TO INVESTIGATE *GREEN* PRACTICES AND RECOMMEND FRAMEWORK FOR IMPLEMENTATION IN ELECTRONIC PRODUCTS MANUFACTURING FIRMS TO ACHIEVE GREEN SUSTAINABILITY

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TO

MY BELOVED FAMILY

WHO AT EVERY STAGE OF THEIR LIFE SACRIFIED
AND ENCOURAGED ME FOR MY WELL- BEING AND PROGRESS

ABSTRACT

This research is aimed to highlight green practices in the electronics industry. The study is based on the theoretical perspectives of researchers whereby pollution in manufacturing represents waste and a loss of productivity. The developed countries like U.S.A, Japan and European Union are switching from conventional practices and have adopted green practices in manufacturing which can result in significant savings in manufacturing and minimizes production cost. This ultimately optimizes energy usage and improves profitability. With economic development and technological advancement, the demand for energy resources is ever increasing which will eventually lead to depletion of energy resources. This situation warrants energy conservation and sustainable development.

The study has been restricted in scope to Electronics Products manufacturing industry in Pakistan. Sixteen green practices as adoptable to environment in Pakistan were shortlisted so that maximum information could be gathered about finding linkage of specific green manufacturing practices with specific competitive outcomes. A total 13 organizations were included in the survey and only 8 responded, therefore overall response rate comes to 61% which can be termed as quite favorable. The status of current manufacturing practices has been identified. Implications for Electronics products manufacturing industry by adopting green manufacturing practices have been discussed. The responses have been analyzed on the basis of manufacturing costs, quality of product, company image, attracting new customers and promotion of innovative ideas in the Electronics manufacturing industry.

The results show that generally, Electronic Products manufacturing firms are pursuing little or no green sustainable practices. Nevertheless, the main focus is energy conservation with more emphasis in the private sector. Overall, 81% believe green practices will lead to reduction in manufacturing cost. Only 36% think it will improve quality of the manufacturing product. 49% foresee improvement in company image and increase in customer base, whereas 44% are of the opinion that it will promote innovative ideas in manufacturing.

Although electronics industry in Pakistan is not very competitive as far as outcomes are concerned, nevertheless, the study does provide an overview with respect to which green manufacturing practices are expected to be adopted more by the electronics industry in the near future due to stringent environmental laws. The public/private

organizations, regulatory bodies, financing institutions and government are required to control the planning, management, financial and technical aspects to encourage adoption and implementation of adoptable green practices in Electronics manufacturing industries of Pakistan.

Sustainable development is going to play a very significant role in overall national economy of Pakistan. The recommendations given will hopefully contribute to highlight the importance of green practices for the developing world and provide some direction to follow towards achieving green sustainability.

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Completing thesis is not a confining effort. It calls for certain interdependence, like patronage, guidance and encouragement. Acknowledgments are not formal but a genuine expression of gratitude.

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TABLE OF CONTENTS

Contents **Page No**

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 SUSTAINABLE ELECTRONICS MANUFACTURING

CHAPTER 4 ROLE OF GOVERNMENT IN SUSTAINABILITY AND ELECTRONICS MANUFACTURING INDUSTRY

CHAPTER 5 SURVEY OF GREEN PRACTICES

CHAPTER 6 DEVELOPING FRAMEWORK FOR SUSTAINABLE GREEN PRACTICES IN ELECTRONIC PRODUCT MANUFACTURING FIRMS IN PAKISTAN

List of Figures

List of Tables

List of Abbreviations

EC	Energy Conservation
EPA	Environmental Protection Agency
EPI	Environmental Process Index
EPP	Environmentally Preferable Purchasing
EMS	Environmental Management System
ESI	Environmental Sustainability Index
GHG	Green House Gases
GM	Green Manufacturing
JPCA	Japan Printed Circuit Association
MSTQ	Metrology, Standards, Testing and Quality
MTOE	Million Ton of Oil Equivalent
NGO	Non Governmental Organization
NEQS	National Environmental Quality Standards
OM	Operations Management
PCB	Printed Circuit Board
PBT	Persistent Bioaccumulative Toxin
PCRET	Pakistan Council of Renewable Energy Technologies
PMP	Product Management Practices
PPP	Pollution Prevention Practices
PSI	Pakistan Standards Institute
PSQCA	Pakistan Standards and Quality Control Authority
PTB	Pakistan Technology Board
QC	Quality Control
RoHS	Restrictions on Hazardous Substances
SPI	Sustainable Process Index
TQM	Total Quality Management
WEEE	Waste of Electrical and Electronic Equipment

CHAPTER 1
INTRODUCTION

1.1 Background

According to (Seliger, 2008)[1], Engineering is confronted with the challenge of paradigm change to provide increasing standard of living without exceeding ecological limits. Present products and processes express the life-style of the developed Western World. Technology has to be adapted according to criteria of sustainability. In this context, the principle of sustainability as a mission statement for development moves is the focus of attention. Green manufacturing covers almost all aspects of manufacturing, including information decisions, process technologies, energy consumption, material selection, and material flow[2]. Many decisions manufacturers make are related to cost, function and quality[3]. Sustainability is the newly added dimension. The goal of green manufacturing is to support future generations by attaining sustainability achieved mainly through product and process design[4].

1.2 Aim

To develop a framework of green practices for electronics industry with an insight into the relationship between sustainable green manufacturing practices and specific competitive outcomes?

1.3 Objectives of the Research

In order to transform manufacturing operations into green practices, the problem is to find a way to manufacture products more efficiently, consistent with identification and suppression of material and energy wastes and extraction of all possible value from every resource prior to subsequent disposal or recycling[5]. Following are the objectives intended to be achieved by this thesis:

- Investigate international green manufacturing practices in developed countries.
- Identify parameters of green manufacturing practices.
- Analyze green manufacturing practices of electronic products manufacturing firms.
- Develop framework for green practices in electronics industry.

1.4 Research methodology

This research analyzes green manufacturing practices of electronic product manufacturing firms in Pakistan using deductive approach and presents a framework for achieving sustainability as per following steps:-

- The collection of information from all relevant ministries (Ministry of Science and Technology, Industries, Environment, Health, Water & Power and Ministry of Law).
- Literature review related to sustainability, international green manufacturing practices and sustainable electronics.
- The Tool / Technique used is case study/survey/interviews.
- Structured interviews with personnel concerned with electronics manufacturing industry.
- Pilot questionnaire was design to get constructive feedback from 5 – 7 individuals.
- Academic validation by inviting comments from 3 – 4 scholars.
- User validation by getting opinions of 2 – 3 personnel from electronics industry.
- Data collection by survey of electronics manufacturing firms.
- Analysis of green manufacturing practices.
- Develop framework for green manufacturing practices in Pakistan.
- Documenting the work as thesis.

1.5 Significance of Research

Green materials are non-hazardous materials. Restrictions on Hazardous Substances (RoHS) useable in manufacturing products were introduced by the European Union and Japan in year 2001, whereas in the United States they were affected with the establishment of the Environmental Protection Agency (EPA)[6]. Internationally, studies done in the recent past have found that a lot of energy-rich material is being dumped as waste, rather than re-used as a resource. So far, no significant research work in this regard, published or unpublished, has been carried out in Pakistan.

Typically, a manufacturing plant would resist the implementation of green technology because of the costs that are associated with redesigning the manufacturing product and process of the entire manufacturing plant. Becoming green can be viewed as a process where one starts using more environment-friendly materials that have low embedded energy and come from renewable resources as per standards given by ISO[7].

Having a successful level of sustainability requires aligning the green manufacturing program with the organization's vision, mission statement, policy and guiding principles, all of which include high quality[8]. Consistent and dedicated efforts are necessary for enabling an organization to achieve sustainability.

This thesis will hopefully provide a set of rules in the form of guidelines to be adopted by present and future electronics manufacturing firms to become environmental-friendly. Also at the same time attain substantial relief in the form of cost savings achieved as a result of implementing and practicing green manufacturing practices. In the long run, the benefits to society could be as following:

- Energy savings.
- Minimized use of resources.
- Cost reduction using sustainable practices.
- Protecting the environment through green awareness.
- Recycling and Reuse of material waste and water.
- Continuous improvement of product, processes and systems.

1.6 Structure of Thesis

Chapter-one covers the background, problem statement, objectives, significance and structure of thesis.

Chapter-two is the literature review pertaining to Green manufacturing practices.

Chapter-three explains the theory of sustainable electronics manufacturing.

Chapter-four describes role of government institutions in sustainable development and lists the existing major electronics industry.

Chapter-five covers the data collection, analysis, results of survey and discussion on probable implications for the electronic industry in Pakistan.

Chapter-six summarizes the research and recommends a framework for implementation by present and future organizations in order to achieve sustainability.

Chapter-seven includes the recommendations for National, Association and Industry level and concludes the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Defining Sustainability

Sustainability in engineering can be defined as the application of scientific and technical knowledge to satisfy human needs in different societal frames without compromising the ability of future generations to meet their own needs. To achieve this goal, scientists and engineers cooperate in international and multidisciplinary groups and organizations. They utilize imagination, judgment and take initiative to apply science, technologies and practical experience to shape competitive processes and products. Management guides the creation, application and evaluation of science, technology, processes, and products, as well as the dissemination of knowledge (Seliger, 2008).

Let us now examine sustainability in more detail in order to understand how to translate this abstract concept into meaningful action. Sustainability or sustainable development has been described in many ways: 'Meeting our needs while not compromising the ability of future generations to meet theirs' (Bruntland Commission)[9], 'Living well within the limits of nature' (Mathis Wackernagel[10], author of *Sharing Nature's Interest*) or simply 'Not cheating on our children' (former UK Environment Minister John Gummer). Regardless of the definition, those working in the field of sustainability generally all envision sustainability as having three realms: economic, social and environmental. Sustainability aims to optimize all three. [11], [12]

Nowadays, the term "sustainable development" has become a complicated phrase. Many support it yet a few define it exactly or honestly probe its implications. A reasonable definition of sustainability has been introduced by the World Commission on Environment and Development in the so-called Brundtland-Report 'Our Common Future' in 1987. Based on this definition,

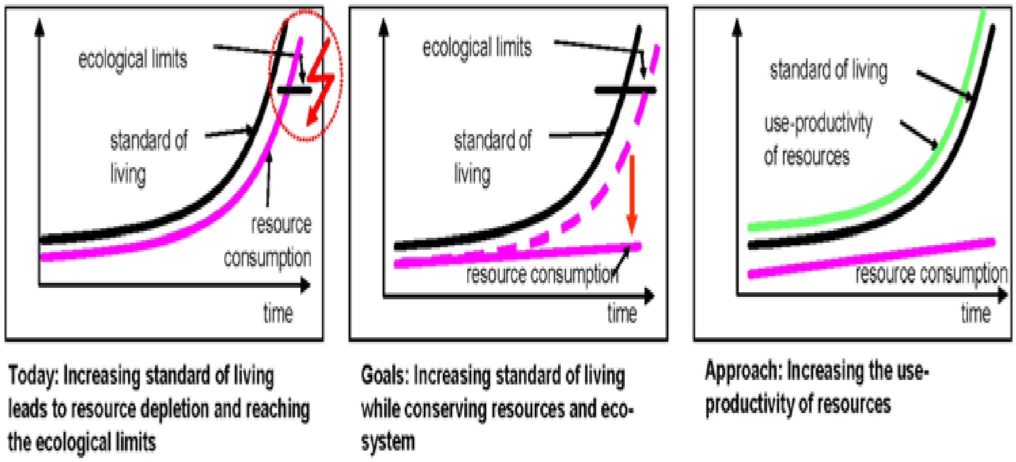


Figure 2.1: Approach to increase the global standard of living without bursting the limits of the globe
Source: Seliger (2004), Global Sustainability – a future scenario

sustainable development is defined as a holistic approach harmonizing ecological, economical and socio-political needs with respect to the superior objective of enhancing human living standards[13]. The availability of natural resources and the task of conserving the ecosystems have to be considered so that future generations have the possibility to meet their own needs(Conkin, 2007)[14]. However, this goal cannot be achieved with current resource productivity and current trifling with the ecosystem without bursting the limits of the globe as shown in figure 2.1 (Seliger, 2004)[15].

According to Pakistan Environment Protection Agency[16], Sustainable development is the development that meets the needs of the present generation without compromising the ability of future generations to meet their needs. As per (Jovanne et. al 2009)[17], it is mandatory for advanced as well as emerging countries to define, move towards and implement a global Competitive Sustainable Development (CSD) paradigm, see figure 2.2, complying with advanced as well new emerging countries conflicting expectations and interests and with economy, society, environment, technology (ESET) context, manufacturing: i.e. products and services, processes, business models, related policies concerning: education, research and technological development, industrial innovation.

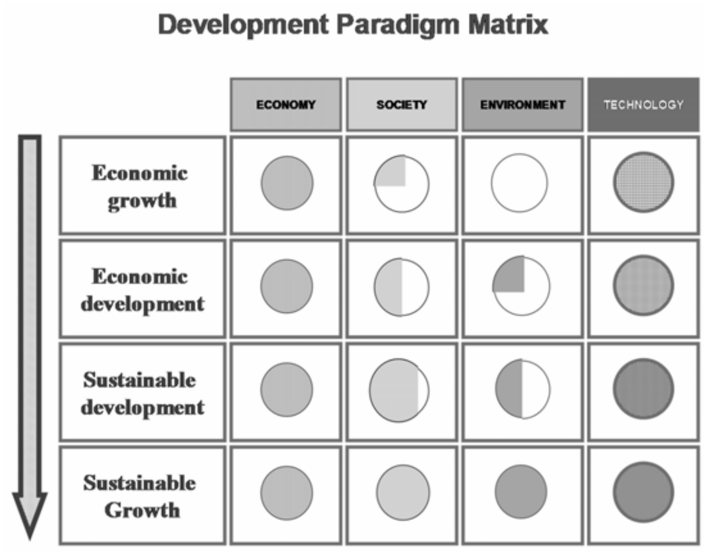


Figure 2.2: Towards Competitive Sustainable Development and Further
Source: Jovane et.al (2009), The Manufuture Road: Towards Competitive and Sustainable High- Adding -Value Manufacturing, pp 5-39

The World Commission on Environment and Development (1987) (the Brundtland Commission) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Kleindorfer et. al., 2005)[18], (Rusinko, 2007)[19] and (Zhu, 2009)[20] further add that community pressures and the threat of liability, however, can drive companies to improve their environmental performance. Clearly, companies are most likely to improve their environmental performance when public pressure results in strong regulations.

Sometimes, companies themselves lobby for regulations if they have developed an environmentally friendly technology and believe that regulations requiring their technology would give them a competitive advantage.

The result in many cases supported by (Lamprecht et .al, 2008), (Rusinko, 2007) and (Zhigang, Hua, 2006) is that a process not only pollutes less, but also lowers costs or improves quality. Processes can be modified to decrease use of scarce or toxic resources and to recycle wasted by-products.

2.2 Challenges of Sustainability

Challenges of sustainability in engineering are illustrated in figure 2.3, whereby human needs are represented as the MASLOW pyramid spanning all societies in the world (Maslow, 1999)[21]. The different coloured columns between the human needs and the available resources describe the dissimilarity of conditions of the global society. Engineering challenges are design of products and processes with improved usefulness and less environmental harm. Technology interpreted as science systematically exploited for purposes offers huge potentials to contribute.

Technology enables for processes transforming natural resources into products to meet human needs. The interaction between research and education imposes dynamics on how creative solutions are developed for relevant tasks. Owing to new means of transport and communication, knowledge and value creation is no longer limited to niches of wealth but more and more accessible by everyone, everywhere at anytime. These dynamics must be mastered by management considering chances for cooperation and risks of competition. Different societal frames with different value systems considering economical, ecological and socio-political issues in different regions of the globe have to be taken into account (Seliger, 2004). Currently, only few companies, governments, organizations and institutions are considering and incorporating aspects of sustainability. Several best practice examples regarding ecoefficient and sustainable products are promoted by predominantly large global-acting companies. However, the potential of sustainability in engineering is not exploited yet. There is still a lack of scientific basic principles, methods, procedures and tools for planning, development, adduction, and utilization(Seliger, 2008).Why is sustainability suddenly on the radar screen? Following are a host of reasons (Hitchcock, Willard, 2006):

- Sustainability is a natural extension of other organizational changes
- Natural resources are now a limiting factor
- Environmental issues are becoming global
- Health concerns are rising
- Social, environmental and economic factors are entangling, creating instability.
- Sustainability tends to produce multiple, unintended benefits.

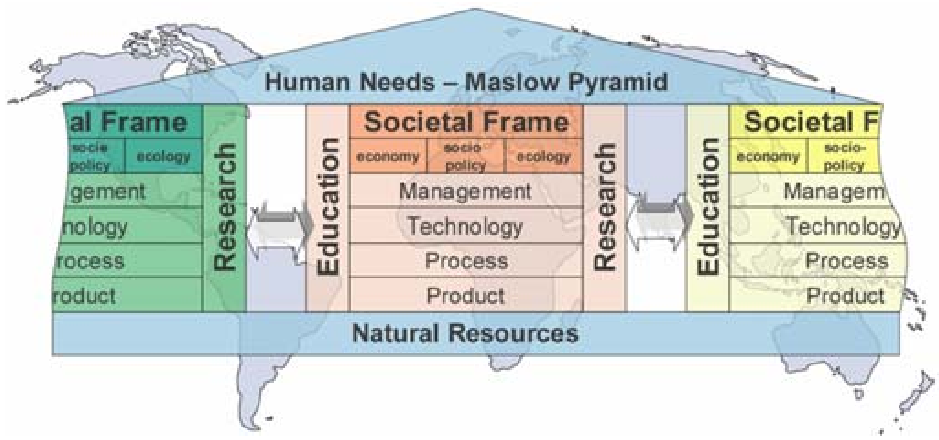


Figure 2.3: Engineering perspectives in Sustainability
Source: Seliger (2004), Global Sustainability – a future scenario

2.3 Sustainability and Competitiveness

Manufacturing concerns from macro (macro-economics) to meso (production and consumption paradigms) to local i.e. micro level (products/services, processes, business models). Manufacturing involves a large variety of stakeholders, from public authorities and financial institutions, to industry, to the education & research and technological development & innovation (E&RTD&I) system. This makes up the Knowledge Triangle (K-Triangle)as shown in figure 2.4.

Figure 2.4: The Knowledge Triangle
Source: Jovane et.al (2009), The Manufuture Road: Towards Competitive and Sustainable High- Adding -Value Manufacturing, pp 5-39

It refers to the interaction between research, education and innovation, which are key drivers of a knowledge-based society. In the 90s, following the sustainable development vision, the sustainable manufacturing paradigm was introduced.

Manufacturing must change from short-time profit orientation towards long-term sustainability of enterprises, innovative products and processes and reduction of energy and material consumption. Sustainability is not only a factor of cost but also a source of value and innovation (Jovane et. al. 2009). At industrial sector level, competitiveness may be described as the capacity to grow, to innovate and produce more and better (higher quality) goods. Further, competitiveness can be seen as comparative concept of the ability and performance of a supply paradigm to respond to a demand paradigm. The evolution of production paradigm, as shown in figure 2.5 has complied with the above. The performance indicator gives indications about competitiveness of manufacturing systems, as shown in figure 2.6.

Paradigm	Craft Production	Mass Production	Flexible Production	Mass Customisation and Personalisation	Sustainable Production
Paradigm started	~1850	1913	~1980	2000	2020?
Society Needs	Customised products	Low cost products	Variety of Products	Customized Products	Clean Products
Market	Very small volume per product	Demand > Supply Steady demand	Supply > Demand Smaller volume per product	Globalization Fluctuating demand	Environment
Business Model	Pull *sell-design-make-assemble*	Push *design-make-assemble-sell*	Push-Pull *design-make-sell-assemble*	Pull *design-sell-make-assemble*	Pull *Design for environment-sell-make-assemble*
Technology Enabler	Electricity	Interchangeable parts	Computers	Information Technology	Nano/Bio/ Material Technology
Process Enabler	Machine Tools	Moving Assembly Line & DML	FMS Robots	RMS	Increasing Manufacturing

Figure 2.5: Evolution of Demand and Related Response Paradigms

Source: Jovane et.al (2009), The Manufuture Road: Towards Competitive and Sustainable High- Adding -Value Manufacturing, pp 5-39

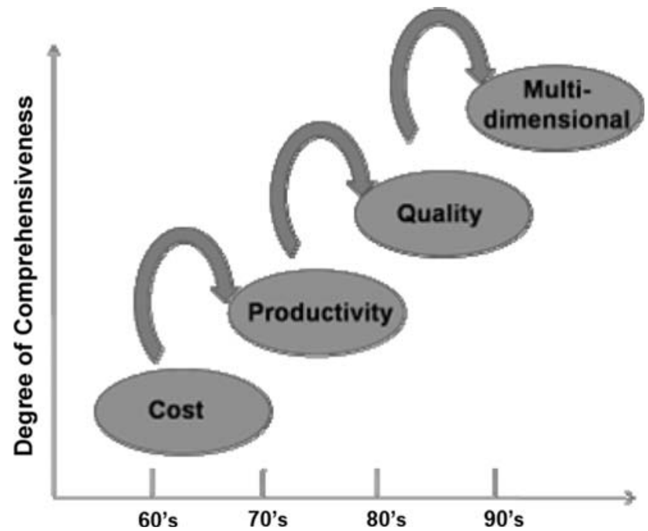


Figure 2.6: Evolution of Performance Measures for Manufacturing Systems
Source: Jovane et.al (2009), The Manufuture Road: Towards Competitive and Sustainable High- Adding -Value Manufacturing, pp 5-39

2.4 Sustainability and Engineering

Engineering in a broader perspective of potentials and applications is to investigate how to cope with the challenge by increasing the use-productivity of resources. Researchers from engineering science, e.g., manufacturing, medical, transportation, design, information, process, electrical, and civil engineering, integrate their domain-specific knowledge and experiences thus developing methods and tools in management and technology for useful applications in selected processes and products according to criteria of sustainability(Seliger, 2008).

According to (Ciocci, 2006)[22], Green engineering requires environmental consideration at the design phase of a product. This consideration includes all material and energy requirements and their effects over the lifetime of the product. Material requirements include those for both products and processes. The focus on energy must include the energy to make, use, and dispose of the product. Green design and manufacture leads to the understanding of the interplay among processes and flows and the optimization of the various considerations that are present. As per (Rusinko, 2007), (Kaplan, 2009)[23] and (zhu, 2009), Green electronics is the application of environmentally considerate design and manufacture to electronic products. Environmentally considerate electronic products include those made with recycled and recyclable materials and energy efficient processes. Green electronic products do not become part of the solid waste stream, and their processes do not contribute liquid and gaseous emissions to the environment. (Polcari, 2007)[24] states that conceptually, the green fab is an integrated system of specially engineered tools, methods, products and supporting technology that together reduce energy and resource consumption, eventually leading to savings in annual operating costs. Closely related to grey lists and black lists is the emerging field of green chemistry. Whenever you produce something, you create not only a product but also unintended byproducts. Until recently, chemists never concerned themselves with how toxic these byproducts were. Environmental risk has long been seen to be a function of the hazard as well as exposure:

$$Risk = Hazard \times Exposure$$

To manage the risk, most effort to date has been put into reducing or eliminating exposure: protective clothing, scrubbers, filters, warning labels, training, etc. Green chemistry, on the other hand, addresses the hazard portion of the equation. Even with our best efforts, accidents happen (Hitchcock, Willard, 2006).

As per (Hoffmann, 2009)[25], building green builds a better education. Educational facilities often provide the greatest and most visible venues for applying sustainable design and construction principles. Unfortunately many owners of educational facilities are leery of incorporating sustainable practices because they think it costs more to be green. Sustainable practices really do have an impact on more than just the environment. Green practices also affect attendance, classroom learning, attitudes and staff. Significant long-term cost savings are among the most exciting benefits an environmentally friendly educational facility enjoys.

2.5 Sustainability Indices

2.5.1 Environmental Sustainability Index (ESI)

ESI is a composite index tracking 21 elements of environmental sustainability covering natural resource endowments, past and present pollution levels, environmental management efforts, contributions to protection of the global commons, and a society's capacity to improve its environmental performance over time[26]. The ESI was published between 1999 to 2005 by Yale University's Center for Environmental Law and Policy[27] in collaboration with Columbia University's Center for International Earth Science Information Network (CIESIN), and the World Economic Forum.

2.5.2 Environmental Performance Index (EPI)

The Environmental Sustainability Index was developed to evaluate environmental sustainability relative to the paths of other countries. Due to a shift in focus by the teams developing the ESI, a new index was developed, the Environmental Performance Index (EPI)[28] that uses outcome-oriented indicators, then working as a benchmark index that can be more easily used by policy makers, environmental scientists, advocates and the general public. The EPI has been published for 2006 and 2008[29]. The Environmental Performance Index (EPI) is a method of quantifying and numerically benchmarking the environmental performance of a country's policies. This index was developed from the Pilot Environmental Performance Index, first published in 2002, and designed to supplement the environmental targets set forth in the U.N. Millennium Development Goals. As of January 2010 three EPI reports have been released - the Pilot 2006 Environmental Performance Index as shown in figure 2.7, and the 2008 and 2010 Environmental Performance Index. In the 2010 scorecard, the top five countries were Iceland, Switzerland, Costa Rica, Sweden, and Norway. The bottom five countries were Togo, Angola, Mauritania, the Central African Republic, and Sierra Leone.

2.5.3 The Sustainable Process Index (SPI)

The Sustainable Process Index is a cumulative index based on the principle that the area of land suitable for feedstock generation, habitat, production, and dissipation of effluents is a limiting resource. It is calculated as the ratio of total land area required to sustainably manufacture a product or provide a service to the average available land area per individual, specific to the location of the production facility. SPI is the only index that specifically accounts for local conditions, such as the density of population, mode of energy generation, as well as ecological and climatic conditions responsible for the dissipation of manmade effluents[30]. SPI includes the social dimension through the number of employees and the area of land required to accommodate the employees in a specific location of the production facilities.

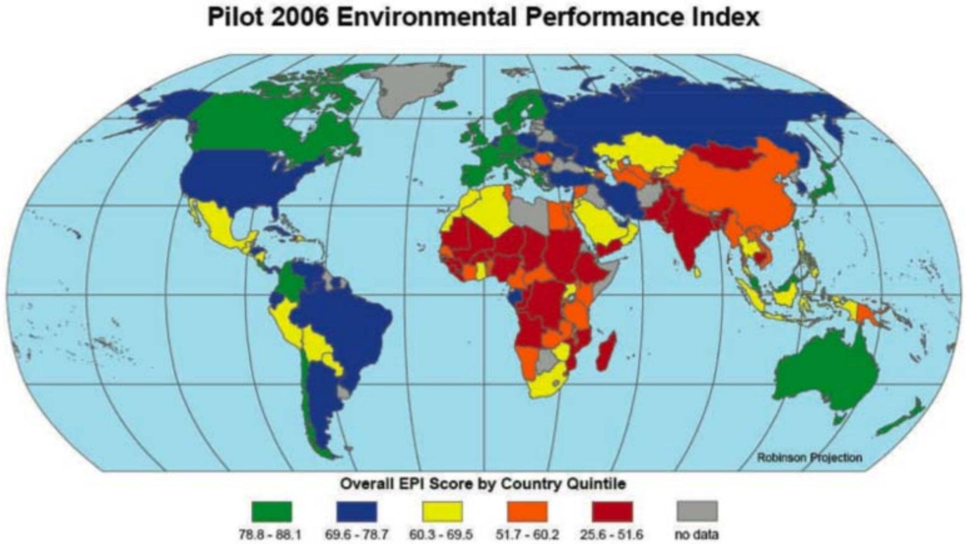


Figure 2.7: Pilot 2006 Environmental Performance Index
Source: http://en.wikipedia.org/wiki/Environmental_Performance_Index

2.6 Green Sustainable Practices

In the literature, by compiling the researches by (Rusinko, 2007), (Ciocci, 2006), (Seliger, 2008), (Hart, 1995)[31], (Porter, 1995)[32], (Christmann, 2000) and (Bansal, 2005)[33], following are the parameters of green sustainable practices:

- **Energy usage** (**Reduction** is the desirable goal) covers:
  - a. Total energy consumed
  - b. Renewable energy consumed
  - c. Power used during operation
- **Water usage (Reduction is the desirable goal) covers:**
  - a. Total fresh water consumed during manufacturing
  - b. Recycling of water for other uses
  - c. Reuse of water in manufacturing
- **Raw material use (Reduction is the desirable goal) covers:**
  - a. Toxic or hazardous materials used
  - b. Total industrial waste generated
  - c. Hazardous waste generated
  - d. Air emissions and water effluents generated
  - e. Greenhouse gases and ozone- depleting substances released
- **Recovery and reuse (Increasing is the desirable goal)covers:**
  - a. Percent of recyclable materials available at end of life

b. Percent of product recovered and reused

c. Purity of recyclable materials recovered

d. Percent of recycled materials used as input to product

- **Source volume (Reduction is the desirable goal) covers:**

a. Percent of product disposed off or incinerated

b. Fraction of packaging or containers recycled

There are two types of green practices which yield different competitive outcomes. They are following:

- Pollution prevention practices, whereby pollution represents waste and a loss of productivity.
- Product management practices, which covers green design and processes.

According to (Ghamewat 1986)[34] and (Klassen, Whyback 1999)[35], the major competitive advantage to be gained through product management is competitive preemption. As per (Rusinko, 2007), research on the impact of environmental practices on organizational outcomes is somewhat inconclusive, however, other researches by (Lampracht et al. 2008)[36] , (Zhu, 2009) and (Worhach P., Sheng P. 1997)[37] indicate that being environmentally proactive can produce competitive gains. Pollution prevention reduces or prevents pollution and can result in lower costs[38]. Correspondingly, a reputation as a green manufacturer can attract new customers. In addition, product management practices, such as redesigning products or manufacturing processes to be more environment friendly, can result in improvements in manufacturing quality, duly supported by (Zhingang, Hua 2006)[39], (Lamprecht et al. 2008), (F.Liu, H.J. Cao 2000)[40] and (Rusinko 2007).

2.7 The Cost of adopting Green Practices

Where does a company begin? In the sustainable world, the emphasis has long been on the three Rs: reduce, reuse and recycle. According to (Brown, 2009)[41], (Gess, 2008)[42], (Polcari, 2007) and (Nesi, 2008)[43], Sustainable practices focus on reducing inputs per unit of output. Inputs are resources like energy, water and materials. Green practices tend to be industry specific[44]. From reducing energy use and recycling water to implementing ISO 14001 sustainability programs and reusing packaging, U.S factories are embracing a more environmentally sensitive manufacturing ethos as fast as they can as they now believe the fact that green can be profitable. (Naffzigar et. al, 2003)[45] found that the green effort was positively and significantly correlated to the company image.

As per (Katz, 2009)[46] and (Sharma, 1999) [47], the reason why more manufacturers haven't extended environmental initiatives throughout their supply chains is likely cost. For instance, consumer-electronics manufacturers pay an estimated $3 billion annually to meet European Union regulations that restrict the use of certain substances in their products, according to a June 2008 study published by the Consumer Electronics Association that may account for why the number of manufacturers adopting green supply chain programs appears to be few. Only 10% of companies have implemented successful green supply chain initiatives, according to a survey of 245 supply chain executives published in February by consulting firm Accenture[48]. As an individual, there are dozens of opportunities for one to begin going green while finding financial justifications. Sustainability includes the ability to continue one's behavior change beyond action and through maintenance, like creating a table of actions for going green and potential cost savings for those activities. It is best to start small and work up. Savings from one activity can be used to fund other more expensive activities. Table 2.1 is a sample cost/benefit chart for going green with a short list of easy actions one can use as a template with big impact that can be implanted in both home and business location(Jonathan, 2009)[49]. A Smart Green company has the same basic elements of a company becoming more sustainable, with a little bit more. There is no clear definition of what sustainability is for everyone, because it will constantly change depending on one's understanding of the level of the crisis, as well as who, when, and where one is in the community, region, or country, or anywhere in the world. However, one can be *smart* about the balance between one's behavior, company's actions, and the impacts (positive and negative) one is having on society and the environment (Jonathan, 2009).

In the well known model about the five stages of change, it is useful to place your decisions and those around you in a framework and to understand the mindset and actions necessary to move from one stage to another. The stages followed by an example as shown in Table 2.2 as follows (Jonathan, 2009):

- *Pre-contemplation*. People in this stage are not aware or choose not to acknowledge there is a problem. Their actions and behaviors are potentially destructive to themselves and to others without their knowing.

- *Contemplation*. People in this stage have become aware that there is a problem and that changes in their behavior need to take place, but they are not ready to take action. Many people remain for long periods of time in this stage.
- *Pre-action*. A person is this stage has moved from being aware of the problem to now being more informed and desiring to take action. This is often considered the tipping point for many individuals' realization

Table 2.1: Sample Cost/Benefit Chart for Sustainability

No.	Sustainability Strategy	Potential Cost Savings
1	Recycle, Reduce, Reuse. The stand – by slogan for some of the easiest activities available for going green	Savings could be significant in choices being made in reduction of materials and reusing others for as long as possible.
2	Seal your space. Includes cleaning and sealing your ducts, sealing windows, switching to double - pane windows, adding window coverings, seal the chimney, add more insulation, change the insulation, seal the crawlspace.	Could realize up to 40% savings on energy usage per year, depending on the changes made.
3	Change automobile behavior. Some options include drive less, driver slower, use a bike or moped, carpool, buy an economy car, keep an old car	Gas savings, new car savings
4	Improve energy efficiency. Add solar panels, wind, or geothermal options. Switch to more efficient appliances, heating/AC, and water heater, change shower heads.	Energy bill savings could be 10 – 50%.
5	Collect rain. Use rain catchment for use in landscaping.	If part of city water, savings on Water bill or compliance with water restriction. If on a well, less impact on ground water supply.
6	Buy local. Join an agricultural coop, purchase local produce, goods, and services.	Savings on food bill with the benefit of supporting local growers and producers of goods and services.

Source: Jonathan M. Estes, (2009) Smart Green: How to Implement Sustainable Business Practices in any Industry – and Make Money

that a problem has existed, and they have a newfound desire to change. Individuals have many false starts toward action in this stage because of the potential risks of failure.

- *Action*. People in this stage take all that they have learned and their desire for change and take steps toward changing their behavior. Since it is early in their process, many people recycle to earlier stages.

- *Maintenance*. People in this stage have taken action and have experienced positive results propelling them forward to continue taking this action. Fewer people in this stage recycle through other stages, and more of them are considered to have experienced change.

Being truly green means adopting a global vision that incorporates environmental awareness into the entire manufacturing process from green purchasing and green fabs to ecofriendly processing and manufacturing waste recycling. The resulting benefits can mitigate and even outweigh the added costs of being environmentally conscious. (Polcari, 2007), (Sharma, 1999) and (Katz, 2009). A producers commitment to green manufacturing begins with the acquisition of raw materials according to (Rusinko, 2007), (Kaplan, 2009), (Polcari, 2007) and (Hongwei et al, 2008)[50]. Many corporations are actively adopting environmentally preferable purchasing(EPP) that favors products manufactured, packaged and distributed with superior environmental, safety and health(ESH) characteristics; these include optimized resource[51] and energy efficiency[52], reduced global warming impact and effective recycling practices.

Purchasing practices includes those policies, procedures and systems that support or encourage sustainable choices (Hitchcock, Willard, 2006). Following are some of the more common best practices:

- Adopt sustainable or Environmentally Preferable Purchasing (EPP) policies
- Embed sustainability language into RFPs and contracts
- Implement a supply chain environmental management system

Table 2.2: Stages of Change. An example of how a company’s sustainable activities can be in several stages at once.

No.	Stage of Change	Sustainable Activity Sample
1	Pre – Contemplative (Unaware)	The company ’ s products are made from a toxic chemical that is a known carcinogen.
2	Contemplative (Aware but Inactive)	Competing companies are beginning to reduce their carbon emissions and the CEO can’t imagine his company doing the same.

3	Pre – Action (Ready for Action)	The company has developed a business case and set a date to establish a profit sharing plan
4	Action (Taking Action in Small Steps)	The company has offered employees the opportunity to work at least one week at home per month to save on fuel.
5	Maintenance (Sustained Action)	The company has been recycling paper, cardboard, bottles, and cans for 3 years.

Source: Jonathan M. Estes, (2009) Smart Green: How to Implement Sustainable Business Practices in any Industry – and Make Money

2.8 Green Influence Factors

The products' requirements of green performance are different at all stages, as different demands imply input of resources and energy. The influence factors of the greenness of products are divided into five kinds, such as environment attribute, energy attribute, Resource attribute, economy attribute and Time attribute as shown in Table 2.3. According to (Hongwei et. al 2008), by using the property indicators of green performance and weighing them, the product's green degree at a certain stage of life-cycle can be measured, enabling enterprises to find the factors which influence the product's green degree.

Table 2.3: Influence factors of greenness of products

	Objective Level	The Influence Factor
The greenness of products(18)	Environment	Air Pollution(1)
		Water Pollution(2)
		Solid waste pollution(3)
		Noise pollution(4)
	Energy	Type of Energy(5)
		Energy utilization Ratio(6)
		Consumption of energy(7)
	Resource	Kinds of materials(8)
		Recovery ratio of materials(9)
		Rate of poisonous and/or harmful material(10)
		Utilization Ratio of advanced and/or high-efficiency equipment(11)

		Popularization of the green information(12)
	Economy	The cost of production(13)
		The cost of utilization(14)
		The cost of society(15)
	Time	The period of exploitation of products(16)
		The time of producing a unit of product(17)

Source: Li Hongwei et. al 2008 Analyzing the influence factors of greenness of products based on ISM, Chinese Control and Decision Conference 2008, pp 1667-1672

2.9 Sustainability in Supply Chains

According to (kleindorfor et al., 2005), as the new economic order unfolded, people recognized that profits and profitability were only one element in the long-term success of companies and the economies (Hay, Stavins, and Vietor 2005)[53]. Also important are the future of people (internal and external companies) and the future of planet Earth. These new legitimacy concerns are captured in measures such as the triple bottom line (3BL), the three Ps of people, profit and the planet, and the goal of maintaining viable social franchises (the trust of employees, customers, and the communities) as well as viable economic franchises (the ability to pay from the cash flows it generates for capital and other inputs it uses to produce its outputs). Operations Management (OM) is increasingly connected to sustainability, and it now concerns both the operational drivers of profitability and their relationship to people and the planet. The emerging synthesis gives researchers in OM exciting opportunities to make a difference. "Sustainability is becoming as prevalent in customer requirements as quality was 10 or 15 years ago, and we're at the tipping point of this movement where our customers, at least, are no longer saying it's nice to know you do it. It's a requirement". (Katz, 2009) informs that Green initiatives are largely taking place within manufacturers' own facilities, oftentimes as energy-reduction projects in disguise, says Larry Lapide, research affiliate at the MIT Center for Transportation & Logistics[54]. "In my view those companies that say they are being more green have really only done so by being energy efficient to drive down costs, not for altruistic reasons," he says. According to (Francis, 2009)[55], the environmental requirements are considered as an additional customer with its needs. It is estimated that the development time and cost can be significantly reduced. Identifying and managing environmental impacts throughout the supply chain is now a focus of OM research. A number of countries and customers are publishing grey lists (of chemicals that they want phased out) and black lists (of chemicals they will not permit in their products). This is where Sony ran into conflict with the European Union by having too much cadmium in certain components of its Playstation. Of course, to know what is in your product, you must also know what is in the components, dyes and other inputs that you purchase from suppliers. What gets a chemical on to one of these lists? Usually it possesses, or its manufacture creates as a by-product with, one or more of the following attributes (Hitchcock, Willard, 2006):

- Carcinogen – causes cancer
- Teratogen – causes birth defects
- Endocrine disruptor – mimics hormones (often also a teratogen)
- Mutagen – causes mutations of genetic code, thus passing on the problem to future generations
- Persistent Bioaccumulative Toxin (PBT) – A chemical that is not easily broken down by biological processes which accumulates in body tissue.

A reformulated framework by Hayes-Wheelwright-Bowen in the context of sustainable operations has been summarized by (kleindorfort et al., 2005) as:

- *The current internal strategies* are to improve internal operations with continuous process improvements related to sustainability, such as, employee involvement, waste reduction, energy conservation, and emission control.
- *The current external strategies* are to improve extended supply chains by analyzing upstream supply chains to make trade-offs in the choice of materials and processes and pursuing closed-loop supply chains for remanufacturing and safe disposal.
- *Internal strategies for the future* include investing in capabilities to recover pollution-causing chemicals during manufacturing, to develop substitutes for non-renewable inputs, and to redesign products to reduce their material content and their energy consumption during manufacturing and use, also supported by (Hongwei et. al., 2008) and (Rusinko, 2007).

A single organization can't be responsible for making all of society sustainable, but each can examine its inputs, outputs, processes and effects on the larger system in which it operates. Becoming a Smart Green company requires a process of change.

The first step toward change of your organization is to start change with yourself through reflection, education, networking, and saving costs. Paulo Nery, writer/editor for *Footprint* magazine, defines sustainability as "leaving the world as good as we found it — or ideally a little better (Jonathan, 2009). According to (Edwards, 2005)[56], the limits of natural resources, declining ecosystems and increasing economic disparity have given birth to sustainable practices in business. Several companies in the U.S have devised their own Sustainability Assessment Tools. Arup, an international engineering firm with over 7000 employees in 32 countries utilizes the Sustainable Project Appraisal Routine (SPeAR) to assess sustainability performance. SPeAR focuses on indicators of environment protection, social equity, economic viability and efficient use of natural resources to assist in managing information for making decisions on sustainability issues.

2.10 Regulations in Japan

In Japan, there is indirect pressure for lead-free products from Japanese legislation. Only certain landfill sites permit dumping of lead, which carries a cost premium, and there is a Home Electronics Recycling Law requiring companies to take back end-of-life electronics. The Electric Household Appliance Recycling Law passed the obligation for collection and recycling of waste appliances to the producers of those appliances. The appliance law is part of "The Basic Law" for establishing the Recycling-based Society in Japan. This law is part of seven laws, which include the Waste Management and Public Cleansing Law and enacting the Law on Promoting Green Purchasing[57]. Japan's motivations for change are the increasing use of electronic products, the physical limitations the country has to house waste products of all kinds, and the recognition that these waste appliances contain valuable materials. The approach is to phase-in the law by adding a specific number of products that must return to the producer each year. Recycling materials will be a large part of the action upon receipt of the waste products, but disposing toxic wastes due to lead content will also require manufacturers' attention (Ciocci, 2006). Although the take-back legislation does not specifically target lead-based solder, electronic manufacturers will ultimately be responsible for the proper disposal of the lead used in their post-consumer products. Elimination of lead from electronic manufacture alleviates the need for controlling lead disposal. In Japan, there is no pending legislation for halogenated Flame Retardants(FR). However, Japanese manufacturers have indicated activities planned or underway to reduce or remove halogenated FRs from their products. For example, Sony has indicated it will provide globally halogen-free products by 2002. Fujitsu is producing halogen-free plastic cover computers. In March 2000, JVC certified a PCB that eliminated the use of halogenated materials from base materials and insulation layers. Japan Printed Circuit Association (JPCA) uses 900 ppm bromine or chlorine to describe a product as "halogen-free"(Deal , 2009) provided it is not an intentional additive to the product (Ciocci, 2006) and (Polcari, 2007).

2.11 Regulations in the US

In the early 1990s, US legislators proposed the Lead Exposure Reduction Act, which would control lead. A successful lobbying effort by the electronics industry at the time saved lead-based solder from restrictions. However, the US Environmental Protection Agency (EPA) did inventory lead-containing products and list those products that would present unreasonable risks of injury to human health(Ciocci, 2006). The question arises is why are Companies looking for Lead-Free alternatives? and whether Lead Unsafe to Use? When considering issues with health and safety, two terms are commonly used - hazard and risk. As per (Bastecki, Chris, 1999)[58], Hazard refers to the inherent toxic nature of a material and its effect if ingested, inhaled, or absorbed into the body. Risk relates more to the safety of a material when used with the proper precautions, or the probability that the hazard will occur.(Bastecki, 2009) and (Deal, 2009) state that lead is a hazardous material; it is known to be toxic. High absorption of lead into the body leads to lead poisoning which is a well-known and serious problem. Low levels of lead absorption may affect cognitive powers, the nervous system, and the reproductive system. The legislative process is a political one, and hence, very unpredictable. At this time, there is not a strong legislative effort to restrict lead use in electronics in the USA. Europe is taking a more aggressive position toward lead-free legislation. (Moschetto,2008), (Bestecki, 2009) and (Ciocci, 2006) describe that the European Union directive calls for a ban on lead in all electronics except automotive and certain other categories by January 2004. Laws on electrical and electronic waste are already in effect in Holland and Switzerland. Recycling statements involving electrical and electronic waste have been enacted in Asia including Japan and Taiwan. Many multinational electronics companies have initiated technical programs to evaluate lead-free alternatives so that they could be prepared to implement lead-free systems in the event that final restrictive legislation is instituted. A handful of companies are implementing lead-free processes as a marketing strategy. These companies are test marketing their electronics as lead-free, environmentally friendly products(Bestecki, 2009).

2.12 Regulations in the European Union

On January 27, 2003, the European Parliament and the Council of the EU passed a pair of directives aimed at reducing the effects of the production, use, treatment, and disposal of waste of electrical and electronic equipment (WEEE) on human health and the environment. Together, they identify lead as a material manufacturer must not include in EEE after July 1, 2006. The directives place EEE into categories such as household appliances, telecommunications equipment, tools, toys, lighting equipment and other consumer products. WEEE includes all components and subassemblies that are part of the product at the time the user discards it . (Ciocci, 2006), (Moschetto, 2008)[59] and (Polcari, 2007). RoHS logo is in the form of a small green leaf or a green circle with a check mark and RoHS imprint. As described by (Deal, 2009)[60], (Ciocci, 2006), (Bastecki, 2009)[61], (Udomleartprasert, 2004)[62] and (Peter et. al, 2002)[63], RoHS is an acronym for a "Restrictions on Hazardous Substances" directive established by the European Union (EU) in 2002[64]. The purpose of the directive is to reduce the use of hazardous substances in electrical and electronic manufactured products and thus promote a safer and cleaner environment[65]. There are a number of substances that are "banned" by the RoHS directive. The primary substances that are restricted under RoHS are lead (Pb), mercury (Hg), cadmium (Cd), hexavalent chromium (CrVI), polybrominated biphenyls (PBB), and polybrominated diphenyl ethers (PBDE). It is important to note that lead, cadmium, and hexavalent chromium are three major elements used in the manufacture of electronic products. Nearly all of the electronic circuit boards found in radios, MP3 players, mobile phones, televisions, etc., use lead as part of the manufacturing and assembly process. The lead is nothing more than the lead alloy we call solder. Electronic products that are intended for export to the European Union must be “RoHS compliant.” This means that they do not exceed the limits for RoHS-specified materials. Accordingly, we see electronic manufacturers changing from lead-alloy solders to lead-free solders. These new solder materials are generally tin, silver, and copper alloys. The lead-free solder alloys present special problems in assembling and manufacturing electronic circuits, such as changes in flux chemistry and higher melting points for lead-free solders. This in turn has created problems for component

manufacturers because the higher soldering temperature for lead-free solders caused component materials to break down and led to component failure[66].

2.13 Regulations in Pakistan

Industrial and manufacturing processes are the primary generators of hazardous wastes. Hazardous wastes include a broad range of materials such as manufacturing residues (e.g. waste acids, contaminated sludges and complex chemicals), PCBs, motor oil, unused cleaning products from homes and discarded batteries. These wastes require special handling to reduce adverse effects to human health and the environment. Standards constitute important aspects of trade, commerce and diffusion of technology. The Development of Metrology, Standards, Testing and Quality (MSTQ) infrastructure, therefore, are necessary for industrial progress and prosperity of a country or a region. Realizing the importance of MSTQ infrastructure, the Government of Pakistan has established the Pakistan Standards and Quality Control Authority (PSQCA) by Act-VI of 1996 to provide one window services for standardization and quality control. There are many regulations dealing with hazardous waste disposal. The Environment Protection Act No. XXXIV OF 1997 provides for the protection, conservation, rehabilitation and improvement of the environment, for the prevention and control of pollution, and promotion of sustainable development. The Pakistan environmental legislation and the National environmental Quality standards (NEQS) are attached as Annexure-A and Annexure-B. Moreover given below in Table 2.4 are few notifications of the government pertaining to the electronic industry.

Standards Institution (PSI) - Established in 1951 under Ministry of Industries with objective of formulation of national standards keeping in view the concept of quality, safety, health efficiency as basic parameters for the sustainable development. The PSI was also responsible for certification and conformity assessment of items to meet national standards on mandatory basis.

Table 2.4: SRO Notifications

SRO Number	Date	Notification
SRO 565(I)/2006	05.06.2006	Exemption from customs duty on import of raw materials, sub-components, components, sub-assemblies and assemblies for manufacture of specified goods.
SRO 575(I)/2006	05.06.2006	Exemption from customs duty and sales tax on import of specified machinery, equipment, apparatus and items.
SRO 659(I)/2007	30.06.2007	Exemption from Customs Duty on import into Pakistan from China.
SRO 483(I)/2008	28.05.2008	Exemption from whole of sales tax on the supply and import of machinery and equipment.
S.R.O. 258-(1)/2000	10.02.2000	Functions of an environmental laboratory

Source: Ministry of Industries, www.minofindustries.com.pk/gov/Regs/SRO

Central Testing Laboratory (CTL) - Established in 1951 under the Ministry of Industries to undertake testing of industrial raw materials and finished products for conformity assessment to establish their quality, with reference to national/international standards.

2.14 Advantages of Sustainable Practices

According to (Hitchcock, Willard, 2006), following are some of the benefits one should expect, based on the experience of other businesses and communities that have embraced sustainability.

- **Reduce energy, waste and costs.** Some organizations have achieved the goal of zero waste to landfill. These organizations are able to eliminate haulage costs and also get paid for the ‘residual products’ (formerly known as waste).
- **Differentiate yourself.** Companies and communities are always looking for ways to differentiate themselves from their competitors. Sustainability, at least until it becomes standard practice, can provide a way of making your organization stand out.
- **Sidestep future regulations.** Regulations are constantly changing. For those who want to get ahead of the curve, sustainability provides a useful framework for understanding the ‘endgame’.
- **Create innovative new products or processes.** By helping you to see the world’s present and future challenges, sustainability can help you develop new products or processes that can be part of the solution. By focusing its funding on sustainability projects, Toyota developed its hybrid technology and is now selling it to other manufacturers.
- **Open new markets.** Most companies focus on serving those in industrialized nations, less than one-sixth of the world’s population. Believe it or not, one can make a handy profit serving even the most destitute 3 billion people, *if* you have a product they want at a price they can afford.
- **Attract and retain the best employees.** Many of today’s employees want to work for companies that share their values. Sustainability can help infuse even mundane jobs with meaning. Sustainability can unleash a sense of passion not possible with most other organizational change efforts. Sustainability, because it includes both environmental and socioeconomic issues, is broad enough to encompass most people’s concerns, whether they are the future of the rainforest or the future of schools.
- **Improve your image with shareholders and the public.** Sustainability can put organizations on the leading edge of an exciting and socially responsible trend. This can help the largest corporations, who are often targeted by non-

governmental organizations (NGOs), build goodwill with the public. But it can also help tiny organizations get recognition.

- **Reduce legal risk and insurance costs.** In order to manage risk, organizations must keep an eye on social and environmental practices. Sustainability can help organizations radically reduce those risks and the overhead costs that go with them.
- **Provide a higher quality of life.** Sustainability helps communities make decisions that maximize the quality of life through ‘smart growth’ design principles.

2.15 Disadvantages of not adopting Sustainable Practices

In addition to the benefits of pursuing sustainability, there are also threats one can avoid. Organizations that choose to ignore this worldwide trend may put themselves at unnecessary risk. Chemical companies may not have had to fight the Registration, Evaluation and Authorization of Chemicals (REACH) Directive in Europe so strongly had they foreseen the need to clamp down on pollutants. Following are some of the more everyday problems that sustainability can help avoid(Hitchcock, Willard, 2006):

- **Liability for pollutants.** Liability is beginning to extend beyond the factory gates. More and more industries are surprised at how far their liability for toxins and other damaging substances extends. The current trend toward product stewardship or producer responsibility increasingly holds manufacturers responsible for the impacts of their products for their entire life cycle. Electronics companies, for example, are scrambling to design end-of-life options for their products in anticipation of state and national regulations that are likely to prohibit the disposal of computers, televisions and cell phones.
- **Supply problems with raw materials and energy.** Sustainability helps you to foresee potential future supply and demand problems. Wouldn’t you like to know in advance if a material or resource is likely to become much more expensive or unavailable?
- **Attacks on your image.** Sustainability helps you to understand the expectations of all your stakeholders. It can take years to recover from one well-publicized mistake or omission.

- **Legal risks.** Many companies have been held responsible for actions that were legal at the time but later determined to be harmful. Sustainability can help you assess your environmental legal risk, taking into account issues beyond compliance with current environmental regulations.
- **Bad-mouthing of your product.** As others become more aware of sustainability, certain materials tend to get labeled as ‘good’ or ‘bad’. Sustainability can help you uncover your product’s weaknesses so that you can overcome them before Greenpeace shows up on your doorstep or the media runs a story.
- **Being closed out of certain markets.** Sustainability is driving the marketplace in many countries. The European Union, which is banning certain toxic chemicals, turned away an entire shipment of Sony Playstations because of too much cadmium in one of the parts. Agricultural sustainability certification schemes are popping up, closing the market to farmers who aren’t yet certified.

CHAPTER 3
SUSTAINABLE ELECTRONICS MANUFACTURING

3.1 Approaches in Sustainable Manufacturing

According to (Seliger et al., 2008), from the 1980s, activities in sustainable manufacturing started to focus on waste reduction in production, so-called cleaner production. The activities were extended to the reduction of resources and energy use in production. After this, the paradigm for sustainable manufacturing has been changed from production-oriented to product–oriented one. The product-oriented approaches are, on the one hand, activities for reduction of resources and energy in a product. On the other hand, there are activities for reduction of toxic materials, and development and use of renewable materials. Even the consolidated environmental regulations such as and WEEE make demands on pretreatment of toxic materials, including components, reuse and remanufacturing of components or products for the profitability of their activities. Until now, the scientific approaches have neglected to enhance sustainability in the use phase and have also focused on the design for environmental and material level recycling. However, sustainable manufacturing for the next generation should focus on enhancing use-productivity in the total product life cycle. For enhancing use-productivity, there are the three strategies illustrated in figure 3.11[67]:

- *Implementation of Innovative Technologies* is a strategy focusing on the evaluation and implementation of feasible and innovative technologies for resource-saving applications.
- *Improving the Use-Intensity* is a strategy to improve use-productivity by increasing the utilization ratio of a product. This strategy intends to maximize productivity per resource input.
- *Extension of Product Life Span* is a strategy focusing on extending the time between cradle and grave of a product by expanding the use phase and realizing multiple use phases. The resource consumption for production and disposal of products shall be reduced with this strategy.

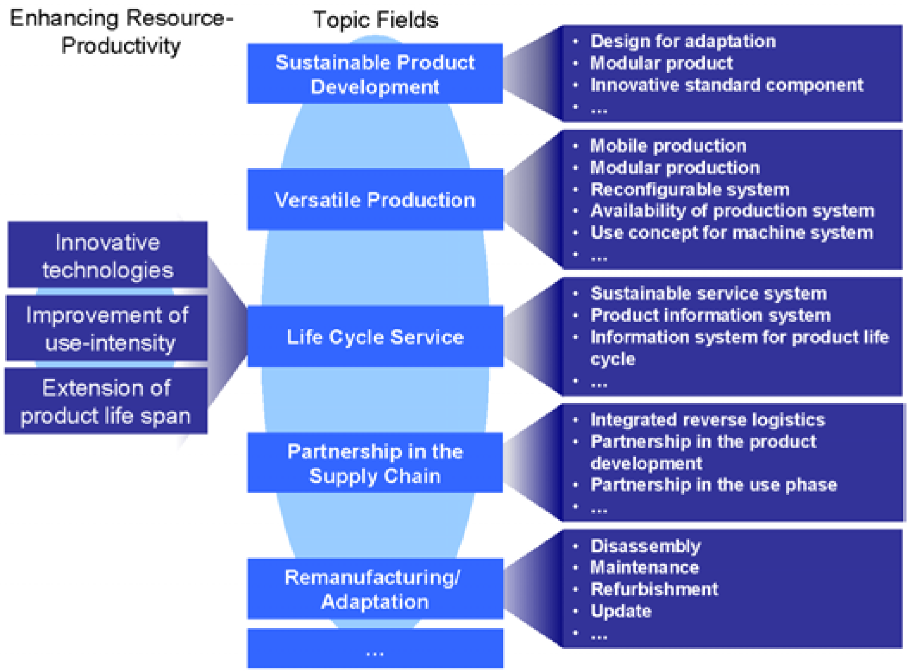


Figure 3.1: Framework for Sustainable Manufacturing
Source: Kim et al. (2006) Roadmap to Sustainable manufacturing by increasing use-productivity, Proceedings of IV Global Conference on Sustainable Product Development and Life Cycle Engineering, Sao Carlos, October 2009

3.1.1 Implementation of innovative technologies

The objective of this strategy is the evaluation and implementation of innovative technologies, which are used for resource-saving applications. Hereby implementation means both, application and implementation. Innovative technologies can be applied to improve product and process design, e.g., modularity and lightweight construction. Moreover, innovative technologies can be implemented in products for resource-saving applications. Innovative technologies are, e.g., fuel cell, photovoltaic and laser technology. Vital element of this strategy is the evaluation of technology according to sustainable manufacturing.

A best practice example for the application and implementation of innovative technologies is the automobile Loremo as shown in figure 3.2. Loremo is an acronym for Low Resistance Mobile[68]. The automobile is powered by a turbo-charged combustion engine and consumes 1.5 l diesel fuel per 100 km. The low fuel consumption results mainly from the reduction of the weight and the air resistance. A new Loremo variant shall be equipped with a hybrid power technology to improve performance and reduce diesel fuel consumption. The Loremo

AG is an innovative start-up company located in Munich, Germany.

Figure 3.2: Automobile concept of the Loremo
Source: Nasr, N., (2007) http://www.mercedes-benz.de/content/germany/mpc/mpc germany website/de/home_mpc /trucks/home/services/charterway/ueber _uns.html

3.1.2 Improving the use-intensity of products

Improving the Use-Intensity of products is regarded as the use phase in the product life cycle. The objective of this strategy is to increase the utilization ratio of a product or of its components. Two approaches have been identified to achieve this goal. First, by applying a business model, where the use of a product and not the product itself is the object of the companies' business. The second approach is related to a more sustainable use of a product by the user.

3.1.3 Extension of product life span

Extension of the product life span can be achieved, on the one hand, by expanding the use phase and, on the other hand, by the realization of multiple use phases. Maintenance and modification are means of expanding the use phase of a product. Multiple use phases are realized by remanufacturing and adaptation. Nasr defines remanufacturing as reviving a product to a like-new condition in terms of performance and durability by disassembling, cleaning, inspecting, repairing, replacing, and reassembling the components of a product (Nasr, 2004)[69]. The Caterpillar Remanufacturing Service has 12 remanufacturing factories all over the world. Its European remanufacturing factory in Shrewsbury, UK, is the largest European remanufacturing factory. Their remanufactured product spectrum ranges from a 1 kg water pump up to 1200 PS military tank engines. 61% of engines and components are directly remanufactured. They say their remanufacturing process saves 85% of the energy in comparison with original production, and 25% of the remaining material is recycled. Figure 3.3 shows before and after views for remanufacturing of a commercial vehicle engine (Hoefling, 2005)[70].

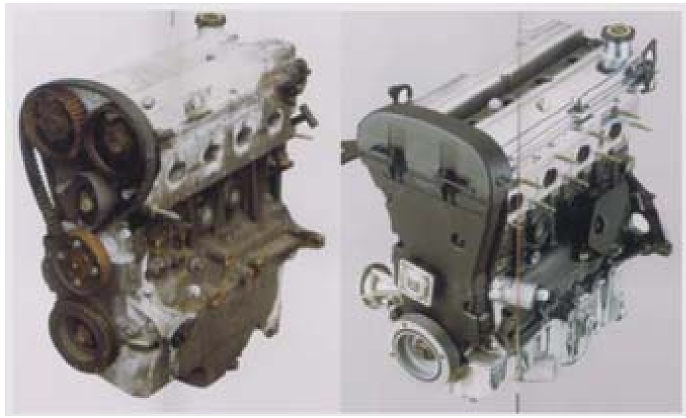
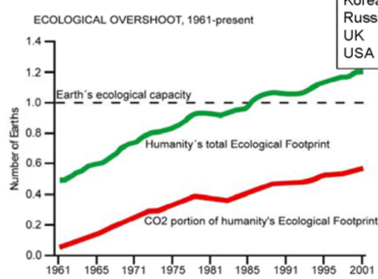


Figure 3.3 Before and after the remanufacturing of a vehicle engine block
Source: Hoefling, K. (2005) The advanced technologies, services, and profits in the remanufacturing industry. Best practices from caterpillar, Proceedings: International Conference on Sustainable Manufacturing, 12–15 October, Shanghai, China

Figure 3.4 derived from (NN, 2007) and (Wackernagel, 2006)[71] specifies relevant aspects of how in the second half of the 20th century parameters, all determined by human activity have developed. About one quarter of earth's surface accounting for 11.3 billion hectares can be considered as biologically productive area contributing to regeneration of resources. The average amount of biocapacity per capita on earth in 2001 is calculated, dividing the productive area by 6.15 billion people with the result of 1.8 global hectares biocapacity per capita. The diagram curves show humanity's total ecological footprint and the respective CO_2 portion of it from 1961 to 2001. Since 1985, resource consumption on global level is higher than the ecological capacity. The global population has increased from 3.08 billion in 1961 to 6.15 billion in 2001. Total energy consumption in 2001 is more than seven times the amount in 1961. Remarkable losses have occurred in biodiversity, where the indices since 1970 show an exponential decrease.

	Population [mio.]	Ecological Footprint [global ha/cap]	Biological Capacity [global ha/cap]	Ecological Deficit (-) or Reserve (+) [global ha/cap]
World	***6148.1***	***2.2***	***1.8***	***-0.4***
Brazil	174.0	2.2	10.2	8.0
China	1292.6	1.5	0.8	-0.8
Germany	82.3	4.8	1.9	-2.9
India	1033.4	0.8	0.4	-0.4
Japan	127.3	4.3	0.8	-3.6
Korea Rep.	47.1	3.4	0.6	-2.8
Russia	144.9	4.4	6.9	2.6
UK	59.1	5.4	1.5	-3.9
USA	288.0	9.5	4.9	-4.7



- 11.3 billion ha biologically productive area, about one quarter of earth's surface; consisting of 2.3 billion ha of water, 9 billion ha of land
- 11.3 billion ha divided by 6.15 billion people gives average amount of biocapacity on planet per person: 1.8 global ha/cap

Figure 3.4: Ecological Footprint
Source: Wackernagel, M. (2006) 'Ecological footprint accounting' The Future of Sustain ability, Springer, pp.193–209

Water, energy, construction, health, mobility and manufacturing are domains of engineering activities to be directed along the guidelines of sustainability. Mathematics and knowledge creation by information science provides tools for modeling solutions without expensive realizations. Manufacturing gives methods for realizing products in processes. Valuation/assessment helps considering the manifold of sustainability criteria in creating physical artifacts and related services. Education enables for convincing and instructing people about the advantages and methods of sustainability in engineering. (Seliger et al., 2008)

3.1.4 Distributed use of products and components

This approach is aiming at increasing the utilization ratio of products and components by its distributed use in different applications. To the same time functionalities and thus functional carriers of products are substituted. The utilization ratio is related to a product or component and can be calculated by comparing the standing time with the operation time. For example, if an automobile is used in average for 2.4 hours a day, then the utilization ratio is 10%. Especially in the electronic industry, such approaches have a high potential to increase the resource productivity. This seems apparent, since the manufacturing of electronic devices consumes plenty of resources as shown in figure 3.5

Figure 3.5 Primary Energy Demand of EEE along the product life cycle
Source: Seliger et.al. (2008) Approaches to sustainable manufacturing, Int. J. Sustainable Manufacturing, Vol. 1, Nos. 1/2, pp. 58–77

3.2 Development of Green Manufacturing Competency

At the turn of the third millennium, rising public awareness of economic, social, environmental and technological problems brings sustainable development and its main enabler, manufacturing, back to political agendas. According to (Jovane et. al., 2009), encompassing products, processes, companies and business models, manufacturing is a very relevant wealth generator, job provider and resources user. Economic, social and environmental problems are developing very fast and must be solved. Sustainable development may be dealt with at macro, meso, and micro level. Sustainable development is a complex concept, concerning three domains: economy, society, environment, and their interactions, as shown in figure 3.6. Several definitions have been proposed. The world Commission on Environment and Development declaration reads: "Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with the future as well as present needs". Sustainability in manufacturing requires that key challenges be met by innovative K-based solutions as shown in figure 3.7 (Jovane et. al, 2009). Sustainability in manufacturing seems to be a cost driver and antipodal to competitiveness. But the reduction of the consumption of resources like energy or material or the dematerialization of product functionality reduces costs. There are already many best practices showing the economic benefits and the potential of adding value. The reduction of resources consumption is a strong contribution to economic success.

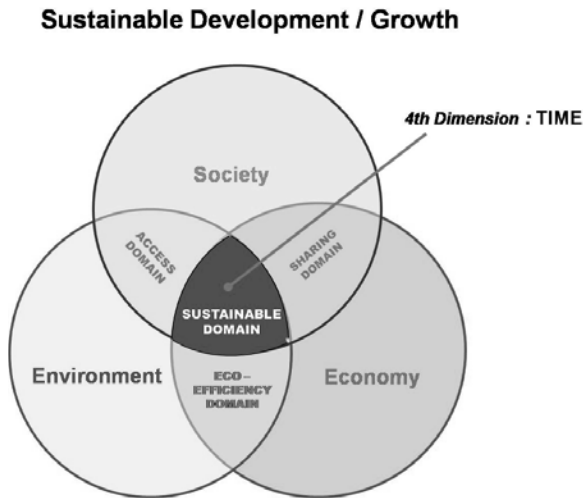


Figure 3.6: Fundamentals of Sustainable Development
Source: Jovane et.al (2009), The Manufuture Road: Towards Competitive and Sustainable High- Adding -Value Manufacturing, pp 5-39

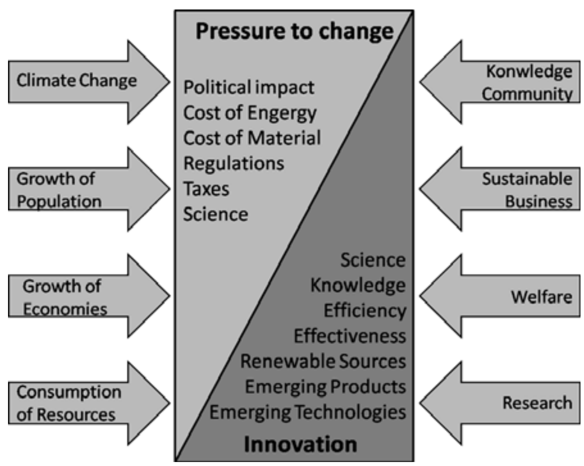


Figure 3.7: Sustainability in the Focus of Globalisation
Source: Jovane et.al (2009), The Manufuture Road: Towards Competitive and Sustainable High- Adding -Value Manufacturing, pp 5-39

Some companies have successfully included sustainability into their strategic orientation and are now seeing the results in terms of profitability and market position. According to (Shina, 2008)[72], internal green competency development takes time, and the choice of the individual(s) is very important. There are two elements to the green competency. One is the knowledge of the regulations, be they local, national or international. The other is the knowledge of the process steps, the chemistry, and analysis tools required to evaluate the material properties for hazardous materials and their proposed green replacements. As per kleindorfort et al., essential to developing sustainable products is sustainable design. The solution to most malfunctions or breakdowns was simply to replace the entire assembly or subassembly. Manufacturers are now moderating this practice, developing designs that avoid environmentally hazardous components and make it economically possible to save components that have high reuse value. (Melnyk et al., 2003)[73] reported a positive and significant relationship between green manufacturing and company reputation. Any product has an impact on the environment during its life cycle. Consumers have a significant role to play in choosing more sustainable products. Designers, manufacturers, retailers and marketing professionals should create and promote goods and services with significantly reduced environmental and social impacts . The role of products and services is rapidly changing, due to the pursuit of competitiveness Production can be seen as a transformation process (figure 3.8) in which employees use machines and energy to transform material into products for customers use. In the production process losses of material and energy generate emissions and waste. An indicator of the effectiveness of the transformation process is the efficiency of all resources (Jovane et. al., 2009).

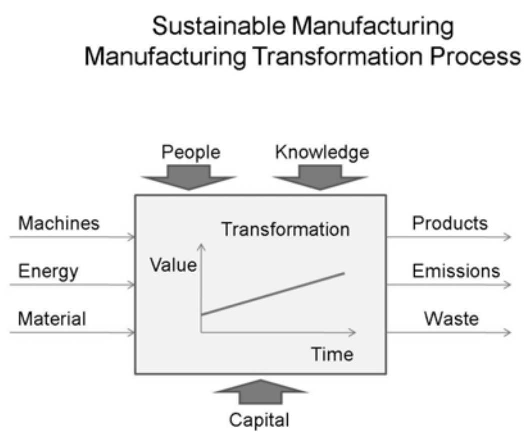


Figure 3.8: Production as Transformation Process
Source: Jovane et.al (2009), The Manufuture Road: Towards Competitive and Sustainable High- Adding -Value Manufacturing, pp 5-39

3.3 Green Manufacturing and Total Quality Management

According to (Yu, Wang, 2006)[74], manufacturing is becoming the pillar industry with the development of science and manufacture technology. But at the same time, it consumes many of the organic resources and causes environment pollution. How to harmonize the contradiction has become the most important task. On the basis of this background, the concept of Green Manufacturing (GM) is presented. GM is a modern manufacture model concentrating on the consideration of the impact on environment and efficiency of resource utilization. It advocates that the enterprises lead the result of least impact on environment and achieve the most utilization ratio of resource. The essence of GM is a kind of sustainable development in the field of modern manufacturing. So GM is the only solution of sustainable development and it is also the enterprise's responsibility for the society. (Nawar, 2008)[75] describes Total Quality Management (TQM) as" Participation, involvement and commitment of all personnel directly responsible for quality of a process at a primary level, or indirectly supporting that quality function at secondary or tertiary level". Broadly speaking, 'green' can be seen as an index of quality attributes. (Richard et. al, 2000)[76] describe that TQM should cover the concept of GM. TQM and GM are both for sustainable development and can mutually complete each other.

3.3.1 The comparison between TQM and GM

GM and TQM belong to two different domains, but they both ultimately do with the integrity "product". The result is shown in Table 3.1. The core value of TQM is for client. Its basic philosophy is to satisfy the client's demands. The core of GM is for sustainable development. Its basic objective focuses on sustainable development. So laws and regulations are needed to push and standardize the activities of the enterprise (Yu, Wang, 2006).

Table 3.1: Comparison between TQM and GM

ITEM	**TQM**	**GM**
Values Attitude	Client-oriented centered	Social duty and sustainable development
Focus	The demands of market or client	The sustainable development requirements of the whole society
Type of Management	Taking the Benefit of Client as central, pushed by the demands of the client	Taking Sustainable Development as central, pulled by laws and regulations
Target	Satisfying the client demands most, zero defect, the stability of process quality, reducing the loss of product defect as low as possible	No waste(including energy, material and other resources), keeping the environment clean
Principle of	Guarantee a product	Guarantee circulating
Stuff Selection		Utilizing

Structure character	To be inspected, assembled and reliable etc	To be restored, disassembled and reused
Technology character	DFQ, robust design, SPC and other corresponding technology	Green design, Life cycle assessment, Measurement system Analysis
Process Demands	Watching the fluctuations of the process quality, guarantee zero defect, making sure the normal usage of the product	Watching the waste disposal, depletion, waste etc, guarantee to dispose the waste properly
Market character	Scattered and detailed	Concentration and Unity
Demands on Staff	Enhancing our consciousness of quality And the capacity of continuous quality improvement	Enhancing environmental awareness, eliminating waste, reducing depletion, clean emission
The degree of client participation in	More participation	Strong participation
The foundation of enterprise survival	Meeting the demands of clients	Bearing social responsibility, abiding by the demands of the laws and regulations
Corresponding standards	ISO 9000	ISO 14000

Source: Yu, Zhonghua; Wang, Zhaowei, (2006) Study on the integration of green manufacture and total quality management, International Technology and Innovation Conference

3.3.2 The integration of GM and TQM

GM and TQM are presented under different backgrounds. They have their own unique ideological system and methodology system. So it is necessary to integrate them organically to enhance the operation efficiency and harmony ability. The integration process is shown in figure 3.10(Yu, Wang, 2006).

According to Electronics Manufacturing handbook by World-bank Group[77], the electronics industry includes the manufacture of passive components (resistors, capacitors, inductors); semiconductor components (discretes, integrated circuits); printed circuit boards (single and multilayer boards); and printed wiring assemblies.

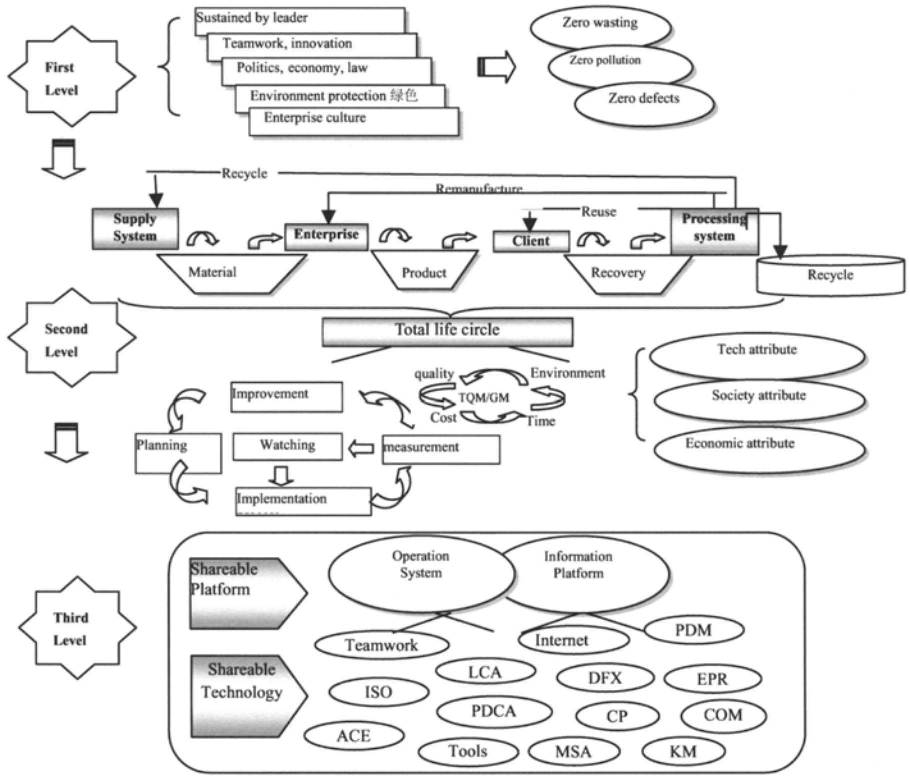


Figure 3.10: Integration of GM and TQM
Source: Yu, Zhonghua; Wang, Zhaowei, (2006) Study on the integration of green manu-facture and total quality management, International Technology and Innovation Conference

Semiconductors are produced by treating semiconductor substances with dopants such as boron or phosphorus atoms to give them electrical properties. Production involves carcinogenic and mutagenic substances and should therefore be carried out in closed systems. In *Printed circuit board (PCB) manufacturing,* there are three types of boards: single sided (circuits on one side only), double sided (circuits on both sides), and multilayer (three or more circuit layers). Board manufacturing is accomplished by producing patterns of conductive material on a nonconductive substrate by subtractive or additive processes. (The conductor is usually copper; the base can be pressed epoxy, Teflon, or glass.) In the subtractive process, which is the preferred route, the steps include cleaning and surface preparation of the base, electroless copperplating, pattern printing and masking, electroplating, and etching. The solder used is generally a tin-lead alloy. The process of PCB manufacturing is explained by Research International[78].

- **Substrate Manufacturing**

Substrate is manufactured from thin sheets of a dielectric material bonded to a sheet of electrically conductive material. Following are the first three steps:-

a. Substrate: copper foil bonded to fiberglass
b. Drilling and deburring
c. Transfer of circuit pattern to copper foil on substrate

FR4 is the most common substrate used in PCBs. Epoxy resin is used to bond fiberglass to copper foil in the creation of Fire Retardant (FR4). A fire retardant is added so the substrate can be safely soldered in later processes.

- **The Subtractive Process**

After the substrate has been made, drilling machines bore holes of different diameters in the exact locations on the board. These holes are called vias. These vias are where circuits electrical connections are created between different layers. Next, an image of the circuit pattern is transferred to the copper foil on the surface of the board with either a Ultraviolet (UV) photoresist film or an ink screening process. In the UV process, another step is required to remove the resist material from areas where the circuit will be. Incomplete removal of this resist material can cause solderability problems later. Then 0.0000150 - 0.000020 inches of copper is chemically deposited (called electroless plating) in the drilled holes. This plating provides a base on which more copper can be electrically plated. The processes are:

a. Electroless copper plating in drilled holes
b. Add plating resist; electroplate copper
c. Electroplate tin/lead over copper plating to protect from next etching.

The final steps of PCB manufacturing are given below:

a. Etch off resist material; then etch tin/lead from circuits & pads
b. Apply solder mask to protect board, and legend ink with part number and other information.
c. Apply solder or organic coating to pads (HASL, fuser, or chemical bath)

A very important process in electronics manufacturing industry is Soldering. The current manufacturing processes for electronic products are well characterized and understood[79]. Many blends of tin and lead are available to satisfy the many different process requirements experienced today. In this relatively stable process world, the cleaning processes and chemicals have been optimized to achieve "Six Sigma" performance in manufacturing reliability. Process temperatures used for soldering operations today range between one and 80 to 240 degrees centigrade. (Deal, 2009) and (Lamprecht et al., 2008) define soldering as the process of joining two or more metals together using a filler metal with a low melting point. Solder that is typically used in the electrical and electronics area is a 60% lead and 40% tin alloy called 60/40 solder. In comparison to traditional production processes "green" production process are characterized by the use of lead-free soldering and the corresponding changes in this step can have a major impact on the electrolytic copper process. More commonly today, a 63% lead and 37% tin is used, known as a "eutectic" alloy. Eutectic alloys exhibit a phase change from a solid state to a liquid state without a "pasty or mushy" state. Additionally, the 63/37 solder composition has a lower melting point than either the lead or the tin metals (Bastecki, 2009). The differences in the use of lead-free soldering in comparison to conventional soldering can be summarized as follows:

- Approx. 30 C higher temperatures during soldering; and
- Longer ramp up times and temperatures during soldering.

The Environmental Push for the " greening of the globe" has given impetus to lead free soldering processes as the world economy exponentially consumes electronic products[80] (which use solders containing lead). Ultimately, this will lead to exponential growth in lead-containing solid waste streams, as new electronics obsolete older generations of equipment, and are subsequently discarded. However, the change to "lead free" solder has major implications for the entire manufacturing process (Bastecki, 2009).

3.4 Manufacturing Waste Charecteristics

If you use energy made from oil, natural gas or coal, you emit greenhouse gases, indirectly perhaps, but it still counts. Your process may also directly create CO2 (as in the manufacture of cement), or you may emit methane, which is 21 times more powerful as a greenhouse gas per molecule. Then there are designer, man-made greenhouse gases such as perfluorocarbons, mostly from aluminium smelting, and sulphur hexafluoride (SF6), used in utility switchgear and substations(Gupta, Lambert, 2008)[81]. The Kyoto Protocol lists following six greenhouse gases and the Intergovernmental Panel on Climate Change has assigned each a factor to make their molecules equivalent to CO2 (Darcy & Marsha 2006):-

- Carbon dioxide (CO2)
- Methane (CH4; 21 times CO2)

- Nitrous oxide (N_2O; 310 times CO_2)
- Hydrofluorocarbons (HFCs; 1300 times CO_2)
- Perfluorocarbons (PFCs; 6500 times CO_2)
- Sulphur hexafluoride (SF_6; 23,900 times CO_2)

For most, however, your biggest climate contribution is likely to be energy: transportation, space heating and cooling, and energy related to producing the products. Of course, every organization is convinced that they are extremely lean and mean. Most carried out energy efficiency measures back in the 1970s and 1980s and now assume that they've already achieved all the efficiencies they can. In 2001, the energy use for a U.S population of 275 millions equaled the total energy use of the eight most populated third world countries with a combined population of over 3 billion as shown in Table 3.2.

3.4.1 Green house Gas (GHG) Emissions

Any effective international agreements to reduce greenhousegas emissions will have quite varied impact on different countries(Conkin, 2007). Emissions levels for the design and operation of each project must be established through the environmental assessment (EA) process on the basis of country legislation and the *Pollution Prevention and Abatement Handbook*, as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group. The guidelines given below present emission levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance. Any deviations from these levels must be described in the World Bank Group project documentation. The emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems. The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable. All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

3.4.2 The Kyoto Protocol

The Kyoto Protocol, signed in 1997, is an amendment to the United Nations Framework Convention on Climate Change agreed to at the Earth Summit in 1992, which assigned mandatory emissions reductions of greenhouse gases to signatory nations. Countries that ratified the Protocol commit to reduce their emissions of carbon dioxide and five other gases – methane, nitrous oxide, sulphur hexafluoride, HFCs and PFCs; collectively known as greenhouse gases – or engage in emissions trading if they increase their emissions. Since carbon dioxide (CO2) contributes more than 75 per cent of human-induced GHG emissions and since more than 95 per cent of global CO2 emissions are due to fossil-fuel burning and land-use change, most of the attention in the Kyoto Protocol is devoted to fossil-fuel-based CO2 emissions reduction(Schreuder, 2009)[82].

3.4.3 Air Emissions and effluents

A per World-bank guidelines on electronics manufacturing, the emissions include fumes from the soldering process, toxic, reactive, and hazardous gases; organic solvents; chemicals and particulates from the process. The changing of gas cylinders may also result in fugitive emissions of gases. CFCs are ozone-depleting substances (ODSs). Their production in and import into developing countries will soon be banned. Hydrochlorofluorocarbons (HCFCs) have been developed as a substitute for CFCs, but they too are ODSs and will be phased out.

3.4.4 Air Emissions

The air emissions levels presented in Annexure - C should be achieved.

Table 3.2: Energy use footprints

	Countries	Population(millions)	Energy per capita (kg oil equivalent)	Footprint (energy x population)
1	USA	275	7937	2,18,2675
2	China	1242	830	1030860
3	India	980	486	476280
4	Brazil	166	1055	175130

5	Mexico	95	1552	147440
6	Indonesia	204	604	123216
7	Nigeria	121	716	86636
8	Pakistan	132	414	58080
9	Bangladesh	126	159	20034
	Total less USA	**3066**		**2,11,7676**

Source: Darcy Hitchcock and Marsha Willard, (2006) The Business guide to Sustainability, Practical strategies and tools for Organizations, pp 3-19, 53-67, 174-231

3.4.5 Ambient Noise

Noise abatement measures should achieve either the levels given below in Annexure - D or a maximum increase in background levels of 3 decibels (measured on the A scale) [dB(A)]. Measurements are to be taken at noise

receptors located outside the project property boundary.

3.4.6 Liquid Effluents

Effluent means any material in solid, liquid or gaseous form or combination thereof being discharged from industrial activity or any other source and includes a slurry, suspension or vapour (PEPA, 1997). As per World Bank directives, the effluent levels presented in Annexure - E should be achieved.

3.4.7 Solid and Hazardous Wastes

Solid and hazardous wastes may include heavy metals, solder dross (solder pot skimmings), scrap board materials, plating and hydroxide sludges, and inks. All three manufacturing processes may generate sludges containing heavy metals from wastewater treatment plants. Organic solvent residues also require management and disposal. Industrial waste disposal by burning/incineration exhibit toxic effects on the part per trillion(ppt) range and below(SPDI, 2006)[83].

3.5 Environmental Management System

An environmental management system (EMS) according to (Cherimisinof, Val, 2001)[84] is any planning and implementation system that an enterprise employs to manage the way it interacts with the natural environment. An EMS is built around the way an enterprise operates. It focuses on an enterprise's production processes and general management system and *not* on its emissions, effluents, and solid waste, as environmental regulations do. An EMS enables an enterprise to address major and costly aspects of its operations proactively, strategically, and comprehensively, as any good manager would want to do. Without an EMS, an enterprise can only *react* to environmental disasters, environmental regulations, to threats of fines and lawsuits and to being undercut by more progressive and efficient competitors. An EMS is integrated into the overall management system of an enterprise. Like an overall management system, it represents a process of continual analysis, planning, and implementation; it requires that top management commit and organize such resources as people, money and equipment to achieve enterprise objectives; and it requires that resources be committed to support the management system itself. There are lots of types of EMSs around. Some are industry specific, with guidelines often issued by industry associations. Many EMSs are uniquely designed for a particular facility. In its broadest outlines, an EMS is like any other system of planning and implementing for continual improvement. The same basic steps apply to managing an enterprise, managing a production line, managing your commute to work, or even managing economic development. This brings us to ISO 14001. The basic steps in the ISO 14001 EMS are a) environmental policy, b) planning, c) implementation and operation, d) checking and corrective action, and e) management review. The aim is to show how enterprises can implement an EMS to reap the benefits of reduced manufacturing costs, greater efficiency, higher product quality, and improved control over production processes (Cherimisinof, Val, 2001). If you want to implement an EMS in your enterprise, your first job is to convince top management. Lists of the benefits of implementing an EMS, and especially of implementing the ISO 14001 EMS standard, abound in ISO 14001-related print literature and Web sites. In addition, some enterprises certified to ISO 14001 offer testimonials on their Web sites about how they have benefited from implementing the standard. The question CEOs sometimes ask when someone proposes establishing an EMS in the enterprise is, "What will it cost?" But that's the wrong question. The right question is, "What is the net benefit?"The net benefit is the sum of the likely benefits, minus the likely cost of EMS implementation and maintenance. The 10 most important broad benefits are listed below (Cherimisinof, Val, 2001):-

- Environmental management cost savings
- Improved environmental performance at lower cost
- Better overall enterprise management and better overall business performance
- Readiness for the coming trends in environmental regulation
- Increased likelihood of long-term sustainability
- Reduced operating costs
- High rates of return
- Improved access to capital and lower capital and other costs
- Improved market access
- Better public, community, and government relations

CHAPTER 4
ROLE OF GOVERNMENT ORGANIZATIONS IN SUSTAINABILITY AND ELECTRONIC MANUFACTURING INDUSTRY

4.1 Pakistan Technology Board

Pakistan Technology Board (PTB)[85] is devoted to take forward its mandate of forecasting the technologies of strategic importance essential for industrial growth and achieving a competitive advantage in global markets. The Pakistan Technology Board aims at prioritizing the research areas to align it with the emerging needs and challenges to the country in the 21st century and making PTB's research team more responsive and efficient in delivering results. This approach helps in designing policies and strategies for a better exploitation of the socio-economic potential of Pakistan.

PTB is also committed to collaborate with the organizations both at national and international level for setting-up of joint ventures with the ultimate aim of technology promotion and indigenous industrialization. The research teams are prepared to acquire skills and enhance their capabilities that will equip them adequately to live in rapidly changing global environment. Its functions include proposing a comprehensive package of incentives for development and growth of key future technologies and determine the period for which the incentives package will operate in the country. The incentive package is expected to include setting-up of joint ventures with the multinationals for manufacturing and overseas marketing and maximizing local engineering design of on-going and upcoming energy and other industrial projects. The proposed incentive package is to be reviewed periodically to study its impact on development and growth of selected technologies in the country with the objective to propose modifications if required. The board is also mandated to promote and strengthen quality assurance system and implementation of ISO standards in the country[86].

4.2 Private Power Infrastructure Board (PPIB)

The mandate of PPIB[87] is to promote and facilitate private sector participation in the Pakistan Power Sector in an efficient, fair and transparent manner, with coherent efforts of key stakeholders, in line with the Private Power Policies of GOP and the electricity demand/supply projections after taking into account the planned public sector power projects.

4.3 Pakistan Council of Renewable Energy Technologies

Pakistan Council of Renewable Energy Technologies (PCRET)[88] has been recently established by merging National Institute of Silicon Technology (NIST) and Pakistan Council for Appropriate Technologies (PCAT). PCRET has been assigned the responsibility to research and development dissemination provide training promote renewable energy technologies in the country. The main areas of thrust are:

- Photovoltaic (Solar Electricity)
- Solar Thermal Appliances
- Micro-hydel
- Wind
- Bio-energy (Biogas, Bio-oil and other Bio fuels)
- Geothermal
- Ocean Waves

4.4 Pakistan Environmental Protection Agency

Pakistan Environmental Protection Agency is an attached department of the Ministry of Environment and responsible to implement the Pakistan Environmental Protection Act, 1997 in the country by providing for the protection, conservation, rehabilitation and improvement of environment, the prevention and control of pollution, and promotion of sustainable development, which has been a government priority since 2004[89]. Pakistan Environmental Protection Agency also provides all kind of technical assistance to the Ministry of Environment for formulation of environment policy and programmes.

4.5 Energy Conservation (EC)

The responsibility of ENERCON[90] is cultivating a new energy culture focusing on achieving sustainable development through conservation and efficient use of energy resources in order t**o** Steer Pakistan towards an Energy Efficient and Environment Friendly Tomorrow. The energy consumption was 33.95 million tons of oil equivalent (MTOE) in 2006 as shown in figure 4.1. Industrial Sector takes the largest slice of national energy consumption closely followed by transport sector (28%). The energy conservation potential in various sectors is shown in Table 4.1. The calculations show that possible savings for Pakistan by EC US $ 3 Billion/Year.

4.5.1 Government Policy

Security and affordability of energy supplies are key inputs to ensure sustainable development. Energy conservation or efficient use of energy resources has been practiced as a cost-effective and environmentally sound option to plug energy deficits in several developed as well as developing societies.

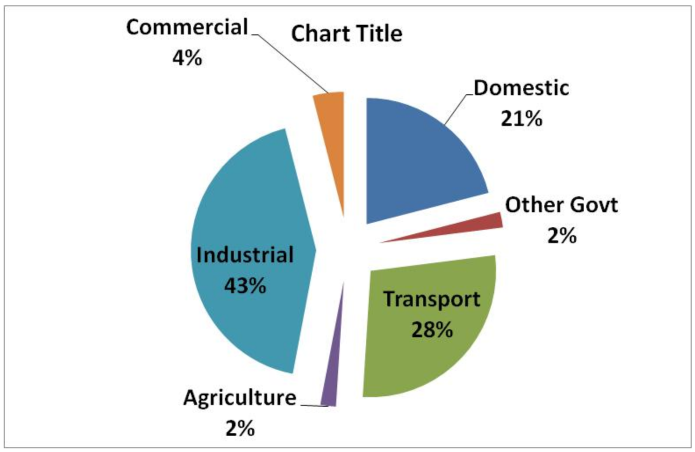


Figure 4.1: Energy Consumption by Sector
Source: Pakistan Energy Year Book 2006

Table 4.1: EC Potential in Pakistan

Industry	25%
Transport	20%
Agriculture	20%
Building	30%
Average	**25%**

Source: ENERCON, http://www.enercon.gov.pk/,

Pakistan today is faced with an energy deficit which, if not addressed timely and appropriately can very seriously hamper the pursuit of sustained economic growth. We face energy shortages which unfortunately co-exist with wasteful energy use in various sectors. The potential and role of energy conservation as a cost-effective energy supply option can no longer be relegated to the back burner. Using energy efficiently makes simple financial sense. It is environment friendly and provides tremendous opportunity to achieve economic self-sustenance. The National Energy Conservation Policy, prepared by ENERCON through an extensive consultative process involving all stakeholders, is a contribution to the national effort to steer the country out of a difficult energy supply situation by promoting efficient use of energy resources. It must be pointed out here that conservation of energy resources covers a very wide spectrum, with a large number of stakeholders in the public as well as private sector. The responsibility for implementing the policy lies collectively on these stakeholders and together we can rise to meet the energy challenge. The recent establishment of the Cabinet Committee on Energy headed by the Prime Minister will provide the hitherto missing coordination and decision-making forum at the highest level.

4.5.2 National Energy Conservation Policy

The policy enumerates broad guidelines to enhance end-use efficiency in various energy consuming sectors of economy. The policy is likely to create an enabling environment to support energy security plans of the government and for effecting a change in course from the present wasteful practices to sustainable energy and environment patterns in the future. Listed below are the sectorial initiatives undertaken by the government for the industry:-

- Introduce and facilitate Energy Audits in Industries and promote targeted technical services.
- Encourage and promote implementation of low-cost, fast payback energy conservation measures in industry.
- Promote energy efficient combustion processes, instrumentation and control and metering practices in industry.
- Promote energy efficiency conservation modernization and revamps

4.6 <u>Electronics Industry Organizations in Islamabad</u>

4.6.1 National Institute of Electronics(N.I.E)

NIE[91] is dedicated to the development and spread of electronics and computer technology in Pakistan, with the long-term objective of helping the country achieve sustainability. NIE has the capability to design, develop and implement projects related to Electronics, Computer and Telecommunications. Following are the Objectives:

- To establish an Electronics Technological base in the Country.
- To act as Center of Excellence for Electronics.
- Develop linkage with local industry to channelize R & D activity and make it relevant to the Socio-Economic needs of the country.
- Design and development of the products and systems specific to user organizations/local industry.
- Provide advance level training in electronics and information technology.
- Assist industry to enable increased use of technology based on indigenous design.

NIE is a Research & Development organization under the Ministry of Science and Technology. The Institute has highly trained/experienced pool of engineers, scientists and technicians, holding post graduate qualification from the leading universities/institutions of the world. The institute is a premier design and development organization in the field of electronics in Pakistan. Since its inception in 1980 the Institute has developed considerable expertise in the area of Digital Electronics, Power Electronics, Computer Hardware/Software and Computer Training. NIE is also an ISP under the name of PERDNet (Pakistan Education Research and Development Network). NIE has two main divisions, namely System and Circuit Division and Components Division with the following laboratories/Facilities: Automation and Control System

- Communication and IT
- Power Electronics
- PCB Design and Fabrication
- Computer Hardware/Software and Training
- IC Nanometer Design

4.6.2 SmartPCBs

SmartPCBs is one of the leading fabricators of printed circuit boards in Pakistan, capable of manufacturing single, double, and multilayer PCB. The company differentiates itself with other competitors in experienced workforce, superior quality, and advanced equipment[92]. Their multifaceted approach to production in terms of engineering prototypes and bulk orders of single and multilayer PCB offer our customers a wide range of flexibility and options. Their strategic plan is to provide our customers with sustainable competitive advantage of products showing complete commitment from initial quotation to delivery of order and beyond. Moreover, this assures customers that SmartPCBs continues to meet the quality conscious approach the customers have grown to expect. They have PCB manufacturing facilities, inspection equipment, Hybrid Circuit, & professional teams in Pakistan.

4.6.3 Micropak Private Limited

Micropak is one of the oldest independent PCB manufacturers in Pakistan. From its start at the very beginning of the electronics industry, Micropak[93] has always been proud to be associated with leading edge technologies in PCB Manufacturing. The specialty has always been the supply of high quality, high specification boards in small and medium batch. Micropak is in the process of undertaking a major expansion. Micropak is equipping itself to become a state of the art electronic manufacturing services provider. Assembly and test equipment, utilizing the latest surface mount technology, is under the process of installation or on order.

4.6.3.1 Micropak's Quality Policy

Committed to excellence in products and services. “Quality is our culture”. Satisfaction of customers is ensured by continuous improvement and conscious quality. Customer's Satisfaction is the most important factor in the production of our products. The following quality control procedures are being followed at Micropak:

- Receiving inspections of incoming materials and inspection of chemicals prepared at Micropak.
- In process quality control inspections at different stages of production.
- Final inspection before delivery to the customer

4.6.4 AH- Automations Private Limited

AH- Automations Private Limited, an ISO 9001:2000 certified company, is a group of highly qualified professionals working in the field of Industrial Automation and Switchgear Manufacturing[94]. The company was established in 1999 with the mission to deliver cost effective technology tailored to customer’s needs. Since then high quality products and excellent services are being provided. The company is fully geared to execute automation projects anywhere in Pakistan. Quality is the key in all the facets of operations and commitment to provide top quality products & services to valued customers is priority one. The services offered by AH include Design, Manufacturing, Supply, Installation, Testing, Commissioning & Maintenance support. AH has the capability to undertake turnkey projects. Since establishment, are fully committed to provide world class products, services and on time delivery through continual improvement in all aspects of operations. By the grace of God, the company is on the strong footings with its customer base in all over Pakistan.

4.6.5 Comcept Private Limited

Comcept is an ISO 9001-2000 certified design and manufacturing company [95] 1992 in the field of IT and Alternative Energy products. The company is determined to be customer focused, starting from a clear need assessment down to delivering solutions. The goal is to exceed customer expectation by offering sustained innovative, high quality and reliability. The operational domain of Comcept covers a wide range of activities, synergistic to its core business i.e product development. These services include following:

- Design and development
- Manufacturing System/ network design and integration
- Consulting services
- Installation and commissioning
- Operation and maintenance
- Training
- Turn-key project management
- Customer support

The company offers design and development facilities to provide tailor-made solutions, in addition to building its own product line of standard telecom systems.

4.6.6 RWR Private Limited

RWR stands for Reengineering with Reverse Engineering. It is a private limited company with expertise in electronic circuit designing & manufacturring. The company is not into commercial production. The major clients of RWR include the Defence forces of Pakistan.

4.7 Electronics Industry Organizations in Lahore

- Pel Elektronic Pvt Ltd Lahore
- Rabta Electronics Manufacturing Pvt Limited Lahore
- Waves Cool Industries Pvt Limited Lahore
- Komponants Manufacturing Industries Pvt Limited Lahore
- Pakland Engineering And Manufacturing Works Pvt Limited Lahore
- Platinum Manufacturing Company Pvt Limited Lahore
- Standard Manufacturing Company Pvt Limited Lahore

4.8 Electronics Industry Organizations in Karachi

- Dawlance Pvt Limited
- PCB Electronics Manufacturing Company Pvt Limited
- Refrigerators Manufacturing Company Pvt Limited
- Systek Pvt Limited
- National Appliances Manufacturing Company Pvt Limited
- Pak Products Manufacturing Company Pvt Limited

The comparison of existing green practices of organizations of electronic industry located in industrial area of Islamabad is given in Table 4.2.

Table 4.2: Comparison of organizations in industrial Islamabad

	Sustainable Practices	**Company / Organization**					
		Smart PCBs	**MicroPak Pvt Ltd**	**Comcept Pvt Ltd**	**N.I.E**	**RWR Pvt Ltd**	**AH-Automation Pvt Ltd**
1	**Sustainability-part of mission**	Yes	Yes	Yes	Yes	Yes	Yes
2	**Green Practices Perception**	Very Good	Good	Good	Fair	Good	Fair
3	**Green Practices Employed**	*EC, Waste treatment, Water recycling	EC, Water recycling	EC	Pollution control	EC, Waste reduction	EC, Speed control of Machines
4	**Energy Losses**	< 10%	< 10%	< 10%	20-30%	< 10%	10-20%
5	**EC Practices**	Energy savers, A/C Control, Resizing Lot-sizes	LEDs, Energy savers, Resizing Lot-sizes	Energy savers, A/C control	Energy savers	LEDs, A/C control, Speed control	Speed control
6	**Green Awareness Level(Middle Management)**	V.Good	Good	Good	Fair	Good	Fair

7	**Green Awareness Level(Workers)**	Fair	Poor	Poor	Poor	Poor	Poor
8	**Reasons for Water Recycling**	Save energy	Save energy, Require-ment	Save energy	Pollution control	Not being done	Not being done
9	**Reasons for not Recycling Water**	Current Supply Suffice, Have own source	Current Supply Suffice, Costly	Current Supply Suffice	Current Supply Suffice, Have own source	Current Supply Suffice	Current Supply Suffice
10	**Quality Control Contributions in Cost Savings**	Reduces rejection rate	Reduces rejection rate, Promotes innovation	Increases market share	Reduces rework	Reduces rejection rate	Reduces rejection rate, Increases market share

*EC stands for Energy Conservation

CHAPTER 5
SURVEY OF GREEN PRACTICES

5.1 Manufacturing Practices in Electronics Industry

This study is based on the theoretical perspectives of researchers including (Hart, 1995, Porter and Van der Linde, 1995), whereby pollution represents waste and a loss of productivity. Therefore green practices can reduce waste, improve productivity and improve competitiveness (Rusinko, 2007).

As mentioned earlier, there are two types of green practices which yield different competitive outcomes, namely pollution prevention and product management practices.

5.2 Propositions

Pollution prevention practices(PPP) such as reductions in the use of resources like energy and water, reductions in the amount of solid waste generated, and recycling can result in significant savings in manufacturing costs (Hart, 1995). Likewise (Nesi, 2008, Polcari, 2007 and Rusinko, 2007) agree that cost savings result from more efficient use and reuse of production inputs. Therefore, the theoretical and case study literature suggests that PPP are related to one of the traditional competitive outcomes i.e. cost. This leads to the following general proposition:-

Proposition 1: Green practices that are classified as PPP will tend to have a positive impact on profitability i.e. PPP will tend to decrease manufacturing costs.

According to (Hart, 1995), Product Management Practices(PMP) includes environment practices that extend the environmental perspective to other internal and external stakeholders in addition to manufacturing such as R&D. product designers and suppliers. Examples of PMP include redesigning products and processes to be more environment friendly, using renewable resources, and encouraging suppliers to practice pollution prevention (PP) and Product management(PM) (Rusinko, 2007). (Hart 1995) argues that the major competitive advantage to be gained through PM is competitive preemption (Ghamewat, 1986, Klassen and Whybark, 1999).

In this case, an organization can preempt competitors with respect to establishing a reputation as a 'green' company (Rusinko, 2007). There is always a reputational "space" available with respect to green performance, which can be used as a source of competitive advantage (Hart, 1995). Other researchers also recognize the importance of green reputation or image. For example, according to (Orsato, 2006), customers increasingly value how organizations manage their environmental processes, independent of the quality or performance of the products or services sold. Some empirical studies have found a positive relationship between green manufacturing or efforts at green manufacturing, and company reputation. (Melnyk et. al., 2003) reported a positive and significant relationship between the use of green manufacturing practices and company reputation. (Naffzigar et. al., 2003) found that the green effort was positively and significantly correlated to the company image. This leads to the following general proposition:-

Proposition 2: Green manufacturing practices that are classified as PMP will tend to have a positive impact on company image i.e. PMP will tend to improve company image. Correspondingly, (Orsato, 2006) argues that an organization's PMP may influence the shopping behavior of customers with green awareness. Therefore, in addition to improving company image, competitive preemption via PMP can also attract new customers. This leads to the following proposition:-

Proposition 3: green manufacturing practices that are classified as PMP will tend to have a positive impact on attracting new customers i.e. PMP will tend to attract new customers.

In addition, (Porter and Van der Linde, 1995) discuss innovations that are discovered as a result of PMP. For example, as a result of redesigning products for easier recycling, Japanese manufacturers also discovered that they could reduce the total number of parts in the products. This type of discovery can be diffused across all product lines in the company. Hence, PMP can promote and spread innovation throughout the company. This leads to another general proposition.

Proposition 4: Green manufacturing practices that are classified as PMP will tend to have a positive impact on innovation i.e. PMP will tend to promote innovative ideas in the company.

Furthermore, PMP can also have a positive impact on competitive manufacturing outcomes such as product quality. (Porter and Van der Linde, 1995) also suggest that PMP can improve product quality. For example when scientists at a U.S company Raytheon redesigned their processes to eliminate chlorofluorocarbons (CFCs) used in cleaning PCBs, the new process improved the product quality, which the earlier CFCbased process had sometimes compromised. This leads to the following general proposition:-

Proposition 5: Green manufacturing practices that are classified as PMP will tend to have a positive impact on product quality.

The above mentioned propositions are very general, and are based on existing literature. They however represent a starting point for highlighting green awareness for our industries.

5.3 Study design

The researcher has attempted to test the above described propositions by taking following steps:-

- Literature review of international green practices.
- Identification of parameters of green practices.
- Conducting structured interviews of concerned personnel of electronics industry (six in total) to identify present status of manufacturing practices.
- Develop survey questionnaire for data collection on PPP and PMP implementation by the electronic industry.
- Find out linkage (if any) between green practices and competitive outcomes.

5.4 Why the Industry choice

In developed countries, past studies of green manufacturing practices and competitive outcomes have often taken their sample from a number of industries (Naffzigar et. al., 2003, Menguc and Ozanne, 2003). Unfortunately, since no published or unpublished research has been traced through available resources, this study has been limited in scope to Electronic products manufacturing industry in Pakistan. The electronics industry is an important industry to study for following reasons:-

- It is an under researched industry.
- It is dependent on raw material import.
- It has ample use of energy and water.
- There is no check on air and water emissions.
- The industrial areas are mostly located in and around cities thereby affecting the local population to some degree by potential production capacity.
- Results from this study may highlight benefits of green practices and help to promote green awareness for other industries in general.

5.5 Measures Undertaken

As discussed earlier, green practices are classified in terms of PPP and PMP. A preliminary list of measures of green practices with respect to PP and PM was collected and modified to the electronics manufacturing industry from earlier theoretical studies (Hart 1995, Porter and Van der Linde 1995) and empirical studies (Handfield et. al. 2001 , Menguc et. al. 2003). Since some green manufacturing practices can be industry specific (Christmann 2000), as the list was developed, a search for measures of green practices was also conducted through internet. Many electronic product manufacturers promote their so called green practices on web sites. Through structured interviews with industry personnel, the present status of the electronics industry has been established and revised based upon their comments.

Based on the findings through structured interviews, a questionnaire was developed consisting of six PPP and ten PMP, totaling sixteen green practices. The list was long so that maximum information could be gathered about finding linkage of specific green manufacturing practices with specific competitive outcomes. Measures of PPP and PMP are listed in the questionnaire (Annexure D).

Consistent with the above mentioned propositions, possible competitive outcomes have been measured in terms of manufacturing cost, product quality, improvements in company image, ability to attract new customers and promotion of innovative ideas.

5.6 Data Collection on Current Industry Practices

The study includes the electronic product manufacturing industry. Although only six electronic product manufacturing industries were located in industrial Islamabad, nevertheless, detailed structured interviews conducted proved quite significant to assess the present situation of green practices in the industry. The study was extended to include major similar firms located all over the country. The survey questionnaire was also forwarded to electronic product manufacturing companies based in Lahore and Karachi through registered post and email. The questionnaire was got filled by the person in each organization (out of six in Islamabad) who was best qualified to respond with respect to the little or no green practices adopted by the organization. Titles included Factory Manager, Director/Manager Quality Assurance, GM Manufacturing, Project Director and CEO/Managing Director.

Preliminary visits and conversations with personnel of the organizations revealed reluctance to provide quantitative data due to confidentiality concerns. In addition, subsequent conversations and visits also revealed that respondents would be much more likely to complete a short survey, therefore questionnaire was kept as short as possible.

The survey was designed so that the respondents were presented with a list of green sustainable practices that included measures of PPPs and PMPs, and a list of possible outcomes. The objective was to gather information on probable effects that could result from adopting and implementing the suggested green practices in future. This was expected to give an insight into relationship between green practices and specific competitive outcomes.

It is to be noted that since the study is exploratory in nature, response were not restricted based upon propositions. For example, respondents were not prevented from indicating that a PPP such as reducing energy usage may result in improving company image, even though this relationship has not been proposed.

5.7 Analysis of Data and Findings

5.7.1 Introduction level

a. 83% of the electronics manufacturers have ‘achieving sustainability’ as part of their company’s mission, whereas 100% believe that sustainability is essential to achieve sustainable growth.

b. 100% had some idea of what green practices are, though their perspectives were quite different as given in table 5.1 and shown in figure 5.1 below.

c. 83% said that they use green practices is one way or the other. 17 % stated high cost as the reason for not employing any green practice. Results are given in table 5.2 and shown in figure 5.2 below.

Table 5.1: Green Perceptions in the Industry

No.	Green Perceptions	Number
1	Conserving energy	8
2	Recycling water	4
3	Recycling waste	4
4	Reduce purchasing	3
5	Reducing pollution	1
6	Efficient time utilization	1
7	Plantation	1

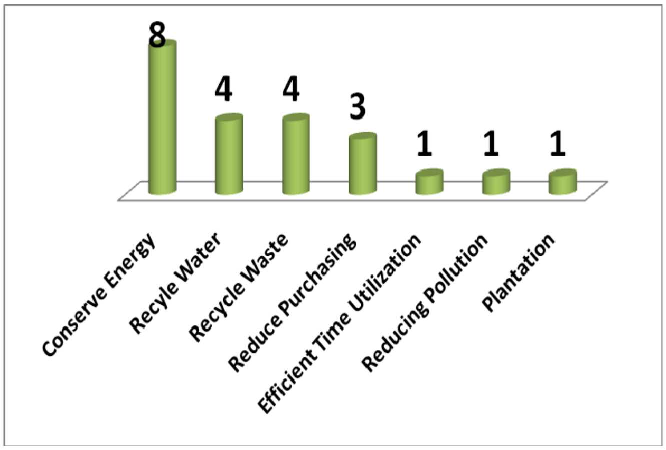


Figure 5.1: Green Practices Perception in the industry

Table 5.2: Present Green Practices in the Industry

No.	Present Green Practices	Number
1	Energy conservation	5
2	Recycling water	4
3	Reducing waste	3
4	Fume control	1
5	Speed control of machines	1

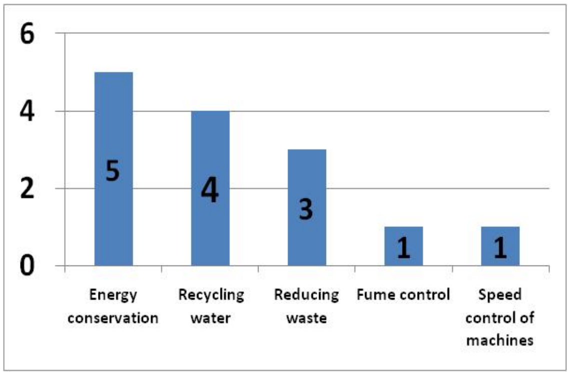


Figure 5.2: Present Green Practices

5.7.2 Energy Aspect

a. All firms have electric power as the main source of energy in manufacturing. 67% have generators as alternate source of power supply. Results are given in table 5.3 and shown in figure 5.3 below.

Table 5.3: Activity in case of power outages

No.	Activities	Number
1	Use own power	4
2	Prefer rescheduling	4
3	Administrative works	1
4	Just relax	1

b. None have been provided subsidies in energy rates. All organizations pay all forms of taxes/duties to the tune of 21% which is verifiable from the website of FBR.

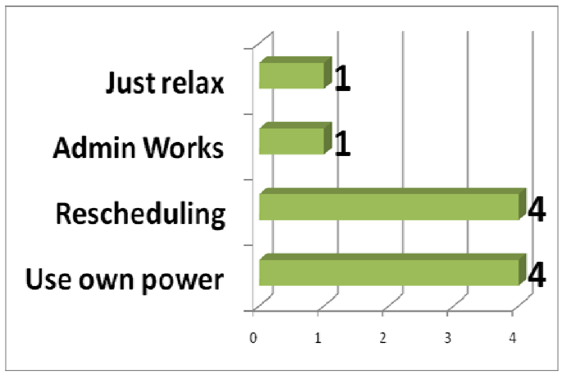


Figure 5.3: Activity in case of Power outages

c. Only 83% think that some amount of energy is being wasted. Their estimates are given in table 5.4 and shown in figure 5.4 below.

Table 5.4: Energy Losses

No.	Amount of energy Losses	Number
1	Less than 10%	5
2	10 – 20%	2
3	20 – 30%	1

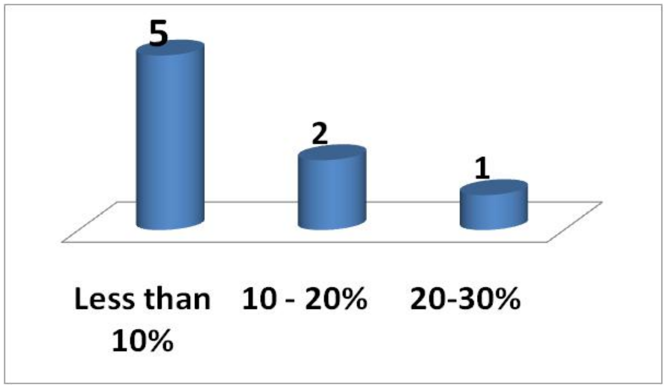


Figure 5.4: Energy losses

d. 83% are determined to take measures to somehow control the losses in energy. All had different ideas and ways of managing as given in table 5.5 and shown in figure 5.5 below.

Table 5.5: Energy conservation practices

No.	Energy conservation practices	Number
1	Use energy savers	6
2	Use LED lights	2
3	Resizing lot sizes	2
4	Control A/C timings	1
5	HAFL heating by gas	3
6	Speed control of machines	1

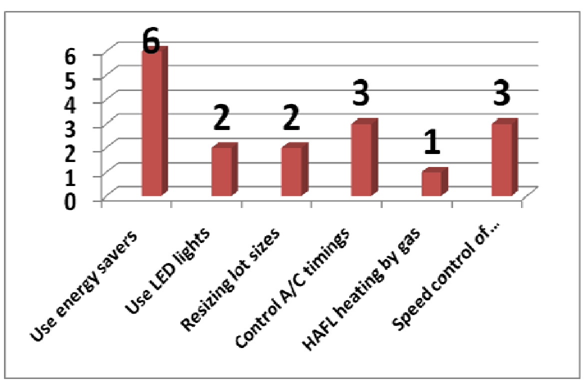


Figure 5.5: Energy conservation practices

5.7.3 Human Resource (HR) Aspect

a. Size of the organizations varied from as low as 20-30 to as high as 212 personnel.

b. Employed graduate engineers (masters) varied from 8% (government organization) to 6% (private companies) of total employment.

c. Green awareness level in the organizations gave following results as given in table 5.6 and shown in figure 5.6 below.

Table 5.6: Green Awareness Level

Management Level	Have no idea	Barely know	Have fair idea	Are well aware
Top management	-	-	-	8
Middle management	-	-	7	1
Workers	3	4	1	-

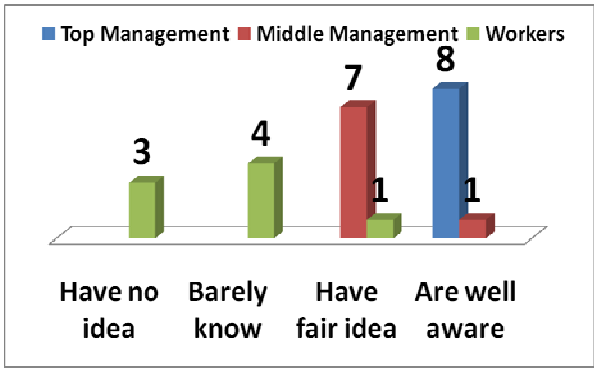


Figure 5.6: Green awareness level in the Industry

5.7.4 Water Aspect

a. All firms require water in manufacturing. Only 17% don't have uninterrupted water supply which however does not affect manufacturing cost.

b. 17% have alternate source of water supply.

c. Only 17% admit water is being wasted to the tune of more than 50%, whereas remaining 83% believe less than 10% water goes waste.

d. Only 50% recycle water citing pollution control, conserving energy and necessity as reasons. The results are given in table 5.7 and shown in figure 5.7 below.

Table 5.7: Reasons for Recycling water

No.	Reasons for recycling	Number
1	Requirement	3
2	Pollution control	3

3	Conserve energy	4

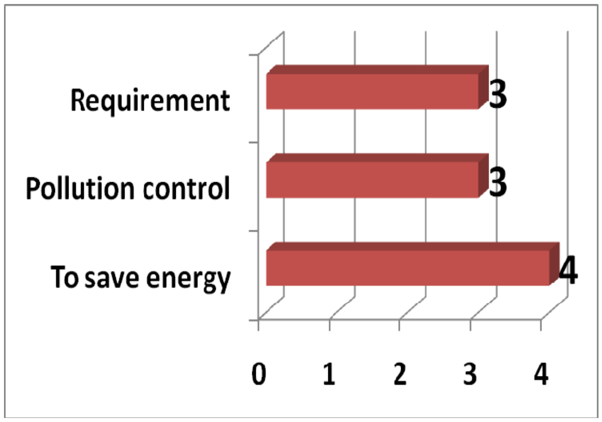


Figure 5.7: Reasons for Recycling water

e. 50% do not recycle water for different reasons which are given in table 5.8 and shown in figure 5.8 below.

Table 5.8: Reasons for not recycling water

No.	Reasons for not recycling	Number
1	Current supply is suffice	8
2	Have own source	3
3	It is costly	3

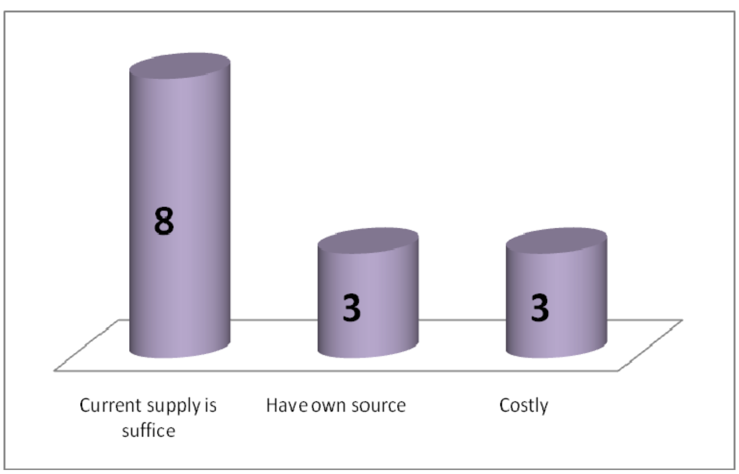


Figure 5.8: Reasons for not Recycling water

5.7.5 Raw material Aspect

a. 67% have copper clad sheet and chemicals as the main raw material. Whereas 34% require electromechanical spare parts/assemblies.

b. Only one company imports 90% of raw materials.

c. 83% claim less than 2.5% wastage in raw material use and 17% disclose wastage of 10-15%

d. 50% believe raw material use can be reduced while maintaining current production levels although 83% have the capacity to do so.

e. 34% have some plans to reduce raw material use in future. The results are:

- Plans to upgrade to more efficient machinery.
- Plans to employ JIT technique.

5.7.6 Suppliers Aspect

Majority (83%) is of the opinion that suppliers should adopt green practices. The benefits expected if suppliers were to go green are given in table 5.9 and shown in figure 5.9 below.

Table 5.9: Perceptions of Suppliers' green practices

No.	Perception of suppliers' green practices	Number
1	Would attract customers	4
2	Would promote company image	2
3	Would result in reduced production waste	4
4	Would improve product quality	3
5	Would reduce energy use	4
6	Would have no effect	1

5.7.7 Quality Aspect

a. Only 67% of the companies are ISO 9001:2000 certified out of which 25% think that it has brought no change to product quality and 50% maintain that manufacturing cost reduces but not significantly.

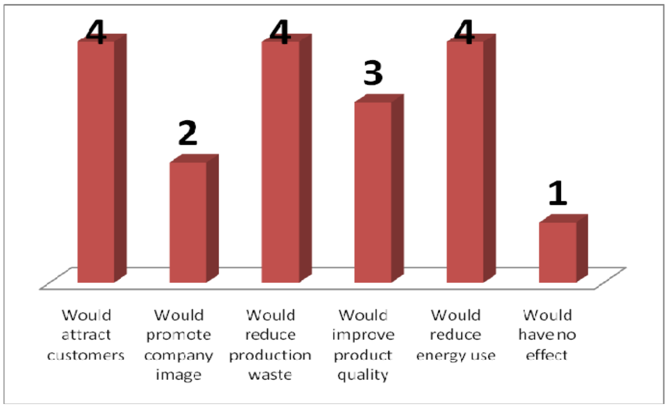


Figure 5.9: Perception of Suppliers' Green practices

b. 100% say EMS 14001 does not apply to them.

c. 83% state that implementing EMS would not be cost-effective.

d. All organizations state that QC contributes significantly in manufacturing cost savings. However, perceptions are different as given in table 5.10 and shown in figure 5.10 below.

e. All organizations maintain that there is no wastage in terms of QC personnel.

Table 5.10: QC contributions in terms of cost savings

No.	QC contributions	Number
1	Reduces rejection rate	7
2	Reduces rework	6
3	Increase market share	3
4	Promotes innovation	1

5.6.8 Regulation Status

a. 100% think government is hardly contributing enough efforts to promote green awareness in electronic industry. 83% think government should enforce green practices being the correct step to take. Reasons cited by remaining 17% who disagree are:-

- Govt should first provide infrastructure for industry
- Govt funding for implementation
- Exemption from taxes/duties

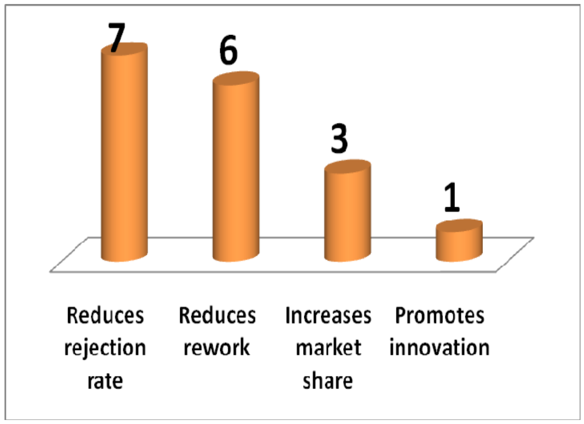


Figure 5.10: QC contributions in manufacturing cost savings

5.8 Survey Results

Survey questionnaire was provided personally to all the six companies/organizations of the electronic industry based in industrial Islamabad area. The questionnaire was also mailed to companies manufacturing electronic products located in Lahore and Karachi. Following is a list of companies included in the survey:-

- PEL Elektornic Private Limited Lahore
- Rabta Electronics Manufacturing Limited Lahore
- Waves Cool Industries Private Limited Lahore
- Dawlance Private Limited Karachi
- PCB Electronics Manufacturing Company Private Limited Karachi
- Refrigerators Manufacturing Company Pakistan Limited Karachi
- Systek Private Limited Karachi

5.8.1 Pollution Prevention Practices

The response rate for Islamabad was 100%. Industrial Islamabad is relatively the largest hub of electronics industry, primary reason being its close location to defence related industries of Pakistan[96]. Since total 13 organizations were included in the survey, therefore overall response rate comes to 61% which can be termed as quite favorable.

The results of the survey are seen in Table 5.11 and shown from Figure 5.11 to Figure 5.24. Due to request for confidentiality by the companies, and given the small population size, data is presented in aggregate form only. The general results will be presented and discussed in next section. Since objectives include highlighting the present status of green practices and exploring the probable relationship between sustainable manufacturing outcomes, results have been discussed in the context of propositions described earlier.

Table 5.11: Survey Results of PPP and PMP

		Number of Firms expected to adopt green practices				
Competitive Outcomes→	**Percentage expected to practice n = 8**	**Will decrease cost of manufacturing**	**Will increase product quality**	**Will improve company image**	**Will attract new customers**	**Will promote innovative ideas**
Pollution Prevention Practices (PPP)						
Reducing energy usage	**8**	**5**	**2**	**2**	**-**	**2**
Reducing raw material usage	**4**	**3**	**-**	**-**	**-**	**-**
Reducing solid waste	**3**	**-**	**-**	**3**	**2**	**2**
Reducing green- house gas emissions	**3**	**-**	**-**	**-**	**2**	**2**
Recycling water	**4**	**4**	**-**	**-**	**-**	**3**
Recycling solid waste(not burning)	**0**	**-**	**-**	**-**	**-**	**-**
Product Management Practices (PMP)						
Reuse of waste material	**0**	**-**	**-**	**-**	**-**	**-**
Redesigning process to improve sustainability	**4**	**4**	**-**	**-**	**-**	**-**
Redesigning product to improve Sustainability	**4**	**2**	**2**	**3**	**3**	**3**
Using Environmental Management System(EMS)	**3**	**-**	**2**	**2**	**-**	**2**
Using Renewable materials	**2**	**2**	**-**	**-**	**-**	**-**
Using eco-friendly energy	**2**	**2**	**2**	**2**	**-**	**-**
Carrying out research on sustainable practices	**3**	**-**	**-**	**3**	**-**	**-**
Carrying out research on sustainable products	**3**	**-**	**-**	**3**	**-**	**-**
Training employees on sustainability	**4**	**3**	**3**	**3**	**3**	**3**
Encourage suppliers to use sustainable practices	**3**	**2**	**1**	**2**	**-**	**-**

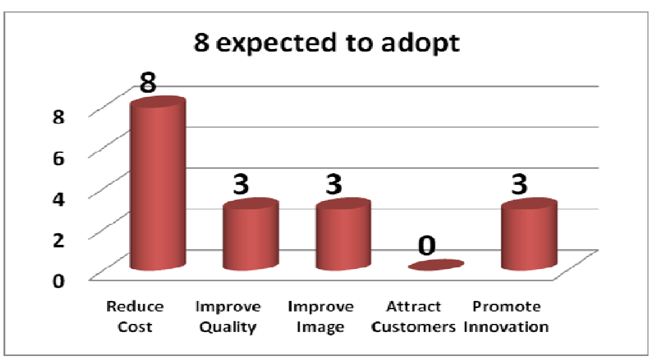


Figure 5.11: Reducing energy use

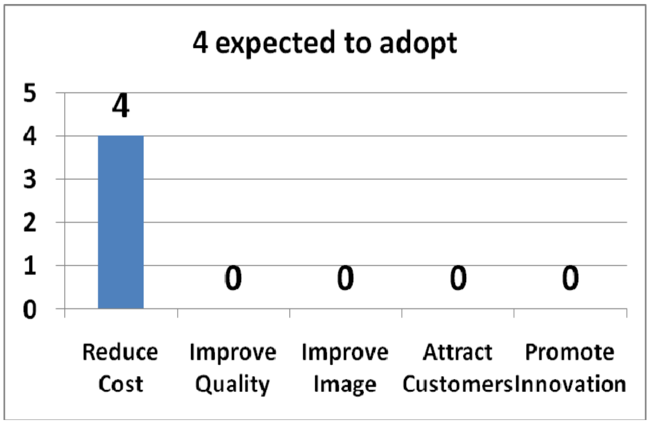


Figure 5.12: Reducing raw material usage

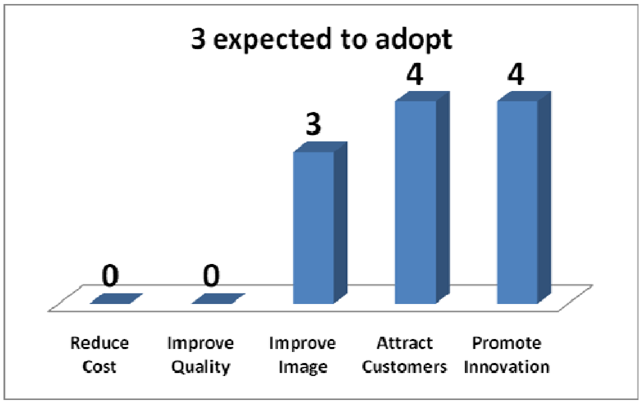


Figure 5.13: Reducing solid waste

reducing energy usage decreases manufacturing cost by decreasing energy costs. Hence Proposition 1 is strongly supported with respect to the electronics industry. In addition, a relatively large percentage of respondents reported that PPPs will hopefully improve company image, will attract new customers and will promote innovative ideas. These relationships have not been proposed and so will not be discussed further.

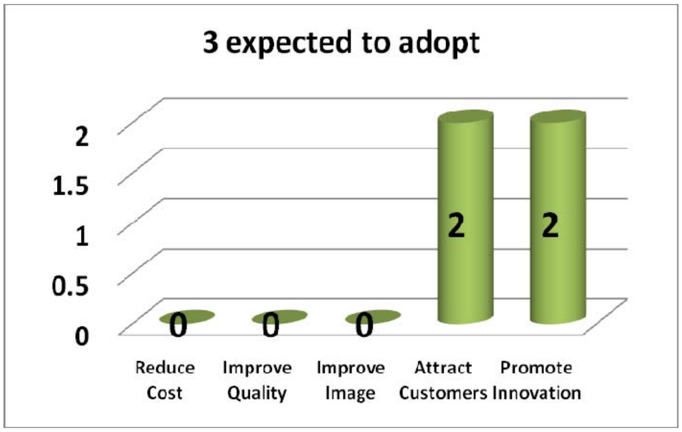


Figure 5.14: Reducing GHG emissions

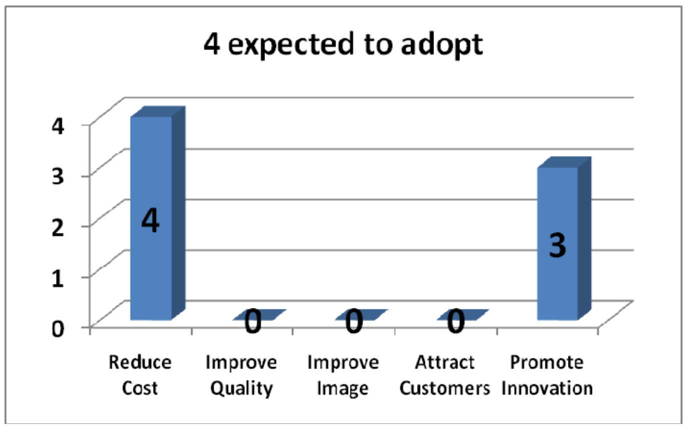


Figure 5.15: Recycling water

5.8.2 Product Management Practices (PMP)

Table 5.11 indicates that most of the respondents are not expected to adopt PMP in the future with hopeful prospects. That is not unusual as use of these practices in the developed countries are not quite as widespread as PPPs. The response ranges from a low zero for reuse of waste material to a high of 4 (for redesigning processes and products to improve sustainability and training employees on sustainability). Among the respondents who are expected to follow PMPs, a significant number seem hopeful that these practices will improve company image ranging from a low 2 (for using EMS and Using eco-friendly energy) to a high 3 (for carrying out research on sustainable processes and products). Feedback on PMPs promoting innovative ideas ranged from a low 2 (for Using EMS) to a high 3 (for redesigning product to improve sustainability and training employees on sustainability). Since overall average is close to 50%, therefore propositions 2,3 and 4 are supported with respect to electronics industry.

In few cases, respondents have also reported that some PMPs will improve product quality, however, this relationship does not seem as robust as that between PMPs and company image. The percentage expecting that PMPs will increase product quality ranges from a low 1 (for encouraging suppliers to use sustainable practices) to a high 3 (for training employees to achieve sustainability). Hence proposition 5 is supported less robustly than proposition 1, 2, 3 and 4 with respect to electronics industry.

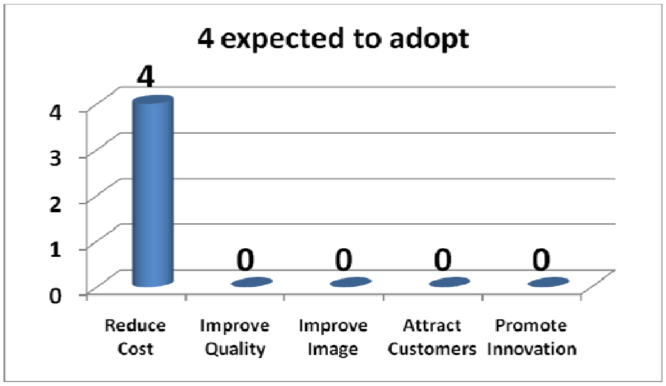


Figure 5.16: Redesigning process to improve sustainability

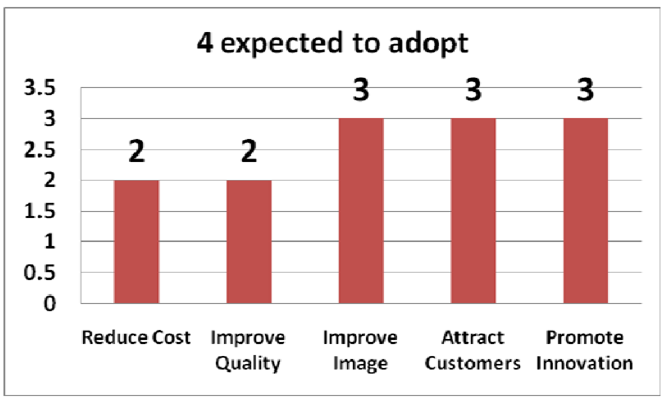


Figure 5.17: Redesigning product to improve sustainability

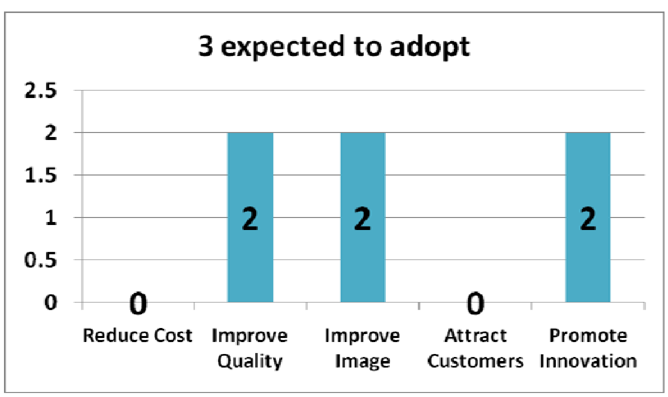


Figure 5.18: Using EMS

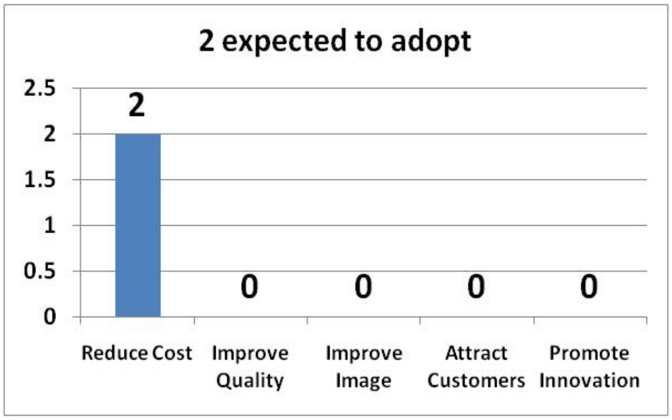


Figure 5.19: Using renewable materials

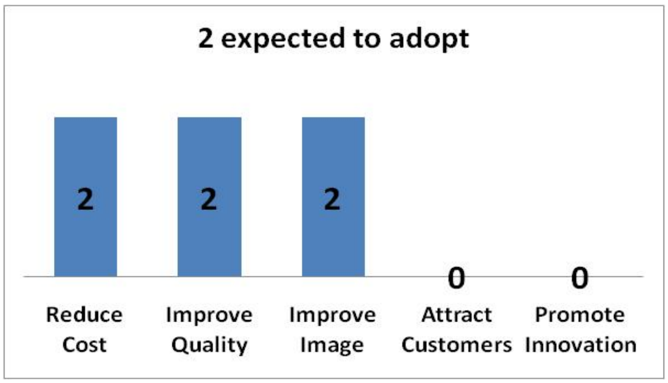


Figure 5. 20: Using eco-friendly energy

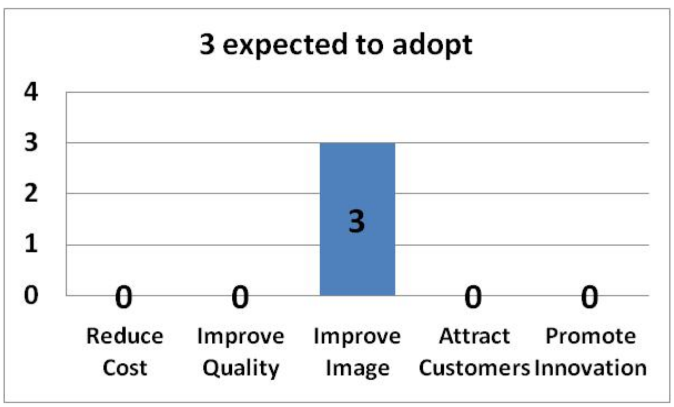


Figure 5.21: Carrying out research on sustainable processes

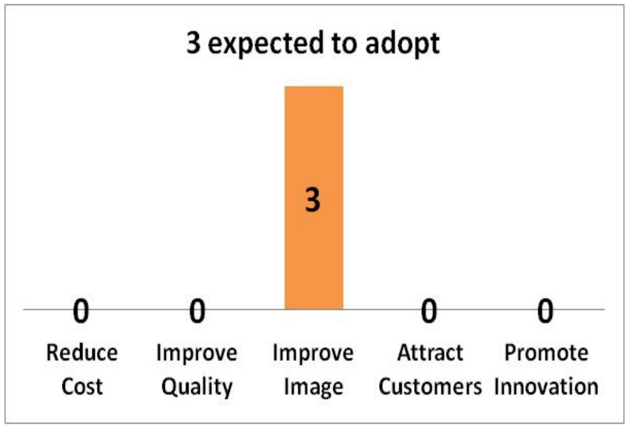


Figure 5.22: Carrying out research on sustainable products

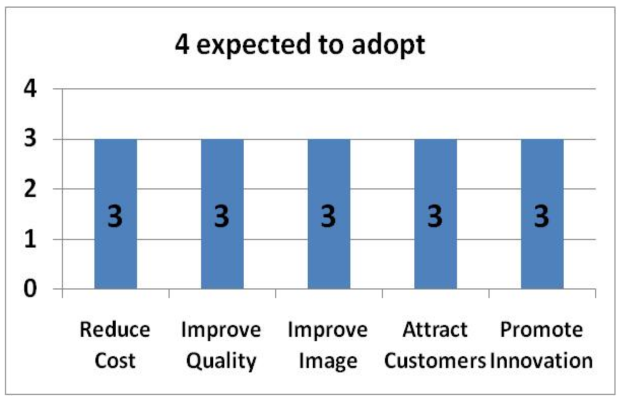


Figure 5.23: Training employees on sustainability

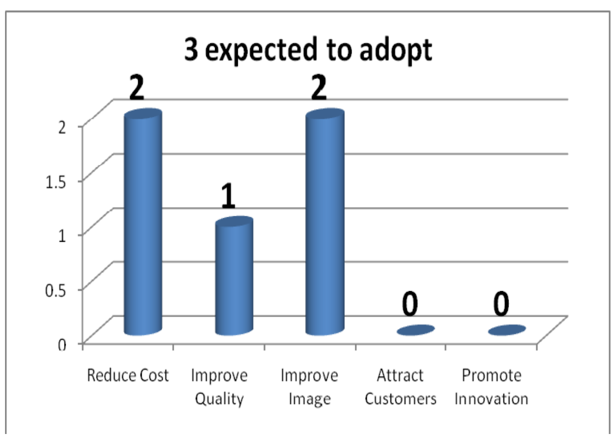


Figure 5.24: Encourage suppliers to use sustainable practices

5.9 Discussion

This research contributes to the literature by providing broad linkage of sustainable manufacturing practices with competitive outcomes. Although electronics industry in Pakistan is not very competitive as far as outcomes are concerned, nevertheless, the study does provide an overview with respect to which green manufacturing practices are expected to be adopted more by the electronics industry in about 15-20 years time. Results have been discussed in detail earlier**.**

5.9.1 Competitive Manufacturing Outcomes (Cost, Quality)

As indicated in Table 5.11, with few exceptions, PPPs seem to be consistently and robustly associated with expectations to decrease manufacturing costs in the electronics industry of Pakistan. This seems logical since PPPs reduce and/or recycle resources which are bound to have a significant effect on manufacturing costs. These findings support proposition 1 and are consistent with (Hart, 1995), who argues that the main competitive advantage yielded by PPPs is cost. Likewise, these findings are consistent with (Porter and van der Linde, 1995), who argue that eliminating waste through practices like resource reduction and recycling can decrease costs.

Since a relatively less percentage are expected to adopt PMPs and are less hopeful that PMPs would likely increase their product quality, therefore proposition 5 is not supported. This argument is supported by (Nawar, 2008) whereby improving quality requires coordination among all management functions of the organization. For example, redesigning products and processes to improve sustainability requires top management support for implementation as well as cooperation from internal and external stakeholders, including R&D, design, purchasing, sales and suppliers. While there has been little empirical research on what types of environmental manufacturing practices tend to increase product quality, the well-established and more general literature on manufacturing (Garvin, 1988)[97] holds that improving quality requires coordination across functions. Correspondingly, according to (Nawar, 2008), organizations must use an organization-wide response when addressing variables such as product quality. Hence, multi-stakeholder green practices, such as PMP, may be more difficult to successfully coordinate than those involving only operations, since they require multifunctional coordination. This may explain the not very strong responses with respect to PMP and potential increase in product quality. However, additional empirical research that is beyond the scope of this research is necessary in order to better support this possible explanation.

5.9.2 Competitive Preemption Outcomes (Image, Customers and Innovation)

As indicated in Table 5.11, with few exceptions, PMPs are generally expected to give positive results as measured by company image, attracting new customers and promoting innovative ideas in the company/organization. This supports propositions

2, 3 and 4 with respect to electronics industry of Pakistan and is consistent with (Hart, 1995) and (Porter and Van der Linde, 1995). However, contrary to theory (Hart, 1995) and propositions, the data suggests that PPP are also expected to be associated with competitive preemption outcomes in some way within the electronics industry. Generally speaking, 63% of the respondents believe that both types of practices: PPP and PMP, would have a positive impact on competitive preemption. Relative to cost advantages that tend to be realized immediately, advantages from competitive preemption i.e. improving company image, attracting new customers, and promoting innovative ideas in the company tend to symbolize the potential for future competitive advantages. Hence, this data suggests that electronics industry does see some potential in both PPP and PMP with respect to future competitive advantages.

5.9.3 Deductions

- The main point of this study is that it broadly examines industry-specific sustainable manufacturing practices and their relationships with specific competitive manufacturing outcomes of cost and quality. In addition, the study examines industry-specific sustainable manufacturing practices and their relationships with specific competitive preemption outcomes of company image, new customers, and innovative ideas.
- Two types of practices have been considered: PPPs that conserve and/or reuse resources and waste products related to the production process, and PMPs that extend environmentalism beyond production to other internal and external stakeholders such as R&D, design, purchasing, and suppliers. Although, both types of practices are less likely to be used by the companies; however, relatively, PPPs are expected to be adopted more than PMPs, as indicated in Table 5.11.
- Results of the study indicate that PPPs are expected to influence manufacturing costs more than PMPs in the electronic industry. Therefore, if companies have decreasing cost as a major goal, then adopting PPPs may be an appropriate choice.
- As discussed above, the goal of increasing product quality may be more complex, risky, and resource intensive than manufacturing cost. This may explain the not very strong responses with respect to PMPs and potential

increase in product quality. Therefore, organizations that lack the resource capability to successfully implement PMPs may be able to reap cost advantages from implementing PPPs.

- The PMPs with the highest number reporting potential increase in product quality is training employees in sustainability. In addition, the practices of redesigning the product to improve sustainability were also positively associated with manufacturing cost, as was the practice of training employees in sustainability and encouraging suppliers to use sustainable practices. Possible explanations are beyond the scope of this research, but can provide an interesting focus for future research.

- Although a relatively less number of respondents anticipate that both types of practices can result in competitive gains via company image, new customers, and innovative ideas, nevertheless, if decision makers have competitive preemption outcomes such as improved company image, attracting new customers, and/or promoting innovative ideas as major goals, either PPPs or PMPs may be appropriate choices.

CHAPTER 6
DEVELOPING FRAMEWORK FOR SUSTAINABLE GREEN PRACTICES IN ELECTRONIC PRODUCT MANUFACTURING FIRMS

6.1 General

The electronic industry of Pakistan is unfortunately not a competitive industry. The main reason is that all component parts, kits and replaceable assemblies required by the electronic industry in manufacturing and fabrication are imported.

In case of green PCB manufacturing, although reputable organizations exist, still, apart from small requirements up to double layer double sided PCBs which is done in Pakistan, the rest of the requirement is catered by China. Besides China, other countries with competitive costs in PCB manufacturing and electronic products include Taiwan, Indonesia, Malaysia, Singapore and South Korea. Given below is a recommended framework for sustainable green practices:-

6.2 Main Parameters to be included in Green practices

In the climate of Pakistan, the seasonal variations bring extreme temperatures in summers. The work environment, especially in the industry is normally not very conducive. For example temperatures in summers greater than 50 centigrade can remain so for upto six weeks, thereby significantly affecting probable green practices intended for implementation. Since this is expected to be the beginning stage for promoting green practices in the Pakistani industry, the parameters have to be limited in scope. Implementing major changes even though they are expected to prove beneficial in the longer run, is not an easy task. Therefore, to begin with, following are the broad parameters recommended to be focused upon:-

a. Energy consumption
b. Raw material usage
c. Water utilization
d. Employee training

6.3 Monitoring Agency

Monitoring is an important task which has to be pursued with honesty and dedication for the results to be fruitful. The level of monitoring is based on the current situation prevailing in the country. Moreover, since implementing comes with exercise of authority, it should be managed by a government agency. An agency with a clear mandate, preferably under the enforcement wing of the ministry of industries, production and special initiatives will be in a far better position to monitor and review green practices being followed in relevant industries.

6.4 Level of Green parameters

Green practices in the broader sense can be defined as primary and secondary activities that do not directly produce a finished product. However, certain standards are required to serve as references for implementation and subsequent monitoring. This is similar to the critical examination of a parameter of quality of an entity to some predetermined purpose (Nawar, 2008). Following are a generalized scope of levels of green parameters expected to be followed.

a. **Energy consumption**. Reduction upto 30% in existing usage of electricity and gas. Number of average commercial units being exhausted can serve as reference and upper and lower limits can be defined relative to each industry.

b. **Raw material usage**. Reduction upto 10% in first phase of adoption and implementation in following steps:-

- Identification of requirements (forecasting)
- Exploiting indigenous sources
- Evaluating requirement
- Purchasing environmental friendly materials wherever possible

c. **Water utilization**. Water is considered to be an abundant resource. In the present scenario of electronic industry, water requirements in manufacturing are not huge and are being met by the existing government supply .nevertheless, saving water from unnecessary waste will only reduce associated costs. In the beginning, the best steps that can be taken are maximizing efforts to treat water for use in other areas like administration purposes. The treatment for reuse would however be the most appropriate provide it is practically feasible.

d. **Employee Training**. Awareness and skill development of worker/employee is a very important aspect of development and sustainable growth. With a low literacy rate of 27%, Pakistan faces an uphill task towards economic growth leading to sustainable development. To begin with at initial phase, level of parameters to be adopted should focus on following areas:-

- On-job-training for technicians/workers
- Periodic lectures on sustainability and green awareness be mandatory
- Cross training of technicians/workers in relevant areas of expertise

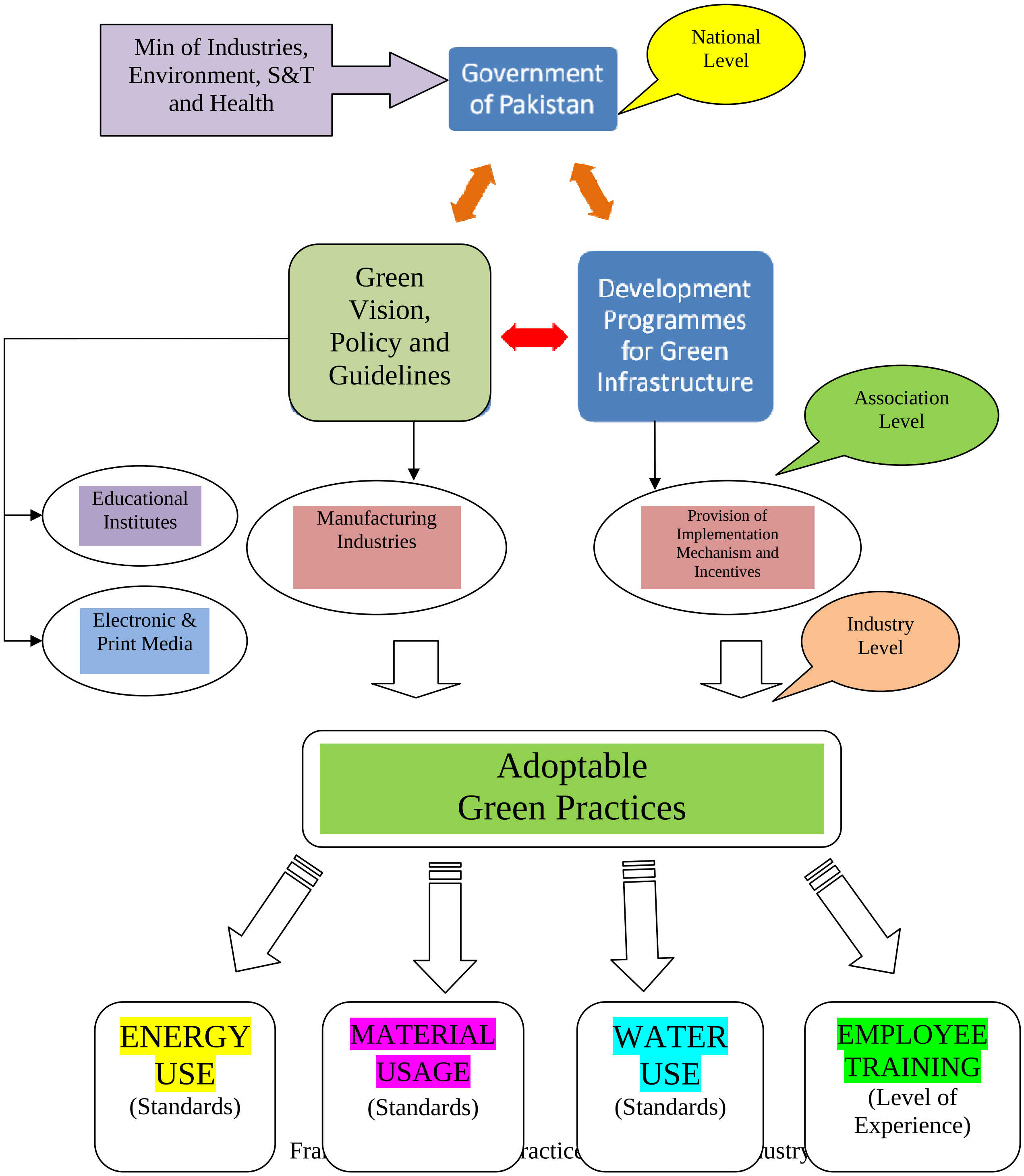
6.5 Framework

There is a basic framework of maintenance applicable to practically every industry, which is part of a total organization's responsibility. In manufacturing, the inspection itself entails the comparison of a product with the specification or standard. It includes determining whether the product or process is efficient or not. Theoretically, in most industrial plants, the final responsibility for maintenance and inspection lies with the engineers. The government needs to conceive a vision and formulate policy on green practices for the electronic industry. The efforts of ministry of Industries, Environment, S&T and Health have to be integrated. This will ensure government involvement in development programmes for green infrastructure.

At the association level, an implementation mechanism and incentives have to be provided. The industry has to implement the adoptable green practices by strictly following standards laid out by various ministries. Following steps are suggested for checking and maintaining green practices:-

a. Every industrial organization should include in its existing Quality control and Assurance department, a section comprising a team of engineers and technicians well informed on green awareness aspects.
b. The mandate of the monitoring agency described earlier would perform green audit of the organization on annual basis.
c. Organizations failing to implement green practices within specified limits and non-adherence to set standards should be warned and penalized with heavy fines. The amount of fines be decided by the competent authority i.e. relevant department of the government of Pakistan.
d. After expiry of three warning periods one month apart, appropriate action will be mandatory, leading to cancellation of license to manufacture, confiscation of property and eventual shutdown of the organization. The framework for

green practices described above in a generalized form is shown in figure 6.1 below. The framework may be applicable to other industries to some extent as well.


Min of Industries, Environment, S&T and Health
Government of Pakistan
National Level
Green Vision, Policy and Guidelines
Development Programmes for Green Infrastructure
Association Level
Educational Institutes
Electronic & Print Media
Manufacturing Industries
Provision of Implementation Mechanism and Incentives
Industry Level
Adoptable Green Practices
ENERGY USE (Standards)
MATERIAL USAGE (Standards)
WATER USE (Standards)
EMPLOYEE TRAINING (Level of Experience)

CHAPTER 7
RECOMMENDATIONS, FUTURE DIRECTIONS AND CONCLUSION

7.1 Recommendations

Following are the points recommended for consideration:-

7.1.1 Government Level

- Government should formulate a comprehensive Green vision, mission, policy and guidelines for the industry.
- The mission to be achieved by virtue of implementation of Green practices by the industry has to be described.
- Government should initiate awareness campaign on "Becoming green – aware" at national level, involving media, educational institutions and the complete manufacturing industry of Pakistan.
- In phase one, development programmes for green infrastructure will have to be formulated.
- Government should make practical rules and regulations for the manufacturing industry in conjunction with providing incentive packages in the form of exemption in duties, sales tax and energy tariff.
- Comprehensive plan on energy conservation be rigorously followed. Use of alternative/renewable energy is recommended. Use of available technologies for renewable energy sources such as wind/solar be promoted.
- Government should outline the mechanism device for adopting standards of Green practices by the industry.

7.1.2 Association Level (Implementation Mechanism and Incentives)

- Association should be responsible for ensuring implementation of mechanism outlined by the government.
- Association should be responsible to provide guidelines for all members of the industry.
- Introduction of a Green Management System by defining upper and

lower control limits and setting standards within green parameters to be followed.

- Association should identify adoptable Green practices
- Maintenance of plant machinery should be regularly carried out for workplace and employee safety.

7.1.3 Industry Level (Standards to be adopted)

- Industry should implement Green practices by following standards outlined by the association.
- Waste minimization should be carried out which will lead to energy and economic efficiency.
- Installation of eco-friendly motors in plant machinery is recommended to reduce energy use leading to reduced energy costs.
- Recycling of waste water should be done in order to save water and associated energy costs.
- Periodic lectures and cross training be made part of job description.

7.2 Future Directions for Research

- Future research can proceed in several different directions. This study was exploratory in nature, and data collection and analysis was somewhat constrained for several reasons including: the dearth of research on the industry; characteristics of the industry (most of the companies are privately held); reluctance of industry members to provide quantitative multisource information; the proprietary nature of the data; and limits on survey length relative to the respondents' willingness to participate. Therefore, future research in the electronics industry can build upon this study, and design studies to examine empirically stronger relationships between specific practices and outcomes (e.g., correlation, regression). For example, future studies can focus more narrowly and collect more data on those green practices that are robustly associated with competitive outcomes.
- This study finds that only a few PMPs have a substantial effect on quality. Some explanations for these results were suggested earlier, however, a closer examination may be a focus for future research.
- Future researchers can also address the differences between respondents

who reported competitive outcomes for particular practices and those who did not (like re-designing process to improve sustainability etc). Since this study focused on environmental practices that were positively associated with competitive outcomes, it might also be interesting to explore which environmental practices are negatively related to competitive outcomes, if any.

- In addition, future research can also more rigorously test the relationships between green sustainable practices and competitive outcomes in other manufacturing industries. There is a general need to focus on green sustainable practices and outcomes in other under-researched manufacturing industries. This kind of research, together with the existing research that examines larger, more widely studied industries, can broaden our knowledge about green practices and outcomes in all organizations.
- In order to promote green awareness, a comprehensive study on possible courses on green practices may be carried out. This will be helpful in education sector reforms for subsequent inclusion in the curriculum.
- The requirement for Diploma and Certification in the field of green practices can be explored for enhancing the areas of expertise and specialization of human resource.

7.3 Conclusion

Green manufacturing practices are not easy and they do not represent an economic benefit in the beginning. However this research, although generalized, still shows that they do represent a good long term investment and benefits to society leading to cost savings, increase in production and competitive advantage.

Clearly, being green in the electronic industry means making a comprehensive commitment to sustainable practices across the spectrum of the manufacturing processes. Not only is green manufacturing good for corporate and community relations, it’s also beneficial to the bottom line. Ultimately, an unintegrated approach is good, but not sufficient. Sustainable development is going to play a very significant role in stabilizing the ever fluctuating economy of Pakistan in the next two decades. The recommendations given will hopefully contribute to highlight the importance of green practices for Pakistan and provide some direction to follow towards achieving sustainability.

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