CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Literature review has been carried out mainly on the following areas:

- Life Cycle Assessment (LCA) and applications.
- Information on the LCA data base available in developed and in developing countries.
- Exergy Analysis (EA) of a refrigeration cycle and tax based on the same.
- Existing tax system in India.
- Environmental tax methods and procedures followed in different countries.

The sections that follow will report a reasonably exhaustive and a critical literature survey in the above three areas highlighting the contributions already reported in the available literature.

2.2 LIFE CYCLE ASSESSMENT

According to Curran (1996), Life Cycle Assessment (LCA) provides a framework, approaches and methods for identifying and evaluating the environmental burdens associated with any product, process or service
from cradle to grave as is also mentioned in PRé Consultants (2004). Literature review on LCA includes a brief study of the available literature on the history and applications of LCA, available software packages, and limitations of LCA.

### 2.2.1 History of Life Cycle Assessment

Keoleian et al (1994), Svoboda (1995) and Curran (1996) have explained the history of LCA, which began as early as 1960. Midwest Research Institute conducted the first LCA in 1969 for the Coca-Cola Company to compare the beverage containers used by various companies and to determine which container produced the least negative effects on natural resources and on environment. Companies in United States and Europe performed similar comparative life cycle inventory analysis in early 1970s. During the energy crisis in late 1970s, LCA methodology was used to identify and measure the energy consumption. As the oil crisis faded, so did the interest in LCA approach for evaluating the use of energy. Activity in the United States on environmental LCA continued at a slow but steady pace of around two to three studies per year. During the period from 1970 to 1980, there were few participants in LCA study and industries began to show interest from 1980s to 1990s. But none of them went further than just quantifying materials and energy used.

Todd and Curran (1999) have pointed out that U.S. Environmental Protection Agency (USEPA), Society of Environmental Toxicology and Chemistry (SETAC) in Europe and other international organizations such as the International Organization for Standardization (ISO) and LCA practitioners worldwide have undertaken efforts to achieve consensus on an overall LCA framework. Karlsson (2001) has discussed about the “Guidelines for life cycle assessment: A Code of Practice” published after the SETAC
workshop in 1993, which gave the standard for most of the life cycle studies in both Europe and in North America. Fava (2002) has shown that SETAC and the United Nations Environmental Programme (UNEP) have embraced LCA as an environmental tool. According to UNEP (2003), LCA standards are available in the ISO 14040 series.

2.2.2 Applications of Life Cycle Assessment

Life Cycle Assessment (LCA) can be used to track system performance for a variety of criteria including emissions, energy use, monetary costs and decision making (use of recycled products regardless of cost). Information about the impacts from LCA can be used by the governments to set regulations, taxes or tariffs or to identify projects worthy to receive tax credits (Gaines and Stodolsky 1997). According to Welford and Gouldon (1993) and Curran (1996), LCA helps to identify design faults that cause environmental and energy consumption problems. It also identifies methods for reducing waste released, energy used and inputs of raw materials. International Organization of Standards has developed standards (ISO 14040 Series of Standards), which sets out framework for undertaking LCA. In the European Union, the badge of acceptance of a product called Eco-label has been introduced. According to Hazel (1998) and Guinée (2001), Eco-label for products is provided based on LCA. A further application has been in the design of more environment friendly products, otherwise known as Eco-design. The disposal of waste in Europe where space is at a premium has been addressed by LCA, which assess the relative merits of chemical and physical processing, incineration and landfill. Berkel (2000), Tillman (2000) and Tukker (2000) have pointed out the strength of LCA as an analytical tool specifically designed for analyzing and evaluating the environmental impacts during the different stages of the whole production chain in the life cycle of a product, process or service.
Eisenhard and Schepper (2000) have explained how artificial neural networks could be trained on product attributes and environmental impact data from pre-existing life cycle assessment studies. Using the trained model, an approximate impact assessment for a new product could be obtained. Gagnon et al (2002) have presented the environmental impacts of electricity generation system in Canada based on LCA.

In India, the government has instituted a scheme for labelling the environment friendly products as ‘ECOMARK’ with a view to provide accreditation and labelling for household and other consumer products, which meet certain environmental criteria along with quality requirements of the Indian standards for those products. Any product, which is made, used or disposed off in a way that significantly reduces the harm, it would otherwise cause to the environment, could be considered as environment friendly product. This assessment could be based on LCA (Singh 2003).

Kulkarni (2003) has pointed out that the first LCA study in India was carried out in steel sector during 1999–2002 with the support from the Ministry of Environment and Forests (MoEF). The main objective of the study was to find out the pollution load per tonne of steel produced and identify the problematic areas. The high coal consumption in blast furnaces has been identified as one of the major reasons to cause high pollution load. The study suggested the full utilization of the processed coal gases to bring down the energy consumption of the plant, recycling of wastes to improve the overall performance of the plant and in-house research and development to make the steel sector more energy efficient. In the power generation process at thermal power stations, Combined Cycle Gas Turbine technology is preferred along with modifications in the coal blend leading to higher generation efficiencies and lower environmental impacts. The performance of the Electro Static Precipitators (ESPs) is improved by using appropriate coal
According to Singh (2003), LCA studies have also been initiated in India in various sectors namely pulp and paper and thermal power generation. The study relating to the thermal power generation sector was completed in 2002-03 while the study in pulp and paper sector has been in progress.

2.2.3 LCA – Software Packages

Norris et al (2003) have discussed various software packages available for LCA as is mentioned in PRé Consultants (2003) also. Simapro 4 is a full-featured LCA software tool by which products with complex life cycles can be compared and analyzed. Special features of the software packages are multiple impact assessment methods, multiple process databases and automatic unit conversion. Simapro 5.1, which follows ISO 14040 series of guidelines has got large inventory databases, many impact assessment methods and runs in many languages.

2.2.4 Limitations of Life Cycle Assessment

Eileen (2000) has pointed out that defining the system boundaries is an important requirement of LCA or else the description of the product life cycle stages would never be complete. Also, environmental impacts associated with each stage will depend to a large extent on the geographic area in which they occur. Lewis (1996) and Curran (1996) have described that LCA is very data intensive and success of any study depends on the availability of reliable database. The lack of readily accessible and credible data has limited the number of studies that have been conducted. LCA is also a time consuming activity. Finally, when the analysis is carried out and the results are presented in a language, which can be understood only by learned toxicologists. No common environmental ‘currency’ exists to deal with the
results of LCA (Guinée 2001). However, Caluwe (1997) has proposed an index based on the environmental damage caused by the component.

2.3 DATA QUALITY AND NORMALIZATION

Since LCA is very data-intensive, a brief review has been carried out and presented about the data quality, available database at international level and existing methods for normalization of available data.

2.3.1 Data Quality

Lewis (1996) has pointed out that the common perception (and often the reality) of LCA is that a team of scientists and engineers are involved in compiling thousands of data into a complex computer model. For this reason, the value and credibility of LCA depends on the quality of data. When every LCA practitioner has to collect his own data, the quality of data will vary enormously. An average or estimated data is often used because every one may not have access to manufacturing data (which is normally confidential). Some data will be left out if it cannot be estimated. The quality of data will also depend on the amount of time and money available for the particular study.

One way to solve these problems is to establish publicly available databases, which is consistent with the ISO Standards, either electronically or as published reports. In Europe, Society for Promotion of Life-cycle Development (SPOLD), an industry group is the primary sponsor and coordinator for electronic databases.
2.3.2 Database Available in the International Level

Norris and Philippa (2002) have discussed the various steps taken by different countries to develop international database for LCA. The Canadian Raw Material Database Project on LCA has covered steel, aluminium, plastics, glass, paper and softwood lumber. In USA, Life Cycle Inventory (LCI) data is available in a manner fully compliant with ISO standards 14040 and 14041. Just as the “power-house” of LCA, many different database and data sources have been developed in Europe.

Germany was one of the pioneers in developing publicly available LCI database, beginning with Global Emission Model for Integrated Systems (GEMIS) database, released in 1989. In Japan, progress in LCA started in 1998. Australian LCA society developed an LCA database from the best Australian data available, for various plastics, glass bottles, aluminium, steel, timber, paper, concrete, electricity and heat from various fuels. Korea and Chinese Taipei have also been developing LCA database.

Various organizations like SETAC-Europe, SPOLD, etc. have facilitated exchange of LCA information among themselves. The Eco-Invent 2000 is a Swiss initiative to build a centralized and harmonized database containing life cycle inventory data on energy, materials, chemicals, transportation and waste treatment, which can be accessed via World Wide Web (WWW) based on the SPOLD format.

Indeed, databases are being developed in various countries, and the format for database is standardized. In practice, data become frequently obsolete, incomparable or having unknown quality. More over, data are generally available for combinations of processes such as electricity production or aluminium production, rather than for individual processes.
2.3.3 Existing Indices for Normalization

Life Cycle Assessment (LCA) of even a tiny object needs a large number of data. The results of LCA depend on the availability of reliable data. Available LCA database can be transferred for use in other countries by normalization, thus eliminating the repetitive work of data acquisition. A brief description of the existing methods for normalization of the environmental themes available in the literature is presented.

Fischer et al (1992) and Kuijpers (1998) have explained the Total Equivalent Warming Index (TEWI) calculated using global warming potential of carbon dioxide. Air conditioning and refrigeration equipments contribute to global warming impacts in two ways: (i) The equipments consume energy usually generated by the combustion of fossil fuels, which is an indirect impact due to the emission of carbon dioxide. Carbon dioxide is the most common man-made greenhouse gas. (ii) The equipments release some refrigerant at the time of manufacture, service and a comparatively large quantity of refrigerant due to the improper disposal at the end of their useful life time, which has a direct impact on global warming. The main drawback is that TEWI takes into account global warming impacts only due to CO$_2$, ignoring all the other polluting emissions.

Curran (1996) has explained the normalization score for environmental themes in order to relate them to a reference, thus relating the contributions of the functional unit to the sum of all emissions and extractions worldwide. The main drawback of this method is that the conversion factor depends only on the national income.
The literature review shows that most of the developed countries have database for LCA. Developing countries could use these databases using proper conversion factors. Two conversion factors for normalization and another index for fixing the boundary of the life cycle analysis have been developed and presented.

It can be concluded from the above discussions that only very little published work on LCA is available. The impact of environmental effects like global warming, ozone depletion and acidification also needs to be evaluated. It has been observed that the Exergy Analysis (EA) overcomes most of the demerits of LCA. Hence literature review on exergy analysis and its applications also have been carried out and reported.

2.4 EXERGY ANALYSIS

An exhaustive literature review has been carried out and presented on the topics including Entropy Added Tax (EAT), basic concepts like energy, entropy and exergy, the origin, development and applications of exergy analysis.

2.4.1 Entropy Added Tax

Hirs (1994) has suggested a tax based on Exergy loss or Entropy Added as the basis for exergy taxing. This tax is termed as Entropy Added Tax (EAT) analogous to Value Added Tax (VAT). Sauer (1996) has pointed out that in most of the western hemisphere there is an intensive debate going on regarding the proper pricing of energy. The energy consumption in the energy intensive industries can be split into two different categories: (i) Energy physically required for making a product, which is the exergy
content of the product and (ii) energy lost during the production, which is exergy lost due to an inefficient process. Without lowering the production, it is only this exergy loss which industries can reduce and which the society can exploit for better utilization. This exergy loss will not only cause higher energy consumption but also cause environmental pollution in the form of global warming. It is to this part of the process, the major industrial energy taxes are allocated. A tax was defined based on this principle to follow some idea of Nobel Prize winner Trygve Haavelmo about entropy taxation.

2.4.2 Energy, Entropy and Exergy

Since the exergy analysis depends on the basic concepts of energy and entropy, a comprehensive literature review has been presented in this section. Schaeffer and Wirtshafter (1992) have defined energy as the capacity to do work and in overcoming friction. Dincer and Cengel (2001) have noted that the concept of energy was first introduced in mechanics by Newton who based his hypothesis on kinetic energy and potential energy. Dincer (2002) has explained energy and exergy, including a number of concepts like entropy, temperature, pressure, enthalpy, heat and work and their applications in the fields of science and engineering. The conversion between heat and work falls in the science of thermodynamics.

The two laws of thermodynamics evolved around the same time in the 1850s, primarily from the works of William Rankine, Rudolf Clausius and William Thomson (later Lord Kelvin) as reported by Dincer and Cengel (2001). Headman et al (1980), Gool (1980) and Schmidt (2001) have pointed out that according to the First Law of Thermodynamics, all forms of energy are convertible to one another. They also mentioned about the statement of Carnot in the second half of the 19th century that there is a maximum efficiency for this transformation. Some energy forms like
electricity and mechanical power can be transformed with theoretically no losses (ordered energy) and others like heat transfer (disordered energy) is transferred only with certain amount of losses. This shows that there is a quality factor for energy. According to Nevers and Seader (1980) and Banerjee (1991), the practicing engineers and designers did the calculations based on the first law because the processes were developed in an era when there was abundant availability of cheap energy. This fact coupled with the apparent complexity of the concept and the difficulty of defining entropy hampered the application of the second law analysis.

In 1865 the German physicist Clausius described the second law of thermodynamics (SLT) using the term Entropy (Haywood 1974 and Requadt 2003). Entropy is a thermodynamic property, which gives a measure of the amount of molecular disorder within a system. Haywood (1974 a) has explained that when an isolated system undergoes an irreversible process, the system always suffers an increase in entropy. According to Ahern (1980), the primary message from SLT is that entropy production must be minimized for efficient energy conservation. The work lost through entropy production is accounted for in the exergy method. Kestin (1980) and Vogler and Weissman (1988) have presented a series of general observations, which place the concept of availability or exergy in the context of industrial process efficiency. Wall and Gong (2001) have explained a concise theory of exergy and introduced exergy useful in engineering and also for improving the resource use and for reducing environmental destruction.

Reistad (1975), Paolino and Burghardt (1982), Amrane and Radermacher (1994) and Aphornratana and Eames (1995) have explained the limitations of exergy conversions. They have said that work can be completely converted into heat, but it is impossible to convert all available heat into work. In the first law, heat and work are defined as energy, which is
conserved. But in the second law, heat and work interactions are better understood when defined in terms of exergy, which always decreases during all real irreversible processes. The magnitude of change in exergy is a measure of irreversibility. According to Dincer and Rosen (1998), designers have accepted the concept of exergy based on SLT as a useful technique for improving the process efficiencies.

Thirumaleshwar (1979), Ahrendts (1980) and Gallo and Milanez (1990) have explained the choice of a reference state for exergetic analysis, since exergy is the amount of work obtained when a matter is brought to a state of thermodynamic equilibrium with the common components of its surroundings by means of reversible processes. Thus exergy is defined as the work that is available in a gas, fluid or mass as a result of its non-equilibrium condition relative to some reference condition.

Kenny (1989) has pointed that Gagioli, Reistad and others wanted to develop a more consistent terminology in the meeting in Rome in 1947. The participants agreed on the use of exergy for the general concept in lieu of terms such as availability, available energy, essergy, utilizable energy, work potential, available work, convertible energy, etc. Kenny also pointed out that Keenan interpreted exergy as available energy in 1948 and Z. Rant suggested the term exergy to denote technical working capacity in 1953.

2.4.3 The Origin and Development of Exergy Analysis

The acceptance and popularity of exergy analysis is shown by the vast bibliography published by Wall (1992) on exergy, containing about 2034 publications most of which are direct references to the concept of exergy. Other bibliographies are: 404 European publications published before
Berg (1974) has reported that Gibbs and Helmholtz introduced exergy method for the analysis of chemical systems based on the concept of available work. Ahern (1980) and Wall (1990) pointed out that Carnot in 1824 and Clausius in 1865 laid down the fundamentals of exergy method. Szargut (1980) discussed the work by Gouy in 1889 and A. Stodola discussed in 1898 about the basis of exergetic analysis in formulating the law, which has been called after them. But Gouy-Stodola’s law did not arouse much interest at first.

2.4.4 Applications of Exergy Analysis

The exergy method is related directly to the irreversible production of entropy in systems as used by Bejan (1975) for analysis of cryogenic equipments and heat exchangers. Banerjee (1991) has done the exergy analysis of a simple condensing steam power plant and concluded that the major portion of energy loss is caused due to the heat rejection in the condenser, which accounts less than 4 percent of the input exergy. But the major exergy loss occurs in the boiler, which accounts for about 68 percent of the input exergy. Rosen et al (1999) have conducted exergy and energy analyses of cold thermal storage systems and concluded that exergy analysis provides more realistic and accurate assessments of efficiency and performance.

In the industrial sector, Ghamarian and Cambel (1982) have done a theoretical exergy analysis of Illinois No. 6 coal to calculate the quality of coal. The exergy flow and losses in a pulp and paper mill and a steel rolling mill has been analyzed by Wall (1988) and has shown that the heating process
are highly inefficient. Tekin and Bayramoglu (1998) have performed exergy analysis of sugar production process and concluded that maximum exergy loss has occurred in steam power system due to the irreversible nature of combustion and also by means of waste exergy in stack gases. They also pointed out that preheating of combustion air with hot combustion gases and oxygen enrichment of combustion air could reduce exergy loss. Rosen and Dincer (1997) have studied the relationship between exergy and environmental impact of electricity generation by coal fired steam generators. They have shown that as process exergy efficiency increases, the resource degradation and waste exergy emission decrease.

Morris and Szargut (1986) have used exergy calculations and reported values of the standard chemical exergy of 49 elements, which could be adopted for exergy analysis. Accordingly, exergy analysis could be applied globally to industrial sector, agricultural sector or an entire nation to develop insights concerning the location and relative significance of key non-idealities, which could be used as guiding measures for improving sector’s overall conversion efficiency, thereby reducing resource waste attributable to that sector.

Exergy analysis is also applied to study the exergy use in society. Schaeffer and Wirtshafter (1992) had performed an exergy analysis of the Brazilian economy from energy production to final energy use. Wall (1995) has presented exergy analysis for the Italian society, Swedish society and society of Ghana. These exergy studies have shown how effective and balanced a society is, regarding the consumption of physical resources.

Another application of exergy analysis is in thermo-economic optimization. Gaggioli and Wepfer (1980) have used the concepts of exergy accounting in designing for determining optimal sizing of piping and
insulation. Gool (1987) has suggested that the exergy of the energy carriers is the proper quantity to establish their values i.e. prices should be based on these exergies. Wall (1991), d’Accadia and Rossi (1998) and Dingec and Arif (1999) have done the thermo economic optimization refrigeration plant using heat pump.

Moran and Sciubba (1994) and Rosen (2002) have explained how an exergy balance enables to determine the location, type and true magnitude of the waste and losses. Such information could be used as a tool to devise better processes or design better components, by testing whether their exergy destruction rates are lower than that of the original process/component. Liang et al (2000) have conducted a study on refrigerant circuitry of condenser coils with exergy analysis and found that the coil performance could be improved by varying the refrigerant mass velocity along the flow path. Yumrutaş et al (2002) have investigated the performance of the components of a refrigerator using ammonia as the refrigerant based on exergy analysis.

From the above review of the available literature, it is seen that exergy analysis has been used mainly in the industrial sector to study the resource use and waste emissions and also to optimize the components for maximum efficiency with thermo economic optimization. Only limited literature is available to locate and calculate the exergy losses in a system or in components.

2.4.5 Entropy Added Tax based on Exergy

Based on exergy accounting, Wall (1993), Hirs (1994) and Gong and Wall (2001) jointly have suggested the introduction of exergy tax on the exergy lost/consumed or entropy generated. All waste exergy emissions and
environmental damage could be taxed, proportional to the cost to remove the pollutants or the damage to society due to pollution. According to Rosen and Dincer (1997), an exergy tax encourages recycling, thus checking resource depletion and environment degradation.

Gong and Wall (1997) have reported that the world is facing fast reduction in the deposit of natural resources along with environmental destruction. They suggested the introduction of an exergy tax for the use of non-renewable resources to encourage the use of renewable sources. A manufacturer has to pay exergy tax for using non-renewable resources and emitting exergy as waste to the environment. The income from these taxes could be used to support research and other activities to reduce exergy losses and its impact to the environment. Szargut (2002) has suggested application of exergy for the determination of the pro-ecological tax replacing the personal taxes.

Further to the exergy tax on the use of non-renewable resources and on waste exergy emissions, an environmental tax based on exergy has been formulated and proposed on the components of a refrigerator proportional to the exergy loss due to the irreversibility in the refrigeration cycle, in the present work.

2.4.6 Advantages of Exergy based Environmental Tax

The main advantage of exergy analysis is that the exergy loss could be easily calculated for any system or component, since it depends only on the physical data for the flow and the environment. Environmental tax proportional to the exergy loss in the components of thermal engineering appliances becomes an incentive for the manufacturers to introduce measures to minimize the exergy loss. Another advantage of this environmental tax is
the strong incentive for investors to conserve energy. The main disadvantage might be the temptation that the government might undergo to use this tax to increase the tax burden as pointed out by Hirs (1994).

From the above exhaustive literature review, it is observed that, even though a lot of research work has been carried out on exergy analysis, no result has been reported yet to reduce exergy loss by imposing a suitable tax on the manufacturer or on the industry.

2.5 EXISTING TAX SYSTEM IN INDIA

The different taxes in India are personal income tax, sales tax and customs and excise duties. The constitution of India empowers the Parliament to make suitable laws with respect to taxes on income. The states in turn are empowered to levy state sales tax, entertainment tax, entry tax, etc.

According to Income Tax Department of India (2003), the first Income Tax Act was introduced in 1860. As the Government is interested in taxing the people according to the economic needs of the country, the tax rates are enacted every year, instead of incorporating them in the permanent enactment of the Income-tax Act, 1961. All the Indian States are empowered to impose sales tax on sale of goods, as per the Government of India Act 1935. Bird (1993) has stated that the vision of the Tax Reform Committee (TRC) of India was for a comprehensive Value Added Tax (VAT) to replace excise and state sales tax. In 1991, TRC reviewed the country’s tax system and recommended simplified procedures and a rationalized rate for the introduction of VAT.

Madhu (2000) has pointed out that VAT is an indirect tax on consumption. The origin of VAT could be traced far back to the writings of
F Von Siemens, who processed it in 1918, as a substitute for the German turnover tax. France was the first country to introduce VAT in the year 1954. The Indian popular daily The Hindu (2001) reported that due to the growing interest among Indian States for replacing the complex sales tax system, Government of India was motivating the states to adopt VAT system, which is charged and collected at each stage of the production/processing/trading, on the portion of the value added to the goods sold. Chatterjee (2003) has explained with examples how VAT eliminates double taxation. Another Indian daily The Deccan Herald (2003) published in the news that VAT will have two rates i.e. 4% for necessary items like agriculture and industrial inputs and declared goods and 12.5% for all other items. The Hindu (2005) reported that over 550 items would be covered under VAT being introduced in 2005.

Excise duties are levied under the Central Excise and Salt Act 1944 and the Excise Tariff Act 1985. The Modified Value Added Tax (MODVAT) scheme introduced in 1986 limits the cascading effect of duty incidence on a number of goods. All manufacturers of excisable goods are required to register under the Central Excise Rules 1944 (CMIE 1995). Customs duties are levied on imports at rates specified in the budget every year. Customs duty has been progressively reduced to a maximum of 65 per cent in 1994-95. The Finance Act 1994 witnessed a general reduction in the duty on capital goods, steel, chemicals, drugs, pesticides and project imports. In addition, there are several schemes under which items can be imported at reduced rates of duties.

When the buyer and the seller are from different states, according to the Entry 92A of the Union List in the Seventh Schedule to the Constitution of India, sales tax will be charged under the Central Sale Tax Act 1956. While the Central Sales Tax (CST) is levied by the Central Government, the State
Governments collect it within whose jurisdiction the movement of goods in the course of inter-state trade or commerce has commenced.

India was the first country to insert an amendment into its constitution allowing the states to protect and improve the environment for safeguarding the public health, forests and wild life. The 42\textsuperscript{nd} amendment was adopted in 1976 and went into effect in January 1977. The language of the Directive Principles of State Policy (Article 47) compels the state to seek the improvement of polluted environment (Lynch 2002). India’s initial national communication to United Nations Framework Convention on Climate Change (UNFCCC) from Ministry of Environment and Forest (MoEF 2001) included emissions/carbon/energy taxes as well as provision and/or removal of subsidies in the national mitigation policies.

2.5.1 Environmental Tax Methods and Procedures Followed in Different Countries

It was reported in TEDDY (2000) and by Kete and Kevin (2000) that the climate change due to the environmental pollution was recognized as a major global concern at the First World Climate Conference (FWCC) held in 1979 as is also reported in Parivesh (2002). Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 to assess the seriousness of the problem and recommend policy instruments. In 1991 negotiations began for a global treaty on climate change, which came to be known as the Framework Convention on Climate Change (FCCC). The ultimate objective of FCCC was to achieve stabilization of Green House Gas (GHG) concentration, without affecting the food production and economic development, in a sustainable manner. This was adopted in the United Nations Conference on Environment and Development (UNCED) at Rio de Janeiro in 1992 and came into force in 1994. All the countries that ratified or acceded to the UNFCCC are
responsible for keeping international efforts to address climate change. They have formed an association called Conference of Parties (COP). The first meeting of COP was in Berlin in 1995 and then onwards, they meet every year to review and examine the commitments of parties in light of the convention objectives. COP 8 was conducted in Delhi, India in 2002.

Vanden et al (1997) have reported that Rio convention in June 1992 called upon the developed-Annex 1 countries to stabilize their greenhouse gas emissions at 1990 levels by 2000 and to move towards quantified emission limits and reduction commitments. It was clear by 1996 that neither the USA nor the European Union (EU) countries would reach the target. The parties to FCCC adopted a historical Protocol at Kyoto, Japan in 1998 and established a few international mechanisms like Clean Development Mechanism (CDM), Joint Implementation and International Emission Trading to achieve reduction targets (Halsnees 2002).

In 1992, India signed the UNFCCC as a non-Annex 1 country, meaning it is not obliged to reduce its emissions of GHG. India ratified the agreement in 1993 and accepted the Kyoto Protocol in 2002. Gupta (2001 and 2002) reported that the Kyoto Protocol did not mandate legally binding reduction targets for developing countries, given their low contribution to the problem. The USA, where the per capita emission is equal to that of 20 Indians said that they would consider ratification of Kyoto Protocol only if India, China and Brazil took on legally binding commitments. Revkin (2003) and Walsh (2004) have reported that Russia could not ratify the Kyoto Treaty because of its negative implications on the economic growth.

Baranzini (1997), Babiker et al (2000) and Holtsmark and Ottar (2002) have explained the taxes and tradable permits based on the functioning of the market, and on the assumption that, once the market is
corrected, it will take care of the atmosphere. Taxes act primarily on the price side of the market, whereas tradable permits affect the quantity of allowed emissions. Milne (2002) has stated that people always think taxation has nothing to do with environment because most of the taxes are introduced to raise the revenue needed by the governments. Governments get involved in the environmental matters only to protect the interest of the people. Review of the available literature has been extended to the environmental taxes like carbon tax and other waste and emission taxes already introduced in other countries.

2.5.2 Carbon/Energy Tax

Siddayo and Perceboil (1994) have explained the fuel switching, pollution prevention and the polluter pay principle as policy strategies in efficient use of energy. Carbon tax in the polluter pay category could lead to efficient use of energy as well as reduced CO$_2$ emissions.

A brief discussion about the countries, which have introduced carbon tax, is presented here. Finland was the first country in the world to introduce carbon tax in the year 1990 according to the report by Määttä (2002). Norway and Sweden introduced carbon tax in 1991 (Kristofferson et al 1997 and Godal and Holtsmark 2001). Roodman (1997) has said that Denmark introduced energy tax and CO$_2$ tax in 1992 and sulphur tax in 1996. Edie Weekly (2002) has reported that Australian carbon dioxide tax is sufficient for the government to provide funds to supplement the pension for all the adults in the country.

Developing countries depending on coal for their energy, felt that carbon tax could hinder their development. According to Balshaw (1995), the Victorian Government branded carbon tax as regressive and would suffocate
the nation’s economic recovery and result in increase in electricity prices for Victorians. Italy and France wanted tax breaks on diesel until the end of 2004.

The following reports show that the countries like Japan, UK and New Zealand are planning to introduce carbon tax in later stages only. Nakata and Lamont (2001) have reported that Japan should develop suitable clean coal technologies to replace coal-based technologies. Down to Earth (2002) and Yomiuri (2003) have pointed that Japan is planning to introduce coal tax from 2005–2007, to achieve the target of reducing green house gas emissions by six per cent below 1990 levels under the Kyoto Protocol. Gordon (2002) has explained that UK has aimed to cut its greenhouse gas emissions by 12.5 percent by 2010, in line with the Kyoto protocol to curb global warming. But it could fall short of this goal unless a tax is imposed on all CO\(_2\) emissions and a system of tradable permits launched. Murali (2002) has reported that New Zealand produces 70 to 90 Million tonnes of carbon dioxide a year. He also said that New Zealand announced the introduction of carbon tax after 2007, in order to move towards the climate change agreement.

The measures adopted by the USA to reduce greenhouse gas emissions, instead of carbon tax are as follows. Fiacco (2001) has questioned the purpose of Kyoto Protocol saying that it does not serve the save-the-earth environmental aspirations. He has pointed out that Kyoto Protocol exempts nine of the top 20 emitters of CO\(_2\), including China and India. Jacobs (2001) has stated that quantity of carbon in the atmosphere, which is about 780 Gt has been increasing by about 3.3 Gt per year and explained the following approaches to reduce CO\(_2\) emissions:

(i) Using energy more efficiently.
(ii) Use hydrogen as fuel, produce energy from hydro, solar and nuclear.

(iii) Carbon sequestration.

Abraham (2003) has said that either greenhouse gas reductions will come at the expense of economic growth and improved living standards or as a breakthrough in new energy technologies to reduce emissions. The US governmental agencies are trying to develop revolutionary technologies for transforming energy production and consumption. The technologies are research on carbon sequestration, which involves permanently storing carbon dioxide from the atmosphere in underground formations and the development of hydrogen fuel, transforming the economy to hydrogen based. Other programs in the USA include energy conservation and increased energy efficiency, use of clean renewable and nuclear energy. Baltimore (2003) has published the proposal of clear skies in the USA that would cut emission of sulfur dioxide, nitrogen oxide and mercury by 70 percent by 2018.

Developed countries like the UK, Japan, New Zealand and developing countries like China and India whose economies are based on coal are yet to introduce carbon tax. The USA is planning for measures to transform its economy to hydrogen based and also for carbon sequestration. Based on the above observations it could be concluded that introduction of carbon tax may be delayed or may not take place in the near future in the above countries.

2.5.3 Waste/Other Emission Taxes

Environmental tax minimizes generation of environmentally harmful waste and emissions, discourages consumption of emission intensive
products and promotes recycling. Roodman (1997) has discussed the tax on toxic waste, tax on CFCs and heavy metal emissions. The Netherlands introduced tax on industrial emissions of heavy metals since 1976. This has reduced the leakage of cadmium, copper, lead, mercury and zinc into canals and lakes and made the country a global leader in water pollution control technologies. Australia, Denmark and the USA have introduced tax on CFCs as required under 1987 Montreal Protocol. CFCs were phased out in these countries in less than a decade. Germany has cut the production of toxic wastes by using the waste taxes. Sweden introduced tax on nitrogen oxide emissions from power plants generating a minimum of 50 GWh, in 1992. The tax revenue is given back to the power plants in proportion to the amount of electricity generated and contributed crucially in halving the emissions in the early 1990’s (PMO 2001).

Morotomi (2002) has reported that Japan wanted to find new revenue sources, because the existing revenue based on income or profit have fallen drastically since the early 1990’s. According to the legislation in the year 2000, local governments introduced industrial waste tax from 2002. Its revenue has been earmarked for recycling and avoiding industrial waste in Japan.

2.5.4 Environmental Tax Shift

The report of the Australian Conservation Foundation (2000) and the report filed by Johansson (2003), shifting taxation away from environmentally and socially sound practices and placing it on polluting and environmentally damaging practices, provide enormous potential for environmental protection, while simultaneously boosts up jobs and economy. A range of overseas and Australian studies and evidence from a number of European countries support this conclusion. Goodman and Reynolds (2001)
have proposed an innovative approach to the environmental tax policy in Massachusetts as Environmental Tax Shift (ETS). The basic idea of ETS is to tax things we want to discourage like generation of pollution or waste rather than raising revenue by activities that are to be encouraged like income, savings or labour. The idea was to find different ways to raise the revenue needed in Massachusetts, while protecting the environment. The ETS has been introduced in several European Countries. Some Canadian provincial governments are having discussions as well. The environmental tax is imposed on a product proportional to the amount of pollution generated by the product. The government decides the price of the product and informs the producers and consumers. This approach makes the pollution intensive products more expensive and gives incentives to invest in alternate technologies, practices and resources, which produce less pollution.

2.5.5 Purpose of Environmental Tax

The environmental tax serves different purposes like change in behaviour of the producer and consumer, which would result in reducing emission, better air and water quality, enhancing public health and helping in improving the production technologies to minimize emission. According to Parry and Bento (1999), Dincer and Rosen (2001) and Patuelli et al (2002), minimizing the emissions and improving the environment is the first dividend from the environmental tax. A considerable reduction in income tax and labour tax could be achieved by taxing the pollutants, which is the second dividend. The attractiveness of ETS is its revenue neutrality i.e. reduction in existing taxes exactly equal to the new taxes on pollution and other environmentally harmful activities. Another approach is to use the revenue or portion of the revenue for giving subsidies for technological progress and for new cleaner technologies, practices and inputs.
According to Goodman and Reynolds (2001), the time has come to reform the tax system in ways that support our environment and economic goals. At the same time, it will generate the required revenue to the government. The European Commission — the administrative arm of the EU has suggested that EU wide tax on carbon emission and energy use may be dedicated to cutting payroll taxes and thus facilitating an estimated 1.5 million new jobs to be created.

Even though the per capita emissions are low in India, based on the present environmental status and the devastating effects of environmental degradation, introduction of environmental tax is the right choice for a developing country like India whose development is mainly dependant on cheap domestic coal, which is of high carbon content and low calorific value. Therefore, two environmental taxes are discussed and proposed based on LCA and exergy. LCA and Exergy Analysis provide the information about the emissions and the losses in the system/components by a systematic analysis. The environmental tax will be an incentive for minimizing the emissions/losses by introducing proper design modifications in the system/component.

2.6 CLOSING REMARKS

Having done an extensive study of the available literature, it is seen that a lot of work has been done on LCA and exergy. In most of the available literature, LCA is mainly used for finding out the most eco-friendly products and process by Eco-labeling. Also LCA is used for design of products and processes by Eco-design to make them more environmental friendly. No attempt is made for the formulation and implementation of an environmental tax based on LCA. Similarly exergy analysis is used to find out the location and quantity of exergy loss in system components as well as in a society.
Some suggestions are available in the literature about the introduction of an exergy based tax for the use of nonrenewable energy resources in order to encourage their conservation. Suggestion has been made in the present work for the introduction of two new environmental taxes based on LCA and exergy with a case study for a refrigerator, one of the widely used thermal engineering appliances.