2.1 INTRODUCTION

With the rapidly shrinking resources of fossil fuels and the growing accent on sustainable and cleaner energy generation, considerable attention has been given to design and development of appliances and gadgets for harnessing solar energy in recent years. In what follows, the various studies and reports on the following aspects of the energy scenario that have appeared in the past, are reviewed:

- Global and Indian focus on renewable energy (RE) deployment and the problems and prospects that have emerged
- Solar energy, its relevance in RE applications and barriers faced in effective utilization
- Solar thermal applications, development of domestic solar water heaters and the barriers for their diffusion
- The application of product development processes including the capture of the voice of the customer (VOC) and the applications of conjoint analysis as a tool
2.2 STUDIES ON GLOBAL AND INDIAN FOCUS ON RENEWABLE ENERGY DEPLOYMENT AND THE PROBLEMS AND PROSPECTS THAT HAVE EMERGED

Loock (2012) has observed that investors prefer a “customer intimacy” business model which provided for better services than better technology or lower prices. This study has advocated service-driven business models for renewable-energy. It has recommended a focus on customer needs. In respect of the United Nation’s “Millennium Development Goals”, Kaygusuz (2012) has opined that lack of access to energy might hamper the achievement of the goals in time. This study has indicated that lasting energy security and a sustainable environment require use of more efficient and economical clean energy technologies. It has also observed that lack of awareness and a sense of apathy in respect of clean energy appliances among the consumers are barriers to a better deployment of various forms of energy.

The need for a closer and mutually beneficial cooperation between China and India in the development of renewable energy sources has been highlighted by Liming (2007). Liming (2009) in a later study has compared the financing of renewable energy in rural areas between China and India resulting in several similarities in the pattern and quite a few dissimilarities, which could lay a ground for collaboration.

While acknowledging that the world is slowly moving towards sustainable energy and environment, Stanford (1997) has advocated a more rigorous regulatory approach in meeting the greenhouse gas reduction targets needed to slow down climate changes. This study has opined that the excellent opportunities offered by the liberalization of economy must be seized to reach larger customer base. It has favoured the energy industry to show people that there is a choice and that there is a good market for renewable energy. Naidu (1996) has suggested a level playing ground in
terms of funding, institutional support, and tariff for an acceptable pricing. It has also suggested increased efforts in R&D and the levy of a sustainability tax on the energy from non-renewable conventional sources towards funding the research efforts.

Panwar et al (2011) have provided an overview of the developmental efforts in respect of CO$_2$ mitigation, while pointing out the advantages of solar power generation in terms of the carbon emission. Where the goal is to maximize renewable energy generation, Oliver et al (2001) have recommended a fixed incentive or set aside policy towards future cost reduction of related technologies.

Improvement and refinement in RE technologies, according to Banos et al (2011) would considerably assist sustainable development and might provide solution to several energy related environment problems. Towards this it has come out with an optimization algorithm for the energy systems. Bhide & Monroy (2011) have acknowledged that a large number initiatives by the Indian government have been carried out, but fault the unrealisable targets set in terms of developmental goals and projected reduction in energy poverty, integrated efforts by the central, state, and local agencies has been found lacking to achieve significant results.

Lior (2010) has concluded that wind, solar-photovoltaics, solar thermal, and, to some extent biomass, would be the promising main technologies for continuing vigorously with RE application while creating great opportunities for engineering and scientific communities leading to innovation, creativity, job-creation and entrepreneurship. This has followed the earlier findings of Lior (2008) that the developing scientific principles should be converted into applicable solutions leading to major environmental, economic and social impact.
Justification for the use of renewable energy systems for different applications has come from the study of the Indian RE scenario by Boparai (1998). This study has highlighted the hurdles in respect of the cost, attitudes of users and the policy makers’ commitment to stop environmental degradation. It has also suggested an integrated approach by the Government, research establishments, user industry, financial institutions and non-profit organizations committed to the cause.

Reddy & Balachandra (2003) have recommended an element of compulsion on lines of the other regulations of safety, etc., which might be required for more effective compliance, especially in the case of developing countries which have been currently undergoing transformations in respect of improved quality of life. Such regulatory measures are sought to supplement other measures like awareness creation, financial and technological help, etc., aimed at higher energy efficiency. This report has recommended a ban on use of coal containing more than 1% sulphur as has been followed in some developed countries.

The need for better management of the energy systems has been emphasised by Jagoda et al (2011) on the energy scenario in Canada. Increasing concerns on the environmental degradation, and the need for reduction of greenhouse effects has necessitated this focus. This study has pointed out the relevance of solar thermal applications, especially for heating the water in severe cold climate. Innovative and collaborative efforts between all the stakeholders, viz., user community, industry, and public policy makers, leading to attainment of common objectives in effective energy utilization. This study has also touched the need for effective commercialization and greater diffusion within the frame work of the national innovation policy for creating a better market condition.
Technological development, economic development and human development go hand in hand for improving the quality of life. However, rapid advancements in technology while ushering in a related economic growth have not brought in a corresponding human development. As energy consumption is sought to be linked to economic growth as an indicator, some issues related to environmental degradation and climate change crop up. The advent of sustainable energy technologies (SET) has sought to correct this anomaly. Balachandra et al (2010) have raised the issue of slow diffusion of these technologies on account of viable efforts in their commercialization. It has pointed out that a paradigm shift from purely governmental initiatives and support these technologies should move towards market based ones. This study has also recommended the use of ‘Diffusion Theory’ for a systematic customer centred approach to development of these technologies with a greater chance for commercialization. This study is novel in the sense that it has advocated a product-process development approach to bring in a better diffusion.

The considerable shortfall in the cumulative adoption of renewable energy from the estimated potential in India has been highlighted by Chandrasekar & Kandpal (2007). Slow pace of appropriate technology development and lack of appropriate strategies for awareness creation have been attributed to this slow pace of diffusion.

Some suggestions on effectively overcoming the barriers to renewable energy diffusion, arising out of market conditions, economic and financial factors, institutional problems and the technology, have been given by Painuly (2001). This study has pointed out the need for effective understanding of the mind of various stakeholders like consumers, non-governmental service organizations, policy makers, other experts in the field
and professionals. It has recommended a resort to marketing research tools like structured interviews, questionnaires, etc.

Kablan (2003) has indicated a possible saving of over 40 million US Dollars in capital expenses through solar water heating in the place of the traditional LPG stoves in a study on the situation in Jordan covering the period from 2001 to 2005. The scope and relevance of pilot plants for demonstration and testing of the relevant new energy technologies and for showcasing the economic and technical feasibility has been analysed by Reddy & Painuly (2004). This study has argued that the government support in establishing such pilot projects would provide needed impetus to the private sector players, considering the costs involved and the risks faced.

Suggestions on involvement of the consumers and end users, through promotion of appropriate self-help groups forming a social network for promoting innovative ways of newer technological ideas have been proposed by Ornetzeder & Rohracher (2006) in respect of energy generation and consumption.

2.3 STUDIES ON SOLAR ENERGY, ITS RELEVANCE IN RENEWABLE ENERGY APPLICATIONS AND BARRIERS FACED IN EFFECTIVE UTILIZATION

Mills & Schleich (2009) have talked about the prevalence of regional clusters in the use of solar thermal technologies in Germany for heating water. They have pointed out the effectiveness of the newly laid mandatory requirements for newly constructed homes compared to the effect of subsidies.
In a recent review of the policies on solar energy world over, Xie et al (2012) have commented China’s efforts in becoming the largest producers of solar water heaters. The Government’s policies and the legislations that resulted in a decade have succeeded in the use of solar thermal energies in civil buildings. This study has also referred the efforts of many more Governments in formulating and adopting friendly policies towards adoption of solar thermal energy.

Solangi et al (2011) has also referred to the inevitable moves by various Governments in formulating solar energy policies that would go a long way in mitigating the adverse climate changes by changing over to environment friendly energy alternatives.

A good review of the various solar thermal technologies and the innovative developments leading to them has been brought out by Thirugnanasambandam et al (2010).

Towards economic manufacture of solar collectors through cost reduction several initiatives have been taken. An extensive review of these initiatives and the progress made is available in the report by Sen (2004). It has pointed out the concept of new product development through value addition for the same cost. It has also pointed out the cost advantages of mass manufacture compared to batch processes thereby reducing labour cost. This study has suggested looking at alternative collector materials to reduce the cost.

The relevance of innovative and more efficient manufacturing processes brought in by competent and leading industries has been sought to be highlighted towards overcoming managerial and economic barriers, while recommending continuance of existing government subsidies by Dorf (1984).
Similarly Zhang et al (2012) in respect of Hong Kong, have identified the barriers to diffusion of solar energy applications in that country.

2.4 STUDIES ON SOLAR THERMAL APPLICATIONS, DEVELOPMENT OF DOMESTIC SOLAR WATER HEATERS AND THE BARRIERS FOR THEIR DIFFUSION

Ogueke et al (2009) have showed that the economics of passive systems in view of the lower cost and the easiness in installation for domestic use and where demand on load is low. This review has also suggested an augmented R&D efforts towards improving the efficiency of the system. Jaisankar et al (2011) have discussed the various efforts in increasing the thermal efficiency of the solar water heater and the techniques used for improving convective heat transfer. This review has recommended sustained research on solar water heaters that use thermosyphoning. The dependence of efficiency on the collector has been discussed in a survey on various solar thermal collectors by Kalogirou (2004).

Use of heat pipes to cool flat-plate collectors has been suggested by Hammad (1995), in an experimental investigation on the comparative performances of the cooled collectors with the regular collectors. It has also discussed the various advantages of the heat-pipe cooled flat plate collectors.

Using the F-Chart method of analysis for designing active and passive solar heaters, Ammar et al (1989) have demonstrated a method for determining the optimal parameters and compared it with results from TRNSYS, a transient systems simulation program. The two methods have yielded very close results.
Evidence of an optimal value for storage tank volume at a given tank height and high load temperature has been demonstrated by Shariah & Lof (1996) using a transient simulation program. The TRNSYS simulation program has also been used by Shariah & Shalabi (1997) for optimal design of a thermosyphon solar water heater for some regions in Jordan, which shows that with the optimal choice of the parameters nearly 10 to 25% increase in solar fraction can be obtained.

While the flow rate in thermosyphon solar water heaters are directly related to the relative height between the collector and the storage tank Zerrouki et al (2002) have found negligible effect on the system efficiency on account of an increased flow rate.

Significant effects on the heater performance have been found due to the tank volume collector area ratio and the ratio of the tank dimensions in the conventional FPC water heaters by Hussein (2003) on two-phase natural circulation in those heaters. There is no pronounced effect on the same due to the height between the heater tank and the collector. This study has also looked at optimal parameters. Optimization study has also been undertaken by Badescu (2006) in respect of the structure and size based on economical indices like net present value and rate of return. This study has pitched for the use of unglazed and single/double glazed collectors for optimal performance.

An experimental analysis of the long term performance characteristics of two phase thermosyphon system by Chen et al (2009) have showed an 18% increase in the efficiency of the system compared to conventional ones. Incorporation of twisted tapes to cause a swirl to promote turbulence has been suggested by Kumar & Prasad (2000). Experiments carried out have showed an increase of 18 to 70 percent in heat transfer rate and a change in pressure drop by appreciable amount.
One of the problems associated with performance degradation of solar water heaters is that of scaling. A number of studies on the effects of scaling on the performance are available. Arunachala et al (2010) have provided a quantified view of effects of scaling on parameters like instantaneous efficiency, mass flow rate, and overall heat loss. Reduction in mass flow rate and instantaneous efficiency by appreciable amounts has been reported in this study.

For flat-plate devices a one-dimensional simplistic model has been developed by Cadafalch (2009) which can be used for analysing different configurations with different components in terms of multiple glazing, insulations, air gaps, etc.

The influence of the types of cover plates and their numbers, and the top heat loss, on the optimal performance of FPC heaters has also been experimentally investigated by Dagdougui et al (2011) in Morocco. Single and double cover plates made of glass, plastic and plexigals. The investigation has revealed the use of double cover plates to reduce the top heat loss. A combination of glass and plexigal has been used to improve the performance.

The harmful effect of humidity on the service life of absorber coating has been discussed by Holck et al (2003). A simulation program to account for micro-conditions inside the collector has been developed by taking into account different collector configurations which include location and size of ventilation holes. Design optimization taking into account the micro-climatic conditions is possible with this program.

There have been several discussions on the comparative merits of conventional glazed FPCs and evacuated tube collectors. A study by Zambolin & Col (2010) comparing the thermal performances of the two has predicted a higher efficiency in the case of the latter, other conditions remaining the same. On the comparison of storage versus conventional
systems Khalifa & Jabbar (2010) have identified a higher performance in storage systems in respect of higher temperature difference, instantaneous efficiency and heat removal factors. This study has also provided experimental verification of theoretical predictions.

There are several variations in the shapes of the heaters which have been considered. A system with pyramid shaped frustum with integral design of collector and storage tank has been proposed by Rehim (1998). Use of Tar coated collector has been suggested by Ammari & Nimir (2003). It has been found that the conventional collectors has definite advantage over the other one, though in the late afternoon the heat conservation in the latter has observed to be better leading to outflow of warmer water for later use. For the applications like space heating and desalination use of parabolic trough collectors has been suggested by Fernandez-Garcia et al (2010) for more effective capture of solar energy.

Alvarez et al (2010) has proposed a corrugated channel FPC to provide for a larger contact surface with the heat transfer fluid. Numerical analysis has indicated that the corrugated model has performed better than the commercially available tube and fin type collectors and has provided higher mean tank water temperature. A dual purpose device with simultaneous water heating and air heating has been investigated by Assari et al (2011). Their experimental study has shown that, the collector plate with a V-shape made by two sections, are more efficient than individual single purpose collectors.

A novel design using black coated spiral tube acting as a collector inside a cylindrical body has been proposed by Al-Madani (2006) who has also undertaken an experimental investigation on the same. Based on these results he has recommended cylindrical solar water heater as a cost effective innovation compared to FPC heaters.
A low cost version of solar water heater using uncovered flat panels made of rigid PVC and a storage tank made of polythene coated with polystyrene has been designed and tested by Siqueira et al (2011). The results have showed a smaller thermal efficiency despite a reasonably good global heat transfer coefficient obtained, compared to conventional solar heaters.

Use of tubes made of thermoplastic natural rubber as absorbing elements in solar collectors has been suggested by Sopian et al (2002) towards reduced weight, economical construction and for corrosion resistant and maintenance free operation. An output temperature up to 65°C is reported to have been obtained with this construction.

A recommendation for use of black chrome plated collector surface with underlying insulation with low density PU foam has been given by Lu et al (2003). This is due to the possibility of a higher preservation of heat combined with lower cost. This study has also analysed the optimal design parameters using Taguchi method for such a design.

An innovative idea of using nickel-aluminium alloy particulates, dispersed in commercial black coating for the collector plates has been suggested by AlShamaileh (2010). A higher absorption rate has been reported in this study for such a coating. The added advantage lies in improved corrosion resistance.

On the relevance of solar water heating towards sustainability one of the points discussed is the advantage in terms of reduced electrical consumption. Berbash et al (1995) have indicated that the savings is proportional to the load, and to make an effective case, the increase in thermal load should come from enlarged consumer base for the best impact of solar thermal energy. This study has also recommended more focussed and
effective campaigns for increased customer awareness of the technology. It has suggested direct marketing and use of the media.

A suggestion on the use of compound parabolic concentrator has come from Santos- Gonzalez et al (2012) and has provided a numerical tool for the design of the concentrator. The use of phase change materials in solar water heaters has been investigated by Shukla et al (2009). The PCM thermal storage has been showed to provide a faster warm up in the mornings and higher temperatures on cloudy days.

Considering the through the year performance of natural circulation domestic heaters in India, Nahar (2003) has provided some design justification in terms of the retention of the heat overnight with an average efficiency of over 50%.

The difficulty in enhancing the diffusion in local markets in Greece Kaldellis et al (2005) have showed some pessimism on account of the techno-economic imperatives of the effect of penetration of cheaper natural gas applications. It has opined that considerations arising out of climate change might move the market towards domestic solar water heating systems.

Societal responsibility in ensuring sustainable environment has been highlighted by Li et al (2011) while investigating the economics of solar water heating in residential buildings in China. The dependence of their diffusion on development of clusters, innovation towards market leadership, local Government and industry relationship, locational advantages and consumer awareness have been analysed in this study.

A framework for assessment of the market potential and for promoting the use of solar water heaters in a city block has been proposed by Pillai & Banerjee (2007).
Better public awareness, role of the media in promoting the products, effective standardisation and quality control measures generally act as the drivers, while socio-economic factors bring in the constraints, according to Sidiras & Koukios (2004) while analysing the situation in Greece. This study pointed out the beneficial effects of emerging business opportunities, greater environmental concerns and developing consumer designer interface.

A design for a multipurpose solar gadget to act as both water heater and a cooker for generating 50 liters of hot water in a temperature range of 55\(^0\)C to 65\(^0\)C, capable of cooking 4 kg of dry food in a day has been suggested by Nahar (1998) at a low cost. This study has discussed its market opportunities in extremely dry regions.

An integrated solar louvre with water heating has been proposed by Abu-Zour et al (2006) which experimentally demonstrates a very promising performance of this new design on account of more efficient heat transfer mechanism.

While investigating the relative merits of non-concentrating and concentrating collectors, Nkwetta et al (2012) have found that concentrated evacuated tube collectors generate a considerably higher thermal differential between outlet and inlet water temperature compared to non-concentrated ones, ranging from 25 to 30 \%. Chen et al (2010) through appropriate tests on both non-glass and glass vacuum tube collectors have showed that the heat loss in the case of the latter is 15\% higher. This study has also proposed an analytical model which indicated the marginal effect on total heat loss under diffusion dominated heat transfer conditions on account of evacuation.
A FPC system with an auxiliary natural gas heating has been showed to provide the best performance among various alternatives considered by Hang et al (2012) in the US. This study has considered the following configurations and their combinations. Flat plate and evacuated tube collector, auxiliary heating through natural gas and electricity, and locations in Los Angeles, Atlanta and Chicago. Typical residential buildings have been taken into consideration along with perspectives on energy, economics and environmental effects. This study has brought in the concepts analogous to the use of morphological alternatives in product development.

In India the rural areas have not seen much of deployment of solar water heaters and hence provide potential markets for the same. An analysis of the prospects and problems in developing these markets have been brought out by Veeraboina & Ratnam (2012). This study has criticized the lack of an independent energy policy and the dependence of markets on the urban middle-class and upper-class households. It has also suggested adoption of policies like effective and mandatory building sector policies, carbon footprints, energy consumption, etc. and has called for more stringent legal framework.

A number of designs and studies on integrated solar water heaters, with absorption of energy and storage of heated water happening in one unit, have been undertaken by several authors, some of which are reported in the work on corrugated absorber surface by Kumar & Rosen (2010). This work has produced higher operating temperature for longer durations. A marginal reduction in the efficiency, however, has also been reported.

Four water heating systems in vogue in Hong Kong have been compared in terms of their utilizations on the potential application of solar thermal technology for heating water by Li & Yang (2009). The systems considered use of electricity or town gas or solar assisted heat pumping or the
conventional solar water heaters. This study has provided an economic comparison of these different water heating systems. It has also demonstrated the economic benefits of solar water heater systems and their high potential in that country.

Kim & Seo (2007) have showed how parameters like the geometry (shape of absorber), solar incidence angle, and the collector tube arrangements affect the thermal performance of evacuated tube collectors.

2.5 STUDIES ON THE APPLICATION OF PRODUCT DEVELOPMENT PROCESSES INCLUDING CAPTURE OF THE VOICE OF THE CUSTOMER AND THE APPLICATIONS OF CONJOINT ANALYSIS AS A TOOL

To sustain businesses and grow in a highly competitive market it is necessary to bring newer products to market in shorter times. The time constraint in turn demands acceleration approaches to New Product Development (NPD). Nine such acceleration techniques have been in use, ranging from involvement of suppliers through effective supply chain management, bringing in users in the early stages of design through lead user involvement, concurrent approaches to speed up activities and tasks, use of value engineering approach towards reduction of parts, better cross function team deployment, effective training and enthusing reward systems for employees, good support systems, simplifying organizational structure and focus on customers, have been taken up for a study by Langerak & Hultink (2005). In this study of 233 manufacturing firms several interesting findings have emerged. It is interesting to note that two of the techniques studied relate to involvement and an understanding of the customer in product development.
For new products belonging to well defined low risk categories, Ozer (1999) has recommended a preset market study to test the marketing variables in a reasonably shorter time. This survey of new product evaluation models in use has recommended dropping the development in the early stages in case of negative returns on investment or if there is no possibility of positioning the product in the market.

In a comparison between product development processes followed in the US and Germany, Gupta et al (1992) have pointed out the lack of emphasis on the speed to market in the case of the former. Conjoint analysis has been used in this study. The usefulness of market simulation studies in respect of a company’s products and of the competitors’ has been highlighted by Walker (1993) on cost effective product development. This simulation has taken into account the project plan, product attributes, product performance and attribute cost in the computer modelling.

The influence of company’s in-house capabilities in customizing new products to ensure greater customer satisfaction is the subject of a study by Du et al (2006). It has recommended including a wider range of customer preferences to provide for diverse individual needs and an assessment of customer value by a variety of utility measurements on perceived quality and cost in terms of product features. It has also perceived the effectiveness of conjoint analysis in quantifying many elements of customer utility as it provides for mapping of functional requirements into the engineering characteristics in the conceptual design stage. Within the constraints of project cost and time development of fit products which ensure greater customer satisfaction has been possible through customer oriented and product focussed design process, according to by Elliott (2000).
Some early attempts at looking at issues related to product life cycle management are in evidence. Herrman et al (2000) has stressed the importance of linking quality management to customer needs and satisfaction in a study on market driven product and service design. This study has resulted in an increasing focus on the incorporation of the voice of the customer through appropriate engineering characteristics in developing a house of quality in quality function deployment (QFD).

Increase in the deployment of shared knowledge by design engineers towards bringing in clarity on product targets, especially in respect of the customer needs, resulting in enhanced productivity has been highlighted by Hong et al (2005). This work has given an insight on the role of cross functional approach in product development.

For a given combination of product, customer and market factors, prediction of purchase behaviour of customer, estimation of lifetime value for the customer in respect of the product, and other related factors involves a dynamic decision making support system. Chan & Ip (2011) have recommended emphasis on these towards formulating effective marketing strategies through an understanding of the customer behaviour.

Perception of newness of the product in the market considerably influences the choices of the early adopters aiding product diffusion, according to a study by Cestre & Darmon (1998) which has set out to assess consumer preferences for new products. This has been done by way of observation of interactions of consumers with the product features.

The earliest of application of conjoint methods have come from the work of psychologists and statisticians Luce & Tukey (1964). McFadden (1974) has brought in the application to econometrics through discrete choice methods. Their application in the design of product platforms have come later
through the contributions from Moore et al (1999). It has showed that consideration of individual products result in sub-optimal decisions on purchase while consideration of product platforms have significant advantages. In cases where the technology is more vital to a company than to an individual product or product feature, importance varies considerably across markets, and there is a danger of sub-optimality.

The need for using complex combinatorial analysis in the case of selecting from multiple choices is emphasised by Kohli & Krishnamurti (1989) in a study on optimal product design using conjoint analysis. A deterministic consumer choice has been assumed in this work. This study has recommended futuristic research in probabilistic analysis in respect of utilities of choice sets and multi-attribute cost estimations.

A price reaction model using a game theory approach for modelling competitor’s reaction to pricing has been suggested in a conjoint based product design by Choi & DeSarbo (1994) through the conjoint simulator.

Conjoint analysis has been used by Yoo & Ohta (1995) to look at optimal pricing and product planning in case of multi-attribute new products. This has been based on utility values of the attribute levels. A full-profile approach for rank ordering of preferences obtained from consumers has been used in this study.

The inadequacy of overall simple multinomial logit model in modelling joint participation and activity choices has been pointed out by Dellaert et al (1996). This study has found negligible differences between participation choice and activity choice which could be structured in an overall nested logit model.
Different kinds of formats (full profile and partial profile) and differing procedures (manual, computer assisted optimization, computerized randomization) used in design optimization through choice based conjoint analysis have been reviewed by Chrzan & Orme (2000). This study has made comparisons in terms of capturing the effects of the various strategies used by choosing three products from manufacturers.

Two methods, viz., segmentation by fuzzy clustering, and a mixed version of ANOVA using conjoint and consumer variables together have been used by Naes et al (2001) for identifying market segments. The fuzzy clustering has been done along with logistic regression of membership values against consumer attributes. The results of the two methods have showed to compare well with each other.

Aggregate models could be more useful in predicting market shares as heterogeneity introduces problems in generalized predictions for the whole market. This has been the result of a study by Natter & Feurstein (2002) on real world performance of choice based models. Ordinary Least Squares Regression (OLS) has been regularly used along with ratings-based conjoint questionnaires to determine part-worth utilities. In this method product attributes become the independent variables and the ratings are the dependent variables. When the respondents are shown only a few product or service concepts at a time, to find their choices, we have the choice-based systems. A cross validity comparison of these two systems has been done by Moore (2004). Some analytical methods for a refined estimate of preferences from the CBC (choice-based-conjoint) have been used which include logit, latent class and hierarchical Bayes (HB) analyses. This work has indicated that the HB models have a higher hit rate. A similar study by Karniouchina et al (2009) have also indicated the advantages of HB Choice-Based Conjoint models over the others. However it is pointed out that some enriched attributes like brand
name assume significance in rating-based models, while attributes like pricing have been found to be more important in choice-based models.

Halme & Kallio (2011) have compared five other methods with the HB method and pointed out the lack of such comparative studies. This work has compared four already published optimization based procedures and a method newly introduced viz., ‘Convex Penalty’ minimization (CP) method with the HB method. Eight field data sets have been taken up for the benchmarking study and go on to show the superiority of the CP method over the others. However there is a good comparison in the estimates provided by the CP and HB methods.

2.6 CONCLUDING REMARKS

A comprehensive review of the literature cited above point out the various developments in the area of changing energy policies of the governments, the effects of the conventional energy systems on the climate and the environment, the relevance and significance of new and renewable forms of energy, the barriers to their advancement and their diffusion, the role of new product developments in enhancing their diffusion, the need for understanding the needs and preferences of the consumers, and the marketing research methodologies for capturing the voice of the customers. While there is enormity of research pertaining to the energy systems and their utilization, very few studies are available on the relevance of application of NPD processes for promoting the use of renewable energy technologies. Still fewer research articles are available for incorporating the various tools of the fuzzy front end of product development, like conjoint analysis, in an effort to augment the diffusion of the RE products in the market. Based on the important observations from the literature review, the background and objectives of the current research work have been identified and elaborated in chapter 3.