systems includes use of techniques such as data normalization and incremental storage. Every "bit" adds to the carbon generation from the data center.

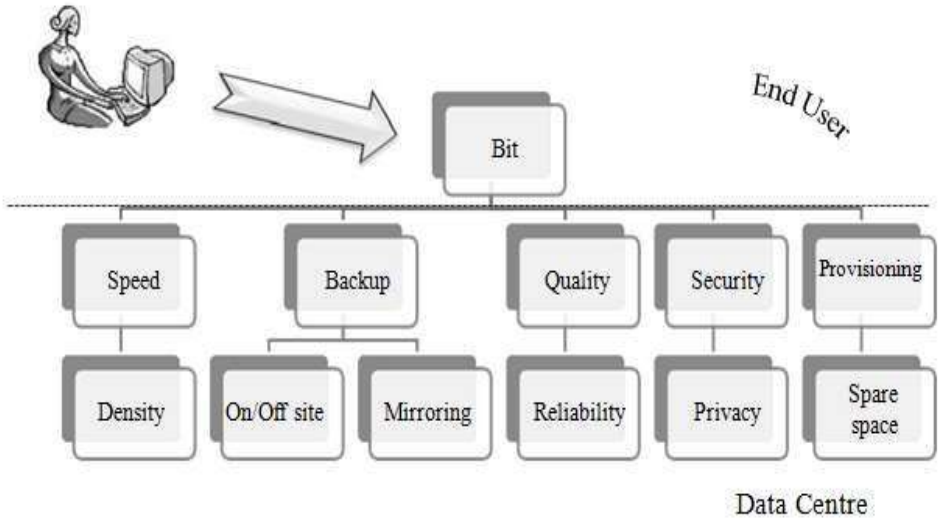


Figure 4.6 A carbon-emitting bit—repercussions on overall carbon emissions.

Following are the ramifications of one extra bit in a data center on the green performance of the organization:

•*Additional free space provisioning*: For example, for every used bit, there is an additional 0.7 bit (70%) is required to be kept aside as an "unused" space that might be required immediately for use in future.

•*Speed and density*: Each additional bit of data comes with an implicit demand for computing capacity. Thus, increase in storage of data is not mere increase in space use, but also increased demand on computing power.

- *Backup*: Every bit needs another bit or more of space used for backing up the data.
- *Mirroring*: A bit may require another bit that is a live copy (and that is more than a backup). This live mirror copy would be required for mission critical systems with security and safety risks.

•*Quality and reliability*: Every additional bit of data adds to the effort required to keep the data clean. Such data cleansing effort are also carbon intensive. Therefore, increase in quality and reliability of data can improve the carbon performance of the organization.

- *Security*: With every additional bit, there is a need to provide security of access.
- *Provisioning*: Each bit requires provisioning for spare capacity.

[1 bit + m bit (additional) *leads to* → 1.m bit × n w atts (direct energy need) → *leads to* nxp watts (support energy-infrastructure) *influences* → People (attitude)]

As shown in the equation, each bit requires an additional m fraction of additional bit as part of provisioning.

IT governance with additional focus on data centers help to manage the overall number of servers, their lifecycle and the underlying server virtualization strategies. Thus, the governance frameworks such as COBIT, ITIL, CMMI, and Six Sigma could be applied to optimize the performance of the servers. Consider, for example, the application of ITIL.

ITIL implementation is made to adhere to carbon control requirements, then use of ITIL can reduce the occurrences of such anticipatory behavior

2.1.9 Data Servers Optimization

•Data server optimization can be improved through better organization of the databases including their design, provisioning for redundancy, and improved capacity forecasting, following RDBMS.

•Optimization also includes consolidation of various physical servers that would reduce their total numbers. Standardization of equipment also reduces the overall capacity needed for backups and mirroring of databases.

•Improved technologies of the servers themselves (e.g., Blade) also help in the optimization process.

More techniques that could be considered by an organization for server optimization are described as follows:

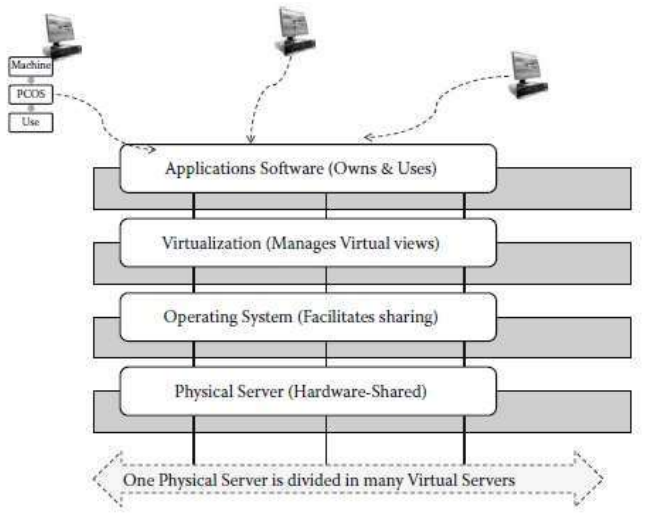
- Undertake intense and iterative capacity planning for the data center.

○Identification of unused capacity of servers and storage disks within them. ○Implement full storage virtualization that will enable hosting of multiple data warehouses on the same server. ○Efficient server operations. For example, a server that is on but idle would consume half the power it needs when being used fully.

○ Efficient management of air-conditioning and cooling equipments.
○ Decommissioning servers once their service level agreement has expired.
○ Enabling virtual servers easily will enable efficient capacity management and reduced hardware maintenance costs.
○ Outsourcing services help organizations reduce their man power and energy utilization in order to complete a particular task.

2.1.10 Data Servers Virtualization

•Data server virtualization, as a key strategy, includes creation of many virtual servers from one physical server**.** it also has significant impact on reducing carbon emissions.
•Through virtualization, data centers can consolidate their physical server infrastructure as multiple virtual servers are hosted on lesser number of servers. This result in reduced power consumption, reduced number of servers, and also reduced demand on the data center infrastructure.
• Virtualization has to be supported by the operating system that would separate the underlying hardware from corresponding application software.



ure 4.7 Data server virtualization.

•There are various ways and at various levels at which virtualization can be implemented. These various virtualization techniques are not independent of each other.

- presentation virtualization
- application virtualization
- desktop virtualization
- storage virtualization
- network virtualization

➢storage virtualization
➢network virtualization
•The physical arrangements of data servers, their aisle organization, and the manner in which the floor space and racks are physically organized also impacts the overall carbon emission from that data center.

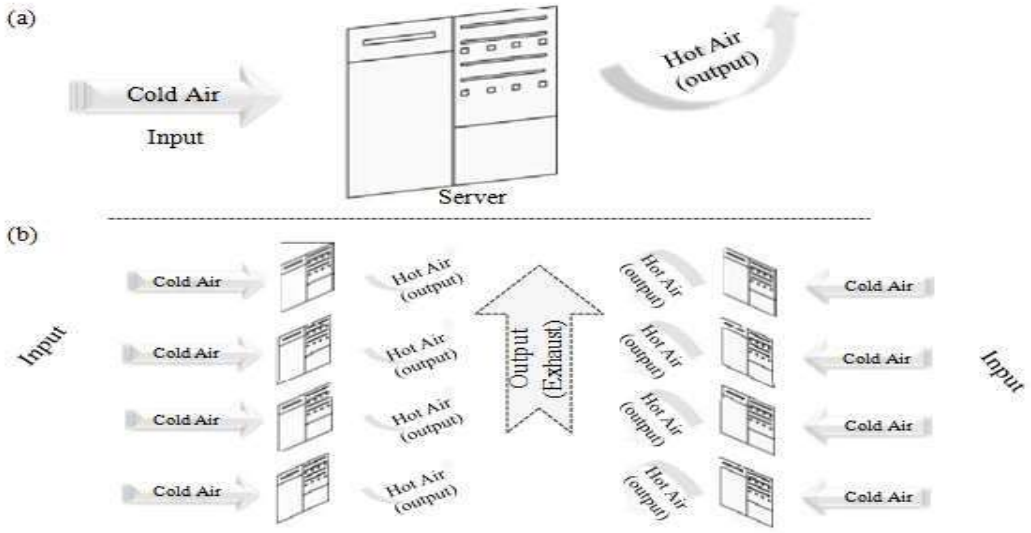


Figure 4.8 Physical server organization to reduce cooling effort.

•The physical cooling of the data center is one of the most important approaches to reducing the carbon footprint of an organization.
•These strategies start with architecture, design, and construction of t he data center building, location o f the center itself, positioning of the servers. And strategies for using air, water and other means for cooling the servers.
•Data centers use a n umber of different techniques to cool their servers,
•Water cooling
•Air cooling.
•These techniques are becoming far more important because they not only reduce the carbon footprint of the organization but, at the same time, improve its economic performance by reducing running costs of power consumption.
Physical arrangements of servers require the following careful considerations:
➢Server optimization
➢Disk identification
➢Equipment Reuse
➢Re-engineer Layout

Employ cooling strategies that are applicable at various levels within the data center—such as room-based, rack-based, and component-based cooling. These cooling strategies are interspersed with water-based and air-based cooling for example.

11. Cloud Computing and Data Centers

Cloud computing (Murugesan, 2011) provides substantial opportunities for organizations to consolidate their hardware and corresponding data space requirements.

With Cloud computing there is opportunity to not only consolidate the costs of services but also shift t he carbon generation to are latively centralized place where it can be better controlled and optimized.

Alford and Morton (2009) estimated that the use of Cloud computing costs an organization two-thirds less than running the same workload on a private non-virtualized data center. The concept o f C loud computing is also applied within t he organizational boundaries, especially for large, multinational organizations.

The "software as a service" (SaaS) business model emanating from Cloud computing allows companies to access key enterprise applications such as customer relationship management (CRM) and supply chain management (SCM) through the Internet.

As a result, the cloud obviates the need to host these applications in a proprietary data center. The opportunities to reduce carbon emissions increase with consolidation of both hardware and software applications.

12. Networking and Communications Infrastructure

The data centers also usually hold the communication equipments and related assets of the organization. These communications infrastructure support the internal and external networks of an organization and play a significant role in its carbon footprint.

The carbon generation includes the switches, routers, the LAN, WAN, and associated mobile transmission devices.

Networking strategies that are part of information architecture can not only help reduce traffic but also improve carbon performance.

Reduction of communication traffic eventually reduces t he server load minimizing memory and processing time on the server. However, this is also a balancing act that re quires careful attention to t he overall performance of an application.

Categories of networks:

➢*Wide Area Networks (WAN).* An organization enables communication amongst its desktop and laptop machines with and beyond its data center. virtual private network (VPN) of the organization which reduce the extent of influence an organization has over its power consumption and carbon generation.

➢*Mobile Networks.* The various mobile network technologies and mobile enterprise architecture that can also provide the backdrop for carbon reduction. The mobile communications infrastructure stack is made up of TCP/IP at the base, WAP, personal area networking (PAN), and, depending on the needs of the applications, metropolitan area networks (MAN). These network communications technologies further include the IEEE 802.1x group of standards and Infrared, Bluetooth, RFID, WiMax, and Wireless VoIP.

➢*Wireless L AN/WAN.* The paraphernalia associated with wireless communication becomes a major source of carbon generation and needs to be considered in comparison with the wired communications. While wireless communication may give the impression of reduced hardware and infrastructure (due to lack of physical wiring), it may still be inefficient and result in substantial carbon.

➢*WiMax* is another mobile standard for point-to-point communication that is based on radio- frequency standardized technology

➢The end-users, however, can play a role in the use of these communications technologies as they are *short-range communications* that can be controlled partially by the end-user. *The long-range communications net works*, primarily made up of the cellular networks (defined through their generations (G)), require a much more organized and consortium-based approach for controlling their carbon emissions.

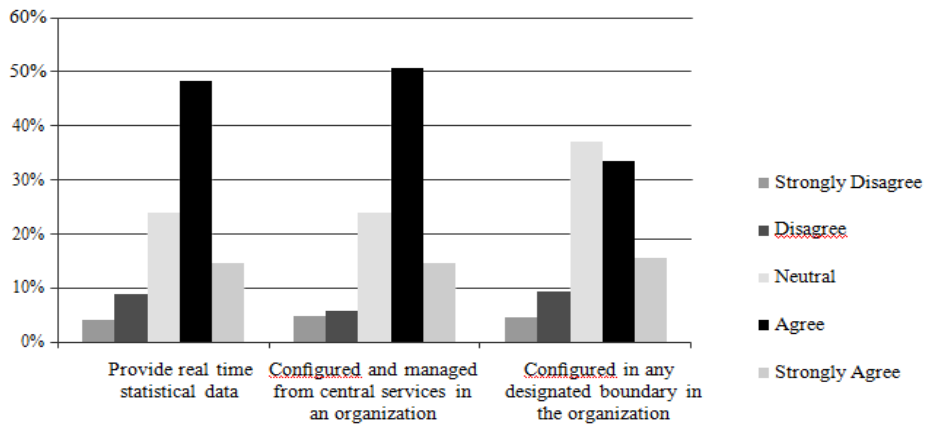


Figure 4.9 ICT devices as green enablers.

Now, it is vital to balance the provisioning of 3G, 4G and 5G with its carbon coefficient.

2.13. End-User Devices

•The gadgets and devices are part of t he movable assets of t he organization. These devices need to be considered from their carbon contribution viewpoint, typically in the initial tactical or operational approach to Green I T by the organization. This is the typical 3 –5 years strategy

•For example, H P lab tests have found t hat configuring P Cs with the optional 80% efficient power supplies along with the other ENERGY S TAR 4. 0 hardware requirements can reduce total system power consumption a s much a s 52%,

•Estimates of 15%–20% overall reduction of CO_2 are possible through virtualization and dematerialization using broadband networks (Hatch, 2009).

•Devices need to be inspected and formally audited to ensure t hey are serviceable. P roper maintenance o f equipments w ill en sure t heir longer operating life and eventually t heir reuse.

•Non-reusable equipments should b e re cycled. Eventually, if t hey cannot be formally recycled, equipments should be ethically disposed.

•A "green" disposal like this would ensure necessary safety as well as security procedures are carried out prior to reuse, recycling, or disposal.

2.14. Smart Meters in Real Time

•Smart meters are meters that not only measure the power consumption automatically, but a lso provide feedback to the users in real time.

•Thus, these smart meters give businesses an opportunity to monitor and take immediate actions to mitigate their power consumptions. By adding price information and by providing trends and patterns, households and businesses can be encouraged to monitor and reduce their use of power consumption.

•smart meters can also transmit this data for further analysis. EI applications can provide actionable information to the users.

•Smart meters can further enable automatic management of a device or group of devices. For example, apart from providing the power consumption data in real time, a smart meter can also be configured to shut the device when a certain level of power has been consumed.

Table 4.3 Polices and Practice of Green P-O-D in the Context of Devices and Peripherals

Tactical Green IT Activities	Comments and Reasoning
Eliminate the use of active screen savers	The amount of energy used by a monitor with an active screen saver is almost the same as the one doing useful work. Therefore, active screen savers should be eliminated.
Implement active power management	Operating systems of end-user devices should be controlling the switching-off of the devices when not in use.
Central management of machines	Central management of these machines will enable much better handling of their on- and off-times.
Specify low-power consumption CPUs and high-efficiency power supply units (80% conversion or better)	Sufficient power supply units can go a long way in reducing energy consumption.
Consider thick versus thin client carefully	Ensure right balance between a thick- and a thin-client architecture. While a thin client is less complex than a PC and contains fewer components
Use timer switches to gadgets (e.g., printers)	Peripheral devices, such as fax machines, printers, and copiers consume power even when on standby. The use of timer switches to turn off such equipment automatically has to be a mandatory feature of these devices.
Printer setup	Setting the printer, centrally, to a default feature of draft, duplex, and grey scale can reduce the amount of ink and paper used by printers. reducing the printing to only legal and formal documents can produce significant carbon savings.
Device consolidation and sharing	shifting from a PC to laptop, using the same laptop in the office and at home and using integrated mobile phones can all reduce emissions.

2.15. Managing Devices for Central Green Services

•Most large organizations (e.g., banks, airlines, hospitals) will have thousands of end-user devices such as computers and printers.

•This can include specific use of tools (e.g., BigFix's power management, http://www.bigfix.com/content/green-it) t hat would enable management of thousands of PCs with a single server that would consolidate and automate the management of their operating system, upgrades, and security management tasks.

•Centralized management of large number of machines for an organization is set to play a significant role in an organization's attempt to reduce its carbon footprint as it enables consistency across all the machines in terms of power management software, low-level power settings, lower energy configurations, and also consolidated green procurement and disposal.

•Centralized services for managing computers can make use o f environmental sensors and intelligent controls to monitor and manage a cluster of computers remotely.

•Smaller-sized, smart, mobile devices can also play a major role in reducing emissions.

•Mobile de vices can also re duce unnecessary movement of people and materials. However, mobile devices may produce electronic waste due to shorter lifespan of their batteries and the devices themselves. Therefore, they should be introduced and used in the organization in a balanced way.

2.16. Devices and Organizational Boundaries for Measurements

•Devices in the Green IT discussion play two roles: those that emit carbon and others that are used to measure, monitor, and mitigate carbon.

•Collaborative businesses and web services make it challenging to calculate an organization's carbon footprint.

Various tools and techniques in carbon measurement,

1, Dashboard displays attached to the devices to display emissions:

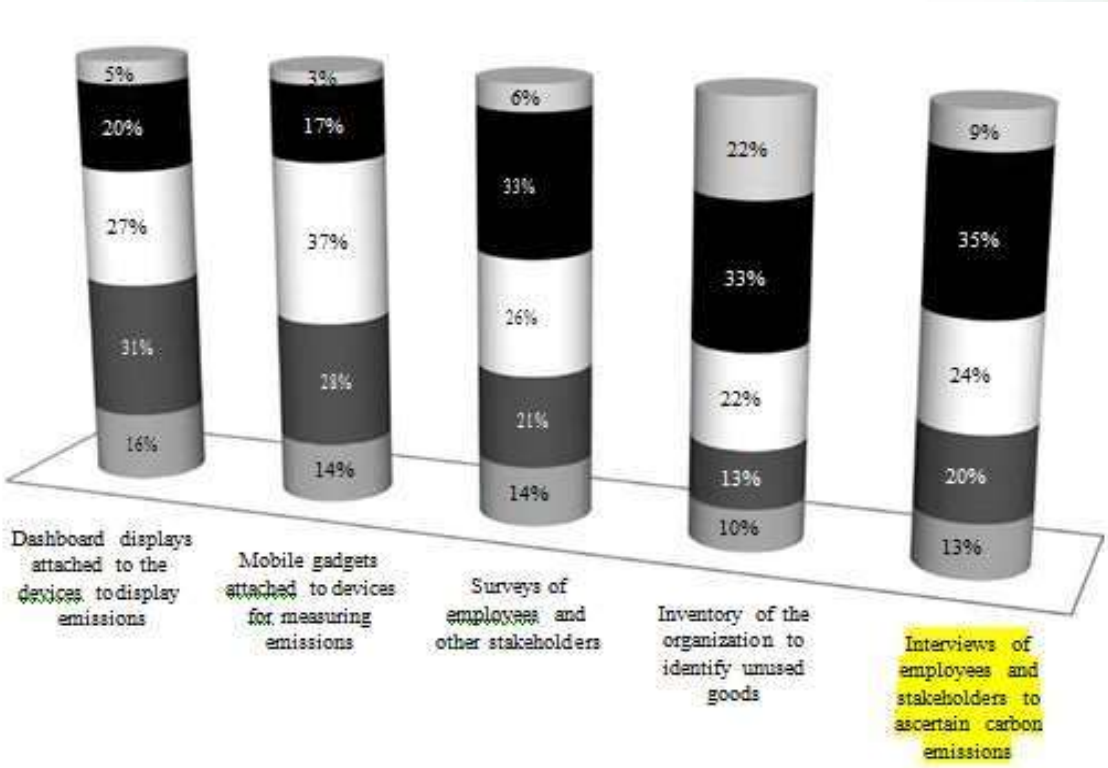
2, Mobile gadgets attached to devices for measuring emissions:

3, Surveys of employees and other stakeholders:

4, Inventory o f t he organization to identify unused goods

5, Interviews of employees and stakeholders to ascertain carbon emissions:

Figure 4.10 Tools used for measuring carbon emissions in your organization.



2.17 Mobile Devices and Sustainability

•Mobile technologies including mobile networks and mobile devices have a substantial role to play in the sustainability effort of an organization.
•Mobile users are increasingly concerned with the cost of energy and the energy consumption of their de vices.
•Focusing on improving energy and reducing the environmental impacts associated with mobile usage by business.
•Mobile technology a round the world has made mobility a unique environmental challenge, requiring attention toward what is called Green Mobile.
•Thus, green mobile affect economic viability, business process optimization, social responsibility, and technological capabilities, which form the four dimensions in a green enterprise transformation.
•Green mobiles en compass carbon-sensitive business strategies, optimized and collaborative business processes based on environmental intelligence approach, mobile networks, incorporation of t he R FID tags, mobile transmissions, improved design of t he devices and their batteries, and also their ethical disposal.

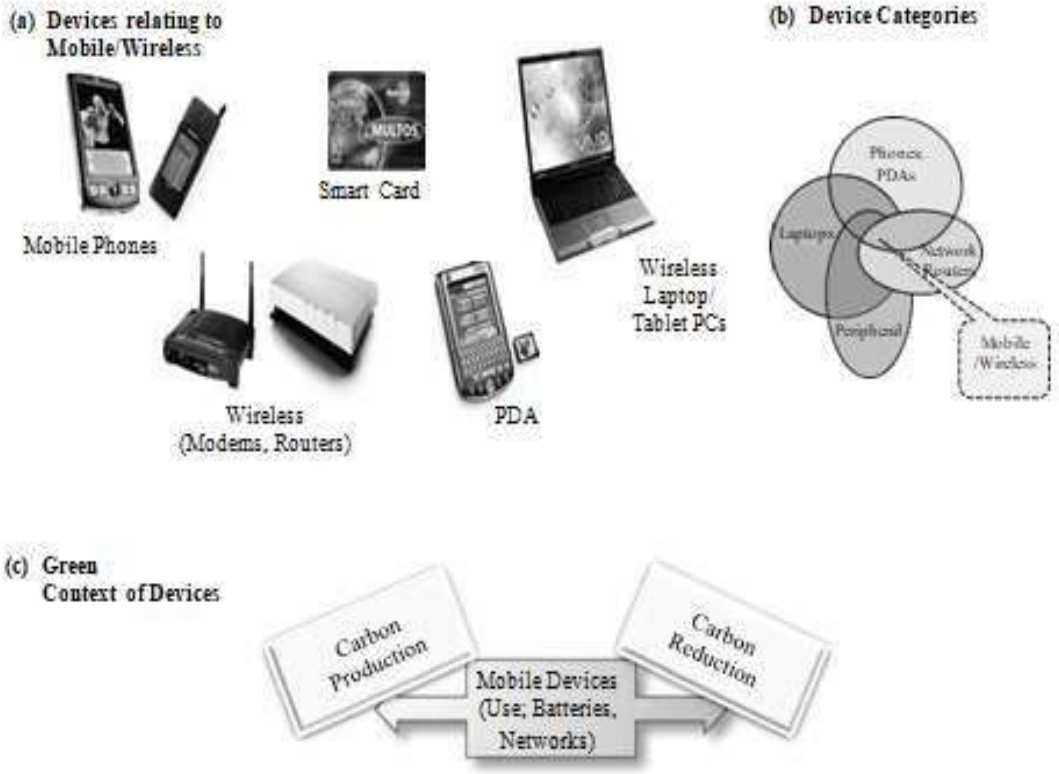
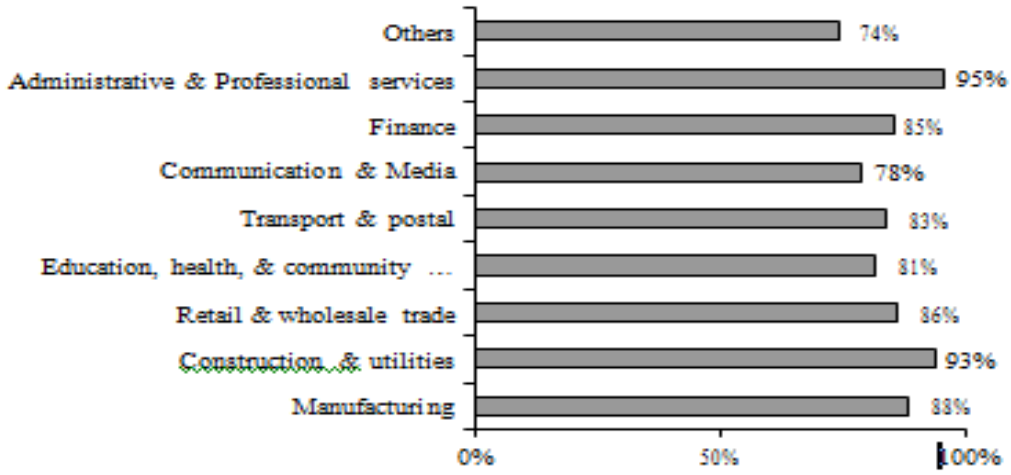


Figure 4.11 Mobile devices and Green P-O-D (outside of data center). The devices shown in (a) are grouped in (b). Each group of devices have their own uniqueness in terms of carbon emissions. For example, phones and laptops have lesser infrastructure but greater operational impact, whereas its the otherway round wiThnetworks and routers. Figure 4.11 (c) further highlights the need to con- sider the carbon production and reduction in boThdesign and operation of these devices.



Green mobile includes policies for reuse rather than upgrade of mobile phone, introduction o f mobile smart meters, improved analysis and reporting on environmental data (EI), and biodegradable material usage in the devices themselves (e.g., Biodegradable "Sunflower Phone" that has a built-in seed that will grow once the phone is planted in the ground; or Nokia— 3110 "bio-cover,"

- The desktop computers are heavy in size, need more power to run, and contains more amount of toxic materials such as lead, cadmium, and zinc. Mobile laptops such as notebooks, sub-notebooks, PDAs, and palmtops require low weight, low-power consumption, and good interactive performance (Douglis et al., 1994). They also tend to consume less power than the corresponding desktop machines.
- Reengineering the process with sustainability in mind can further lead to potentially eliminating the mobile phone as a device and, perhaps, replacing it with a messaging system combined together with a laptop or a tablet PC. This responsible approach toward mobility is in sync with the thoughts on sustainability by business experts working in this area.

2.2 Green Business Process Management: Modeling, Optimization, and Collaboration

Introduction

BPM is a well-established industry practice encompassing process modeling, reengineering, and optimization of processes, and the measuring, merging, and elimination of business processes.

For example, in the cash withdrawal process by a customer, efficiency from a carbon perspective can be achieved by, say, not printing a physical receipt; or reducing the time in the queue for a physical cash withdrawal by applying the principles of operations research.

Develops the concept of BPM further to a Green BPM, that of a lean business process to a lean-green business process and that of BPR to a Green BPR.

Table 5.1 Basic Process Characteristics and Corresponding Green Connotation

Process Characteristic	*Description (Lean Business)*	*Green Business Connotations*
Necessary	Challenges the need for the process in the first place. There is no point in making a process efficient and effective if it is not creating business value.	Eliminating an unnecessary process (not involving in value creation) will also eliminate its carbon contribution.
Efficient	Models the process to study its various activities/tasks. Challenges, automates, and merges activities to ensure they are performed with the best tools, technologies, and people.	Aims to reduce the carbon generation within the process by optimizing and/or eliminating the activities/tasks within the process. Technology is used by being embedded in the process.
Effective	Ensures that the process is actually achieving the goals it is meant to achieve. A process that is otherwise efficient and agile, but does not achieve business goals is not considered as effective.	Substantial wasteful carbon is generated by a process that is not effective—as it does not achieve business goals. Also, a process that is repeated more than once in order to produce the desired effect is a carbon- *inefficient* process.
Agile	Deals with the ability of the process to change itself in response to (or in anticipation of) external and internal changes affecting the organization. Deals with the dynamicity of the process.	An agile process will change easily and effortlessly in response to changing external situation. The agile virtue also renders the process green, as it can change with minimum carbon generation.
Measurable	Enables monitoring, control, and ascertaining the success of its optimization. Ongoing management of process performance is also supported.	In addition to the standard process measures, such as cost, time, and quality, now the "carbon content" of a process is measured. This helps in identifying the slack and optimizing it.

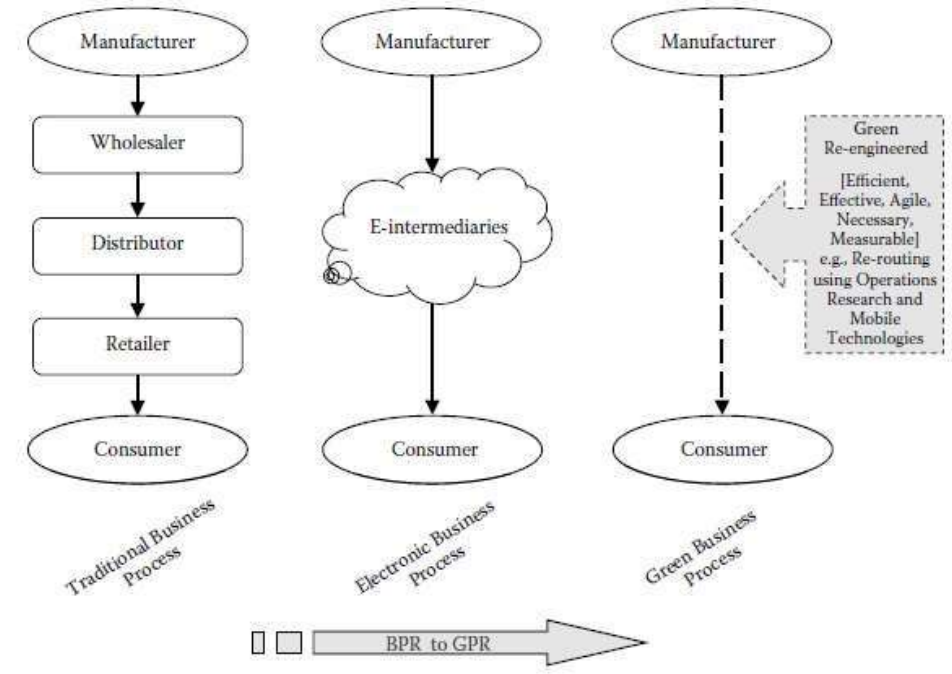
2.2.2Green Business Process Management

- Green BPM is an overall approach to modeling, optimizing, consolidating, and executing business processes of an organization from a carbon perspective.
- BPM can be understood as a discipline of modeling, realizing, executing, monitoring, and optimizing business processes (ACS, 2010). E ach of these aspects of BPM can be applied toward a green enterprise.
- Green BPM, as discussed in this chapter, has opportunity to capitalize on the BPM approach in an organization and can be considered as a set of management and technology disciplines focused primarily on workflow and process automation that drives the implementation of optimized and sustainable business processes.
- Processes can be optimized to ensure efficient utilization of resources.
- Processes can be reengineered to creatively eliminate the use of some redundant or duplicate resource.
- For example, a home loan (mortgage) process that requires application by a broker, credit check validation, and risk assessment through three separate agencies can be electronically consolidated as one.
- Reengineering has been described as the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance such a s cost, quality, service, and speed
- Reengineering of processes and application of the lean principles has a major role to play in Green BPM using an environmental parameter. Thus, lean-green can be viewed as a change to business practices together with changes to business models and methods.
- Thus, it is not only the changes to the processes or “how” an organization operates that is important, but also the underlying business models, technologies, and social aspects of that business.
- IT plays a substantial role in providing a utility or a service to the business that can then be used by the business in its models and methods, such as lean, to become green.

2.2.3.Green Reengineering

- Green BPM includes reengineering of business processes to optimize their emissions.

- Reengineering is the green processes, will incorporate reevaluation of processes and also an understanding and modeling of their supporting hardware, software, and people in order to cut down the carbon generated through them.
- The success of Green process reengineering (GPR) depends heavily on undertaking a model-based, performance-driven approach that is applied to the entire organization.
- Distribution process on the left in Figure 5.1 shows a manual distribution.
- Process, with steps leading from the manufacturer through to the warehouse, retailer, and the end-user electronically enabled process.
- The product of an organization's web site and enabling the consumer to order it directly from t he website. With such reengineering, t he steps associated with t he wholesaler and t he retailer can both be avoided—although the intermediaries can be the technology service providers and content managers



igure 5.1 Core concept of GPR—a distribution example.

- This reengineered process is efficient and effective from a cost and time viewpoint, and also from a carbon viewpoint for example eliminate the E-intermediaries
- Location--sensitive mobile technologies can improve the carbon performance by eliminating intermediary steps that result in carbon the end result would be a carbon-efficient process.

- Green metrics help in understanding the effects of reengineering. For example, green reengineered process can be measured for the total carbon content of the production process, the carbon generated by customer searches, and the overall carbon produced in ordering, packaging, and distribution to the consumer
- The resultant quality, end-user experience, and carbon reduction would all come under the umbrella of BPM
- Green BPM includes fundamental changes to the processes and their ongoing management. The change to the processes is that Green BPR aims for a dramatic drop in the carbon emissions by a combination of process changes and systems (technology) support.
- BPR initiatives lead to customer-focused processes whose end-goal is to achieve customer satifaction rather than create hierarchical reorganization. Serving a customer efficiently and providing an enhanced customer experience reduces waste and therefore reduces carbon. An efficient and optimized supply chain will also reduce the organization's carbon footprint
- In addition to lean and reengineering, it is also worth considering TQM (total quality management) and its impact on the green process dimension of an organization
- The resultant improvement in quality leads to reduction in rework. This reduced rework can be directly correlated with reduction in carbon emission.

2.2.4.Green Processes: Individual, Organizational, and Collaborative

- The various levels of processes within an organization and their corresponding key factors. These are the individual, organizational, and collaborative processes.
- Individual processes tend to be tactical and tend to provide quick-wins, such as individuals switching-off their computers when not in use.
- Collaborative processes tend to deliver longer-term results.
- There is a need to understand and relate the core processes as well as peripheral activities of the organization to the corresponding carbon contents. Modeling and optimizing core processes from a carbon perspective has higher risks than peripheral

- For example, a hospital has its core competency of treating patients. A hospital is often associated with pharmacies for dispersal of medications and pathology laboratories for conducting a suite of tests on patients. Then, A hospital cannot afford to modify its patient-related core processes even if they are carbon-intensive.

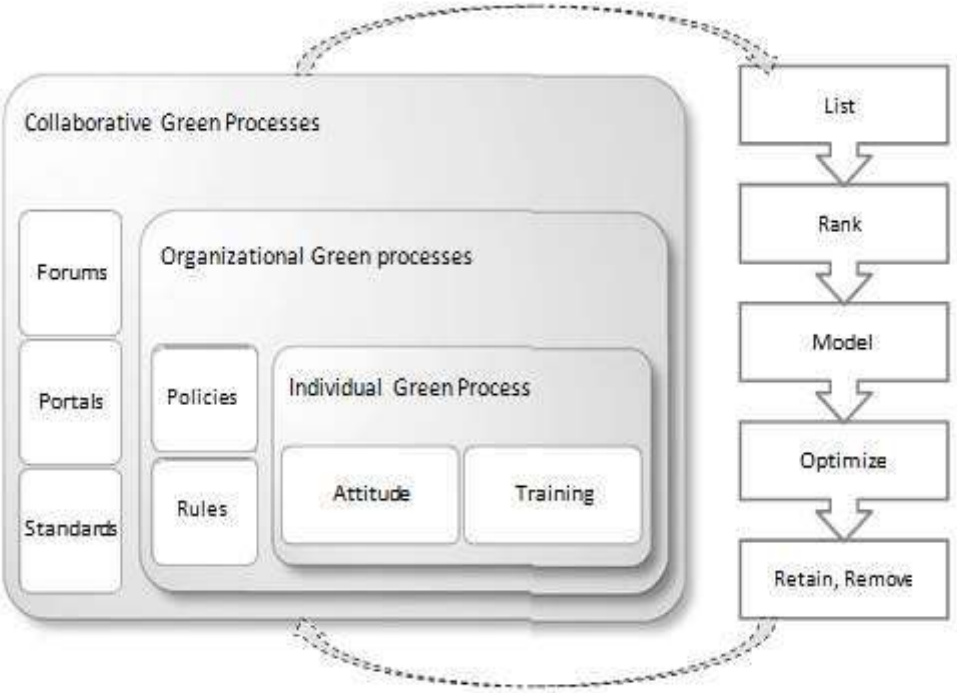


Figure 5.2 Individual, organizational, and collaborative green processes and their reengineering.

Table 5.2 Green Process Categories and Their Carbon Impact

Green Process Categories	***Key Factors That Influence Carbon***	***Comments***
Individual	Attitude, Training	Personalized processes are influenced by attitude and training. Motivation of the individual may be based on personal value system, personal reward, and growth.
Organizational	Policies, Rules, KPIs	Dynamic creation and management of business rules that optimize processes. Metrics are crucial to demonstrate the ROI on investment for green enterprise.
Collaborative	Portals, Forums, Standards	Collaborative processes transcending organizational boundaries. Portals containing green knowledge, regulations across regions.

- ***Listing***—ofallprocesses within an organization
- ***Ranking***—of the processes within the process list. This ranking is meant to provide which particular processes should be given highest priority
- ***Modeling***—process reengineering requires accurate modeling of those processes. Process modeling, the (Unified Modeling Language) UML (particularly its use cases and activity graphs), user stories, BPMN (business process modeling notation), and (Integration Definition) I DEF a re all well-known techniques.
- ***Optimizing***—this step is the study o f the processes that a re modeled from t heir carbon impact.
- ***Retaining***—processes that are modeled and optimized will reduce their carbon contribution. These are the processes that can be retained and placed in a continuously optimized mode.
- ***Removing***—the BPM exercise will also identify processes that are either redundant/duplicated or are so excessively carbon inefficient that they have to be replaced. These are the processes that will be removed from the suite of business processes

2.2.5.Green BPM and Standards

- Green BPM can be carried out in a number of ways, and using different tools and techniques.
- It includes technical approaches, such as service oriented architecture (SOA) that are closely intertwined with BPM. The relationship between SOA and BPM becomes more important in the green enterprise space as changes to processes to make them green cannot be brought about independent of the information and enterprise architecture.
- Excellence in Green BPM is based on understanding and application of the reengineering and process management concepts to the organization but with the focus on carbon reduction together with cost reduction.
- The end-user is shown accessing the device, which in turn is linked to a presentation process. This is then supported by the business or system level processes. The business processes are supported by applications, corresponding data warehouses, and eventually the technical infrastructure such as data servers and communications networks

Green BPM is a combination of technology-enabled but business-driven process management.

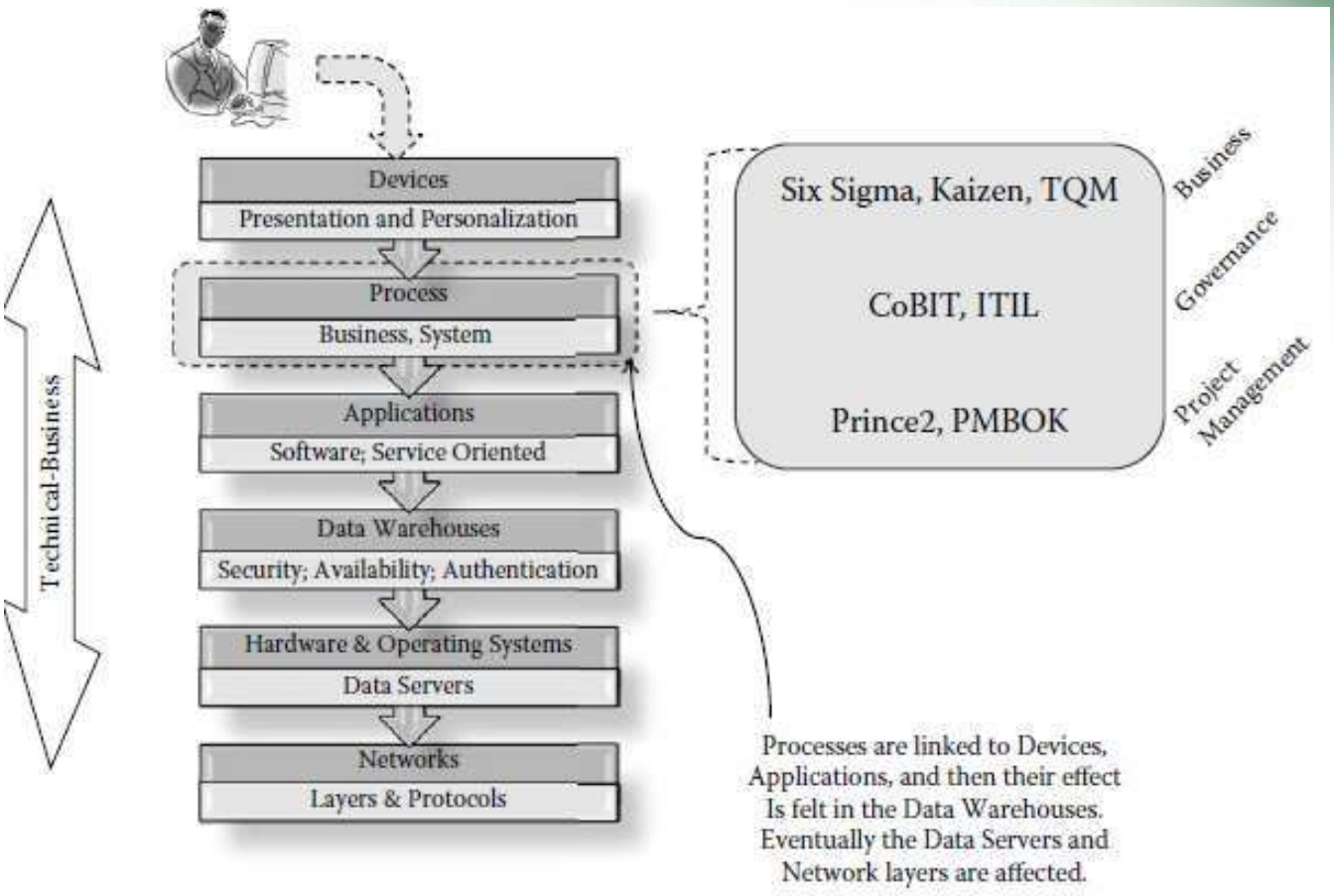


Figure 5.3 Applying business, governance, and project management standards to green business processes.

Standards in Green BPM

- TQM, Kaizen, and Six Sigma provide standards and techniques to optimize and improve business processes. This will result in improvement in quality of product and, thereby, improve organizational performance also be used to improve the carbon credentials of the organization.
- Efficient business processes to produce greater quantity of goods which improved production capacity.
- Customization and personalization of product to ensure that personalization does not lead to addition of carbon in the process.
- Reengineering of processes optimizing the internal organizational structure. This includes rearranging and repositioning people.

- Knowledge management enables keeping track o f customer preferences to manage green preferences of the customer.
- Integration of underlying applications and systems which creates opportunities foroverall carbon reduction.
- Outsourced processes are another example f t he opportunity to re duce overall carbon emissions

During green reengineering of business processes to ward green processes, customers should not be considered as "external parties" but, instead, invited to participate in the modeling, optimization, and management of the processes.

- ***customer-driven reengineering*** Setting up of regular communications with the customers reducing the carbon overheads associated with unplanned provisioning of customer requirements
- Customer participate in t he green strategic planning sessions as well as green policy formulation.
- Measurement and feedback on customer service in terms of carbon associated with a business process (such a s with smart meters) can result in a immediate impact on customer behavior.
- Green BPR can involve use of virtualization technologies or, alternatively, incorporation of a new technology in the process with the intention of reducing its carbon footprint.
- There are risks associated with customer satisfaction if only carbon performance is kept in mind during Green BPR.
- Careful weighing of every green process optimization needs to be made to consider the technology-process.

2.2.6.Green Business Analysis

- The role of business analysis activity, including the gathering of business requirements, understanding and modeling processes, process analysis and optimization, and testing prior to deployment.
- This role of a Green BA can provide analytical help and support for green business process modeling.
- The BA is also responsible for working with the key business executives and users to determine the goal and expectation of the business process. These expectations are documented by the BA with reference to the technical capabilities of the IT solution

- A green-conscious participation of a BA in the system requirements lifecycle can result in new business processes that are optimized right from the beginning.
- A Green BA can play a dual role: First, modeling requirements for a Green IT project and, second, modeling existing processes for their optimization from a green perspective.
- Green BAs incorporate channels within the processes to foster creation of green groups and spread corresponding green knowledge amongst them.

2.2.7.Green Requirements Modeling

- The requirements modeling can be considered a s a sub discipline of systems engineering that is concerned with the behavior, quality attributes, and also technical constraints.
- Green BA can work to model requirements using other approaches such as user stories, scenarios, and simple flowcharts.
- Green practices can affect requirements related to hardware, software, and business processes.
- A requirement may establish, for example, a solution that must not only fulfill business goals, but also measure and report energyimprovement over previous generations.
- Approaches such as server consolidation and virtualization, storage virtualization, Cloud computing, and power management, among other green-related technologies, can help ICT solutions become more efficient, flexible, resilient, and environmentally friendly while economical to operate.
- Green requirements modeling can be divided in two major parts—:

1. functional and
2. nonfunctional (or operational).

1. Functionalrequirements,

- The most well-known type of software requirements, They are associated with the required behaviors and operations of a system, defining its capabilities in terms of actions and responses.
- Functional requirements are frequently captured in the form of use cases. Green IT frequently impacts functional requirements as a consequence of new procedures or business rules emergingfromcorporate environmentalpolicies and industry standards.
- For example, to help to reduce paper reports b y encouraging online reporting. The BA must sp end time investigating t he capabilities needed in t he system to convince users (system users and indirect users, such as managers and customers who do not work directly with the system, but need access to its outputs) to stop printing, and read from their computer screens instead.
- In order to achieve this objective, functional requirements may be added to the software specification, to facilitate tasks related to reading and distributing online reports to their intended audiences.

2. *Nonfunctional requirements*

- There are requirements, however, that go beyond system behavior. These requirements describe the properties and attributes of the solution and are referred to as *nonfunctional requirements*. Such requirements include availability, performance, usability, portability, robustness, etc., and they provide t he design constraints for t he project.

- Green IT policies typically add nonfunctional requirements to software projects, imposing new demands in terms of quality attributes that become necessary or desirable, and also establishing new constraints.

- For example, a company adopting a mechanism to control all monitors and computers, so they can be placed into a low-power consumption mode (such as shutdown, hibernation, or standby) when they are not being used.

Corporate environmental practices, sustainability policies, regulations, and contractual obligations to meet environmental standards may impact both functional and nonfunctional requirements of ICT applications.

2.2.8.Green Business Processes—Incremental Complexity

How the four dimensions of green business transformation (economic, technical, social, and process) influence the formulation of green business strategies and policies.

Increasingly complexities of these processes and also indicates that at the operational and collaborative levels, the application of lean and agile principles will support business sustainability.

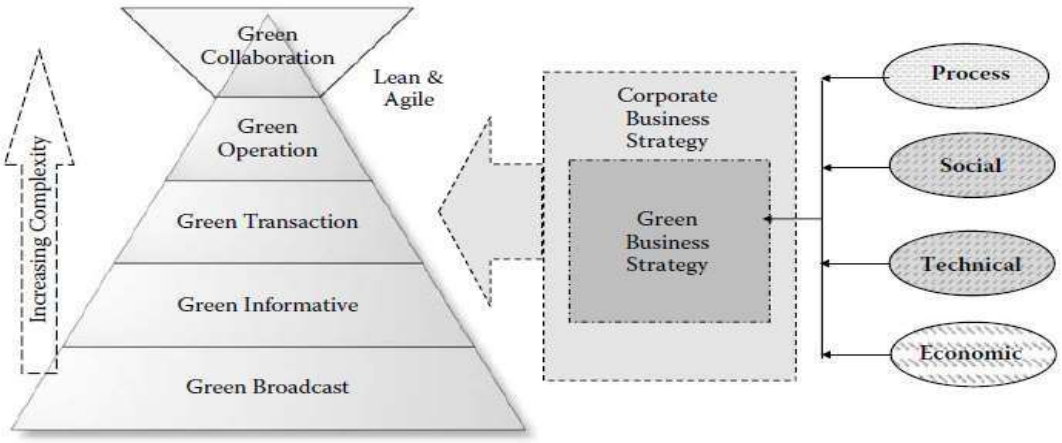


Figure 5.4 Green business strategy drives incrementally complex GPR.

Broadcast processes—These are easiest processes to understand, model, and optimize when

they are the one-way broadcast processes typically used by the organization to promote and advertise their products.

Informative processes—The green aspect of this informative category comes from the fact that the receiver of the output of this informative process is known to the organization. These informative processes provide data on carbon emissions per day, per asset, and so on.

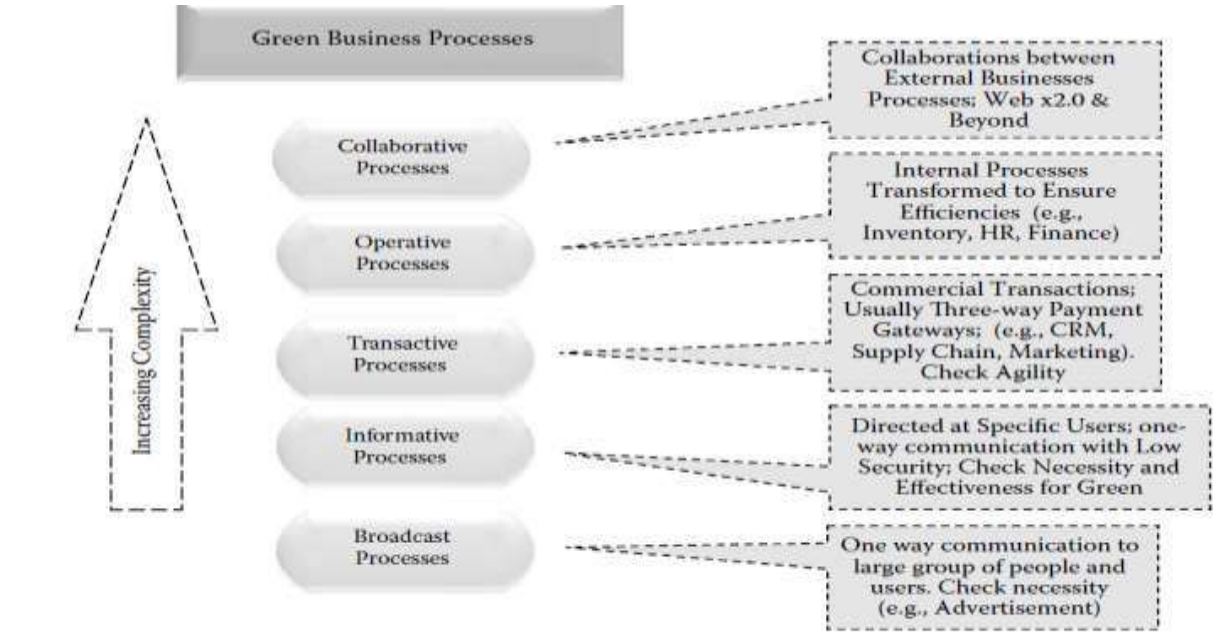


Figure 5.5 Increasing complexity of green processes.

Transactive processes—Typically called the electronic commerce processes requiring a 3-way interaction between the vendor, the customer, and the payment facility (such as PayPal or Visa credit).

- The carbon content of a transactive process is higher than the previous two processes because multiple parties are involved and the transaction is stored electronically in a secured.

Operative processes—These processes are of more complexity and deal with the internal, operational aspect of the organization. Therefore, they include processes such as HR, inventories, and time keeping. These processes also include the supply chains, the procurement, and eventually, the disposal processes of the organization.

Collaborative processes—When multiple organizations interact with each other through collaborative web -based processes, the carbon generation is not only significant, but also increasingly challenging to trace because the organizational boundaries of these processes is extremely fuzzy. It becomes difficult to ascertain whether the Scope-3 emission of one organization is actually a Scope-1 emission of another organization. collaborative processes have the potential for saving carbon, as they prevent reinvention of the basic business functions.

For example, name and address can be sourced as a service from a third-party provider, thereby preventing the need to create the software to manage name and addresses in the systems of every participant organization in that collaboration.

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2.2.9.Green Business Applications

- Most green business processes will have to be supported by corresponding green systems and applications.
- Understanding this relationship between processes and applications is important as, during the BPM exercises, changes to the processes will require corresponding changes to those systems and applications that support the processes.
- This relationship and impact of green business processes on corresponding organizational level systems and applications.
- The broadcast, informative, transactive, operative, and collaborative processes impact business applications such as—financial management information systems (FMIS), enterprise resource planning (ERP), supply chain management (SCM), and customer relationship management (CRM).

2.2.10.Modeling Green Business Processes (UML, BPMN)

- The modeling notations are made available through process modeling tools (Unhelkar, 2003) and can be used in a team structure wherein a group of BAs could be working in unison to produce and optimize process models.
- The modeling of processes is a crucial step in process optimization. In the case of Green BPM, the value at the end of the process is not independent of the carbon generated.
- Therefore, all process modeling has to include carbon consideration at each step and for each process. Thus, each process needs to be modeled in an optimized way, with minimum activities and tasks that relate to each other and that achieve the process goals with reduced carbon footprint.
- This modeling of processes can be undertaken with the help of process modeling standards such as the UML or the process-specific notations of the BPMN.

2.2.11.Quality of Service (QoS) and Green Business Processes

- While process models play a crucial role in Green BPM, they have to be also validated and verified for their quality and their impact on the quality of services offered by the organization. The activities within the process are then optimized for their carbon content.
- Apart from the functional accuracy of the processes, this QoS is usually the result of the nonfunctional or operational demands on the business processes.
- In a Green BPM, however, QoS is not enhanced entirely for the sake of customer satisfaction. In fact, the carbon content of enhancing a customer experience and, thereby, improving the QoS is also demonstrated to the customer.
- Therefore, Qo S, in a Green BPM, is now balanced with quantity of carbon (QoC) within the process.
- Enhancing the QoS will result in increased carbon content may not be correct. This is so because an enhanced QoS will result in less repetition and therefore less wastage.

- In fact, enhancement in QoS has a high potential for reduction in QoC over the entire life of the interaction of the customer with the organization.

2.2.12.Documenting Process Goals

Processes can be measured for their efficiency and effectiveness as described by Unhelkar (2003). When applied in the green context, each process has to be measured for its carbon content.

For example, the business process dealing with "cash withdrawal from a bank counter" has a certain carbon content that is based on the activities, t he people undertaking t hose activities and t he deliverables produced.

The UML diagrams are also relevant in measuring the carbon generation when they are executed.

Achieving Green BPM

- People know processes and execute processes. They need to know the purpose and the passion to perform processes in such a way to achieve Green BPM goals.
- The Green B PM should essentially reduce the need of transports while doing jobs.
- Facilities are essential for any business and these facilities should be rearranged to suit green business goals.

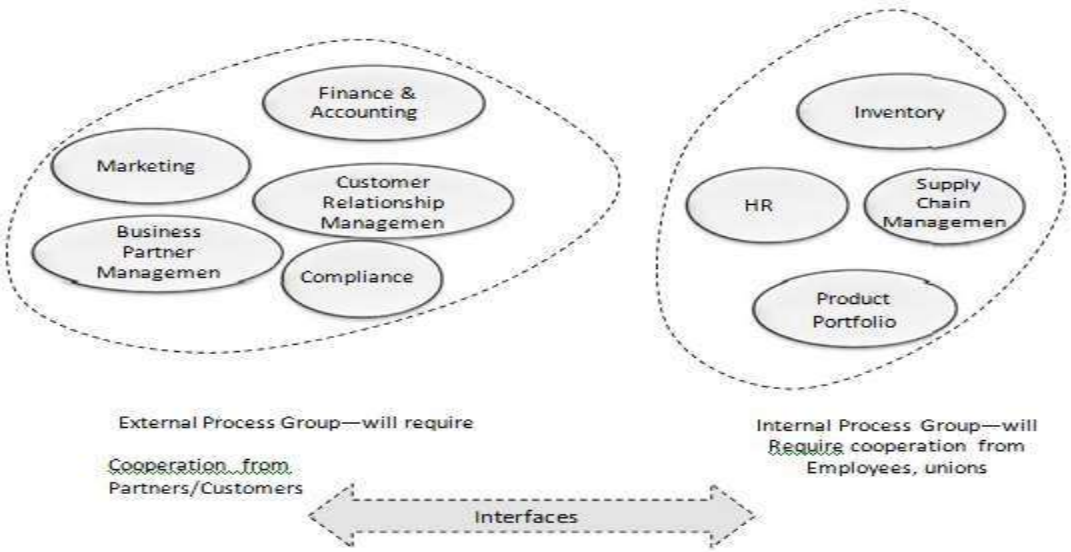
Figure 5.7 The Green BPM factors.

- The development processes should be carefully modeled so thatthe carbon footprint for the development of any product or service could satisfy the Green BPM goals.

- Production is a continuous work done in businesses which also add carbon footprint to the outputs
- The way of managing information is the key to achieve the Green BPM goals in any business. it can provide the knowledge of green status of the processes.
- Effective communication will pave the way to achieve Green BPM goals quicker and it can also reduce the effect of carbon footprint.

Organization-wide GPR needs to consider processes in groups. Business processes can be grouped as internal and external.

The external group is made up of processes that require cooperation and coordination with business partners of the organization. Therefore, this may be a more challenging group to apply green practices.



ure 5.8 Grouping of "business processes" for green reengineering.

The second group, shown on the right in Figure 5.8, is internal process group. This group can benefit by support from the employees and unions within the organization.

2.2.13.Green Mobile Business Processes

Mobile-Broadcast—use of mobile technologies enables sending of one-way information to a large group of people who may or may not be registered as users.

Mobile-Informative—use of mobility provides the organization with the ability to provide environment-related information to t he various stakeholders within the business.

Mobile-Transactive—usage includes collection, collation, and reporting of environmental data with the use of handheld mobile as well as stationary but wireless devices. For example, the measurement of the temperature of a furnace or an engine can be conducted using wireless devices.

Mobile-Operative—usage provides opportunities for the organization to model and optimize its

internal processes that will produce environmentally friendly results. Mobile telecommuting is a serious consideration for mobile-operative use by business, wherein workers need not be physically present at the premises of the company. The employees have an access to the environmentally intelligent systems which can help them carry out their day-to-day activities in an eco-friendly way.

Mobile-Collaborative—where organizations are influenced by their business partner's policies and strategies toward green environment. Instead, the mobile collaboration influences the entire "ecosystem" of companies that are together, dealing with each other using mobility.

The four dimensions are also discussed from the environmental- mobile context.

- ***Environmental–Economic Mobile Use***
- The economic influence of mobility needs to b e considered here in terms of its relevance to t he environment.
- For example, the economic reasons for transitioning to mobile business can be extended and discussed interms of the economic reasons for transitioning to and managing a sustainable mobile business.

Environmental–Technical Mobile Use

- Millions of new mobile phones are bought each year worldwide under various reasons including the social reasons for the adolescent market. Mobile gadgets are environmental challenges both during manufacture and at disposal (Unhelkar and Dickens, 2008).

- Beginning with their design, manufacturers can improve reuse and recycling of their mobile products, including the use of effective and responsible take-back and recycling that can be put to good use by the users.

- Technical designers seek to create mobile gadgets which will have minimum impact on the environment Nokia has released a model called " 3110 Evolve" which is claimed to use " bio-cover"—the casing of t he phone, And "Sunflower Phone" by Green Mobiles introduced in t he United Kingdom that claims to be biodegradable as it has a built-in plant seed which will grow once the phone is planted in the ground.

Environmental–Process Mobile Use

- The modeling, study, and optimization of business processes need to be undertaken f rom a mobile perspective. Enterprises are looking to mobility solutions to extend their BI solutions to involve and coordinate office, field, and home decision making resulting in potentials for the communities.

- These improvements enable organizations to gain environmental advantage by optimizing mobile field and workforce.

Environmental–Social Mobile Use

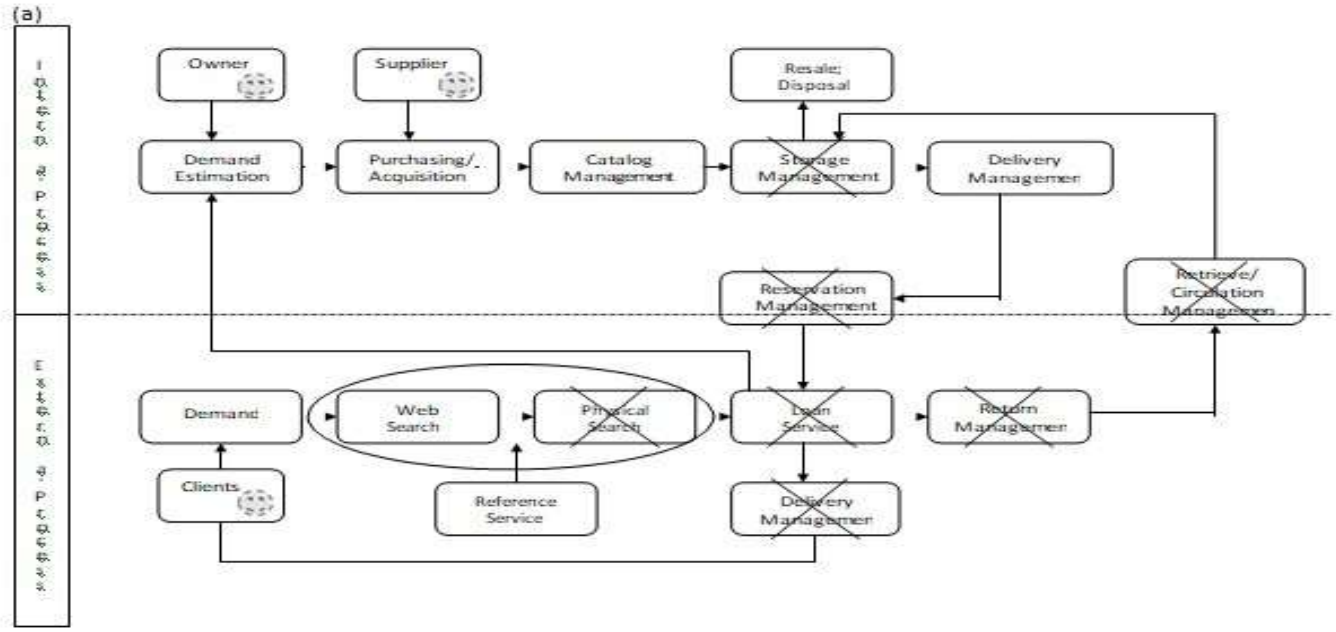
- The social dimension of mobile technologies—particularly the devices and the social networks—relate to the environment in many ways. For example, the ability of personalized transmission of messages can be utilized in raising environmental awareness amongst specific users.

2.2.14.Example—Digital Library GPR

The process can be divided into internal and external domain.

Demand estimation, purchasing, catalog management, storage management, delivery management, disposal are some of system comprising the internal business process. Web search, physical search, loan service, return management, delivery management are some of the systems present in the external process.

For example, the physical search on the external process can be eliminated and replaced by an overall search system.



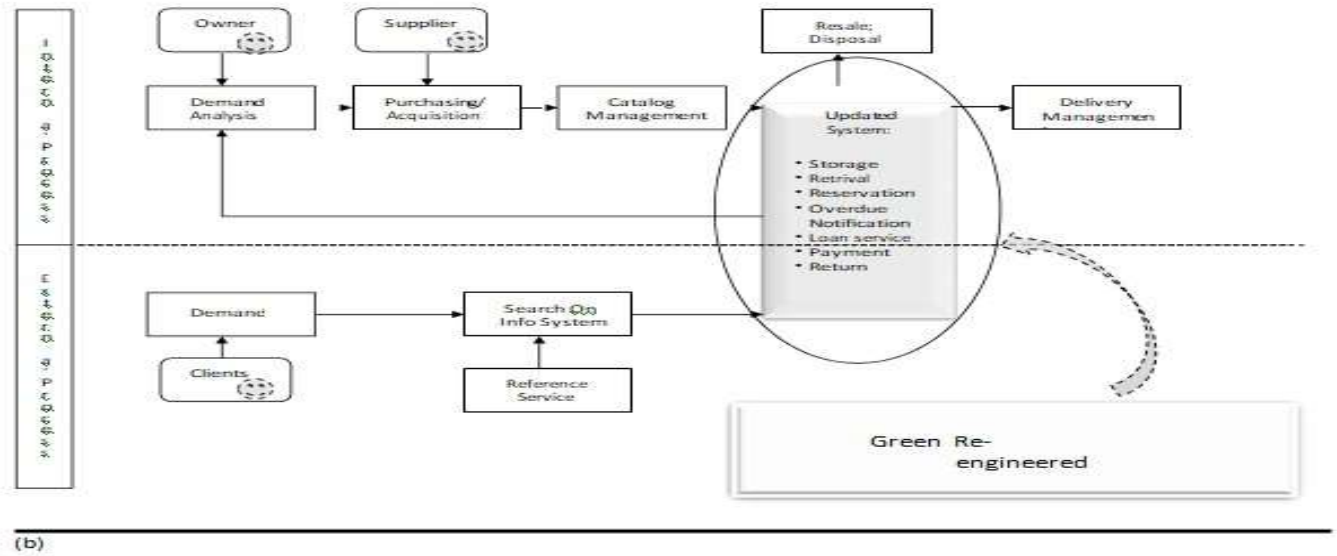


Figure 5.10 (a) Digital library GPR. (b) Digital library GPR—results.

- The centralized system could either be maintained in-house or can be outsourced to external agencies or can be deployed into the Cloud environment.
- Also when deployed to external agency or to cloud environment, the services could be offered to other digital libraries. This could reduce the number of systems which individual libraries have and reduce the overall carbon emissions cumulatively.
- The green business policies will help in rewriting the business rules related to digital library processes. Once t he policies and rules are documented and necessary performance indicators are established, t he core process can b e re–engineered.
- All these processes should be monitored through K PIs that are defined together with green business K PIs.
- These KPIs results will enable the business to gain more knowledge on the carbon footprint generation throughout the processes and helps to improve the digital library and make it green.
- Enabling online search and lending services will reduce transport and thereby help to reduce the carbon generation. Adaptation of Cloud computing by the digital library can also help to reduce carbon generated due to the information storage and processing.

2.3. Green Enterprise Architecture – Environmental Intelligence – Green Supply Chains

- The Enterprise Architecture defines relationships between the specific domain architectures and how the different architectures relate to each other and contribute to the overall enterprise.
- When these architectural relationships are further investigated and developed from the point of view of their underlying carbon impacts, the end result is a Green enterprise architecture (GEA).
- Extending an EA to a GEA, and then using that GEA as a basis for transforming the systems, applications, and processes of an organization to a green one provide the following advantages:

- An understanding of the existing systems, applications, and processes of the organization and its current technological capabilities and constraints.
- The relationship of the systems within the current EA to the new Green IT systems and applications.
- Alignment of existing and new infrastructure, operations, systems, and applications with each other and with the environmentally responsible business strategies (ERBS) of the organization in a synergetic manner.
- Creation and description of commonly used terminologies, semantics, and business rules relating to the organization as well as to its green initiative.
- Creation of specific Green IT frameworks, that are based on known architectural frameworks, are developed or ground up, specific to the organization.
- Enhancing existing knowledge of the enterprise and using emerging technologies (such as Cloud, SaaS, SOA, and Web 2.0)
- Incorporating mobile technologies with the evolving EI

Green Enterprise Architecture

- The aim of a GEA is to develop an understanding of different viewpoints of business, technology, and the environment in which the business exists.

- Developing such an EA would imply an understanding and modeling of the business as well as technology space of the organization.
- This results in data integration, process integration across multiple systems, collaboration amongst internal and external business applications, and extension to real-time information using mobile technologies and systems.
- The end result is a unified view of the business that can be updated and tuned for a green enterprise. A GE A also incorporates interfaces to the organization's customers, suppliers, and other trading partners.
- GEA is also crucial in providing technical basis for development and implementation of a GIS. These GIS provide t he organization with software system level support in measuring, monitoring, and reporting carbon data.
- GIS are a combination of implementing a new software system, together with significant upgrade o f and integration with existing systems.

The following activities are undertaken, with help and support of a GE A when it comes to GIS in an organization:

- Integration of new systems with existing organizational systems (typically ERP packages, CRM) using SOA-WS interfaces.
- Modification of existing data structures with a Green IT hardware and other carbon-emitting assets.
- Conversion of existing organizational data in a new format
- Evolution of existing decision support and knowledge management systems toward environmentally intelligent systems
- Creation of a suite of green services using SOA and WS
- Applying mobile technologies to provide location-independence and personalization to GIS.
- Quality assurance and testing of Green info systems.

Views of Green Enterprise Architecture

- GEA encompasses an understanding of the various views of the organization and its interrelationships.
- The Green information architecture (GIA), primarily deals with the models of information capture and information provisioning to both external and internal parties in the business space.
- The information architect and the business analyst work in this space identifying and modeling the information requirements.

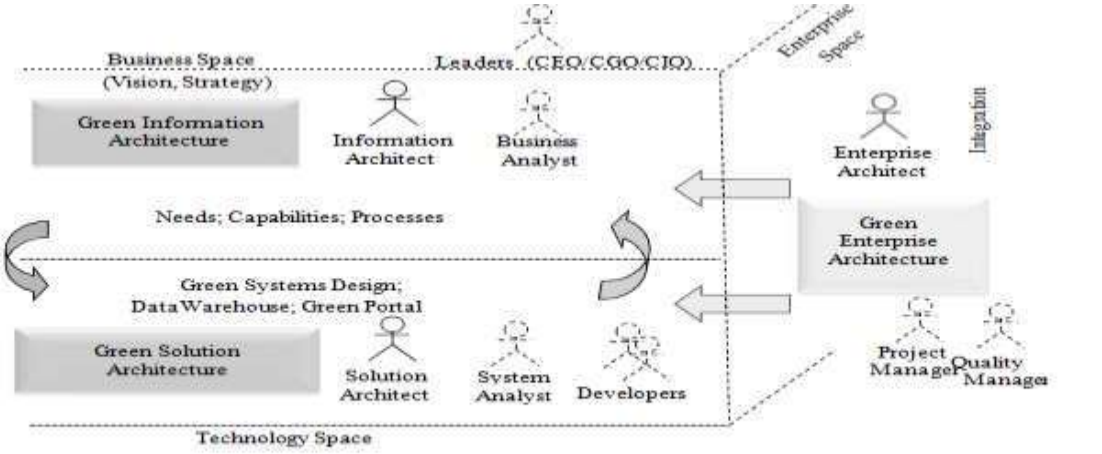


Figure 6.1 Various views of a comprehensive Green enterprise architecture: Business, technology, and enterprise spaces.

- The GIA de scribes the enterprise from a business perspective.
- This would result in a prioritized suite of functional and operational requirements that become part of the green transformation program.
- Green solution architecture appearing in the lower half of the architectural spaces, deals with the design and development of systems from a technical perspective.
- The GEA also influences both the information and solution architecture models.
- Different architectural domains such as the business architecture, information architecture, application architecture, technology architecture, and operational architecture.
- The overall GEA encompasses all of these architectures and provides constraints, limitations, and requirements for each of these architectural domains.
- The project manager and quality manager support the architectural work by helping in formulating and scoping Green IT projects and using appropriate and matured standards and processes.

Green Enterprise Architecture—Categories of Requirements

- The business and information aspect of the organization are primarily the requirements; the ones that a re in t he solution space a re related to the data and applications;
- The GEA in the background is influencing and influenced by the GIA as well as the GSA from the problem and the solution space respectively.

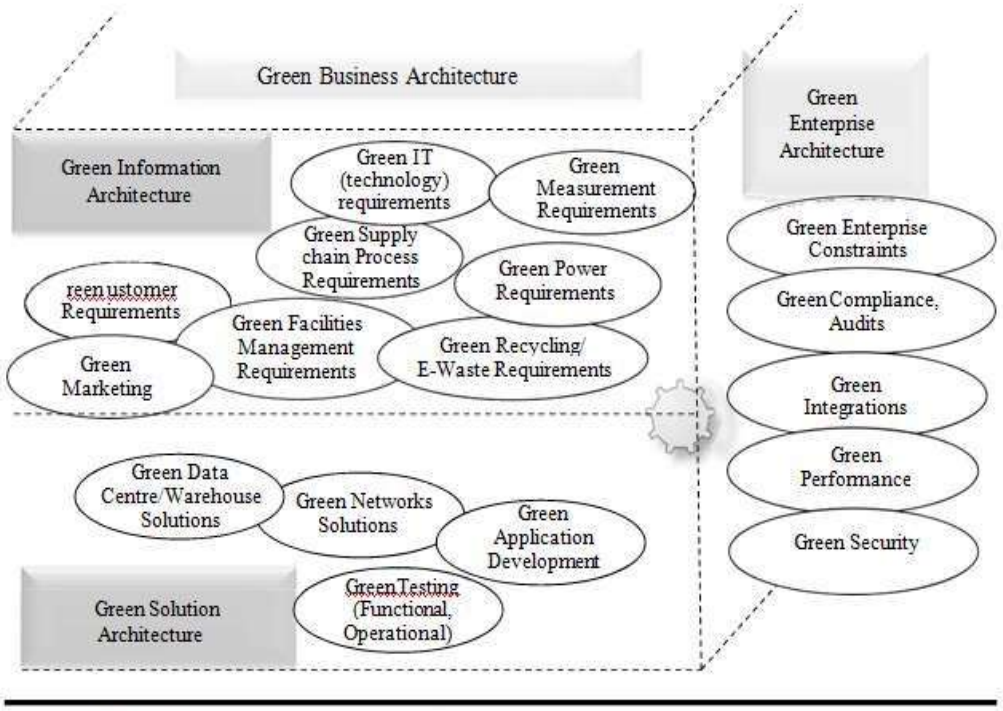


Figure 6.2 Categories of requirements in the various green architectural spaces.

- The requirements that influence the information architecture come from the business, information, and enterprise domains. This information architecture provides the context for facilitating integration across various applications.
- The information architecture also contains a repository of overall applications and their inter relationships.
- A good understanding of this interrelationship can help eliminate redundancy and eventually also contribute to the reduction of resources.

➢ Green customer requirements t hat are based on t he demands o f t he customer for green products and services.

➢ Green marketing requirements that promote the organizations green products and services.

➢ Green supply chain process requirements that interface with the suppliers systems.

➢ Green technical requirements that are specifying the technologies that are needed to handle the Green IT initiative.

- Green metrics and measurement requirements that specify the elements to measure and report.
- Green recycling and e-waste management requirements that deal with the one-off disposal of assets

- Thus, this is a two pronged approach is the solution space use of IT to reduce emissions and reduce the IT domain's emissions.

- Green data center design and solutions relates to the building and facility requirements that are IT specific.
- Green content strategies that are influenced by the backup, mirroring, and so on.
- Green networks and architecture solutions that provide the communication hardware.
- GIS programming solutions that relate to green information and solution.

Green IT and Organizational Systems

- A GEA provides various views of the organization and its systems.
- These views reflect the effect of changes in one area of the organization on the other areas and systems.
- The typical IT systems that are affected by the change. These include the existing systems that need to change, and also t he changes associated with the new GIS's implementation.

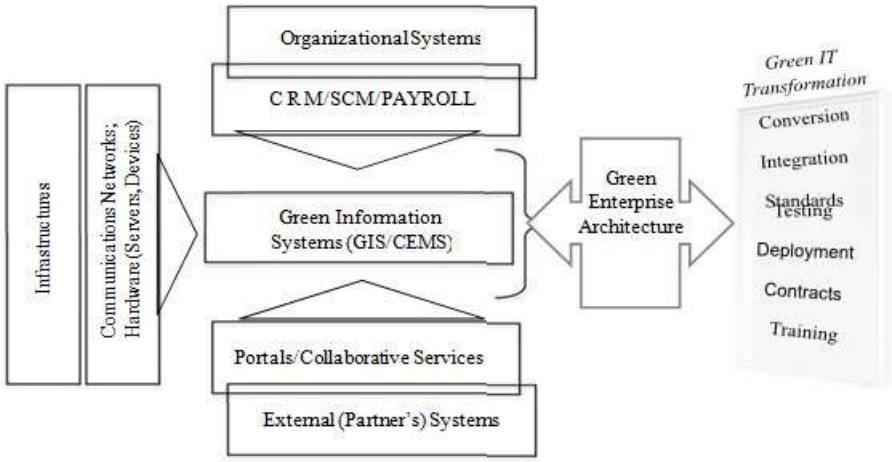


Figure 6.3 Green enterprise architecture helps in handling the impact of Green IT transformation on the rest of the organizational systems.

Organizational Systems

- These are the core systems that are primarily internal to the organization. For example the typical CRM, SCM, and Payroll applications that need to be updated with the new carbon data and that also need to be integrated with the GIS/CEMS. SOA provides basis for these integration

External Systems

- These are not just systems external to the organization, but also external interfaces of the organizational systems. These external systems and interfaces belong to the green organizational portals that relate with the regulatory portals, and also the collaborative services offered and consumed by the organization.

Infrastructure

- These are the communication Networks and Servers. These are the IT-specific infrastructures of the organization as against building and facilities. They change to replace existing carbon-intense equipment's and also provide basis for GIS/CEMS communication and integration.

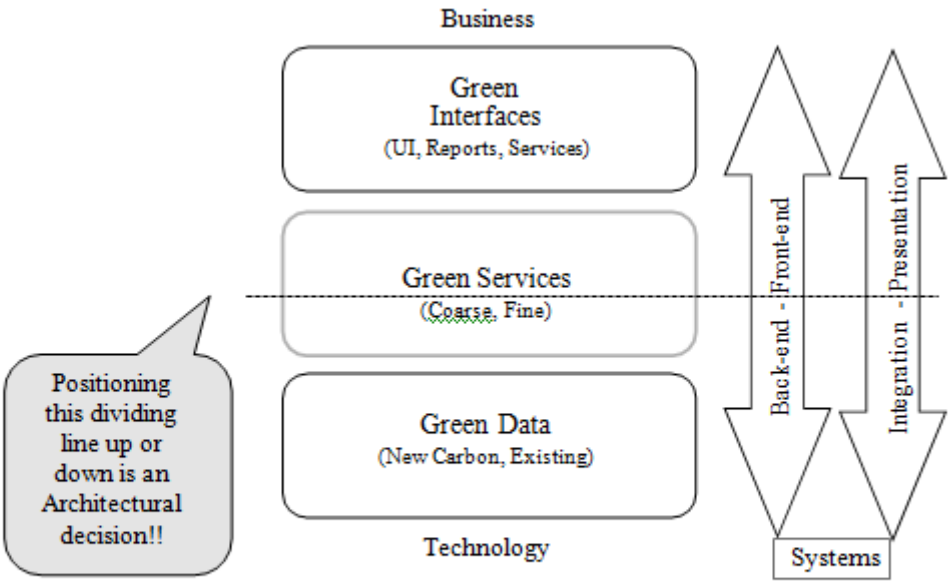
The various IT areas that need to be handled when an organization embraces Green IT. These are as follows

- *Conversion*: Existing data that will ensure it works well with the new carbon data.
- *Integration*: Applications that are both existing business applications as well as new carbon-specific applications
- *Standards:* web service interfaces at technical level and ISOstandards applies to the systems at organization level.
- *Testing: C*arbon test data to test the functionality and operational aspects of the systems and their integration
- *Deployment ofnew application*: CEMS aremost likely to be SaaS-based deployments using Cloud computing.

- *Contracts: I*mplement policies in SOA and SLAs. Electronic contracts becoming prominent when green organizational portals deal with other external portals of partnering organizations and regulators.
- *Training:* Users as well as support personnel for the new green applications, in terms of how to use their metering capabilities, recording, and analysis of carbon data and identifying the trends in carbon emissions.

Green Solutions Architecture

- The transformation of the organization to a green enterprise entails changes to its systems. Change in their three basic areas—data, services, andinterfaces.



igure 6.4 Fundamental considerations of a Green solutions architecture.

- *Data*: Changes here deal with creation of new carbon data and modification of existing enterprise data.
- *Services*: These include the functions, applications, and their use in analyzing green data. Services plot trends, estimate emissions, enable reporting, and create opportunities for collaboration. Services can be coarse or fine, depending on their reuse requirements.
- *Interfaces*: These are primarily the display mechanism o f the services and ap plications. The three interfaces as graphic user interfaces (GUI), the reporting and related physical interfaces, and the web service interfaces. The solutions architect's views of the data, services, and interfaces.

- This view predominantly handles integration challenges at back-end of the system, and presentation challenges at the front-end. Modifying existing ERP software versus buying a new and external ERP package.
- This effort caninclude conversion, integration, and deployment issues.

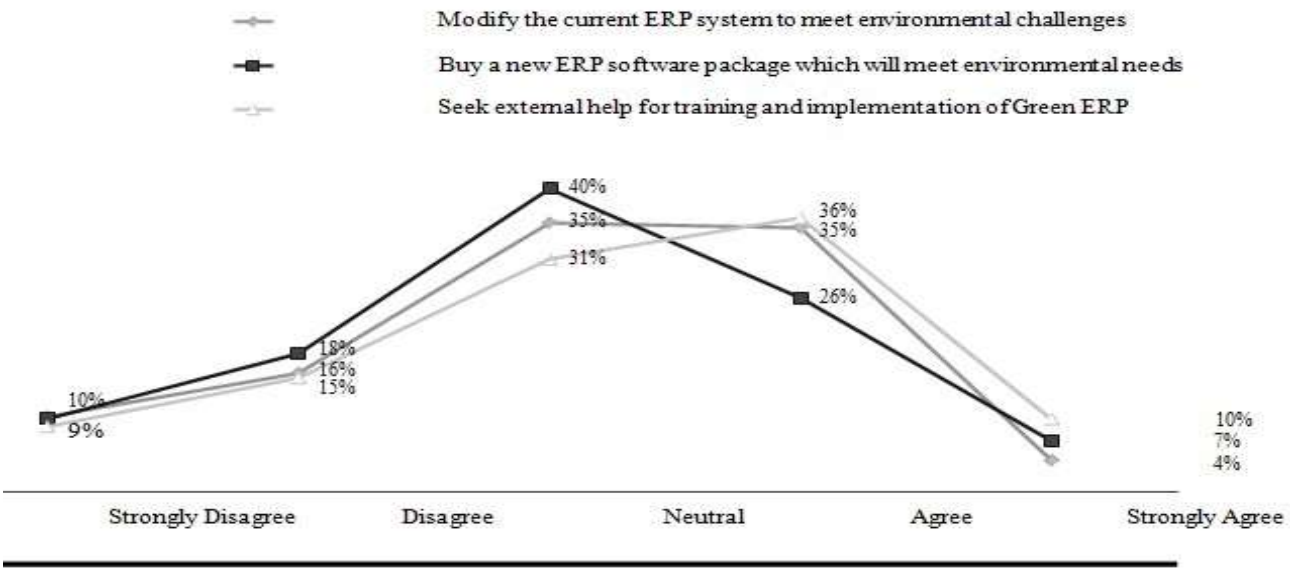


Figure 6.5 ERP software—organizational action.

Evolving Green Systems Architecture

- How basic systems architecture evolves into a more complex and a collaborative green process-based architecture. Collaborative green processes that make use of the concepts of SOA and WS.

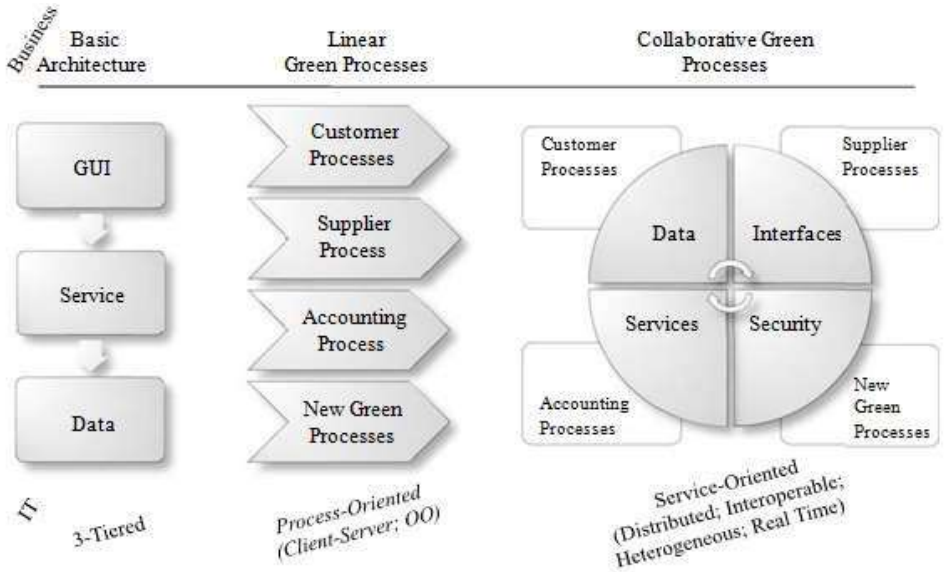


Figure 6.6 Evolving Green systems architecture: Basic to linear process and then collaborative process-based architecture.

- The linear green processes would be the typical business processes such as customer, supplier, and accounting.
- The collaborative processes on the right will include the data, services, interfaces, and security now interconnected through WS.
- These collaborative processes are both internal and external to the organization.
- For example, the customer processes are modified internally, through their data models, to reflect the carbon in a particular sale of product or service.
- When that customer process is exposed as a WS, the modifications are to the interfaces of the CRM—an external impact.
- Similarly, the service offering of a supplier may include the guarantee of a certain carbon emission during the operation of an equipment supplied (e.g., a green monitor).
- The green initiatives and enthusiasm shown by the organization needs to be shared by its suppliers and customers to achieve the overall objective of the transformation.

Aspects of Green Solutions Architecture

- That can enable efficient use of IT resources. This Green IT solutions deal with internal carbon recording, reporting of carbon externally, implementation of SaaS-based solutions, collaborative green services` and also technology-based opportunities for new green services

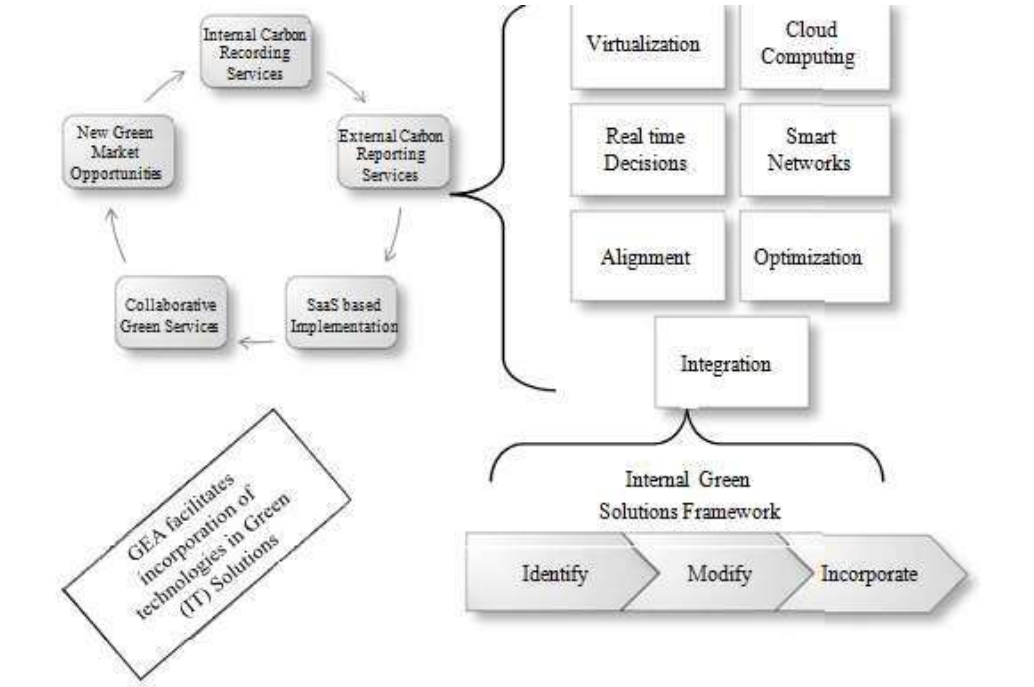


Figure 6.7 Various aspects of a Green solutions architecture.

- GEA facilitates incorporation of technologies in the Green IT solutions by providing the right interfaces and models
- These technologies as virtualization, Cloud computing, real-time decision making, smart network management, self healing, alignment, integration, and optimization
- Internal Green IT framework that encourages the solutions architects and the systems analysts to continuously identify new and emerging technologies, model them to examine their repercussions, and eventually incorporate in the overall architecture of the organization

Cloud Computing

- Identification and incorporation of Cloud-based solutions bring about immediate change in the carbon emissions of large data centers
- With the remaining end-user computing devices and Therefore limited carbon responsibility.

- Document in the service contract the sharing of carbon emissions resulting from this shift in the infrastructure.
- The carbon responsibility is shared appropriately amongst the users and providers of Cloud computing in result assured delivery of service and the sharing of risks.

Virtualization

- virtualization provides the basis for consolidation of the data center's hard-ware that reduces the overall carbon emissions of the organization
- creates multiple operating views on the same physical machine resulting in much reduced use of hardware than if the servers were all physical
- identified, documented, and measured in accordance with the overall green strategies and objectives of the organization

Smart Networks

- Smart networks and their management make use of automated devices, sophisticated switch management, optimized network operations and real time reporting of the network performance
- In both the wired and wireless network architecture is the ability of these networks and communications devices to self diagnose
- These networks are able to make corrections to their links and thereby provide uninterrupted operations.
- Incorporating the self-healing capabilities of the networks in the green solutions space creates opportunities for network efficiencies in operations and thereby, reduces the overall carbon emissions of the organization.

Real-Time Decision Making

- Real-time decision making in the solution space is based on availability and delivery of information precisely and in the context of the need of the user.
- Such real-time delivery of information is primarily achieved through mobile technologies, devices, and applications.

interrelated advantages:

1. Also frees up staff to spend more time on value-added services. Travel times are reduced.

Improved ability to understand and interpret carbon data and information of the organization in real time to reduce the carbon emissions

Alignment

- Alignment of data, processes, and interfaces Is an architectural issue in the solution space that focuses on reducing the friction within and amongst the systems
- This factor focuses the attention on modeling and investigating the impact of changes in data, processes, and interfaces
- Green IT systems need to be aligned with the existing organizational systems in order to have the desired positive impact of carbon reduction
- If Green IT systems are themselves not aligned, they will create the friction mentioned above—resulting in waste of organizational energy.

Optimization

- Optimization is closely associated with alignment and deals with the alignment of the solution technologies such a s the servers, applications, and databases
- carbon footprint minimization objective of the organization.

Integration

- It works across two technological areas

I. Integration of carbon data with green services and interfaces within an application; and

II. .Integration amongst the different applications themselves.

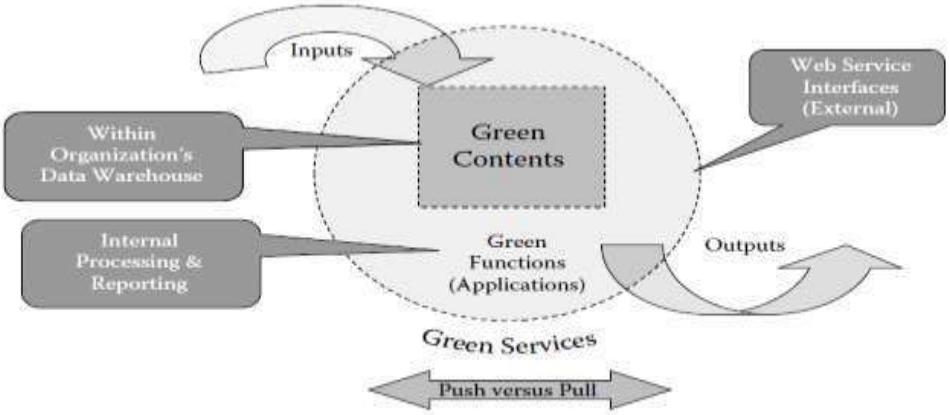
Contents and Integration with Service-Oriented Architecture

- An important challenge in the solution space relating to green technologies is the rapidity and complexity of carbon-specific changes.
- These carbon data are going to b e a m ix of existing data that is modified as well as new carbon data
- The technology of WS together with the concept of SOA needs to be discussed in this context. Services are self-contained software components
- A software architecture that comprises many self-contained services and which process data and information through the interfaces of these services is known as SOA
- This enhanced ability of information systems to connect and communicate with each other leads to a collaborative opportunity for green enterprises.
- To interact with each other over the Internet irrespective

Characteristics of these services:

- self-contained so that they are able to process data and information within themselves
- a well-defined interface with the intention that inputs to and outputs from these services can be easily understood.

➢ available for communication—that is they are Internet enabled.



gure 6.8 Sourcing and dissemination of green contents through functions and services.

- The ability of executable services being made available across different communication channels enhances collaboration with results in overall less software code, lower cost of developing and deploying software solutions, and increased standardization

Four major groups of applications that are benefitted by a service-oriented approach to the GEA

1. CEMS—has to deal with new green (carbon) data, as well as modeling and implementation of new green services.
2. Green CRM—primarily deals with modification of data models that will accommodate the elements of carbon emissions in them. Mostly external.
3. Green SCM/ERP—also has to deal with modification of data models that will enable inventories and other operational information to be expanded to include carbon data.
4. Regulatory—relevant authorities through a regulatory portal through a web service.

- Each service has three basic features (Hazra, 2010) of a service: modularity, granularity, and loose coupling.
- Modularity enables carbon data to be properly encapsulated and then exchanged with other data and systems; granularity of a service deals with the level of abstraction incorporated in a service; and, finally, loose coupling separates services from each other, thereby enabling implementation of GIS without disturbing the existing services

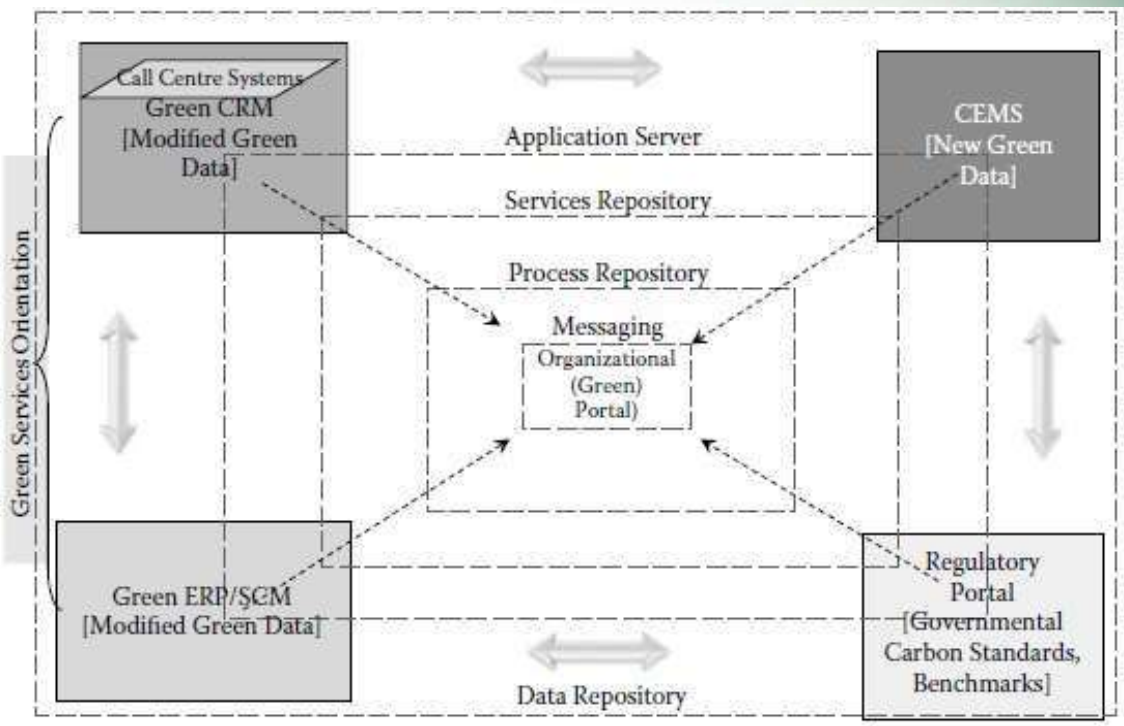


Figure 6.9 Detailed Green-SOA (this figure is a 3-dimensionsal top view with the center part of the figure indicating height).

Various layers of repositories in a SOA:

- Data repository is made up of data that belong to each of the four groups of systems. integration should be kept to minimum, as existing data will require substantial effort.
- Application server that enables data to be analyzed
- Services repository that provides storage, consumption, and exposure of WS
- Process repository that creates processes based onservices.
- Messages that eventually provide the integration amongst the various layers of a SOA collaboration and coupling of remote resources.

Green Supply Chain Management

- Together the suppliers, customers, employees, and senior management in order to produce an integrated and efficient supply chain t hat w ill re duce carbon emissions cannot be overstated.
- The SCM of an organization needs to be analyzed, planned, and optimized for sourcing and deliveries in an environmentally conscious manner web -based.

- One ill-performing participant in the supply chain will affect the performance of the entire supply chain

Following are the advantages of GISCM:

- Reduction in unwanted inventory through accurate identification of material requirements within the integrated process leads to reduced storage space and less materials resulting in corresponding carbon savings.
- Sharing of resources reduces number of equipment's and infrastructure needed.
- Optimize the number of people that need to handle material on their way to the end customer, thereby reducing the carbon content of that process.
- Eliminate business processes that do not add direct value to the most optimum movement of goods
- Real-time integration and improved logistics of distribution centers reduces carbon.
- Electronic payments are integrated and measured to ensure reduction in carbon.
- Disposal of electronic waste and consumed products is handled much better
- Improved and effective handling of returns from customers, especially as the organization

Mobility in Green Supply Chain Management

- Mobile technologies in SCM enables business transactions to be location independent, reduces unnecessary inventory and transportation of material.
- The WS (XML, SOAP, UDDI, and WSDL) standards on mobile gadgets can simplify information exchange and optimize supply chain business processes within the enterprise and between supply chain partners.
- MSCM bring together technology infrastructure, demand planning, forecasting, sourcing, production, logistics, scheduling, inventory, and transportation that are also supported by mobile devices. (RFIDs)

- For example, mobile order tracking, mobile package tracking, instant messaging, exception alerts, vehicle tracking, mobile reporting, fuel tax calculations, GPS, route, and vehicle information and integration to various data collection devices.

- This results in reduction in carbontogether with an increase in productivity, customer satisfaction, and employee satisfaction

Building Environmental Criteria into Supplier Contract Conditions

Table 6.1 Supplier Contract Conditions in the Context of Environmental Intelligence

Supplier Contract Condition	*Comments from EI Perspective*
Certification	Proves the green credentials of the supplier. Ensures compliance. This would apply to all dealings with the supplier, externally auditable.
Maturity	Shows the ability of the supplier to repeat carbon-efficient processes in providing materials and services. This criteria is applied to all iterations of the process.
Supplier's supplier	Enforceability of collaboration amongst a suite of suppliers.
Attitude	Indicates the sociocultural factor of the organization. This is the least measurable of all in a supplier contract.
Reactivity and Responsiveness	Ability of the suppliers to respond to increases in carbon outputs along the supply chain.

Green Portals in Green Enterprise Architecture

The creation and use of Green ICT portals and the consequent use of information.

- The first one is the possible sources of green information.
- The second aspect is the scale of this green information that is available at any given time.
- The third aspect combines reliability and relevance of the available information to the organization in question.

Green ICT portals can collect (source) and provide (disseminate) information in various ways. Outsourcing, in-sourcing and "crowd-sourcing" a re applications of distributed problem solving and production models

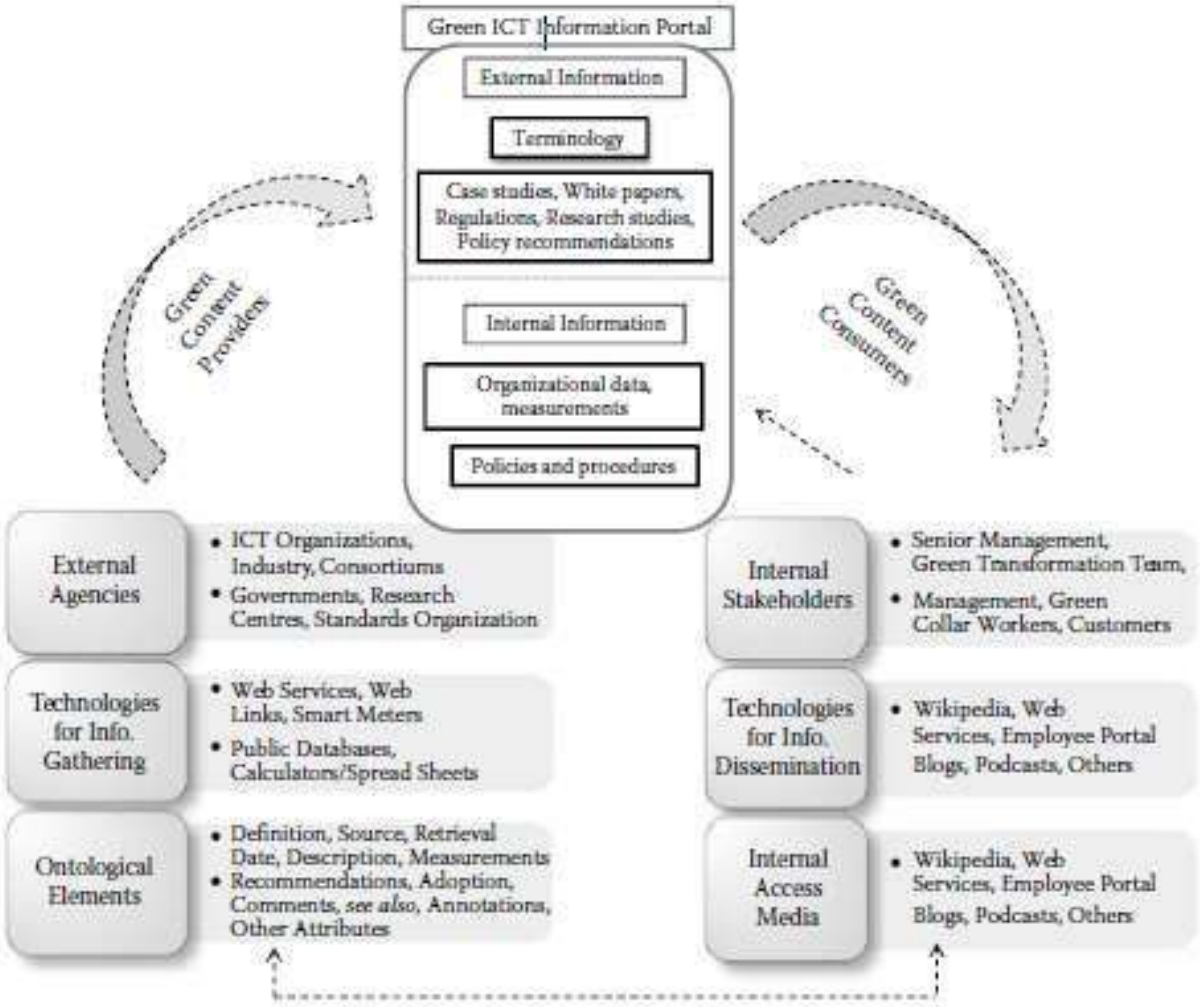


Figure 6.12 Inputs and outputs in a Green ICT information portal. (Based on Deshpande, Y.

- These data collections and dissemination strategies for an organization.
- It would have external agencies, technologies, and ontological elements supporting its data collection strategy—external to the organization.
- This portal is shown at the center, with sources and destinations of information on either side of the portal.
- to information coming from external sources.
- internal sources and destinations for information. These are the content consumers who, in turn, provide internal information.

Business Intelligence and Green IT

- BI can be thought of as a rich matrix of applications that access, collect, store, process, and analyze data within and outside the organization to produce new bodies of knowledge.
- Decision support system (DSS), online analytical processing (OLAP), statistical analysis, forecasting, and data mining are examples of BI tools (see Bryla and Merchant, 2009, for BI tools) that need to be revisited from EI perspective, wherein they help to reduce the number of data services and, thereby data centers.
- BI is the process of using collective information within the organization to optimize its business performance, enhance its customer service, and provide it with overall competitive advantage and sustainability (Unhelkar and Tiwary, 2010).
- In the earlier examples, EPR together with the HR system can help in scheduling the right staff for the patients on an almost real-time basis.

The Environmental Intelligence Domain

- In fact, the business environment today mandates a highly intelligent approach that would make optimal use of all resources avail- able to an organization. The environmental issues of a business are not too far removed from the issues of business efficiency and customer service.
- example would be that a reduction in paper usage by the organization should not result in greater use of server space.
- EI systems consist of the tools, technologies, and processes that turn environmental data into information and knowledge that optimizes decision making. E I processes ensure effective and efficient use of green enterprise resource as well as compliance of the enterprise with its green policies and procedures.
- Enabler of environmental initiatives through the use of an organization's existing BI capabilities.

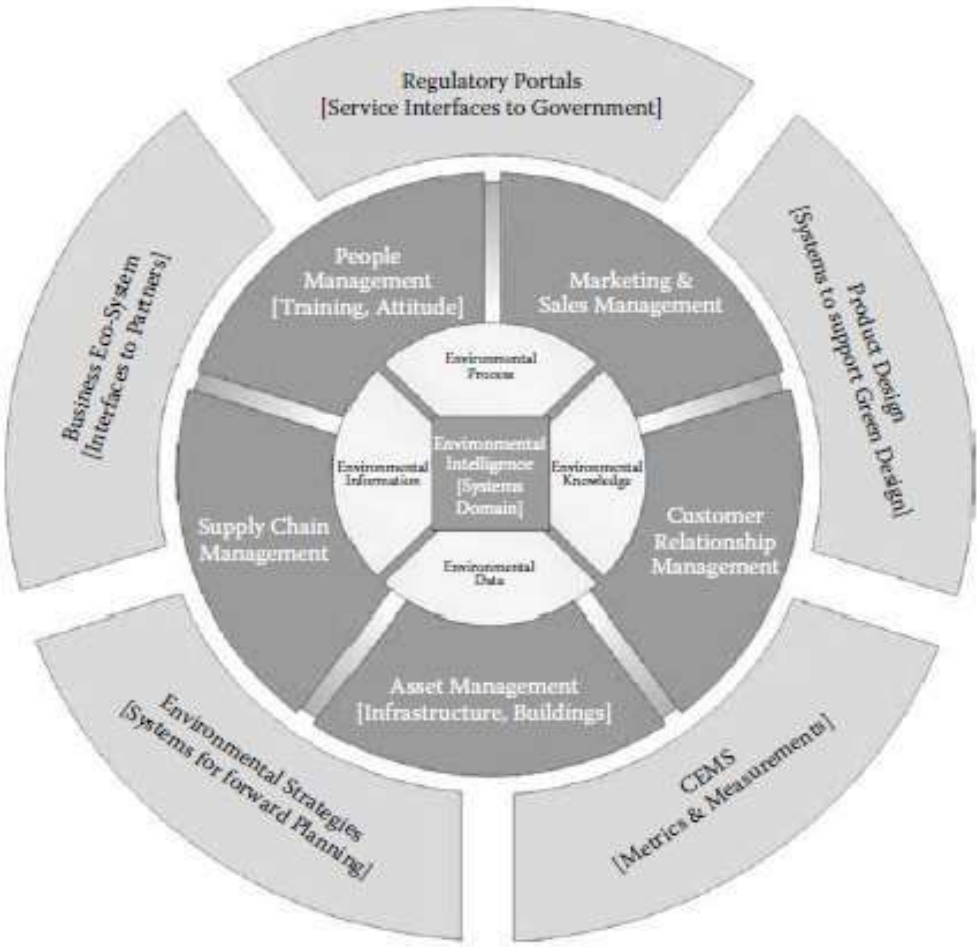


Figure 6.13 The environmental intelligence. (Systems Doamin—Based on Unhelkar,

- EI domain, this domain is made up of systems and interfaces that deal with regulatory portals, design portals (aimed at green product design), interfaces to various business partners (as a part of business ecosystem), systems for environmental strategies (futuristic scenarios), and normal measurement and reporting systems (CEMS)
- These systems and interfaces, as also shown in Figure 6.13, are based on people (HR), suppliers, marketing, customers, and asset management systems. These systems exist in the organization and are upgraded to provide help and support to t he external interfaces.
- The fundamental basis of these systems and interfaces, however, is the data-information-process-knowledge base that is shown in the inner circle.

Environmental Intelligence Systems' Evolving Complexity

- The evolving complexities of EI systems. These evolving complexities are of data-information-process-knowledge, Highlycollaborative and complex EI

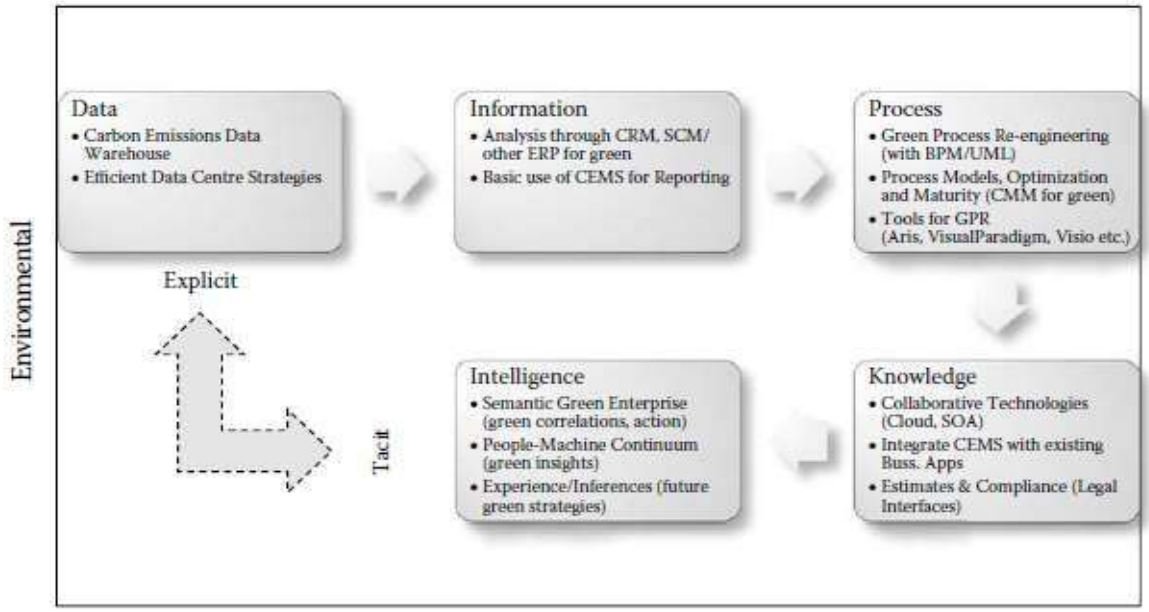


Figure 6.14 Evolving complexities in environmental intelligence systems.

(a) *Data*: Identification of carbon data related to equipment's carbon-related data within the organization.

(b) *Information*: Analysis and processing of the data in order to provide information detailed and timely feedback to t he decision makers/strategists

(c) *Process*: Optimizing procedures and controls within the organization using the concepts of business process modeling (BPM)

(d) *Knowledge*: using WS and Cloud computing fundamentals

(e) *Intelligence*: This is the semantic green enterprise. EI system requires two major activities from an organization: upgrading existing BI systems to incorporate environmental data, information, processes, and knowledge; and, analyzing, designing, developing, and deploying systems that are specific to the environmental needs of the organization.

- Thus intelligence is a combination of ground-up Green IT systems, existing BI systems, and organizational processes that combine them with the tacit knowledge carried by people.

Communication Channels in Environmental Intelligence

Environmental intelligence, as mentioned earlier, combines not only myriad systems through correlations, but also synergistically brings in people. EI systems interface with people.

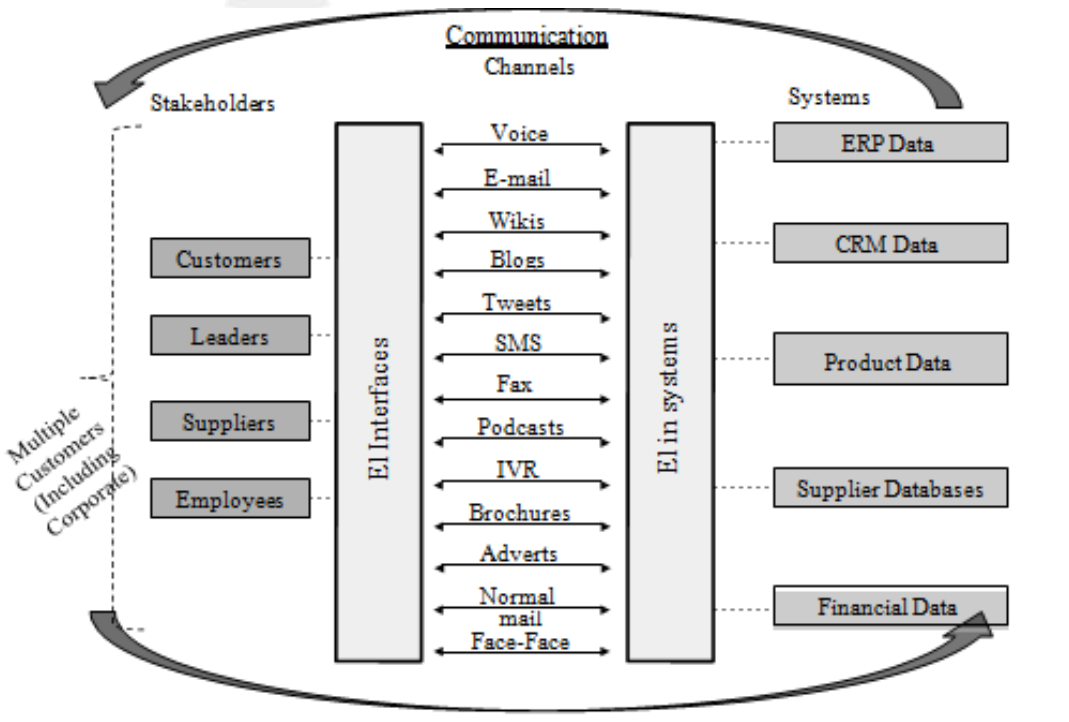


Figure 6.15 Environmental intelligence—people to system interactions.

In a GEA that has to incorporate Systems intelligence (shown on the right in Figure 6.15) with the human intelligence

Environmental Intelligence Implementation with Web Services

- EI implementation using C loud computing and WS. Typically, this would be either a CEMS or an existing ER P system that is specifically upgraded to deal with data, information, and processes environmentally.
- WS can be used in the business environment to measure, monitor, and finally help for the process optimization with respect to the environmental factors.

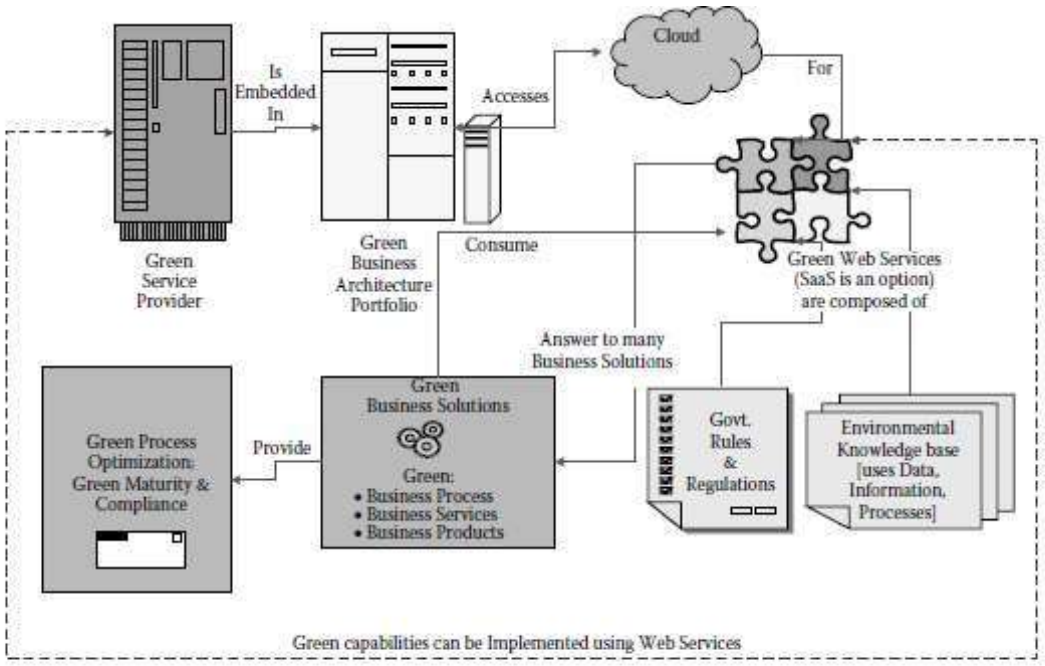


Figure 6.16 EI implementation using Cloud/web services (From Unhelkar, B. and Trivedi, B.,

- With the help of the tools such as Green web services (GWS), business can begin to develop EI systems, implement them in the business, monitor, measure, and mitigate the emissions and monetize the process
- Process improvements not only improve the compliance and performance but also decrease the business cost.

Environmental Intelligence with Mobility

Further enhance the data sharing among the EI application. This is so because mobility enables location in dependent data sharing. It offers location-based insights.

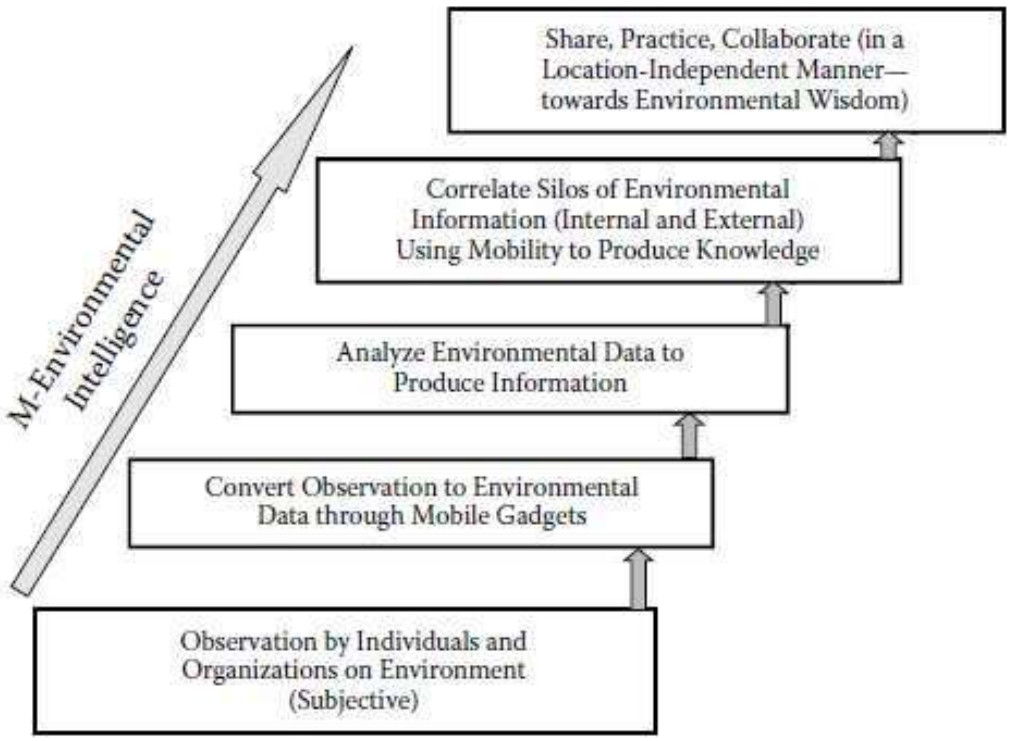


Figure 6.17 Path to environmental intelligence with mobility.

- The correlation of environment-related information and utilizing that information in a knowledge management system can lead to environmental intelligence systems (EIS).
- Mobility is a key player in EIS. shows how, starting with subjective (tacit) observations, and re cording them (and making them explicit), the organization can move up toward knowledge and wisdom related to the environment.
- Application of mobility to BI results in mobile EI that combine enterprise information access with mobile devices like mobile phones, PDAs, smart phone, the BlackBerry, and other handheld wireless devices
- Such combination can enable the production of carbon-specific BI reports, key performance indicators (KPI), and business analytics.
- This correlation is created, maintained, and utilized by bringing together data and information using the mobile platform.
- EI-based software tools are able to provide visual reports, historical and emerging carbon data and interfaces with external regulatory data.

An Example of Green Enterprise Architecture

- The business, technology, process, and people dimensions of a n organization environmental principles and practices, development of environmental competencies and protocols, and facilitates novel application opportunities for CEMS.
- Input-analysis-output activities, which are technically supported by the emissions monitoring layer (CEMS).
- These smart meters need to be attached to the equipment whose emissions are required to b e measured and monitored on a regular basis.

2.4. Green Information Systems: Design and Development Models.

Introduction

- A GIS is a system that is dedicated to management of carbon data. Therefore, a GIS forms the basis for measuring, monitoring, and reporting on the carbon data of the organization.

Describing a GIS

- A GIS (or a CEMS or EIS) is a software system that provides support to the business to implement its environment responsible business strategies (ERBS). Thus, this system has to cover the length, breadth, and depth of various structural and dynamic aspects of the business.
- The technologies to be used will include an underlying content management system, an object-oriented approach to design, an object-relational database, support for mobile devices and interfaces, and implementation in an object-oriented language (say, Java).
- Therefore, the system should be aware of SaaS and Cloud computing.

Phases in a GIS Development and Deployment

The major phases of any typical software development lifecycle.

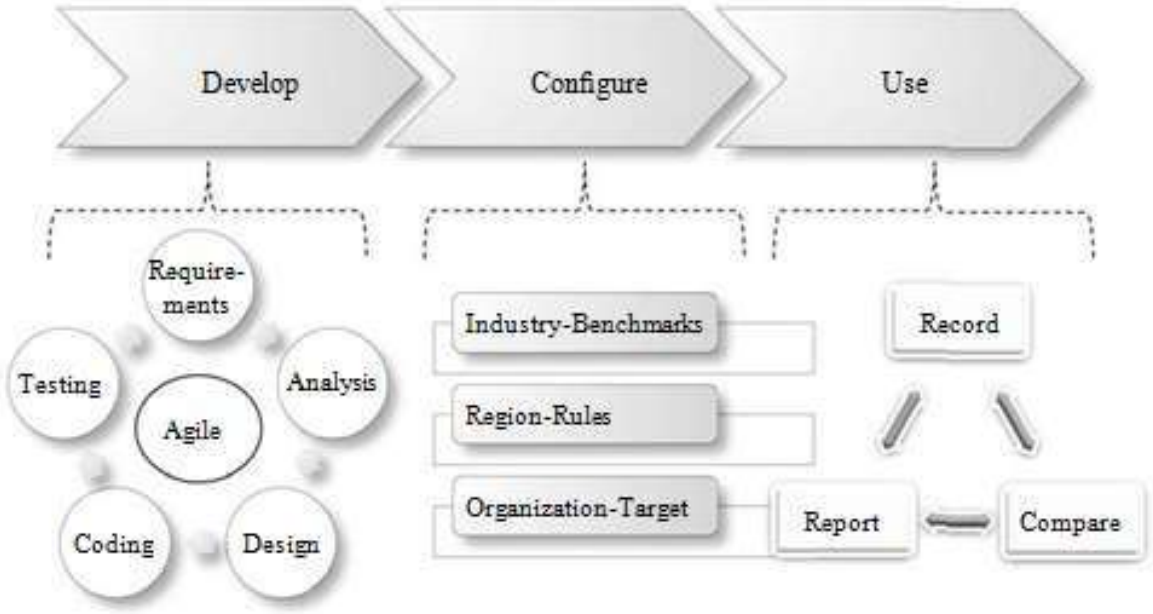


Figure 7.1 Major phases in GIS: development, configuration, and use.

- **Develop**—GIS needs to be developed by following agile practices and considering the important phases of a SDLC starting from requirements, analysis, design, and code to testing.
- **Configure**—Configuring GIS according to benchmarks and rules of organization. This would be an activity specific to each organization within each industry sector.
- **Use**—Use of GIS will lead to ongoing recording of carbon data creation of reports as well as comparisons.

Features of GIS

- Collecting environment-related data in real time. The GIS has to be geared to collect data such as number of devices in use and on standby.
- Providing querying tools, key performance indicators (KPIs), and business analytics to field workers and decision makers in the area of EI that enables closing down of unused servers, desktops, and other equipment's.
- Enhancing the decision-making capabilities of senior management by collating and computing up-to-date information from varied external sources (e.g., government regulatory bodies and weather information) and feeding that into GIS.
- Providing positive feedback and impact on the employees' job satisfaction.

- GIS also provides feedback to customers and other external users of the business on its environmental performance—potentially resulting in increased customer service and

satisfaction

- GIS extends the tools and techniques of business management (such as KPIs, business analytics, and reporting) and applies them to the environmental aspect of business.
- GIS enables collaboration amongst businesses for the purpose of achieving environmental responsibilities.

Modeling and Architecting GIS—Requirements, Design, Implementation, and Testing

- **Package diagrams**—used to create increments and sprints in an agile development approach.
- **Use cases**—Used to show functionalities and business processes from a user's point of view.
- **Use case diagrams**— Provides a model describing all the related business processes/functionalities of a particular package.
- **Activity graphs**— Provides a detailed view of every step of a business process. They provide the flow within a use case or a package of GIS.
- **Class diagrams**— Provides a static model of GIS based on its key business entities. This diagrams can also be used to model underlying carbon data warehouse
- **Sequence diagrams**— Provides a model for the interactions between objects and also rules for these interactions that are architectural decisions.
- **State Machine diagrams**—Provides a view in which a particular entity passes through different states as a business process is executed.
- **Component diagrams**—Used to show the interaction of every component with each other.
- **Deployment diagrams**—Used to show the way application will be deployed including hardware and related infrastructure.

GIS Requirements

- This document will concentrate on process of gathering requirements, the resources needed to build the standards module of the project, and monitoring the progress of the project through a Gantt chart.
- Green ICT system analysis and design is performed using the UML. UML diagrams such as use case, class, sequence, activity, state machine, package, component, and deployment diagram are used in modeling the problem space and in designing of the system.
- These diagrams help in modeling the operations and interactions at the business level and also in system design thorough classes, packages, components, and deployment diagrams.

A typical GIS would involve two subsystems:

- Green organizational portal (GOP)
- Regulatory standards portal (RSP)

- Regulatory portal provides the standard emission value determined by the regulatory body for each emission type based on the industry and company.
- Organizational portal focuses on the capture of emission data and its comparison with the emission standards.

Green Organizational Portal

- The GOP is made up of organizational data on its "green" performance. These data are updated by the organizational representatives on an ongoing basis.
- These data record the organization's pollutant performance such as,

a) generated by the desktop machines, data centers and network equipment's within the organization,

(b)) carbon heat emissions in the petrol/diesel consumed by the organization, and

(c)hazardous materials produced by the organization's activities such as lead in batteries and mobile phones.

- However, this GIS will not store the details of the organization's inventory, but only its carbon emissions. Therefore, the GIS's organizational portal will have to have an interface with the existing inventory management system, supply chain system and the customer relationship management system.
- The system is not meant to immediately measure the scope 3 emissions. However, it should have the provision to do so later, when scope 3 emissions become mandatory and need to be included in the system.

Regulatory Standards Portal

- RSP is a large portal that will be maintained by the government agency responsible for emission control within a country or region.

(a) Various types of pollutants that may not be directly related to IT such as petrol fumes from vehicles.

(b) Pollutants that are related to IT equipment and consumables—such as monitors, printer ink, and lead batteries.

(c) The approved standard for each of the pollutants—for example, 0.03 mg carbon per liter of petrol, and 0.05 mg of carbon per cartridge of printer ink.

(d) The variations to the pollutants depending on the type of industry. Currently, RSP supports hundreds of industries such as airline, hotel, car rental, packaging, computer manufacturers, restaurants, farms, and so on.

(e)The standards also vary depending on the size and location of the organization. For example, in developed regions, organizations with less than 20 employees are categorized as small, 20–100 as medium, and more than 100 employees as large organizations.

Stakeholders/Actors

- There are number of actors (also called stakeholders) in the GIS system. These actors are typically the people who are directly responsible for measurements, monitoring, and mitigation of emissions.
- In addition, these people/roles also include employees directly responsible for production or services within an organization

- For example, in an airline or a hotel industry, for example, there will be an "Environmental Manager" who will be responsible for the implementation of the strategies for reducing greenhouse gases. In addition, the check-in manager (airline) or the duty manager (hotel) will have some responsibilities toward carbon management as well, which need to be supported by the GIS.
- There will be numerous additional roles in this system
- The workers responsible for entering the environmental data,
- The government representatives responsible for entering the standards or acceptable benchmarks,
- And also the senior management of the organization, who will be interested in having a bird's eye view of the "green" performance of their organization.
- "General public" will also be interested in finding out the performance of the organization in relation to its greenness.
- End-users, there are also administrators of the system, both within the organization and external to the organization, who will be maintaining the data, information, and the applications.
- Finally, these users can be individual users and there can be organizational users (who have individual nominees) who can use this system.

Databases

- The back-end, underlying carbon data needs to be stored in a database that can handle multimedia contents. The basic carbon data relating to emissions and compliance can be modeled and stored in relational structures.
- carbon data is likely to be multimedia data, demanding provision for storing video posts and webinars that can also be used for carbon dashboards.

- Ability to identify polluting equipment's, materials, and other assets of the organization
- Ability to store the relationship between assets and corresponding pollutions
- Storage of various types of GHG emissions on a time-period basis
- Creation of various pollutant types and storing them in a reference table
- Storing energy rating of all assets (devices)
- Storing of benchmarks/standards for each polluting asset
- Storage and management of user accounts

Package Diagrams and System Scope

- The system should cover all the functionalities required to record, calculate, analyze, and report on carbon emissions.

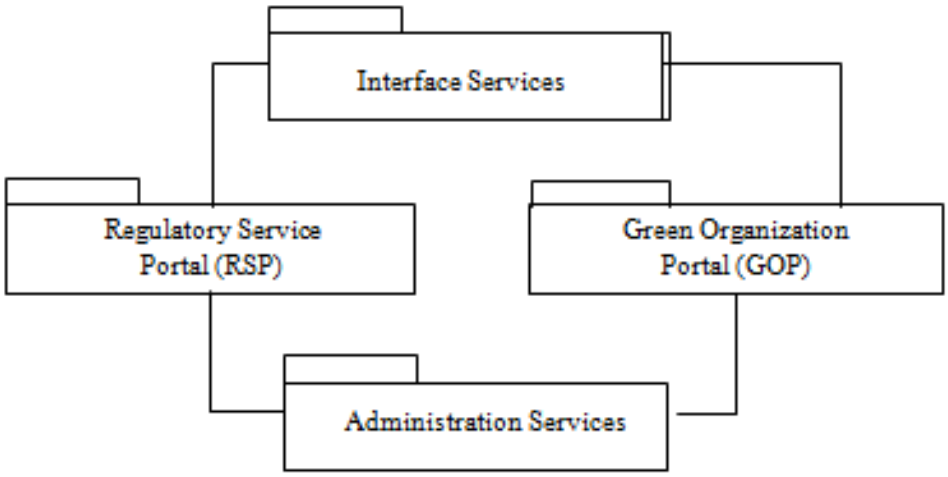


Figure 7.3 GIS major packages (subsystems).

- GOP and RSP functions like emission details management and comparing them with

standards are done based on the company size and location.

- Emission performance check done by environmental manager in the organizational portal.
- Emission Standard's value are managed through create, update, and delete performed by the government administrator.
- User ID and password authentication to access the system and also permissions to any user

are managed by the administrator in the two portals.

- The GOP and RSP are shown as two packages that also interface with the interface and administration services.
- While the GOP will have multiple instances across various organizations, the RSP will have a single instance. Both portals will be deployed using SaaS.

Use Case Diagram for GOP

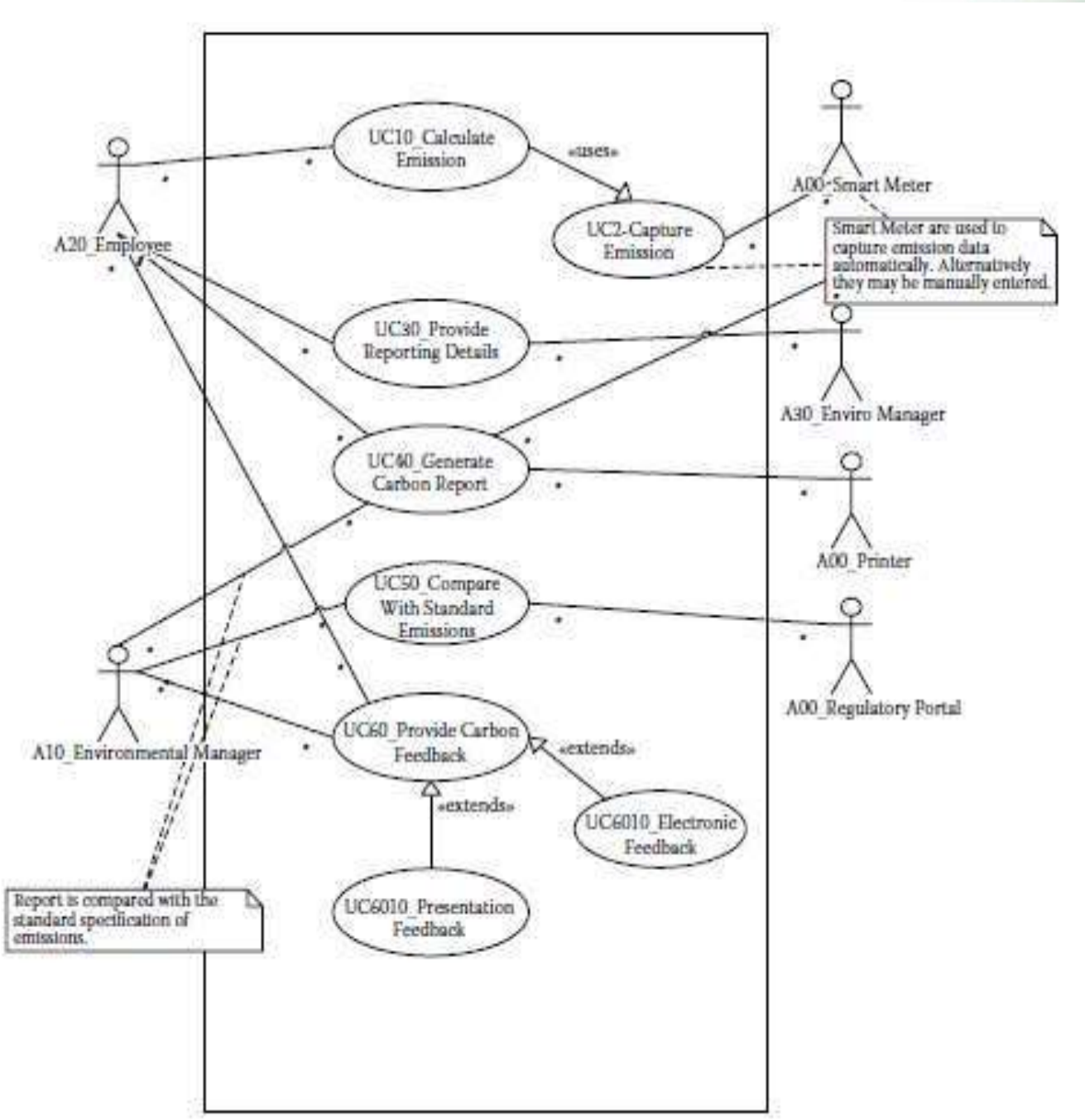


Figure 7.4 Use case diagram for "green organizational portal."

The use case diagram for GOP. It shows actors, use cases, and their relationships. Some of the use cases shown in this diagram are documented in subsequent sections in this chapter.

Use Case	UC10-Calculate Emission
Actors	A20-Employee, A00-Smart meter
Description	The employee calculates the amount of emission of one or more assets by capturing carbon data through handheld device or a smart meter (or handheld device)
Precondition	Employee is authenticated Employee is authorized to access the smart meter data
Postcondition	Emission value is successfully calculated
Complexity	Medium
Normal Course of Events	1. The employee prepares a list of assets for which emissions are to be calculated. System validates the list (through asset management) 1.1 <<include>> UC20-Capture emission 2. Employee initiates recording of emissions 3. The value of carbon emission from each smart meter is provided (A1) 4. System validates value of carbon emissions 5. The employee requires total amount of emission to be calculated (per dept per day) 6. System calculates and reports on total emissions
Alternate Course of Events	A1-The emission values could not be provided by the meter, manual collections of data will be required
References	Government document outlining pollutants per assets, their categories, and their emission limits. This data is available electronically as a web service from the government portal

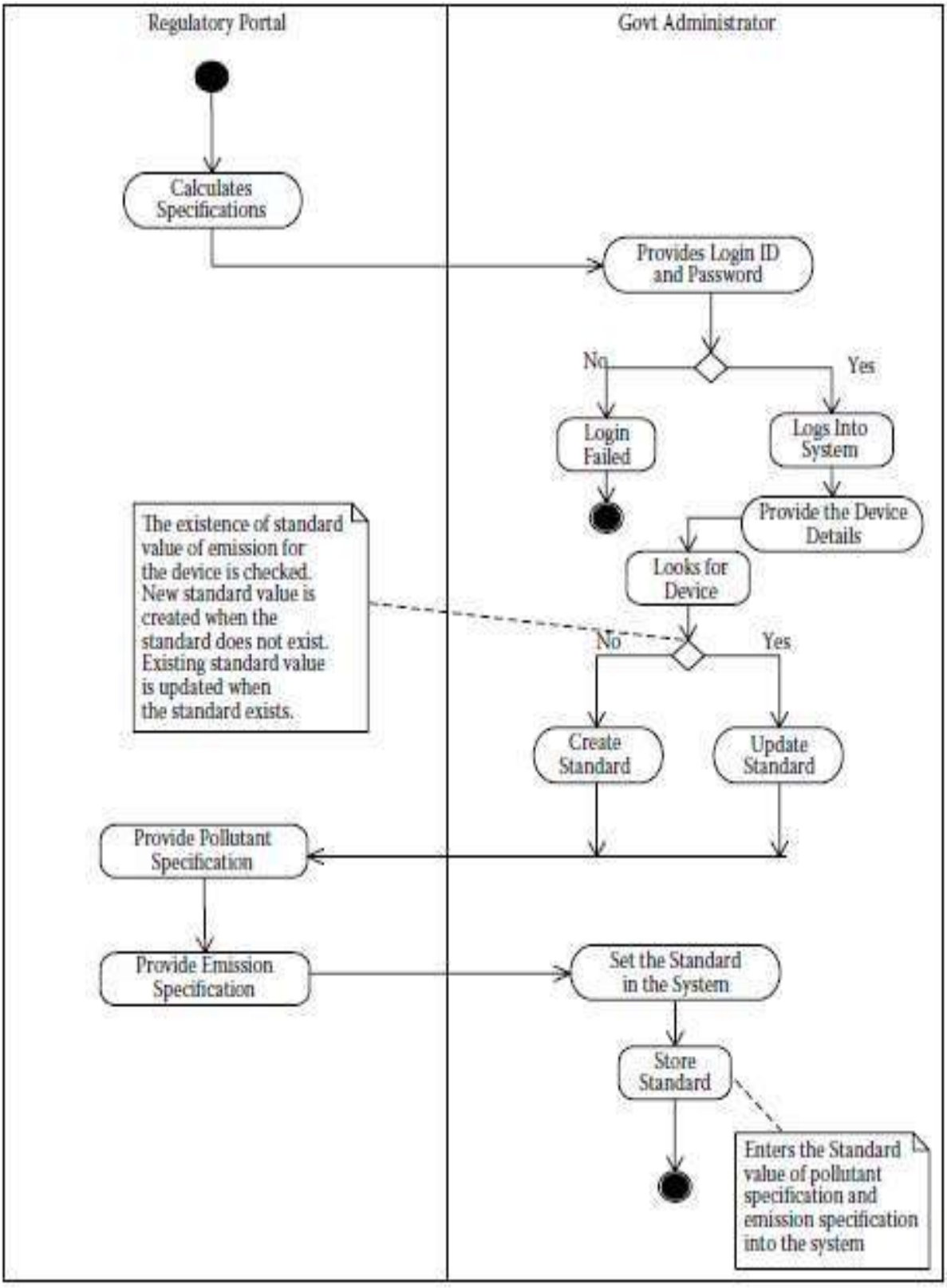


Figure 7.8 Activity diagram for maintaining emission standards.

- Depicts activity diagram for use case “Maintaining Emission Standards.” Government administrator logs in portal and provides device details as well as create/update standard on basis of emission and pollutant specifications provided by portal. After creating/updating those standards, government administrator sets standards in the system and stores them.

Class Diagram for GOP

- This diagram shows the key entities i n t he portal and t heir interrelationships. These entities are derived from the “Use Case Analysis.”
- This object-oriented structure will also have to be configurable in practice for each company, depending on different industry sector. “User” and “Organizational User” are the primary actors of the system. Environmental

manager and worker are major organizational users of system. User works in a department of a company which is dedicated to specific industry.

- Different types of reports such as emission specific reports are created by user.

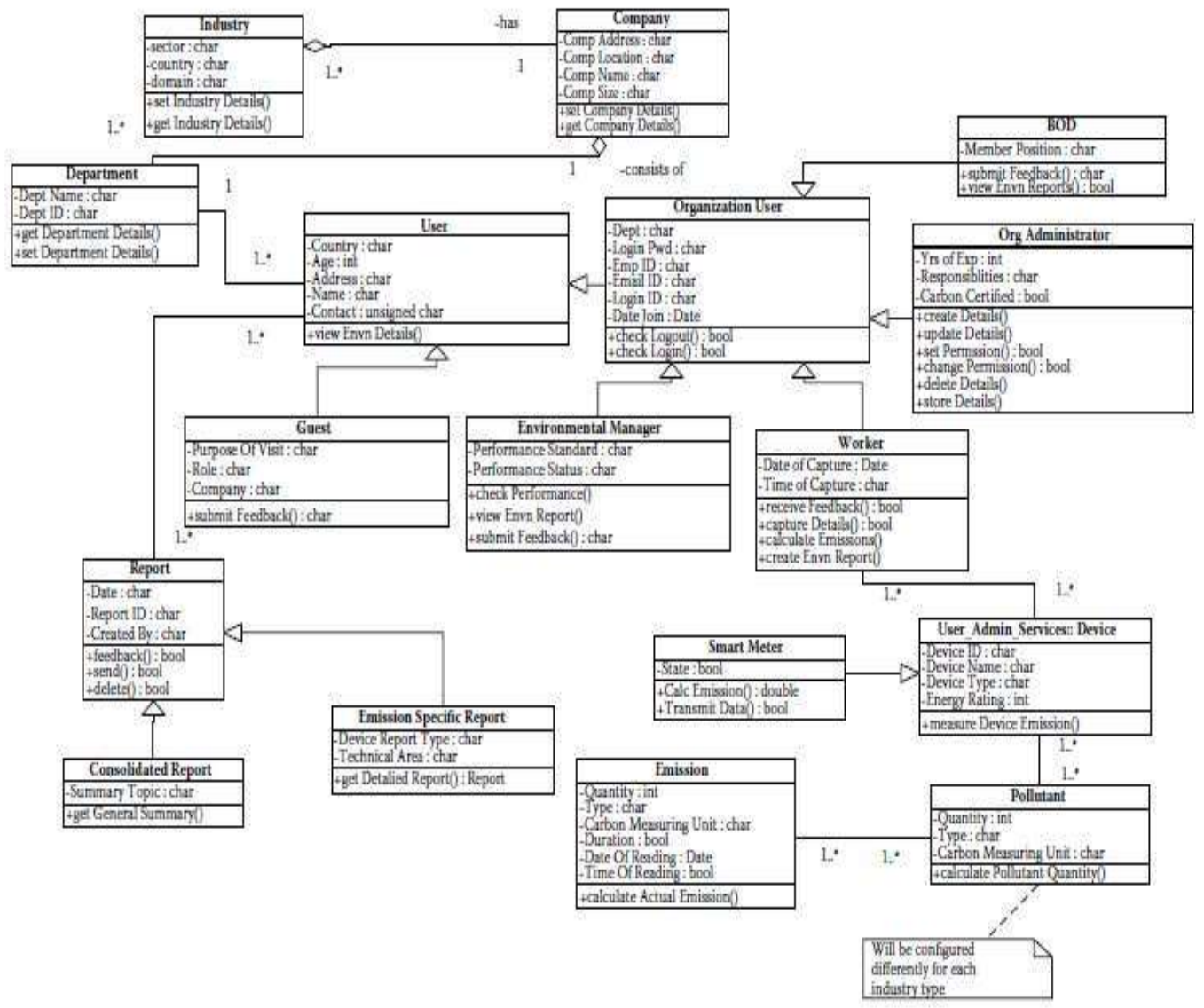


Figure 7.9 Class diagram (static model) within "Green Organizational Portal."

Sequence Diagram for "Setting Standard Emissions Value"

- A sequence diagram for setting standard emissions values within a Regulatory Server Portal.
- Regulatory Server Portal sets standards that are created by government administrator. Government administrator collects industry details, company details, and emitter details. On basis of those details, government administrator calculates emission standards, pollutant specifications , and emitter specifications.

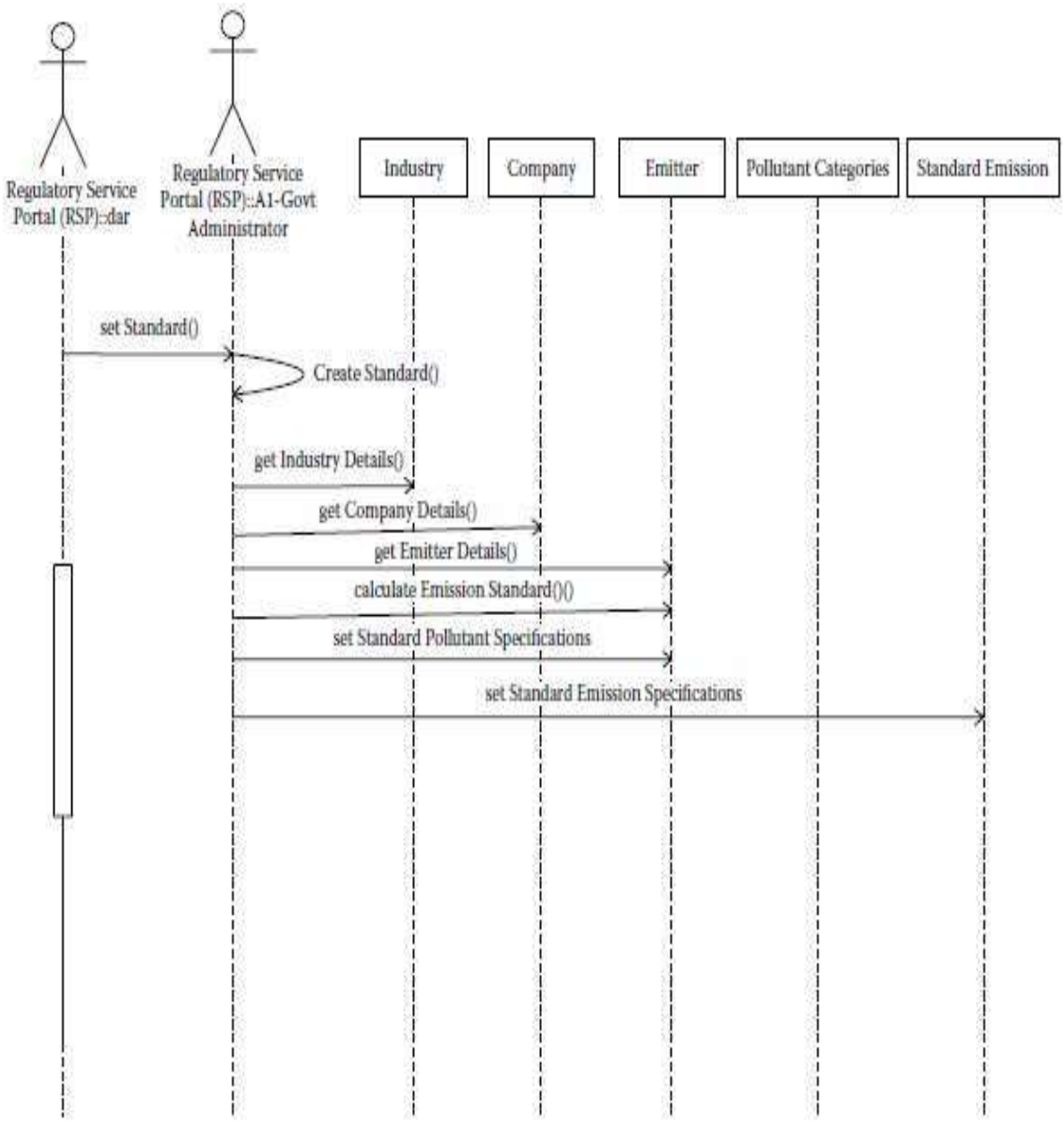


Figure 7.12 Sequence diagram (dynamic model) for "setting standard emissions value."

State Machine Diagrams for "Emission Standard Value" Objects

State machine diagram for an emission standard value. It shows all the states starting from providing emission standard values till it getsstored.

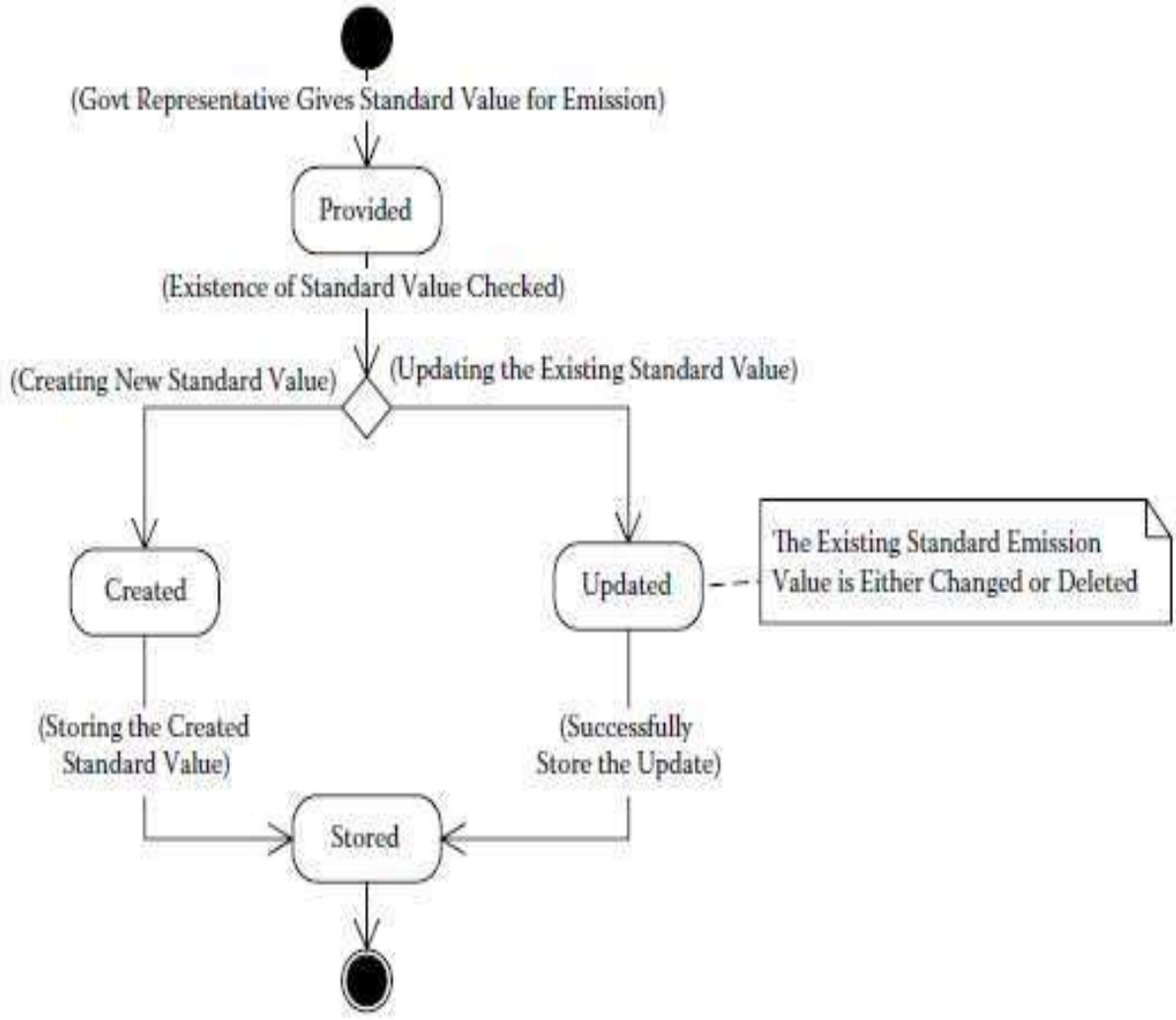


Figure 7.14 State machine diagram for class—emission standard value.

- Government representative provides standard values for emissions and checks for the standard values. If the values are existing and need updates, then the values are updated and stored successfully, but if the values are new, then they are created and stored in the database.

Implementation Diagrams for GIS

- The component diagram for complete GIS including all the important components like ROP and GOP.
- Organizational portal and regulatory (government) portal are two major components of the system. They are connected with major interfaces for create, update, remove, and view functionalities.

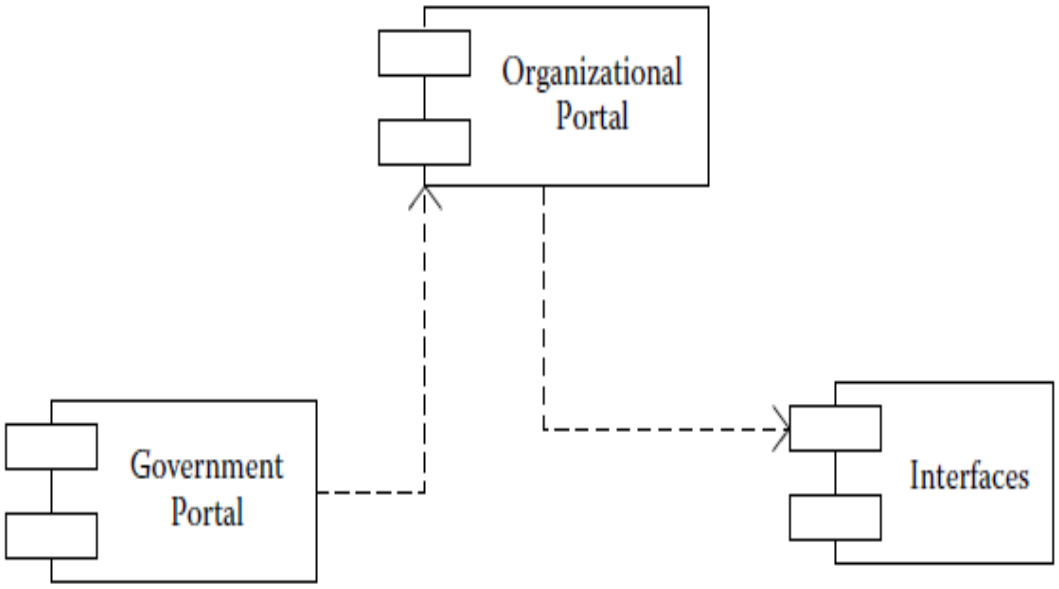


Figure 7.15 Component diagram for GIS.

- The deployment diagram of the complete GIS including all the external actors connected to major components of the application
- Two high-end servers are connected to each other. GOP and RSP sits on each server. Standard emissions are provided by RSP and they are provided to be compared for each pollutant. GOP creates report and sends for enquiry. Handheld device is useful in creating reports and tracking emission values in units.

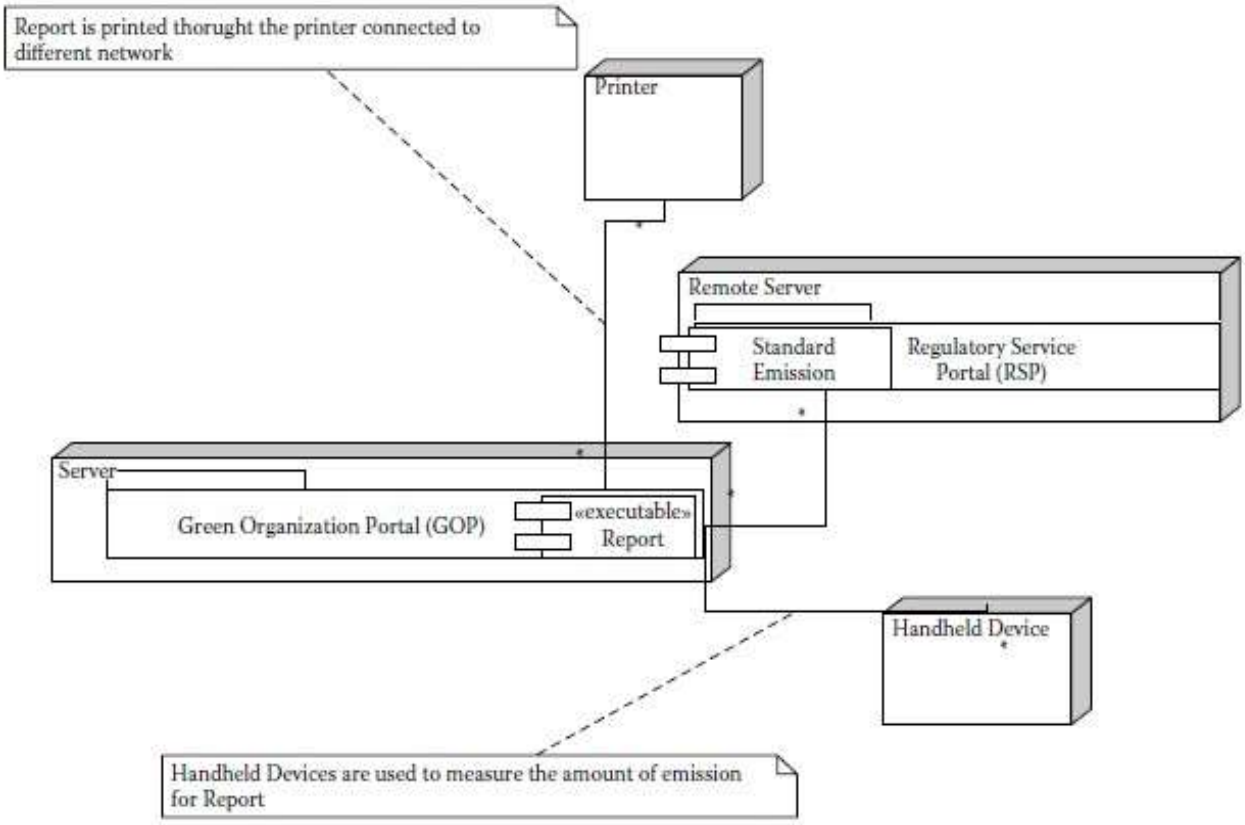


Figure 7.16 Deployment diagram for GIS.

GIS—Technical Requirements

In addition to functional requirements, GIS also has operational technical requirements. They are listed as follows:

- GIS should be able to run in a wide variety of platforms such as Windows, Unix, Linux, and so on.
- GIS should be able to operate on a variety of hardware including PC, laptop, and mobile devices.
- The data should be stored in a server located in a secure environment. However, network connectivity with the applications should be on a 24×7 basis.
- GIS user access should be based on a secured identification and password. Users will have levels of authorization and access. Those access levels will be administered by system administrators.
- The GIS should have a sophisticated firewall that would block unwanted connections from outside the organizational boundary.
- GIS should incorporate encryption.
- A virtual private network (VPN) would be established to ensure private communication between collaborating organizations using the same GIS.

Assignments

Assignment - II

1. Explain how you understand individual, organizational, and collaborative processes.

2.List the Various tools and techniques in carbon measurement

Part A
(CO2, K2)

1. What is Green Assets?Assets have been grouped from an accounting perspective in tangible and intangible assets, it is worth grouping them into two groups from a carbon perspective: the static, infrastructural assets (e.g., the data center) and the non-static assets (which are mobile, such as a laptop computer) of the organizations.

2. List the three major phases of green assets.

1. Establish (Procure)
2. Operate (Run)
3. Dispose (Demolish)

3. What is Data Server?

The physical machines and the specific buildings in which they are housed. These servers also have both wired and wireless networks and corresponding communications equipment associated with them that are directly emitting carbon.

4. What Data Servers Virtualization?

virtualization, data centers can consolidate their physical server infrastructure as multiple virtual servers are hosted on lesser number of servers. This result in reduced power consumption, reduced number of servers, and also reduced demand on the data center infrastructure.

5. List the various virtualization techniques.

1. presentation virtualization
2. application virtualization
3. desktop virtualization
4. storage virtualization
5. network virtualization

6. Define Cloud computing .

Cloud computing there is opportunity to not only consolidate the costs of services but also shift t he carbon generation to are latively centralized place where it can be better controlled and optimized.

7. List the Categories of networks?

Wide Area Networks (WAN)
Mobile Networks
Wireless L AN/WAN
WiMax

8. What is Smart meters?

Smart meters are meters that not only measure the power consumption automatically, but also provide feedback to the users in real time.

smart meters can also transmit this data for further analysis. EI applications can provide actionable information to the users

9.List the Various tools and techniques in carbon measurement .

Dashboard displays attached to the devices to display emissions Mobile gadgets attached to devices for measuring emissions:
Surveys of employees and other stakeholders:
Inventory o f t he organization to identify unused goods
Interviews of employees and stakeholders to ascertain carbon emissions

10. **Define BPM**.

"BPM is a well-established industry practice encompassing process modeling, reengineering, and optimization of processes, and the measuring, merging, and elimination of business processes .

11. **What are various levels of processes within an organization**

- the individual,
- organizational,
- collaborative processes

12. **What is Green Reengineering?**

Green BPM includes reengineering of business processes to optimize their emissions.Reengineering is the green processes, will incorporate reevaluation of processes and also an understanding and modeling o f their supporting hardware, software, and people in order to cut down t he carbon generated through them.

13. **What are role of Green business analysis?**

The role of business analysis activity, including the gathering of business requirements, understanding and modeling processes, process analysis and optimization, and testing prior to deployment.

14. What is Green Requirements Modeling?

The requirements modeling can be considered a s a sub discipline of systems engineering that is concerned with the behavior, quality at tributes, and also technical constraints.

15. Green requirements modeling can be divided into ?

- Functional
- nonfunctional (or operational).

16. The four dimensions of Green Business Transformation are?

Economic,

Technical,

Social, and

Process

17. What is Documenting Process Goals ?

Processes can be measured for their efficiency and effectiveness as described by Unhelkar (2003). When applied in the green context, each process has to be measured for its carbon content.

18. What is the aim of Green Enterprise Architecture ?

The aim of a GEA is to develop an understanding of different viewpoints of business, technology, and the environment in which the business exists.

19. What is the Views of Green Enterprise Architecture?

GEA encompasses an understanding of the various views of the organization and its interrelationships.

The Green information architecture (GIA), primarily deals with the models of information capture and information provisioning to both external and internal parties in the business space.

The information architect and the business analyst work in this space identifying and modeling the information requirements.

20. What is the Green Supply Chain Management?

Together the suppliers, customers, employees, and senior management in order to produce an integrated and efficient supply chain t hat w ill re duce carbon emissions cannot be overstated.

The SC M of a n organization needs to be analyzed, planned, and optimized for sourcing and deliveries in an environmentally conscious manner web -based.

Unit 2 - Part B - Questions: (CO2)

1. Describe how organizations Green IT strategies could be translated into practices in terms of procurement and disposes of assets that leads to reduction in carbon emission?
2. Describe how the building location, design, and architecture has direct impact on the overall carbon generated by the organization?
3. What is the role of smart meters in Environmental Intelligence?
4. Explain how you understand individual, organizational, and collaborative processes.
5. What is Green BPM? Discuss the role Green BPM plays in the reduction of an organizational carbon footprint.
6. Explain the role of SCM systems in the GEA.
7. What is Green ICT information portal? Discuss the important elements of the inputs and outputs of a green portal.
8. Create a use case diagram for the major aspect of a GIS relevant to supply chain management.
9. What are the major areas of a GIS (using pakage diagram)?

Supportive Online Courses

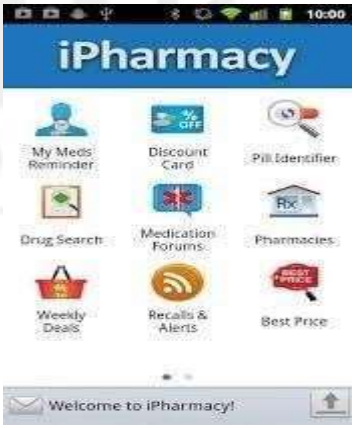
Relevant Online Courses

S. No	Course Title	Link	Platform
1	Green Computing	https://nptel.ac.in/courses/106/105/10610517/#	NPTEL / Swayam
2	Renewable Energy and Green Building Entrepreneurship	https://www.coursera.org/learn/renewable-energy-entrepreneurship	Coursera
3	A Green Computing Professional Education	https://www.tomw.net.au/technology/it/green_computing_professional	Udemy
4	Corporate Sustainability. Understanding and Seizing the Strategic Opportunity	https://www.coursera.org/learn/cor p-sustainability	Coursera
5	Enterprise Data Architecture Strategy - Build a Metadata Repository	https://www.experfy.com/training/courses/enterprise-data-architecture-strategy-build-a-metadata-repository	Experfy

Real-time Applications

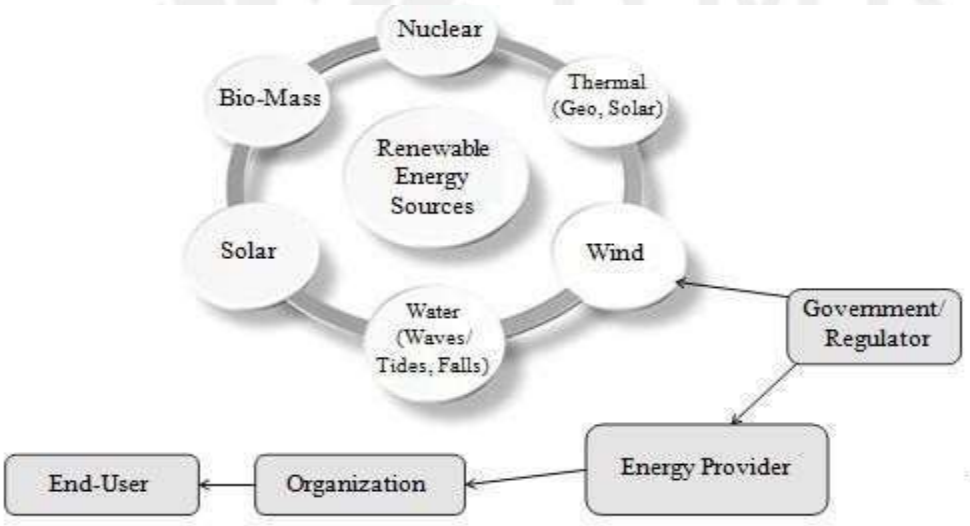
Real world Examples of Green Computing

- Green Resource:
  - Renewable Energy Resources
  - Green peripherals
  - Energy conservation
- IT Sector:
  - Data Servers
  - Virtualization
  - Cloud computing
  - Blackle
- Enterprise:
  - Supply chain Management
  - Smart Meters
  - CMES



Real Life Analogies

- **What would you prefer, Renewable Energy Resources?**
- The policies and practices associated with the organization in its current state, it is also worth considering the impact of totally different types of energy as is currently consumed within an organization.
- For example, if instead of oil or gas, the energy was generated from coal—will that make a difference in the way the organizational policies.
- The use of renewable energies will require the government and the regulatory bodies to p lay a vital role in encouraging its use by changing market levers through legislations and use of carbon offsets.
- Using renewable energy is one way that businesses can minimize their greenhouse gases. Consumers, businesses, and organizations may use renew- able energy to reduce the environmental impacts



Renewable energy sources need to be increasingly incorporated in green policies.

Contents Beyond Syllabus

1. Green IT

- The essential elements of technology and the latest domain knowledge from Desktop to Data Center. In nine interactive modules students use text, video, and hands-on analytical exercises to master the fundamentals of sustainability for the ICT industry and specific techniques for applying that knowledge. The course includes in-depth work with the latest developments in "Green IT 2.0", the use of ICT to enable sustainable solutions across the enterprise. The capstone project is the creation of a practical plan for an enterprise Green IT initiative.

  The course is certified by the World Education council to meet the highest standard of online education. Instructors for the course have actual field experience in designing, leading and implementing Green IT projects.

- Students that successfully master the course content and pass the final examination earn a certification as Sustainability Professional – Information and Communications Technology (SP-ICT).

- It is designed to be beneficial to a broad audience, not just IT leaders and managers. The Green IT course content is essential knowledge for career success as Chief Sustainability Officer, Facility Manager. Architect and Building Design Engineer, Procurement and Purchasing Manager, and Corporate Social Responsibility leader. There is also increasing demand for professionals in Sales, Business Development, and Consulting who are knowledgeable about sustainability for ICT.

- The course requires approximately 100 hours to complete and costs $1,800 US, including materials, instructor support, exams, and certification.

- **Mastering the course content and receiving the SP-ICT certification gives professionals in many fields a unique competitive advantage for success in the technology-driven 21st Century world.**

2. Energy conservation

- The industrial sector uses about 50% of the total commercial energy available in India. Of the commercial sources of energy, coal, lignite, and oil and natural gas are mainly used. The Indian energy sector is highly energy intensive and efficiency is well below that of other industrialized countries. Efforts are made on a regular basis to promote energy conservation in these countries as this will help reduce the cost of production.
- There is considerable scope for improving energy efficiency in industries dealing with iron and steel, chemicals, cement, pulp and paper, fertilizers, textiles, etc. If such industries can promote energy conservation, it could lead to substantial reduction in their costs of production.
- Energy management is very important as all well-planned actions can help reduce an organization's energy bills and minimize the damage it does to the environment. The two main energy management strategies are conservation and efficiency. This requires the establishment of a system of collection, analysis, and reporting on the organization's energy consumption and costs.
- In the industrial sector, the major consumers of energy are fertilizer, textile, sugar, cement, and steel. It has been estimated that the **total conservation potential of this sector is around 25% of the total energy used** by it.

Conservation initiatives

- Waste heat recovery systems, cogeneration, and the utilization of alternative sources of energy are also important for the conservation of energy.

Technology, up gradation, modernization, and the introduction of control instrumentation are necessary to realize the full potential of energy conservation in industry.

ASSESSMENT SCHEDULE

- **Tentative schedule for the Assessment During 2022-2023 odd semester**

S.NO	Name of the Assessment	Start Date	End Date	Portion
1	Unit Test 1	22-08-23	28-08-23	UNIT 1
2	IAT 1	09-9-23	15-09-23	UNIT 1 & 2
3	Unit Test 2	09-10-23	14-10-23	UNIT 3
4	IAT 2	26-10-23	01-11-23	UNIT 3 & 4
5	Revision 1	06-11-23	08-11-23	UNIT 5 , 1 & 2
6	Revision 2	09-11-23	14-11-23	UNIT 3 & 4
7	Model	15-11-23	25-11-23	ALL 5 UNITS

Prescribed Text Books & References

Text Books and References

TEXT BOOKS:

- Bhuvan Unhelkar, —Green IT Strategies and Applications- Using Environmental Intelligence ‖, CRC Press, June2014.
- Woody Leonhard, Katherine Murray,—Green Home computing for dummies ‖, August2012.

REFERENCES:

1. AlinGales, Michael Schaefer,MikeEbbers,—Green Data Center: steps for the Journey‖, Shroff / IBMrebook, 2011.
2. John Lamb,—The Greening ofIT‖,PearsonEducation,2009.
3. Jason Harris,—Green Computing and Green IT-Best Practices on regulations & industry‖, Lulu.com, 2008
4. Carlspeshocky,—Empowering Green Initiatives with IT‖, John Wiley & Sons,2010.

Miniproject Suggestions

Mini Project Ideas

1. Design a Digital Library management system to reduce the carbon emission.
2. Implement a Environment Intelligence using Cloud and Web services .
3. Conduct a survey on how to implement the energy consumption by individual, organizational, and collaborative processes in green IT.

Thank you

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