ICTSD Programme on Trade and Environment

Mapping Climate Mitigation Technologies and Associated Goods within the Buildings Sector

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Executive Summary

The study focuses on the context of the scope of different strategies for carbon emission reduction from existing and new R&D technologies in the residential and commercial building sector of the developing countries. In order to do that it highlights the range of technologies and goods which could be applied in the residential and commercial building sector for reduction of carbon emissions. With this regard, a specific mention on energy efficiency measures is given on the residential and commercial building sector of the developing countries with a purview of the global situation. The study shows that carbon emissions from residential and commercial buildings of developed countries have been higher than the level of emissions in the same sector from developing countries. For a convergence in carbon emissions between developed and developing countries, it is essential to mitigate carbon emissions from the residential and commercial building sector of developing countries also. In order to achieve the path of carbon emission reduction in the residential and commercial building sector of developing countries, carbon mitigation goods and technologies would be required. Already many technologies and goods are commercially available in the developing countries to address energy efficiency in the thermal envelope, daylighting, household appliances, consumer electronics, building integrated solar applications. But R&D is still going on to produce cheaper varieties of these technologies and goods on a large scale. Policy measures have been also in place in many developing countries to facilitate development of these technologies and its uptake. But smoother technology transfer regimes are also required to promote larger technology diffusion in the developing countries in order to curb the threat of monopolistic market dominance in this segment of technology. This would help the developing countries to move ahead in the convergence path of carbon emission reduction. Holistically all these would contribute towards the larger goal of reduction of global negative externalities from carbon emissions.

CHAPTER 1: An Overview of the Findings of the IPCC Working Group III on Building for Mitigation and the 'Wedges' Analysis by Pacala and Socolow

Introduction

"The global construction boom in the developing world has created a tremendous opportunity to build differently and dramatically decrease energy demands," said UTC (United Technologies Corporation) Ex-Chairman and CEO George David. "Existing technologies combined with common sense design can increase energy efficiency by 35% and reduce heating costs by 80% for the average building in industrialized markets."[1]

It is essential that energy efficiency in buildings is dealt with utmost care since buildings can make a major contribution to tackling climate change and energy use. Building energy use is driven by demographics, economic development, lifestyles, changes in energy sources and technology. Efficiency gains in buildings are likely to provide the greatest energy reductions and in many cases can be the most economical option. A study by McKinsey[2] estimated that demand reduction measures in residential and commercial building with no net cost could almost halve expected growth in global electricity demand. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report estimates that by 2020, CO_2 emissions from building energy use can be reduced by 29% at no net cost. Also implementing carbon mitigation options in buildings is associated with a wide range of co-benefits. There is increasing evidence that well-designed, energy efficient buildings often have the co-benefits of improving occupant productivity and health (IPCC). Energy-efficiency investments are also likely to have positive effects on employment, directly by creating new business opportunities and indirectly through the economic multiplier effects of spending in other ways the money saved on energy costs (Laitner, 1998; Jochem and Madlener, 2003). The European Commission (2005) estimates that a 20% reduction in EU energy consumption by 2020 can potentially create (directly or indirectly) as many as one million new jobs in Europe, especially in the area of semi-skilled labour in the building sector. Other co-benefits include increased access to energy services, improved energy security situation of the country, improved indoor and outdoor air quality, as well as increased comfort, health and quality of life.

A large number of technologies that are commercially available and applicable can substantially reduce energy use while providing the same services. In spite of the availability of these high-efficiency technologies and practices, energy use in buildings continues to be high in many developing as well as developed countries.

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[1] WBCSD (2008): "Slashing buildings' energy use: Why not?". Details available at http://www.wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=Mjk1NzM, last accessed on 1 July 2008

[2] berc.berkeley.edu/flyers/**McKinsey**Q.pdf, http://www.iht.com/articles/2007/05/17/business/greenhomes.php

Trends in Building sector energy consumption and emissions

The IPCC suggests that buildings-related emissions account for nearly 30% of total global CO_2 emissions from energy use (19% from the residential sector and 10% from the commercial sector). The IPCC report (2007) further notes that the rate of growth in emissions from developing countries was over four times the average world rate between 1973 and 1990 (4.4%), and that their share of world building emissions has grown from an estimated 11% of the world total in 1973 to 19% in 1990[3][4]. According to the IPCC working group III report, direct emissions from residential and commercial buildings grew by 26% between 1970 and 1990 and? did not increase by a large extent from 1990 onwards till end of the 1990s. According to the working group III of the fourth assessment report of IPCC, carbon dioxide emissions through the use of electricity in residential and commercial buildings increased at an annual rate of 2% between 1970 – 2004. Some of the largest rise in carbon dioxide emissions came from developing Asia (30%)[5] followed by North America (29%) and OECD Pacific (18%) during 1970 - 2004.

Another recent analysis of the carbon emissions by the Energy Information Administration (EIA) (2006)[6] confirms this trend. In the EIA analysis, which covers 65 countries that use over 90% of the current world energy use, residential and commercial sector carbon dioxide emissions account for about 25% of total emissions. The EIA also found growth rates of emissions in developing countries are similar to those of the IPCC report (table 1). The flat growth in Eastern Europe and the former Soviet Union reflects the economic restructuring occurring in the region. According to the International Energy Agency, total energy-related emissions from the former Soviet Union fell by 13% between 1988 and 1992, with similar proportional drops occurring in the buildings sector as well.

Table 1.1 : CO_2 emissions from buildings

Region	Share of total emissions in 1990 (%)	Average annual growth rate in building emissions 1980-90 (%)
OECD	32	1.1
EE/FSU	17	0.0
Developing countries	18	5.5
China	19	5.5
Other Asia	19	6.3
Latin America	14	3.3
Africa	17	6.0
Middle East	25	7.8

Source: Weil S et al (1998)

[3] http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf last accessed on 16 th Nov 2008
[4] http://energypriorities.com/entries/2007/06/ipcc_fourth_assessment.php last accessed on 16th Nov 2008
[5] http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter6.pdf, pg. last accessed on 16th Nov 2008
[6] Emissions of Greenhouse Gases Report, Energy Information Administration, 2006 http://www.eia.doe.gov/oiaf/1605/ggrpt/ last accessed on 4th Nov 2008

IEA estimates [7] show that in the time span of 2004 – 2030 with rapid economic growth the CO_2 emissions from countries of developing Asia, Middle East/North Africa, Latin America and Sub-Saharan Africa would increase at the rate of 2.4%.

Global CO_2 emissions resulting from energy use in buildings have increased at an average of 2.7%[8] per year during the period 1999-04. The largest regional increases in CO_2 emissions (including through the use of electricity) for commercial buildings were from developing Asia (30%), North America (29%) and OECD Pacific (18%). Whereas the largest regional increase in CO_2 emissions for residential buildings was from developing Asia accounting for 42% and Middle East/North Africa with 19%[9]. This increase has taken place during 1999 – 04[10].

Buildings are responsible for at least 40% of energy use in most countries. The absolute figure is rising fast, as construction activity is booming, especially in the developing countries such as China and India. The International Energy Agency (IEA) (2006) estimates that current trends in energy demand for buildings will stimulate about half of energy supply investments to 2030.

Final energy use for commercial buildings in the US is higher (in terms of TWH) than Europe, China, India (see Figure 1). In fact, in the United States, the building sector (residential and commercial) uses more energy than the transportation sector, and almost as much as the industrial sector. Consumption in China and India will grow rapidly, and China's building energy consumption will be approaching that of Europe by 2030, while India will have overtaken Japan. If current trends continue, commercial building energy use in China and India will more than double during this period. Energy consumption in Western Europe will rise only moderately and will remain flat in Japan. Building energy in Brazil will grow, but will remain relatively small in 2030 compared to the other regions. In India most commercial buildings have energy performance index (EPI) of 200-400 kwh/sq m/year. Similar buildings in North America and Europe have EPI of less than 150 kwh/sq

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[7] Levine, M., D. Ürge-Vorsatz, K. Blok, L. Geng, D. Harvey, S. Lang, G. Levermore, A. Mongameli Mehlwana, S. Mirasgedis, A. Novikova, J. Rilling, H. Yoshino, 2007: Residential and commercial buildings. In Climate Change 2007: Mitigation. Contribution of Working Group III, to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A., Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.IPCC 4th Assessment Report, Working Group III report, Chapter 6, Residential and commercial1 buildings

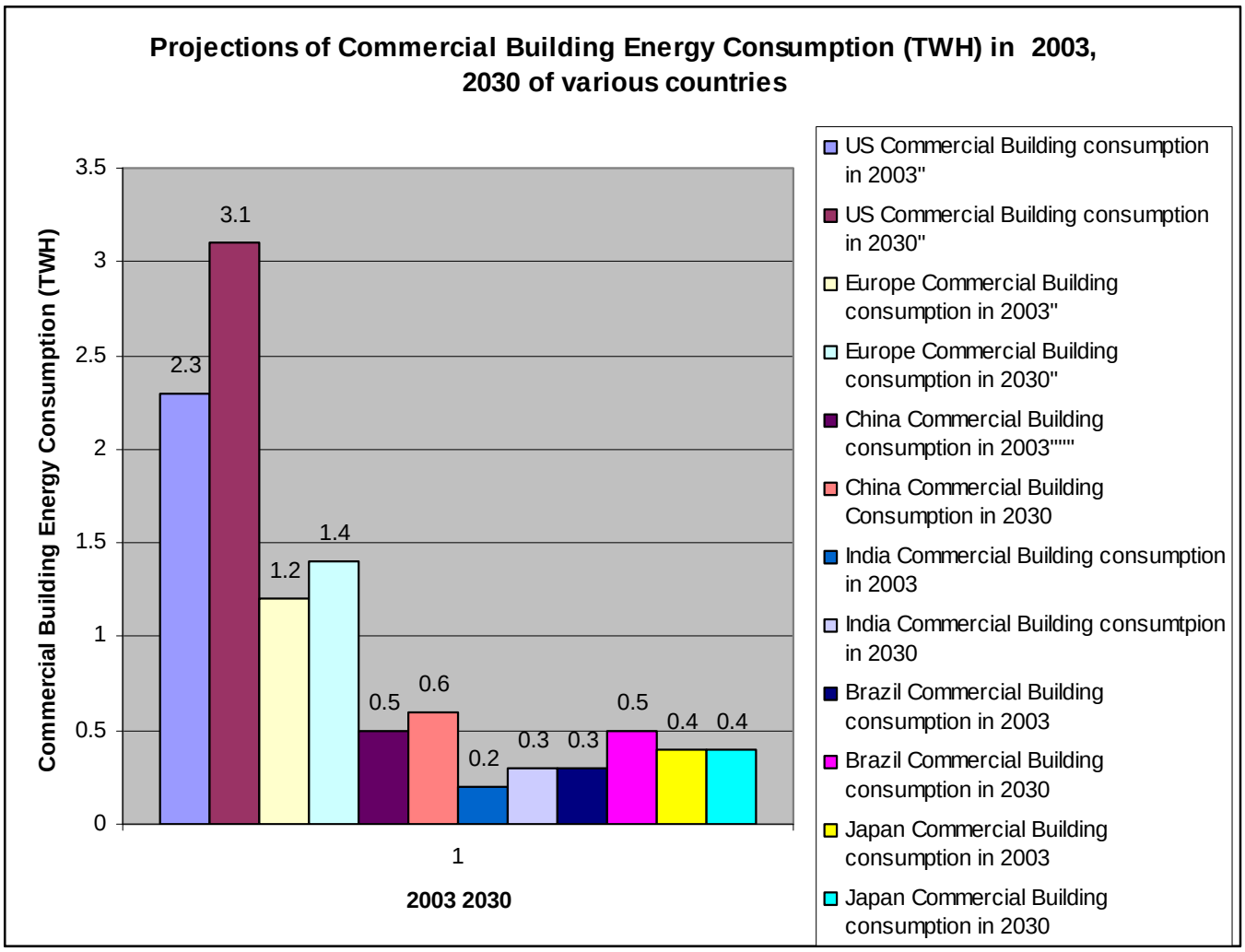
[8] Carbon Dioxide Emissions from the Generation of Electric Power in the United StatesJuly 2000Department of EnergyWashington, DC 20585 Environmental Protection Agency, Washington DC 20460, http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html last accessed on 4th Nov 2008, *Emissions of Greenhouse Gases Report, Energy Information Administration, 2006 http://www.eia.doe.gov/oiaf/1605/ggrpt/ last accessed on 4th Nov 2008*

[9] Carbon Dioxide Emissions from the Generation of Electric Power in the United StatesJuly 2000*Department of* EnergyWashington, DC 20585 Environmental Protection Agency, Washington DC 20460, http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html last accessed on 4th Nov 2008

[10] Carbon Dioxide Emissions from the Generation of Electric Power in the United StatesJuly 2000*Department of* EnergyWashington, DC 20585 Environmental Protection Agency, Washington DC 20460, http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html last accessed on 4th Nov 2008

m/year[11]. One of the reasons behind it is energy efficient building designs which are applied in North America and Europe[12].

Figure 1.1: Building energy projections by region and countries (2003 vis-à-vis 2030) (Source - *WBCSD (2008)*



Source – WBCSD (2008)

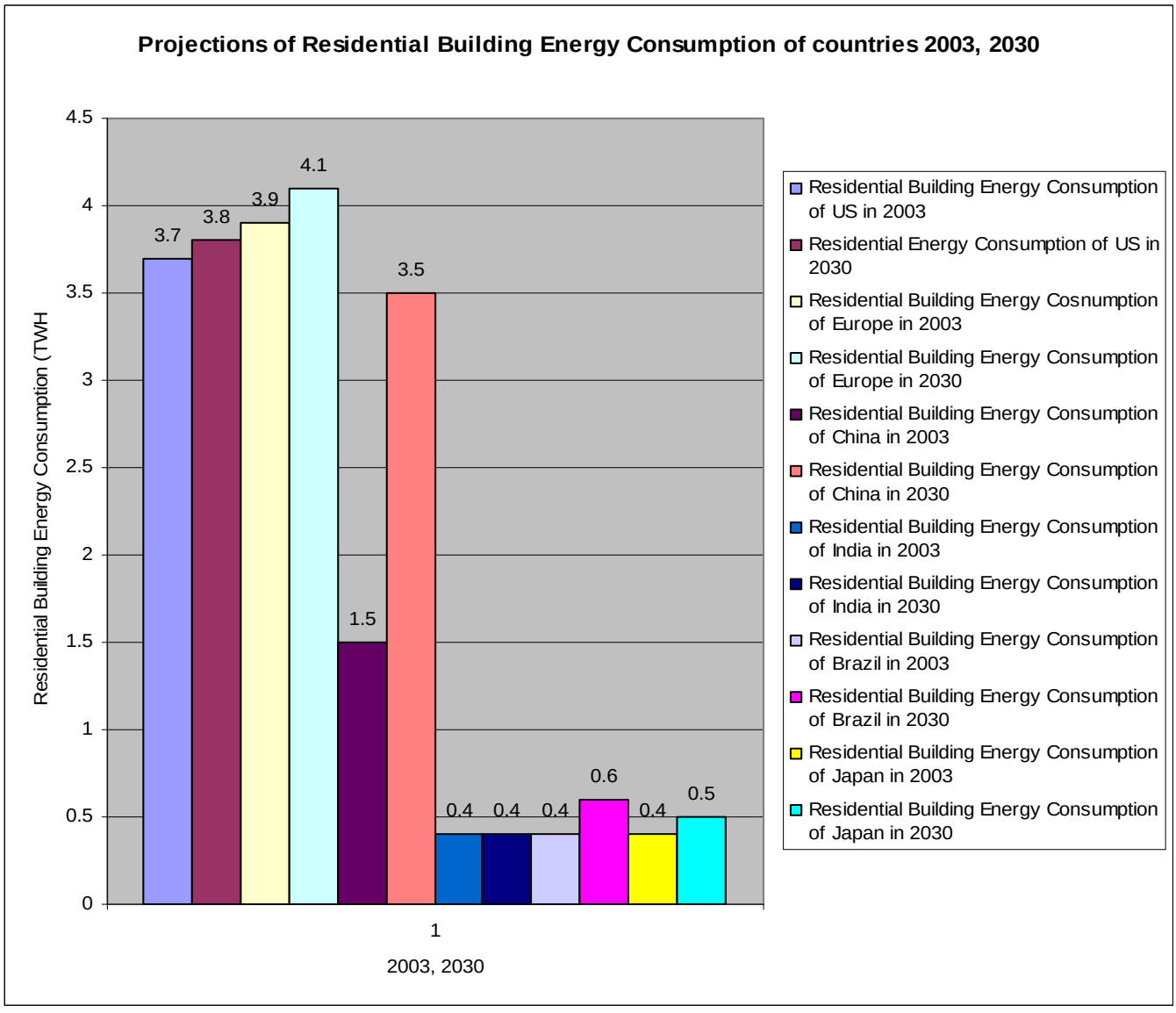
One of the intuitions which is used behind the projections as shown above is that - large differences in space per person between the above mentioned regions persists. The amount

[11] Emissions of Greenhouse Gases Report, Energy Information Administration, 2006 http://www.eia.doe.gov/oiaf/1605/ggrpt/ last accessed on 4th Nov 2008, IPCC (2007), http://powermin.nic.in/whats_new/pdf/BEE_Energy_Efficiency_in_Buildings_in_India.pdf last accessed on 16th Nov 2008

[12] http://powermin.nic.in/whats_new/pdf/BEE_Energy_Efficiency_in_Buildings_in_India.pdf last accessed on 16th Nov 2008

of residential space per capita is much higher in U.S in comparison to the other regions as mentioned above. Such differences in space per capita are lesser in commercial buildings of the regions as mentioned above. But it does not hold for China as it currently uses much lesser commercial space per capita in comparison to other regions. This has significant impacts on energy use. However it is assumed that space demands in China move toward those in Europe and Japan in the long run. Similar intuitions apply for India also which explains the nature of projection as shown in the figure above.

Figure 1.2: Projections of residential building energy consumption of countries 2003, 2030



Source – WBCSD (2008)

One way in which China is trying to reach the goal of reducing greenhouse gases is by focusing on buildings. The U.S.-based, nonprofit organization Natural Resources Defense Council estimates that the country uses more than half[13] of its total energy on buildings: through manufacturing and transportation of materials, construction, heating and cooling. A nine-story, modern office building in Beijing provides one example of how the government is tackling the problem. It was built by China's Ministry of Science and Technology a few years back in collaboration with the U.S. Department of Energy and the defense council. In 2005, the structure became China's first to get gold-level certification from the Leadership in Energy and Environmental Design rating system, recognized internationally as a standard of excellence. China's goal is to make all new buildings 50 percent[14] more efficient by 2010[15]. In this respect it is also important to note the level of energy usage in making the buildings. A complete value chain analysis of energy usage needs to be done in this regard to find out what would be the level of energy savings in the buildings by attaining such a goal. This would entail usage of energy in making the inputs used for the building making. Along with that it would also entail the amount of energy used in the buildings after they have been constructed.

In India, electricity consumption has increased at the rate of 7.4% [16] between 1990-2003 in the commercial sector. It is estimated that on an average in a typical commercial building in India, around 60%[17] of the total electricity is consumed for lighting, 32% for space conditioning, and less than 8%[18] for refrigeration. The residual amount of total electricity is used for used for ITC, water heating, cooking and other appliances. Although, the saving potential of each option may vary with typology, climate, space conditioning needs and the initial base design proposed by the client/designer, on an average it is estimated that the implementation of energy efficient options would help in achieving around 30% electricity savings in new residential buildings and 40%[19] electricity savings in new commercial buildings in India. The average electricity consumption for space conditioning and lighting in India is around 80 kWh/m2/annum and 160 kWh/m2/annum for residential and commercial buildings respectively although the overall energy performance index in commercial buildings ranges between 200-400 kwh/sq m/year. This is because energy performance index is calculated based on energy consumption across various segments of a building – Thermal Envelope, Lighting, Heating, Ventilation and Air – Conditioning and Glazing, House Hold Appliances. Under a Business As Usual (BAU) scenario and based on a 10% annual increase in new built-up area, energy saving potential with technological and policy options in the residential and commercial buildings sector has been estimated to be 82.4 million tonnes of CO_2 and 246.1 million tonnes of CO_2 respectively by 2031[20].

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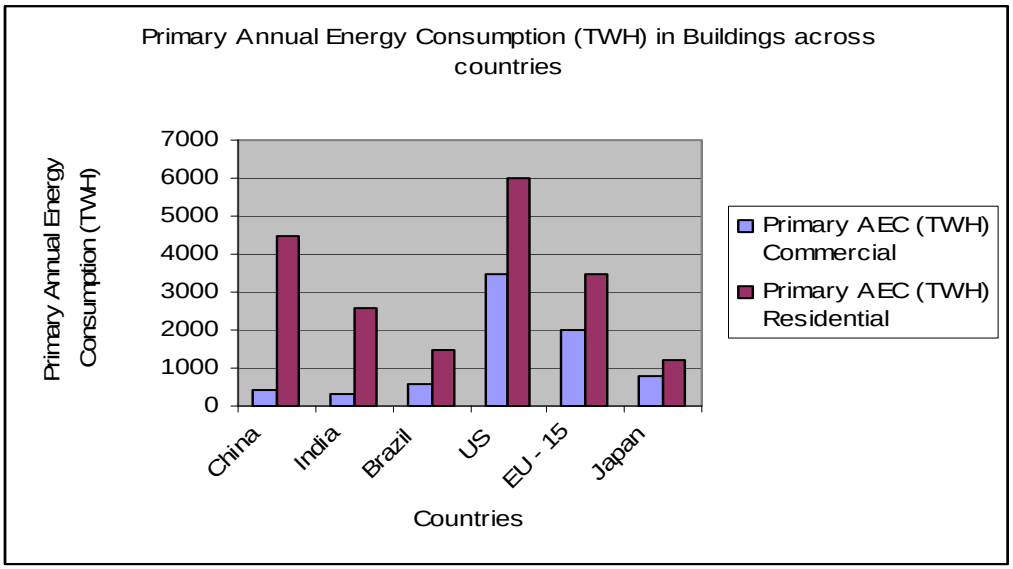
[13] www.nrdc.org/globalwarming/cost/cost.pdf last accessed on4th Nov 2008
[14] www.npr.org/templates/story/story.php?storyId=89575832 – last accessed on 4 th nov 2008
[15] Details available at http://www.npr.org/templates/story/story.php?storyId=89575832. Last accessed on 7 June 2008.
[16] WBCSD(2008)
[17] WBCSD(2008)
[18] WBCSD(2008)
[19] WBCSD(2008)
[20] WBCSD(2008)

In countries like India and China, a significant amount of coal and biomass is burnt on site to produce electricity. Switchover to cleaner sources of energy for buildings could mean larger consumption of primary energy across countries due to a net increase in additional demands of power generation and distribution for buildings across countries. This could contribute to differences in primary energy consumption because of the additional energy demands of power generation and distribution. The figure below shows the extent of differences in the primary energy consumption across residential and commercial buildings of various countries.

Figure 1.3: Primary energy consumption in buildings



Source: WBCSD(2008)

According to IPCC (2007), during the past few (five) years, CO_2 emissions (including through the use of electricity) in residential buildings have increased at a much slower rate (annual rate of 0.1%) than the average trend of 1.4% during the period 1971 – 2004. The average emissions associated with commercial buildings have grown at a faster rate (3% per year in last five years) than the average emission rate for a 30-year period between 1971 – 2004 (2.2%). So it could be said that contribution of carbon emissions from the residential and commercial building sector has increased due to an increase in the emission rate. This has thereby contributed to the global problem of climate change also. So there is a need to identify GHG mitigation options in residential and commercial buildings in order to reduce carbon emissions. One of the options could be through application of GHG mitigation technologies in residential and commercial buildings. The next section highlights some of these options.

GHG mitigation options in buildings

The IPCC (2007) mentions about a broad range of GHG mitigating technologies that could be used in new as well as existing residential and commercial buildings. In general, the single largest end use of energy in residential buildings is for space heating, followed by water heating. For instance in China, 32% of the energy use in residential buildings is towards space heating, and 27% towards water heating. This is followed by appliance usage (21%), lighting (9%) and cooking (7%)[21]. As far as commercial buildings are concerned, the nature of usage varies from country to country. For instance space heating is the single largest use of energy in commercial buildings in the EU accounting for two third of the total energy use, where as lighting and space cooling is the largest use of electricity in commercial buildings in tropical countries.

Table A1 in the appendix discusses about the specific energy saving technologies. It gives a brief description of the technologies and their effectiveness in terms of energy savings. The IPCC also describes a host of energy efficiency principles, some of which are the following:

- *Reduce heating, cooling and lighting loads* – One of the strategies for reducing heating and cooling loads is to isolate the building from the environment by using high levels of insulation, optimizing the glazing area and minimizing the infiltration of outside air.
- *Utilize active solar energy and other environmental heat sources and sinks*- Utilization of active solar energy systems can provide electricity generation, hot water and space conditioning and thereby reduce the necessity of electricity.
- *Increase efficiency of appliances and improve operations and maintenance*- Increasing the efficiency and where possible reducing the number and size of appliances within conditioned spaces reduces energy consumption directly and also reduces cooling loads. Also, continuous performance monitoring, automated diagnostics and improved operator training are complementary approaches in improving the efficiency of commercial buildings
- *Utilize system approaches to building design*- Considering the building as an entire system can lead to much less energy usage and are also not more expensive than conventional buildings. The systems approach requires an integrated design process (IDP), in which the building performance is optimized through an iterative process that involves all members of the design team from the beginning. Using a systems approach can achieve energy savings in the order of 35–50% for a new commercial building.
- *Change lifestyles*- Lifestyles of the occupants and owners of buildings also have a substantial impact on energy use. Levermore (1985) found a variation of 40% gas consumption and 54% electricity consumption in nine identical children's homes in a small area of London. In this respect it is important to train and increase awareness among people and also tighten the monitoring mechanism, so that there is an urge among consumers to utilize energy efficiently.

[21] IPCC (2007): IPCC 4th Assessment Report. Working Group III Report "Mitigation of Climate Change". Chapter 6. Residential and Commercial Buildings

Substantial reductions in CO_2 emissions from energy use in buildings can be achieved over the coming years using existing technologies (discussed in table A1) for energy efficiency that already exists and have been successfully used in various countries. Most of these technologies (except for a few) are either in the demonstration phase or commercially available and economically feasible both in the developed and developing countries. However, the appropriateness of technologies vary from country to country. Appropriateness includes climatic and cultural applicability and adaptability. For instance, direct evaporative cooling is appropriate in dry and warm climates but it is not applicable for humid and warm climates.

Energy and cost saving potential

Accurately assessing building energy consumption and savings potential is challenging because buildings are complex systems defined by the way in which they are designed, constructed, and operated. Yet doing so creates a foundation for making sound policy decisions. IPCC calculations suggest that globally, approximately 29% of the projected baseline emissions by 2020 can be avoided cost effectively through mitigation measures in the residential and commercial sectors. In the EU, partly because of its large share of total consumption, the largest cost-effective savings potential lies in the residential and commercial buildings sector, where the full potential is now estimated to be around 27% and 30% of energy use, respectively[22]. In residential buildings, retrofitted wall and roof insulation offer the greatest opportunities, while in commercial buildings, improved energy management systems are very important.

Barriers to adopting building technologies and practices that reduce GHG emissions

Occupant behaviour, consumer preferences and access to technological options are all important determinants of energy use in buildings. But there are knowledge gaps about energy efficiency among building professionals, as well as a lack of leadership throughout the industry. In some cases, awareness is high but involvement is low. Energy efficiency performance standards and labels for appliances and lighting needs to be adopted for bringing about market transformations and stimulating the adoption of more efficient technologies and products. However, implementation of building codes is difficult to enforce as well as monitor. Successful implementation of performance-based codes requires education and training of building officials and inspectors. Also, subsidies on energy prices act as a deterrent to efficient use of energy and need to be targeted appropriately where required and gradually removed in order to provide a higher incentive for energy saving.

[22] Communication from the European Commission. Action Plan for Energy Efficiency: Realising the Potential. Brussels, 2006

According to WBCSD (World Business Council for Sustainable Development, 2008), the four main barriers to greater consideration and adoption of energy efficiency by building professionals are the following:

Personal know-how – whether people understand how to improve a building's environmental performance

Business community acceptance – whether people think the business community in their market sees sustainable buildings as a priority

A supportive corporate environment – whether people think their company's leaders will support them in decisions to build sustainably.

Personal commitment – whether action on the environment is important to them as individuals.

These barriers could be overcome only through proper identification of policies for promotion of GHG mitigation in buildings. The policy could be designed once the mitigation technologies which are in commercial phase and under R&D have been identified. The following section suggests some of the policy options. -

Policies to promote GHG mitigation in buildings

Life-cycle analysis shows that 80-85% of the total energy consumption (through energy for meeting appliances, lighting, heating, cooling loads) and CO_2 emissions of a building comes from occupancy through heating, cooling, ventilation, and hot water use. Along with that embodied energy for constructing a building also adds to carbon emissions from the building sector. So therefore combining the right materials when designing a building envelope can greatly reduce a building's energy requirements, increase its life span and ensure consistent performance over time.

As mentioned earlier that in some cases it is seen that though awareness on energy savings within the building sector is there, there is lack of involvement and commitment among people. Therefore it is important that governments should provide improved policy frameworks, including better urban planning, more effective building codes to enforce minimum required technical standards, and information and communication to overcome the lack of know-how and to highlight the energy performance of individual buildings. A combination of voluntary and mandatory schemes is already emerging: for example, voluntary labelling schemes such as CASBEE (Comprehensive Assessment System for Building Environmental Efficiency, Japan) and LEED (US) (Leadership in Energy and Environmental Design) and the mandatory building "passport" under the EU Buildings Directive (EU). In India, with regard to commercial and residential building sector green building practices have been followed. The buildings are rated in terms of their energy

efficiency. According to some estimates[23], there is a potential to achieve 30% to 40% savings in energy usages through energy efficient practices in residential and commercial buildings. In order to attain energy efficiency in the residential and commercial buildings of India, Energy Conservation Building Code (ECBC) was started by the Bureau of Energy Efficiency. The LEED programme was also introduced in India in 2001 in the residential and commercial building sector. Other than this building codes have been introduced by Ministry of New and Renewable Energy, Hyderabad Urban Development Authority.
Other policy improvements, such as tax and market incentives could encourage the purchase of energy efficient building equipment, materials and occupant consumption; energy pricing to make energy more valued by users and to decouple utilities' revenues from the volume of energy supplied; and enforcement, measurement and verification to make sure policies and regulations (including building codes) are effective and support market measures such as trading.

One of the most important aspects is consumer behaviour, which must change as well. There are two separate aspects of energy behavior: buying efficient equipment and using energy efficiently. In Europe and the US the market for appliances has changed over the last decade. Despite the price premium for energy-efficient equipment, there was a switch during the 1990s towards buying more energy efficient appliances by people. The implementation of appliance efficiency standards played an important role towards this uptake by consumers. A mandatory policy driven approach contributed to a large extent in uptake of energy efficient appliances by consumers. So policy played a role in changing consumer behaviour. Changing both consumer and building professionals' behaviour could result in substantial energy and emissions reductions, putting the industry on a committed path toward zero net energy buildings in the near future.

A diverse portfolio of policy instruments would therefore be required to address the barriers to efficient energy use in the residential and commercial sectors. A UNEP study[24] evaluates various national policies and addresses certain barriers towards creation of energy efficiency in buildings. One of the barriers highlighted by the study depicts the hindrances of developing CDM projects in the building sector. The study mentions the need to promote national policies on life cycle approach for buildings and construction. It also highlights the need for designing global benchmarks for sustainable building designs and capacity building in sustainable building construction. The study also brings out the need to reduce transaction costs towards development of CDM projects related to energy efficiency in buildings. There is a need to continuously update appliance standards and building energy codes and labelling, move towards rational energy pricing measures, provide financial incentives for efficiency improvements, and promote energy service companies (ESCOs). Also technology available today can achieve dramatic improvements in building energy efficiency, but market failures and behavioural barriers are blocking progress.

[23] Presentation by Mili Majumdar (2008), TERI at Indo-German Symposium on Energy Efficiency, May 2008, New Delhi
[24] www.unepsbci.org last accessed on 5th Nov, 2008, http://www.jiko-bmu.de/files/inc/application/pdf/bmu-nrw-side-event-2008_niclas-svenningsen.pdf last accessed on 5th November, 2008

Table 1.2. Energy efficient technologies for buildings

Efficient systems	Description	Effectiveness
Thermal envelope		
Insulation	The choice of insulation material needs to maximize long-term thermal performance of the building element overall	A few specific applications with effective control of end-of life emissions have been identified in which foams containing high GWP blowing agents will lead to lower overall climate impacts from carbon emissions
Windows	Thermal performance of windows has improved greatly through the use of multiple glazing layers, low-conductivity gases (argon in particular) between glazing layers, low-emissivity coatings on one or more glazing surfaces and use of framing materials (such as extruded fiber glass) with very low conductivity	Glazing that reflects or absorbs a large fraction of the solar radiation reduces solar heat gain by up to 75%, thus reducing cooling loads
Heating systems		
Passive solar heating	This can involve extensive sun-facing glazing, various wall or roof-mounted solar air collectors, double-façade wall construction, airflow windows, thermally massive walls behind glazing and preheating or pre-cooling of ventilation air through buried pipes	Aggressive envelope measures combined with optimization of passive solar heating opportunities, as exemplified by the European Passive House Standard, have achieved reductions in purchased heating energy by factors of five to thirty (i.e., achieving heating levels less than 15 kWh/ m2/yr even in moderately cold climates, compared to 220 and 250–400 kWh/m2/yr for the average of existing buildings in Germany and Central/Eastern Europe, respectively
Space heating systems	Multi-unit residences and many single-family residences (especially in Europe) use boilers, which produce steam or hot water that is circulated, generally through radiators. Heat pumps use an energy input to transfer heat from a cold medium (the outside air or ground in the winter) to a warmer medium	Fuel Utilization Efficiencies (AFUE) are above 80% to for the boiler, not including distribution losses. Due to the large energy losses (typically 60–65%) in generating electricity from fossil fuels, heat pumps are particularly advantageous for heating when they replace electric-resistance heating, but may not be preferable to direct use of fuels for heating.

Efficient systems	Description	Effectiveness
Cooling systems		
Reducing the cooling load	This may include (i) orienting a building to minimize the wall area facing east or west; (ii) clustering buildings to provide some degree of self shading (as in many traditional communities in hot climates); (iii) using high-reflectivity building materials; (iv) increasing insulation; (v) providing fixed or adjustable shading; (vi) using selective glazing on windows with a low solar heat gain and a high daylight transmission factor and avoiding excessive window area (particularly on east- and west-facing walls); (vii) utilizing thermal mass to minimize daytime interior temperature peaks, viii) increasing roof and road albedo and planting trees are also being used for reducing cooling loads	Rosenfeld *et al.* (1998) computed that a very large-scale, citywide program of increasing roof and road albedo and planting trees in Los Angeles could yield a total savings in residential cooling energy of 50–60%, with a 24–33% reduction in peak air conditioning loads.
Passive and low energy cooling	This requires no mechanical energy input, but can often be greatly enhanced through small amounts of energy to power fans or pumps. This can include natural ventilation, evaporative cooling and other passive cooling techniques. - Natural ventilation will require a number of openings to produce airflow. - In case of evaporative cooling, there are two methods by which it can be done. In a direct evaporative cooler, water evaporates directly into the air stream to be cooled. In an indirect evaporative cooler, water evaporates into and cools a secondary air stream, which cools the supply air through a heat exchanger without adding moisture. - Underground earth-pipe cooling consists of cooling ventilation air by drawing outside air through a buried air duct. Desiccant dehumidification and cooling involves using a material (desiccant) that removes moisture from air and is regenerated using heat	- For Beijing, da Graça et al. (2002) found that thermally and wind-driven night-time ventilation could eliminate the need for air conditioning of a six-unit apartment building during most of the summer if the high risk of condensation during the day due to moist outdoor air coming into contact with the night-cooled indoor surfaces could be reduced. - A new indirect-direct evaporative cooler in the development phase indicated savings in annual cooling energy use of 92 to 95% for residences and 89 to 91% for a modular school classroom in simulations for a variety of California climate zones (DEG, 2004). - The energy used for dehumidification can be reduced by 30 to 50% compared to a conventional overcooling/reheat scheme
Air conditioners and vapour-compression chillers	Chillers are larger cooling devices that produce chilled water (rather than cooled air) for use in larger commercial buildings. Cooling power (COP) generally increases with size,	Although additional energy is used in chiller-based systems for ventilation, circulating chilled water and operating a cooling tower, significant energy savings are possible through the choice

Efficient systems	Description	Effectiveness
	with the largest and most efficient centrifugal chillers having a COP of up to 7.9 under full-load operation and even higher under part-load operation	of the most efficient cooling equipment in combination with efficient auxiliary systems.
Heating, ventilation and air conditioning (HVAC) systems		
Conventional HVAC systems	HVAC is generally used in reference to commercial buildings. HVAC systems include filtration and, where required by the climate, humidification and dehumidification as well as heating and cooling. In the simplest HVAC systems, heating or cooling is provided by circulating a fixed amount of air at a sufficiently warm or cold temperature to maintain the desired room temperature. There are a number of changes in the design of HVAC systems that can achieve dramatic savings in the energy use for heating, cooling and ventilation. Some of these include (i) using variable-air volume systems so as to minimize simultaneous heating and cooling of air; (ii) using heat exchangers to recover heat or coldness from ventilation exhaust air; (iii) minimizing fan and pump energy consumption by controlling rotation speed; (iv) separating the ventilation from the heating and cooling functions by using chilled or hot water for temperature control and circulating only the volume of air needed for ventilation; (v) separating cooling from dehumidification functions through the use of desiccant dehumidification; (vi) implementing a demand-controlled ventilation system in which ventilation airflow changes with changing building occupancy which alone can save 20 to 30% of total HVAC energy use, etc.	Computer simulations by Jaboyedoff et al. (2004) and by Jakob et al. (2006) indicate that increasing the thermostat by 2°C to 4°C will reduce annual cooling energy use by more than a factor of three for a typical office building in Zurich, and by a factor of two to three if the thermostat setting is increased from 23°C to 27°C for night-time air conditioning of bedrooms in apartments in Hong Kong (Lin and Deng, 2004). Efficient HVAC systems could reduce the heating, ventilation and cooling loads and could contribute to the energy efficiency in the buildings.

Efficient systems	Description	Effectiveness
Alternative HVAC systems	- Radiant chilled-ceiling cooling: A room may be cooled by chilling a large fraction of the ceiling by circulating water through pipes or lightweight panels. Chilled ceiling (CC) cooling has been used in Europe since at least the mid-1970s. - Displacement ventilation (DV): air is introduced at low speed through many diffusers in the floor or along the sides of a room and is warmed by internal heat sources (occupants, lights, plug-in equipment) as it rises to the top of the room, displacing the air already present.	- Significant energy savings arise because of the greater effectiveness of water than air in transporting heat and because the chilled water is supplied at 16°C to 20°C rather than at 5°C to 7°C. This allows a higher chiller cooling power when the chiller operates, but also allows more frequent use of 'water-side free cooling,' in which the chiller is bypassed altogether and water from the cooling tower is used directly for space cooling. - Overall, DV can reduce energy use for cooling and ventilation by 30 to 60%, depending on the climate
Building energy management systems (BEMS)		
	BEMS are control systems for individual buildings or groups of buildings that use computers and distributed microprocessors for monitoring, data storage and communication. The BEMS can be centrally located and communicate over telephone or Internet links with remote buildings having 'outstations' so that one energy manager can manage many buildings remotely.	
Commissioning, Operation, maintenance and performance benchmarking	Building commissioning is a quality control process that begins with the early stages of design. Commissioning helps ensure that the design intent is clear and readily tested, that installation is subjected to onsite inspection and that all systems are tested and functioning properly before the building is accepted. A systems manual is prepared to document the owner's requirements, the design intent, equipment performance specifications and control sequences. Once a building has been commissioned, there is a need to maintain its operating efficiency.	Results of building commissioning in the USA showed energy savings of up to 38% in cooling and/or 62% in heating and an average higher than 30% (Claridge et al., 2003).

Efficient systems	Description	Effectiveness
Cogeneration and District Heating/Cooling	Cogeneration and District Heating/Cooling- If the heating, cooling and electricity needs of a larger collection of buildings can be linked together in an integrated system without major distribution losses, then significant savings in primary energy use are possible. Key elements of an integrated system includes: 1) district heating networks for the collection of waste or surplus heat and solar thermal energy from dispersed sources and its delivery to where it is needed; 2) district cooling networks for the delivery of chilled water for cooling individual buildings; 3) central production of steam and/or hot water in combination with the generation of electricity (cogeneration) and central production of cold water; 4) production of electricity through photovoltaic panels mounted on or integrated into the building fabric; 5) diurnal storage of heat and coldness produced during off-peak hours or using excess wind-generated electricity; and 6) seasonal underground storage of summer heat and winter coldness. Chilled water supplied to a district-cooling network can be produced through trigeneration (the simultaneous production of electricity, heat and chilled water), or it can be produced through a centralized chilling plant independent of power generation. District cooling provides an alternative to separate chillers and cooling towers in multi-unit residential buildings that would otherwise use inefficient small air conditioners.	- While district heating can have major environmental benefits over other sources of heat, including lower specific GHG emissions, such systems suffer from the legacies of past mismanagement and are often obsolete, inefficient and expensive to operate. Making DH more efficient could save 350 million tonnes of CO_2 emissions in countries annually - District heating and cooling systems, especially when combined with some form of thermal energy storage, make it more economically and technically feasible to use renewable sources of energy for heating and cooling
Collection and transformation of solar energy		
	Buildings can serve as collectors and transformers of solar energy, meeting a large fraction of their energy needs on a sustainable basis with minimal reliance on connection to energy grids	By combining a high-performance thermal envelope with efficient systems and devices, 50–75% of the heating and cooling energy needs of buildings as constructed under normal practice can either be eliminated or satisfied through passive solar design.
Building-integrated PV (BiPV)	Building-integrated PV (BiPV) consists of PV modules that function as part of the building envelope (curtain walls, roof panels or shingles, shading devices, skylights). BiPV systems are sometimes installed in new	Electricity costs from BiPV at present are in the range of 0.30–0.40 US$/kWh in good locations, but can drop considerably with mass production of PV modules

Efficient systems	Description	Effectiveness
	'showcase' buildings even before the systems are generally cost-effective.	
Solar thermal energy for heating and hot water	Most solar thermal collectors used in buildings are either flat-plate or evacuated-tube collectors. Integrated PV/thermal collectors (in which the PV panel serves as the outer part of a thermal solar collector) are also commercially available	Depending on the size of panels and storage tanks, and the building thermal envelope performance, 10 to 60% of the combined hot water and heating demand can be met by solar thermal systems at central and northern European locations.
Domestic hot water	Options to reduce fossil or electrical energy used to produce hot water include (i) use of water saving fixtures, more water efficient washing machines, cold-water washing and (if used at all) more water-efficient dishwashers (50% typical savings); (ii) use of more efficient and better insulated water heaters or integrated space and hot-water heaters; (iii) use of tankless (condensing or non-condensing) water heaters, located close to the points of use, to eliminate standby and greatly reduce distribution heat losses ; (v) recovery of heat from warm waste water; (vi) use of air-source or exhaust-air heat pumps; and (vii) use of solar thermal water heaters.	The integrated effect of all of these measures can frequently reach a 90% [25]savings.
Lighting systems		
	Lighting energy use can be reduced to the extent of 75% compared to conventional practice through (i) use of daylighting with occupancy and daylight sensors to dim and switch off electric lighting; (ii) use of the most efficient lighting devices available; and (iii) use of measures such as ambient/task lighting. These savings could emanate from the perimeter zones of the building.	

[25] Levine, M., D. Ürge-Vorsatz, K. Blok, L. Geng, D. Harvey, S. Lang, G. Levermore, A. Mongameli Mehlwana, S. Mirasgedis, A. Novikova, J. Rilling, H. Yoshino, 2007: Residential and commercial buildings. In Climate Change 2007: Mitigation. Contribution of Working Group III, to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A., Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.IPCC 4th Assessment Report, Working Group III report, Chapter 6, Residential and commercial1 buildings

Efficient systems	Description	Effectiveness
	- High efficiency electric lighting: Continuous improvements in the efficacy of electric lighting devices have occurred during the past decades and can be expected to continue. - Daylighting systems involve the use of natural lighting for the perimeter areas of a building. Such systems have light sensors and actuators to control artificial lighting	- For lighting systems providing ambient (general space) lighting in commercial buildings, the energy required can be reduced by 50% or more compared to old fluorescent systems through use of efficient lamps (ballasts and reflectors, occupancy sensors, individual or zone switches on lights and lighter colour finishes and furnishings. - A number of recent studies indicate savings in lighting energy use of 40 to 80% in the daylighted perimeter zones of office buildings
Supermarket refrigeration systems	Supermarket buildings often employ large quantities of HFC refrigerants in extensive and often leaky systems, a significant share of total GHG emissions are due to the release of the refrigerant. Two basic mitigation options are reviewed in IPCC/TEAP report: leak reduction and alternative system design. Alternative system design involves for example, applying direct systems using alternative refrigerants, better containment, distributed systems, indirect systems or cascade systems.	It was found that up to 60% lower LCCP values can be obtained by alternative system design
Energy savings through retrofits	The equipment inside a building, such as the furnace or boiler, water heater, appliances, air conditioner (where present) and lighting is completely replaced over time periods ranging from every few years to every 20–30 years.	
Conventional retrofits	Cost-effective measures that can be undertaken without a major renovation of residential buildings include: sealing points of air leakage around baseboards, electrical outlets and fixtures, plumbing, the clothes dryer vent, door joists and window joists; weather stripping of windows and doors; and adding insulation in attics, to walls or wall cavities. External Insulation and Finishing Systems (EIFSs) provide an excellent opportunity for upgrading the insulation and improving the air-tightness of single- and multi-unit residential buildings, as well as institutional and commercial buildings.	A Canadian study found that the cost-effective energy savings potential ranges from 25–30% for houses built before the 1940s, to about 12% for houses built in the 1990s. Studies summarized by Francisco et al. (1998) indicate that air-sealing retrofits alone can save an average of 15–20% of annual heating and air conditioning energy use in US houses. Additional energy savings would arise by insulating pipework and ductwork, particularly in unconditioned spaces.

Efficient systems	Description	Effectiveness
Solar retrofits	Solar renovation measures that have been used are installation of roof- or façade-integrated solar air collectors; roof-mounted or integrated solar DHW heating; transpired solar air collectors, advanced glazing of balconies, external transparent insulation; and construction of a second-skin façade over the original	Solar retrofit performed in Europe under the IEA Solar and Cooling Program achieved savings in space heating of 25–80%.

Source: IPCC (2007)

The above table of the energy efficient technologies show that energy efficient technology could be one of the strategies to reduce carbon emissions. Energy efficiency in buildings could be an efficient wedge to reduce carbon emissions. One specific wedge with respect to efficient use of electricity suggested by Pacala and Socolow is a 25% – 50% reduction in electricity usages of commercial and residential buildings. The largest savings in carbon emissions from buildings lie in space heating, cooling, water heating, lighting and electric appliances. The next section highlights the wedges (including the incorporation of energy efficiency in residential and commercial buildings) suggested by Pacala and Socolow for reducing carbon emissions.

Pacala Socolow Wedge Analysis

Projections by Pacala and Socolow highlight that carbon emissions have increased from 1.9 billion tones in 1955 to 7 billion tones in 2005 at an increasing rate. The projections predict that the carbon emissions each year could increase from 7 billion tones to 14 billion tones in 2050. The interim goal is to restrict the carbon emissions at 7 billion tones. In order to achieve that, tougher targets of carbon emission reductions have to be taken. One of the ways to achieve that is by moving onto energy efficient systems, pricing of carbon and replacement of physical plants by more energy efficient plants. So in order to restrict the carbon emissions at 7 billion tones and prevent it from rising upto 14 billion tones, seven wedges have to be taken. A “wedge” is a kind of strategy to mitigate carbon emissions and reduce it in a span of 50 years. Thus the strategy reduces carbon emissions that grow in 50 years from zero to 1.0 GtC/ year. In first 50 years, a “wedge” helps in mitigating or reducing 25 Gigatones of carbon. This entails a revenue realization of 2.5 trillion dollars at the rate of 100$/ tc. Any carbon dioxide mitigation strategy should involve atleast one wedge. According to Pacala, Socolow wedge analysis there are seven wedges to restrict the carbon emissions and to stabilise its increase to 14 billion tons in 2050. The seven wedges involve strategies with regard to – a) Methane Management, b) Forests and Soils, c) Fuel Displacement by low carbon electricity, d) Decarbonized Fuels (cleaner fuels), e) Decarbonized Electricity (Electricity with lower carbon emissions), f) Energy Efficiency. The current available technology options which could be used in providing the wedges for carbon emission reduction in certain areas are as follows – a) Improvement in fuel economy, b) Reduction in reliance on cars, c) Increase in energy efficiency of buildings, d) Improvement in power plant efficiency, e) Decarbonisation of electricity and fuels, f) Replacement of coal by natural gas, g) Technology for carbon capture and storage, h) Technology for nuclear fission, i) Technology for wind electricity generation, j) Technology for generation of photovoltaic electricity. Along with this – a) Forest Management and Agricultural Soils Management could also be used as a natural sink towards reduction of carbon emissions. Some of these technologies are under commercial application. Some of them are in the process of R&D. According to the wedge analysis by Pacala and Socolow, realization of carbon emission reduction would mean an application of all relevant technologies under the seven wedges as mentioned above. Application of a single technology would not be able to stabilize and

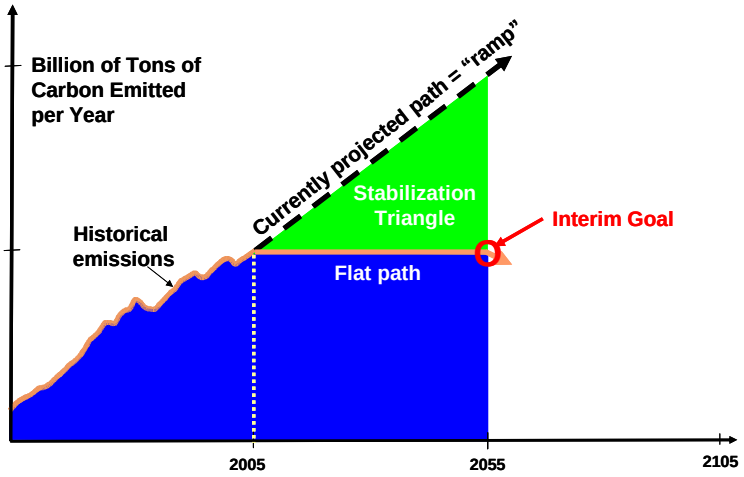
restrict the carbon emissions from 7 billion ton per year in 2005 to 14 billion tones in 2050. Thus a portfolio of wedges technology has to be followed to realize a reduction, stabilization in carbon emissions. It can also happen that in that path of reduction, stabilization all available technologies under the seven wedges might not be applicable.

According to IEA (2006) estimates, there was an emission of 6.2 GtC/ year in 2000. This emissions came from the usages of gas, crude oil and coal in electricity, transportation and heating. Gas usages contributed - .5 GtC/ year emissions from electricity, .7 GtC/ year from heating. Crude Oil usages contributed to .3 GtC/ year emissions from electricity, 1.4 GtC/ year from transportation and .8 GtC/ year emissions from heating. Coal usages contributed to 1.7 GtC/ year from electricity and 0.7GtC/ year from heating. Coal used for heating and cooking results in carbon emissions. So different wedges (strategies) could be taken to reduce the carbon emissions from usages of gas, crude oil and coal in transportation, electricity and heating. One wedge suggested by Pacala and Socolow for reduction of carbon emissions could be achieved through efficient use of electricity in buildings. The wedge analysis suggests that 1 million windmills of a capacity of 2 Mw could displace the equivalent energy demand from coal power and could also contribute to the targets of carbon emission reductions. This would entail a generation of 2 million Mw electricity from wind power for the buildings to achieve the targets of carbon emission reductions . Pacala Socolow wedge analysis also suggests that 1 GtC (giga ton carbon) could be saved every year with from the use of solar photovoltaics. Pacala and Socolow also suggest that nuclear power generation could be an effective wedge of carbon emission reduction through reduction of usage of coal for power generation. Energy efficient power generation and its subsequent usage in buildings could also entail carbon mitigation. Another wedge to reduce carbon emissions could be through the carbon capture and storage in 800 GW power plants. The wedge analysis mentions about coal gasification power plants where coal feeder ramp, oxygen plant and gasifier are being used. In such plants, carbon monoxide and water gives rise to carbon dioxide which is separated from the hydrogen. The captured carbon dioxide is stored and the hydrogen is used to rotate the turbine for power generation. The carbon dioxide absorbed is transferred through pipeline and are stored offshore under the earth. The Sleipner project in Norway has been implementing this. According to Pacala and Socolow, many such projects are required which could then reduce carbon emissions close to a rate of 1 million ton per year. Pacala and Socolow wedge analysis highlights that a flow of carbon dioxide into the earth should be equal to the outflow of oil from within earth to stabilize the carbon emissions. These clean sources of generated power could be used in buildings. Another option to reduce carbon emissions from usages of gas could be through more efficient usage of cleaner natural gas by reducing the losses from flaring of natural gas. According to Pacala, Socolow analysis carbon emissions per unit of electricity are half for natural gas power plants in comparison to coal-based power plants. Thus one of the wedges could be to displace 1400 GW of baseload coal with baseload gas by 2055. The process involves removal of carbon dioxide and its subsequent nearby injection. In Algeria, this process is already being carried out in Salah. Another wedge is

the creation of 1000 Mw coal plant with an injection potential of 60 Mt of carbon dioxide. Thus the stabilization wedge analysis of Pacala and Socolow emphasizes the fact that doubling of carbon emissions in the time span of 2005 to 2050 might not be an inevitable outcome in the presence of certain wedges (strategies) to reduce, stabilize carbon emissions from electricity, transportation and heating. These clean sources of power generation could be used to supply electricity for growing building sector. The wedge analysis defines a specific set of tasks that has to be undertaken to stabilize and mitigate carbon emissions from generation and use of electricity. Generation would mean a greater focus on cleaner sources of power generation and usages would mean efficient usages of electricity. Many of the wedges related to usages would deal with energy efficient applications in buildings. These tasks have certain costs and risks. Moreover the tasks have to be implemented at a certain pace.

So if all these wedges are taken there would be a change in the level of carbon emissions (forming a stabilization triangle through several wedges) as shown in the figure below –

Figure 1.4: Stabilization Triangle

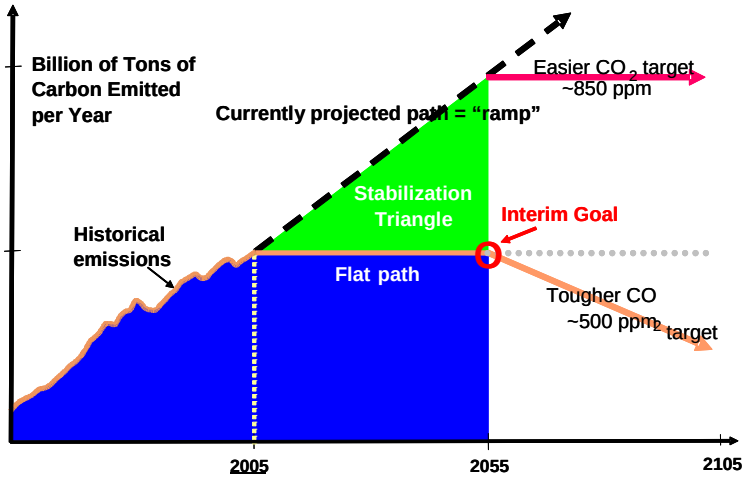


Source – Presentation on Stabilization Wedges: Mitigation Tools for the Next Half-Century , Robert Socolow , Princeton University
socolow@princeton.edu, World Bank, Washington, DC, March 6, 2006,
www.princeton.edu/~cmi/research/Integration/Presentations/06%2003-06%20Socolow_Washginton%20World%20Bank.ppt – last accessed on 5th Nov, 2008

The wedge analysis suggests that policy should be prioritized in favour of reducing investments in buildings that are not energy efficient due to high electricity consumption. Energy efficiency has to be built in the new buildings through policy support across the world to reduce carbon emissions. Introduction of new technologies in developing

countries to attain efficiency in energy usages in new buildings have to be achieved through the support from the developed countries in terms of facilitating technology transfer. This would help in reducing the global public bad viz. carbon emission and pollution for addressing the global problem of climate change. Thus the path has to be in the form of coordinated effort that would lead to global carbon mitigation. However such a mitigation strategy would work only with a consensus building across developing and developed industrialized countries. Several of these measures if taken could lead to different pathways of CO_2 target emissions. Tougher policy measures could lead to more steep carbon emission reduction as shown in the figure below. Easier policies for reducing carbon emissions could lead to a cut in carbon emissions but at a higher level in comparison to what could be achieved by stricter policy regimes as depicted in the figure below –

Figure 1.5: Projected path of carbon emission



Source – **Presentation on Stabilization Wedges: Mitigation Tools for the Next Half-Century , Robert Socolow , Princeton University socolow@princeton.edu, World Bank, Washington, DC, March 6, 2006, www.princeton.edu/~cmi/research/Integration/Presentations/06%2003-06%20Socolow_Washginton%20World%20Bank.ppt – last accessed on 5th Nov, 2008**

So the need for identifying climate mitigation goods to reduce carbon emissions is key for achieving the projected path of carbon emissions as shown in the figure above. Policies have to be in place which would identify such technologies which are at commercial phase and also under R&D. These have to be then followed up by efficient technology transfer across countries of the globe to reduce carbon emissions. Energy efficient technologies would play a key role in achieving such carbon emission reductions in the growing residential and commercial building sector of developing countries. Taking this argument the following chapters specifically highlight the "Key Mitigation

Technologies/Goods within the Residential and Commercial Building Sector" in developing countries that are commercially available and also the ones which are in a R& D stage with a possibility of being commercially available in a span of next 5 – 10 years. The sections on the two chapters have been framed keeping in mind what is happening globally in technology applications in the residential and commercial building sector.

CHAPTER 2: Key mitigation technologies/goods within the building sector that are commercially available in developing countries

Introduction

As stated in the first chapter it is clear that energy efficiency in the residential and commercial building sector could contribute in reduction of green house gas emissions. Certain mitigation technologies could play a key role in such green house gas reduction. Those technologies could address various dimensions of building construction pertaining to – a) Thermal Envelope, b) Daylighting, Household Appliances, ITC Equipment and Consumer Products, c) Active Collection and Transformation of Solar Energy, d) Heating, Ventilation and Air Conditioning and Refrigeration Systems.

The following sections highlight the key mitigation technologies and goods that are available in each of the above-mentioned segment. These technologies and goods are selected based on the current policy scenario and market realities which are existing in the developing countries.

This chapter identifies certain technologies and goods under various segments of applications in residential and commercial buildings of developing countries of South Asia, Africa, Asia Pacific and South East Asia. Such applications include –

Thermal Envelope	
	a) Fibrous Insulation Technologies, Rigid Materials, Conventional Roof Insulation, Under Deck Insulation, Over Deck Insulation, Air Conditioning Insulation, Glazing and Shading

The key goods under each of these segments starting with insulation are –

Fibrous Insulation	Insulation
	RESIN BONDED MINERALWOOL
	Rigid Polyurethane Foam (PUF)
	Polyisocyanurate Foam, Perlite, Phenolic Foam, Polyisocyanurate foam
	Cellulosic Insulation, Expanded polystyrene (EPS), Polyisocyanurate / Polyurethane foam slab, Spray applied polyurethane, aluminium foil or polythene sheet vapour barrier

The goods under glazing technologies are –

Glazing Technology	Goods
	a) tinted glasses
	b) glasses with thin coatings of pure metal like gold, silver or bronze

In shading some of the goods which are considered are –

Shading Technology	Goods
	a) Moveable opaque roller blinds, curtains
	b) Adjustable, fixed louvers
	c) Fixed overhangs

In lighting and household appliances some of the goods are-

Lighting and Household appliance	Goods
	a) GLS (glass shell)
	b) incandescent lamps
	c) Tungsten Halogen lamps
	d) Compact Fluorescent lamps
	e) Linear Fluorescent tubes
	f) Gaseous Discharge lamps such as Mercury vapour, Sodium vapour, Metal halide
	g) LEDs,
	h) Fibre Optics
	i) Electromagnetic ballasts
	j) Electronic Control Gear
	k) Variety of Sensors

In active collection of solar energy the goods are –

Active Collection of solar energy	Goods
	a) Solar Water Heaters
	b) Solar Photovoltaic Cells
	c) Solar Thermal Systems
	d) Solar Modules
	e) Solar Batteries
	f) Solar Cookers

The various goods in heating, ventilation, air conditioning and refrigeration systems are

Heating , ventilation, air conditioning and refrigeration systems	Goods
	a) Energy Efficient refrigerators, air conditioners and chillers
	b) Heat Pipes, Energy Recovery wheels
	c) Variable frequency drives

The following section of the report emphasizes the nuances of the various technologies which are commercially available in the residential and commercial building sector of the developing countries. The last section further emphasizes on the technologies in which R&D is being carried on in the residential and commercial building sector.

Overview of energy efficiency in some developing countries

The building envelope and its components are key determinants for maintaining energy efficiency in the buildings of residential and commercial sector of developing countries. The building envelope consists of – a) materials and construction techniques, b) roof, c) walls, d) fenestration, shading and e) finishes. Various developing countries are using new techniques to upgrade energy efficiency measures in their buildings. For instance, in China, the Agenda 21 Demonstration Energy-Efficient Office Building was a joint effort of the Chinese Ministry of Science and Technology (MOST) and the U.S. Department of Energy. The building has a number of energy conservation features, including both building envelope and mechanical system measures. A cross-shaped building design was used to maximize day-lighting potential, with windows located on the north and south facades to better control solar heat gain. A whole-building or integrated-design approach was used to identify the most cost-effective energy strategies for this building, including passive solar and other clean energy options such as photovoltaics (PVs) and geothermal power systems. Measured performance data indicated that the building is much more

energy efficient than similarly equipped office buildings in East Asia and the U.S. In 2004, China's Ministry of Construction gave the building its top award for best green building in China. In 2005, the building received the first LEED Gold rating for a building in China.

The Low Energy Office (LEO) building is the first government building in Malaysia to be built with integrated energy-efficient design. The building orientation and envelope uses several features. For instance, the windows are primarily orientated to the north and the south, with less direct sunshine. This is useful for a particular tropical climate. But the orientation could be different in a cold climate. In addition to their optimum orientation, the windows are protected by appropriate shading mechanisms to allow for maximum light to penetrate while minimizing the transfer of heat. Towards the east, shading is deeper to protect against the low morning sun. The western façade has virtually no windows. The window glazing allows 65 per cent of the available daylight in while keeping 49 per cent of the heat out. The thick, light-colored walls of the LEO building reduce solar heating of the walls and insulate 2.5 times better than a traditional brick wall.This building has the potential of saving 50%[26] more energy in comparison to the other office buildings of Malaysia. The building has the potential of saving 2193164 Kwh[27] of energy per year leading to a building energy index of 114 Kwh[28] per metre square.

In some of the developing countries like India, the residential sector accounted for 11%[29] of total commercial energy use in 2001.. Electricity consumption in the residential sector is primarily for lighting, space conditioning, refrigeration and other appliances. According to TERI estimates[30] on energy consumption in the residential sector in the city of Delhi, while lighting accounted for around 8%-14% of total electricity consumption, space-conditioning accounted for nearly 52% and refrigerators accounted for around 28% of electricity consumption in the residential sector (in the summer months). Accordingly, energy saving measures related with space conditioning (heating and cooling), refrigeration and lighting have great significance in moving towards sustainable energy use in this sector. Technologies that could save energy in the above mentioned segments could be very useful for attaining an overall energy efficiency in the sector through a sustainable energy use. The commercial building sector comprises various institutional and industrial establishments such as banks, hotels, restaurants, shopping complexes, offices, and public departments supplying basic utilities. According to TERI estimates ,

[26] http://www.ktak.gov.my/leo/building_overview.asp, http://www.ktak.gov.my/leo/images/performance.pdf last accessed on 5th Nov, 2008
[27] http://www.ktak.gov.my/leo/images/performance.pdf last accessed on 5th November, 2008
[28] http://www.ktak.gov.my/leo/images/performance.pdf last accessed on 5th November, 2008
[29] http://www.adb.org/Documents/Reports/Consultant/TAR-IND-4066/Energy/ahluwalia.pdf, last accessed on 4th Nov, 2008
[30] TERI Report prepared for the Prime Minister's Office on "Energy Efficiency in Residential and Commercial Building Sector", 2008

electricity consumption has increased at the rate of 7.4% between 1990-2003 in the commercial building sector. According to TERI estimates, on an average in a typical commercial building in India, around 60% of the total electricity is consumed for lighting, 32% for space conditioning, and 8% for refrigeration, cooking, ITC and other housing appliances. However, end use consumption varies largely with space conditioning needs. While a fully air-conditioned office building could have about 60% of the total electricity consumption accounted for by air conditioning followed by 20% for lighting. But in a non air-conditioned building the consumption patterns would be significantly different.

Energy consumption in residential and commercial buildings differs across income groups, building construction typology, climate and several other factors. There is a significant scope to reduce these energy requirements with the provision of the requisite energy in a more efficient manner in case of both existing as well as new constructions. Larger energy efficiency could be achieved by reducing energy consumption in residential and commercial buildings. Some of the existing goods that are being applied in residential and commercial building sector for achieving energy efficiency are stated below –

Options for reducing energy consumption

Some of the existing options for reducing energy consumption in residential and commercial sector are highlighted below –

Table 2.1 : Energy-saving options in residential buildings

Application	Energy-saving opportunities
Thermal Insulation	Using enhanced and more efficient fibrous insulation techniques for an improved insulation.
	Using efficient glazing technologies like tinted glasses for an improved insulation.
	Using enhanced, efficient shading technologies like moveable opaque roller blinds, curtains for improved shading.
Lighting	Replacing incandescent lamps with compact fluorescent lamps (CFL) and light-emitting diodes (LEDs)
	Replacing existing fluorescent lamps (40 W) with T- 5 lamps
	Replacing electromagnetic chokes (ballasts) in fluorescent lamps (40/36 W) with electronic ballasts/starter for fluorescent light tubes
Space cooling	Replacing conventional ceiling fans with energy-efficient ceiling fans Partial replacement of air-conditioners and space heaters with earth tunnel systems
Water heating	Replacing electric geysers with solar hot water systems for domestic water heating

Source: TERI Analysis, 2008 (Centre for research on sustainable building Science, TERI)

Table 2.2 : Energy-saving options in commercial buildings

Application	Energy-saving opportunities
Lighting	Replacing incandescent lamps with compact fluorescent lamps (CFL) and light-emitting Diodes (LEDs)
	Replacing existing 40 W fluorescent lamps with T- 5 lamps
	Replacing electromagnetic chokes in 40/36 W fluorescent lamps with electronic chokes
	Installing timers for external lights
	Installing occupancy sensors in toilets, stores, and lobby areas
	Installing photo-sensors for use of daylight
Space cooling	Replacing conventional ceiling fans with energy-efficient ceiling fans
	Replacing inefficient chilling machines by efficient chillier
	Replace single skinned air handling units by double skinned air handling units
	Replacing inefficient chilled water and condenser water pumps with efficient ones
	Replacing aluminium blades of cooling towers with FRP (fibre reinforced plastics) blades in cooling towers
	Converting constant chilled water flow to variable flow
	Regulating chilled water flow and condenser water flow to the rated capacity
	Using variable frequency drive at AHU (Air Handling Units) fans
	Installing wet-bulb-operated frequency drive at cooling tower fans
	Converting constant chilled water flow to variable volume flow
	Regulating fresh air to the design value
	Using economizers and enthalpy controls at AHUs

Source : TERI Analysis, 2008 (Centre for research on sustainable building Science (CRSBS), TERI)

Some of the energy savings potential through energy efficiency measures in residential and commercial building is highlighted below -

Table 2.3 : Energy efficient measures and associated energy saving potential for a new residential and commercial building in India

Residential building	
Measure	*Savings potential (percentage of energy usage)*
Proper orientation, fenestration and shading, roof and wall insulation (wall insulation for air conditioned buildings only)	15%
Energy efficient lighting for internal application	5%
Solar water heating system	10%
Commercial building	
Measure	*Savings potential*
Proper orientation, fenestration and shading, Roof and wall insulation (wall insulation for air conditioned buildings only), efficient glazing system	10%
Energy efficient lighting for internal application	15%
Efficient space conditioning system	15%

Source – TERI Compilation, Analysis 2008, (CRSBS, TERI)

Thus the goods and mechanisms stated in the above table could be used in attaining electricity saving in residential and commercial buildings. Other than these, various other technological applications and goods could be applied across various segments of a building design which includes – a) Thermal Envelope, b) Daylighting, Household Appliances, Consumer Electronics etc, c) Active Collection and Transformation of Solar Energy, d) Heating, Ventilation and Air Conditioning Systems. One of the applications that could be used in bringing energy efficiency in residential and commercial buildings could be through the use of insulation techniques and various kinds of goods for insulation in the buildings. The next section highlights the various types of insulation goods used as a part of the thermal envelope of a building -

Insulation

In most of the developing countries of the world, insulation of both roofs and walls are very common. It is also quite prevalent in countries which fall in cold climatic zone, having maximum indoor temperature in the range of 18 to 25 degrees Celcius in winter time, and somewhat higher in summer.

Now across the world people use either fibrous or chemical based insulation materials. Many of the insulation materials deal with roof insulation, based on the fact that building absorbs most of the heat from the roofs, which has now further graduated to wall insulation as well. Places where central heating system for the buildings are common, thermal insulation is used to conserve the heat inside the building. Thermal insulation is a combination of materials, ancillaries, protective finishes & application methods. In an

efficient thermal insulation, the insulation of both the roofs and wall are mandatory. Similarly those countries which fall under hot and humid climatic zone, where central cooling systems are common, thermal insulation is recommended for roofs mainly and walls to some extent. Globally the PROPERTIES OF THERMAL INSULATION are -

- Low thermal conductivity
- Low thermal diffusivity
- High thermal resistance & low thermal conductance
- Adequate density
- Nominal thickness
- Low water absorption
- Withstand high & low ambient temperatures
- Non combustible / non easily ignitable
- Fast application

The commonly used techniques for insulation are highlighted below –

Fibrous Insulation

According to some estimates, thermal insulation using these insulation techniques could save on an average 26 W/ square metre of energy depending on the nature of the climate. This could lead to close to 30% reduction in carbon emissions[31]. The technical features of this kind of insulation are –

- RESIN BONDED MINERALWOOL insulation comprising of fine fibres generated from molten rocks and bonded with Phenolic formaldehyde resin. These fibres entrap millions of air cells in between which resists passage of heat and cold water.
- Comprises of Rockwool and Glasswool in the form of slabs and rolls of density 24 to 48 kg/m^3 and thickness ranging from 25 to 75 mm.
- These materials are available with or without lamination of aluminium foil.
- High-density 96 & 144 kg/m^3 rigid slabs and boards are also available. The typical thermal conductivity is around 0.029 W/mk which is S.I unit equivalent of watt per kelvin [32]at 10 deg.C mean temp. It is also available as pipesections in densities from 85 to 144 kg/m^3. Resin Bonded mineral wool confirms to BIS : 3958(Pt.5) (Bureau of Indian Standard) , ASTM C553 (American Society for Tasting and Materials)
- Used in insulation of roof, metal roof insulation, wall insulation

[31] http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2V-4MS3J91-1&_user=3214518&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_version=1&_urlVersion=0&_userid=3214518&md5=03225e71e0bfce8318526924689c8e59#secx13 last accessed on 4th Nov 2008

[32] Wat per kelvin is an unit of thermal conductivity

- Insulation of Roof- Insulation done under deck that is fixed below the RCC roof with wooden batten frame work or fixed over deck (rigid boards) from outside the building directly on the RCC slab with adhesive
- Covered with waterproofing and protective treatments
- Metal Roof Insulation – Usually fibrous insulation fixed between the purlins or placed in between 2 layers of metal profile sheet (double skin roofing)
- Wall Insulation –a cavity fill insulation between 2 layers of brickwall. Insulation boards are fixed to the wall with fasteners and held in position between horizontal ties with an application of second layer brickwall. Another method is through fixing insulation boards between wooden framework on to the brick walls from inside and then finally bolting cement particle boards on to the wooden frame work or doing plaster with wire mesh re-inforcement.

Rigid materials

These are the plastic foam materials comprising of three types of materials:

a) Rigid Polyurethane Foam (PUF) – This is a foam material generated out of an exothermic reaction between two chemicals viz Polyol & Isocyanate This material is available in several densities starting from 30 kg/m^3 to as high as 300kg/m^3 for pipe supports. It has a very low thermal conductivity value of 019 W/mk at 10 deg.C. It is available in slabs, pipesections and in-situ foaming. PUF confirms to the following indian and international standard with a specification title BIS: 5608, ASTM: C 591.

b) Polyisocyanurate Foam – This emanates from the Polyurethane foam with certain modifications to make fire proof. It is used for insulation applications in ships and also on RCC roof as underdeck insulation. PIR boards are fixed with adhesive and fastened to the roof slabs. This is an urethane foam insulant having low thermal conductivity, low smoke emission and low water absorption. These products are fire resistant and confirms to IS:12436, BIS : 5608 (Indian Standard).

Polyisocyanurate is used for roofing applications. Some of its unique properties include –

1) Energy efficiency – Polyisocyanurate has the greatest energy efficiency performance of any building insulation product having the highest thermal resistance (R) value in comparison to any other insulation materials.
2) Polyisocyanurate combines fire safety and compliance with building codes.
3) Polyisocyanurate possess good compressive strength
4) It provides very effective moisture barrier during its usage with laminated aluminium foil
5) It is not affected by oil based waterproofing compounds, insecticides or fertilizers when properly protected.

c) Phenolic Foam – Phenol formaldehyde is a rigid foam insulation material having low thermal conductivity and negligible smoke emission. The product is manufactured from Phenol formaldehyde condensation process and confirms to BIS : 13204.

Some of the advantages of Phenolic Foam are :

1) Good non-flammability.
2) Low smoke density and toxicity
3) Non dipping[33] during combustion
4) Thermal stability over broad temperature range

Some of the disadvantages limiting its extensive applications are :

1) The high friability, brittle nature, de-bonding, low volatility to handling and dust pollution in working area.
2) Corrosiveness due to residues of acid catalyst
3) High water absorption properties

d) Cellulosic Insulation – This is a spray applied cellulose fiber designed for wide range of project types It is a very good thermal insulation material. It sticks to any surface configuration such as domes, steel beams, concrete columns. The high performance adhesive binds it to virtually all-common construction materials including sheet rock, plaster, wood, metal, and concrete.

The advantage of this material includes:

1) It sticks to any properly prepared surface without mechanical support offering insulation, noise reduction, condensation control
2) It has good fire resistance property

Major disadvantages of this product is:

1) High Cost
2) Difficult house keeping as dust settles over the covering of insulation leading to difficulties in cleaning
3) Imported material

[33] Non dipping during consumption means that the corrosive nature of the insulation materials is less. For metallic coating of insulation materials a dipping process is carried out which enhances the durability of the material.

e) Perlite – An organic rigid board for overdeck roof insulation used earlier in Europe. It has high thermal conductivity value and is a porous material. It is not used to a large extent now. Perlite confirms to ASTM C610.

The above mentioned rigid materials are used in buildings contributing largely to the category of insulation technology goods. Insulation technologies are being used in walls, roofs. Presently, 40 mm thick expanded polystyrene insulation on walls and vermiculite concrete insulation on roof is already commercially available in India. This could reduce space-conditioning loads by 15%. PDEC systems are available for space conditioning. Half round ceramic pipes are available which are used on the outer face of the inlet and exhaust shafts of the PDEC system to reduce the entry of dust particles. Effective roof insulation is also available in the form of roof shading device. Such roof-shading device has a removable cover. The roof-shading device could be made closer to the roof and rolled to permit radiative cooling at night. The upper surface of the canvas is painted white to minimize radiation. Effective insulation could be built in by reducing the air cavities. Air cavities resist heat flows and heat transfers. The radiative component of heat transfer could be reduced by low emissivity and high reflective coating using aluminium foil. This kind of insulation is quite standardized. It mounts aluminium foil on paper. Radiative heating is reflected in one direction after allowing the heat from another direction. This is often a good option for roof insulation.

The roofs of buildings receive the thrust of heat throughout the day**. In developing countries like India construction practices mainly involve reinforced cement concrete (RCC) as the roofing element, which is noted for its high thermal conductivity. High thermal conductivity does not lead to the protection of building from heating.** But superior structural engineering technologies have given rise to deployment of thinner and thinner concrete thickness, ranging from under 100 to 150 mm. If the roof can be protected from heat incidence the conditions down below can be controlled to a great extent. The atmosphere inside the building shall remain below the ambient temperature through out the day. If the roof is exposed to solar heat the temperature inside the building will also rise as the day progresses.

When buildings are air conditioned, the purpose of the system is to maintain a lower temperature than ambient temperature inside the building. If the roof is exposed to solar heat it will generate continuous heat inside the building that in turn will increase the A.C. machinery load. Now for a situation when the roof is protected from solar heat, it will reduce the running time of A.C. compressors because continuous heat input from outside has stopped as well as cold going out would also stop. That is once a regulated temperature is reached inside it will remain there for a long time even when power goes off only if the building is well insulated and there is a minimization of air infiltration/exchange.

This concept of protecting the roof is termed as Roof Insulation. There are many different types of insulation materials to choose from when applying on a commercial roof or reroofing an existing structure. The function of roof insulation is to insulate the building against heat inflow from outside during the day.

In the sector of insulation, companies like Honeywell, Lyod, Mexmil, Sura, Xiamen are going to export their insulation technologies to India. Research on thickness of walls is being done with minimum impact on the net indoor floor area[34]. Bureau of Energy Efficiency has come forward with a regulation of 3.5 inches of insulation that could reduce the impact on the carpet area of the building. Insulated RCC diaphragm walls are available which prevent heat losses. Polyurethane board insulation is available in India. Adjustable venetian blinds in double windows are being used to reduce insulation and allow daylight. In certain cases roof insulation is also being used by using terracotta tiles. Solid timber board shutters are also available in the inner side for insulation. Windows with double rebates are available which could reduce infiltration and contributes to insulation. Insulated walls with construction sandwich are also commercially available in developing countries. Wall insulation using 40 mm thick expanded polystyrene and roof insulation with vermiculite concrete topped with China mosaic for reflection of heat is commercially available. Insulation of the roofs with earthen pots laid in mud phuska is also commercially available at the moment. Vermiculate insulation is also used extensively for insulation in roof and cavity walls along with cement, brickbat based waterproofing.

Now in developing countries of South Asia, escalating focus on energy conservation and sustainable construction are being given. This has led to increased consideration of the selection and use of efficient and reliable roof insulation materials. Demand for energy conservation has been a major catalyst for enhanced energy codes throughout the country. Concerns for the environment have led to calls for the use of more eco-friendly roofing systems, from application to re-roofing and disposal. Most of the building designers provide building insulation especially roof insulation. Some of the techniques of building roof insulation are highlighted below -

[34] "Carpet area of any floor shall is the covered floor area worked out excluding certain portions of the building which are - Sanitary accommodation, except mentioned otherwise in a specific case. Verandas, except fully enclosed and applied as internal passages and corridors. Corridors and Passages, Kitchen and Pantries. entrance halls and porches, vertical sun brakes, box louvres. Staircase and mumties. Shafts and machine rooms for lifts. Barsaties*, lofts. Garages. Canteens. Air-conditioning ducts and air-conditioning plant rooms, shafts for sanitary piping and garbage ducts more than two sqmtr in area" – Source - http://www.allahabadbank.com/tender-05aug-08c-carpet.doc

Techniques for building roof insulation

There are conventional, underdeck and overdeck type of insulation under the category of roof insulation. The three types and their subcategories are discussed below -

Conventional roof insulation practices

In India Roof Insulation with conventional materials like Foam Concrete, Mud Faska, Brick Batt Coba[35] are practiced to a large extent. However these products are heavy and add load to the roof slab. Thermal conductivity value is very high for these materials. It results into higher thickness and a tendency to develop cracks which leads to water absorption. These products are open cell and porous resulting into water absorption.

A comparison of the properties is given below -

	FOAM CONCRETE	MUD PHASKA	BRICK BATT COBA
Thermal Conductivity (w/mk)	0.085	0.519	0.750
Normal Density kg/m^3	320-400	1622	1820
Dead Weight for 50mm (kg/m2)	16	81	91
Effect of Temp. fluctuation	Cracks	Pointing Crack	Cracks with passage of time
Resistance to Fungus & Rot Attack	Good	Poor	Poor
Application	Good Workmanship Mandatory	Good Workmanship Mandatory	Good Workmanship Mandatory
Life in Years	4-5	6-8	2-4
Material configuration Cell Structure)	Open Cell Porous	Open Cell Porous	Open Cell Porous
Thickness (MM)	100	200	200

Source : Compiled from TERI Studies, TERI Analysis 2008(CRSBS, TERI)

(iii) Wall Insulation

The features for wall insulation are –

- fixed up insulation in rigid form on to the walls
- common in cold climatic zone where ambient temperatures during winters go below 5 or sub zero temperatures.
- works well in environment with low temperatures
- high density insulation is used
- mineral wool slabs are used on the brick wall by using clips and fixed in place with speed washers

[35] For Illustration of Brick Batt Coba refer to the Picture in Page 80

- brick layer and plastering is done along with a wire
- insulation from within the brick wall through frame work of wood or GI channels

(iv) Insulation over false ceiling

The traits are –

- Used mostly in AC buildings to reduce conditioned space area
- Comprises of fibrous insulation material, resin bonded mineral wool slab with a density of 48 kg/m^3 and thickness 25mm
- Packed in polythene bags and placed over false ceilings
- Needs provision of decorative ceiling
- Needs ducts & cables
- Needs flush mounted HVAC grills & lighting. Reduction in air volume for HVAC
- Attic space is used as return air passage

Underdeck Insulation

In this system a thermal barrier or insulation is provided so that the heat of the sun from over the roof is not allowed to enter inside the roof. A good thermal barrier should have low thermal conductivity, adequate density, low thermal diffusivity, non-hygroscopic, easy to handle property and should be preferably non-combustible in nature. Materials used for underdeck insulation are:

i) Fibrous Material

a) Resin Bonded Mineralwool (Rockwool and Glasswool) - They are made from selected siliceous rock melted at 1600 deg C and spun into fibers of diameter 4-5 microns. These fibers are resin impregnated, felted and cured to form rigid, flexible slabs and rolls of optimum density and resilience. Fibres are laid in parallel, pre determined pattern so that they are disposed perpendicular to the flow of heat. The fibres entrap millions of air cells in between which resist passage of heat flow and sound waves. Resin Bonded Mineralwool confirms to the following standards IS:8183, BIS : 3958 (Pt.5) (Indian Standard), ASTM : C513, C612.

These materials are compatible with materials with which it comes in contact in normal building applications. They have good fire performance characteristics and are rated non-combustible in accordance with BIS: 476 Part-IV (Indian Standard) and IS 1366. These goods are available in various densities from 24 - 48 kg/m^3 possessing low thermal conductivity and high durability.

The disadvantage with this material is that it leads to difficulties in house keeping. Settling of dust which leads to covering of insulation leads to a difficulty in cleaning.

Overdeck Insulation

The characteristics of this system are –

- Provision of a thermal barrier or insulation
- No allowance of the sun heat on the RCC slab of the roof
- Adequate compression resistance, lesser water absorption, resistance to ambient temp. and lesser thermal conductivity.

Under over deck insulation one has the following types which are –

A) Preformed Insulation Material: Preformed Insulation material are subdivided into:

i) Expanded Polystyrene slabs
ii) Extruded Polystyrene slab
iii) Polyurethane / Polyisocyanurate slabs
iv) Perlite boads

(i) Expanded polystyrene (EPS) - The characteristics of this are -

- Light weight cellular plastic foam material comprising of carbon and hydrogen
- Derived from petroleum products
- No use of CFCs
- Confirms to BIS : 4671.

(ii) Etruded Polystyrene - Extruded Polystyrene has the following traits –

- Improved variety of Expanded Polystyrene material.
- Consists of closely linked beads / globules to form rigid slabs and pipesections to reduce air gap between the beads
- Lesser amount of water absorption

(iii) Polyisocyanurate / Polyurethane foam slab – The traits of these goods are –

- Consists of urethane foam insulation materials
- Has a low thermal conductivity, lesser smoke emission & water absorption properties
- Product matches the IS:12436 & BIS 5608 standards

(iv) Perlite – The traits of this insulation are –

- organic rigid board insulation consisting of expanded volcanic glass, wood fibres bonded with asphaltic binders.
- light in weight, stable dimension and larger compressive strength.
- low ‘R’ value, high ‘K’ value and a tendency to absorb moisture

B) In-Situ Technology

(i) Spray applied Polyurethane : The traits of this technology are –

- Direct application on roof by spraying.
- Formed through mixing of Isocyanate and Polyol in the presence of a blowing agent
- Consists of close cell homogenous jointless insulation cover for roof
- Provides surface moisture resistance properties.
- Has good adhesive properties
- Has a low density
- It has a very low thermal insulation (K-value)
- The material is formed of 92% closed cell content by volume and are available in high density,
- Good dimensional stability to the material
- Reduction in thermal movement of the roof deck
- Prevention of the failure of the roof covering
- Needs additional protection against UV radiation
- Prolonged exposure to UV rays leads to yellowing and embrittlement

Roof Insulation also deals with another kind of insulation called metal roof insulation the features of which are highlighted below -

Metal Roof Insulation

In India and across the world, steel buildings are also coming up where steel structures absorb the heat. Steel temperature touches 600 degree Celcius when ambient is around 40-45 degree Celcius. This raises the insulation of metal roof buildings. The technical features of these buildings (insulation technologies) are as follows –

- Resin Bonded Mineralwool slabs of density 32-48 kg/m^3 are used as an insulation material
- The slabs are placed over a metal framework and welded to the steel structure
- Insulation is done with aluminium foil
- Pre-insulated buildings are constructed using pre-fabricated sandwich panels. made out of two metal sheets having an insulation of Polyurethane Foam or Expanded Polystyrene that is kept in between.
- Sturdy Polyurethane Foam panels with a higher density of 40-45 kg/m^3 as compared to Expanded Polystyrene of max. density of 22 kg/m^3.
- Panels (which panels) are used for shelter construction in high altitude areas and for Telecom Control Cabins.

Panels (what panels) are highly energy efficient and are used for construction of cold storage.

Building insulation also encompasses air conditioning insulation other than roof insulation. The features of air conditioning insulation is highlighted below –

Air conditioning insulation

In air conditioned building, the areas which require insulation with respect to air conditioned equipments are :-
a) Duct Insulation
b) Chilled Water Pipe Insulation
c) Chilled Water Pipe Support
d) Equipment Insulation

The important advantages of Air Conditioning Insulation are -

- Low Thermal Conductivity
- Low Thermal Diffusivity
- Proper Vapour Barrier Application
- Adequate Density
- Non-combustible Insulation
- Proper Application Procedure

The technologies under Duct Insulation, Chilled Water Pipe Insulation, Chilled Water Pipe Support, Equipment Insulation entails a range of goods and technologies which could reduce carbon emissions by better management of energy usages.
Various materials contribute to these types of insulation. Thus these materials if used in buildings would contribute to lesser carbon emissions through larger energy efficiency in buildings due to their properties of thermal conductivity. The properties of duct, water pipe insulation, water pipe support and equipment insulation are given below –

a) Duct Insulation

Important factors for duct insulation are –

- Proper selection of density of insulation
- Non-combustible materials
- Adequate thickness
- Vapour barrier
- Holding system
- Final finish
- Insulation slab are fixed with bitumen based cold adhesive on the GI duct surface and positioned with self adhesive pins
- Covered slabs with aluminium foil or polythene sheet vapour barrier

- Usage of protective cover comprising of aluminium sheet, sand cement plaster, nitryl rubber without the requirement of the vapour barrier

The materials used for duct insulation are:-

- Resin Bonded Mineralwool in density 32-48 Kg/m^3 and thickness 25 & 50mm.
- Polyurethane Foam 36 + 2 Kg/m^3 and thickness 30mm.
- Nitryl Rubber elastomeric close cell material of density 55-70 Kg/m^3 and thickness 13-90mm.

b) Chilled Water Pipe Insulation

The materials commonly used are (use the word characteristics also over here)

- Expanded Polystyrene Pipesection of density 18-20 Kg/m^3 and thickness 50-75mm.
- Polyurethane Pipesection 36 + 2 kg/m^3 and thickness 30 to 50mm.
- Rockwool Pipesection of density 144-160 kg/m^3 and thickness 50mm.
- Nitryl Rubber of density 55-70 kg/m^3 and thickness 6-32mm.
- Upgraded insulation of Polyurethane Foam pipesection have joints for complete sealing stopping vapour migration.
- Pipesections are applied with cold adhesive and are covered with aluminium foil, polythene sheet or mastic vapour barrier
- Covered with aluminium sheet or sand cement plaster which is not required in the presence of nitryl rubber

c) Chilled Water Pipe Support

The features are –

- High density Polyurethane Foam pipe support of density 90-100 Kg/m^3
- Thickness same as that of insulation (30-50mm) and length 300mm is fixed with metal fittings
- The support has the same property as that of Polyurethane Foam insulation
- No condensation at support points
- More life as compared to wood

d) Equipment (polystyrene, polyurethane, aluminium) Insulation

- Expanded Polystyrene slab 20-22 kg/m^3 and thickness 50-75mm.
- Polyurethane Foam slab 36 + 2 kg/m^3 and thickness 50mm.
- Insulation fixed with cold bitumen adhesive
- Vapor Barrier and Aluminum covering is used

Thermal Envelope of a building also consists of the glazing and shading component. Various technologies and goods in this component are already commercially available in many developing countries of South Asia, Asia Pacific, South East Asia. The next segments highlight them.

Glazing

The infrared portion of solar radiation is the main component which is responsible for the heat transfer (in addition to convection and conduction) through the glass of buildings.

Glazing technologies could regulate such heat transfer. Energy efficient glazings with different coatings are available commercially in developing countries like India. Multiple glazings are available that insulate the air cavity between glass layers and are known as Insulating Glass Units. The glasses in this case are held apart by spacer bar and the air cavity contains a desiccant material. Apart from this there are solar control glazing also which control the entry of solar heat and light into the buildings. These are non – selective metallic films deposited on glass, polymer substrates. Other than this heat absorbing glasses are available which comprises of metallic oxides. Owing to the thickness, these glasses can minimize the glare and excessive sunlight entering into these buildings. These glasses are often called tinted glasses. Heat reflecting glasses are also available. These glasses are based on the reflective property of thin coatings. They comprise of thin coatings of pure metal like gold, silver or bronze between two layers of glasses. Low emissivity type of optical coatings are also available in newly developed spectrally selective glazed glasses. In the windows with these glasses the infrared portion of the solar spectrum is prevented whereas the visible light is allowed for daylighting. Glasses with low emissivity reduce the radiative heat transfer from inside to outside of the room and vice versa. **These glasses are being imported from *Japan, U.S.A and Europe*. The double glazed glasses imported from Europe with proper sealing are also being used commercially in India. This includes glasses from Saint Gobain. High performance glasses are imported from Europe, U.S for efficient glazing. Apart from this, Louver's embedded double glazed glasses are also coming from Europe. Thus even in the market of glazing technologies there exists a preference for brands from Japan, U.S and Europe. There is also a dominance of these brands in the market of glazing technologies.**

Other than this, triple glazed glasses are also used in many windows. These glasses does not allow heat to pass and provide larger warmth by not not allowing the escape of heat. The glasses are warm not only on the edges but also on the entire glass surface that is glazed. In Europe, triple glazed units are available with a U value of .8w/ m2k. The values could be as low as .5w/m2k along with a krypton fill.

Shading

Shading devices for windows, walls in low residential buildings are already available. Window shading by a horizontal .76 m deep chhajja[36] could reduce maximum room temperature by 4.6 degree celcius. Some of the shading devices which are available include – a) Moveable opaque roller blinds, curtains, b) Adjustable, fixed louvers and c) Fixed overhangs. Wind towers are also commercially available in developing countries like India, South Africa and China In developing countries like Malaysia, South Africa, Brazil external shading by means of natural vegetation, building-integrated vegetation, such as green roofs and walls are already available. They are being used to make the building cool through the evapo transpiration method.

Space Heating, Ventilation and Air Conditioning

Application of efficient appliances in residential and commercial sector

Energy-efficient appliances (such as refrigerators and air conditioners) have a huge potential to save energy. The Bureau of Energy Efficiency of a developing country like India has recently introduced voluntary energy labelling for lamps, air conditioners and refrigerators. Studies indicate that there is nearly 17% energy saving by moving up from a 3-star refrigerator to a 4-star one. Similarly, there exists a large energy saving potential in case of air-conditioners as well. A shift from energy efficient refrigerators 7 (unlabelled) to 10 (5 star) can lead to a reduction of about 30% of annual energy consumption.

In case of motors, 11 kw motors with an efficiency of 86% at given load with a power factor of 88% could contribute to an annual energy saving of 1495 million USD. Energy efficient motors could cost 30% more than the equivalent standard motors. Energy efficient motors could have lesser losses through using low loss steel, longer core length, thinner laminations, air gap between stator and rotor. It also uses copper bars in the rotor instead of aluminium in the bearings. Energy saving controllers is also being used in certain applications.

[36] "**Chhajja** is the term for projecting eaves or cover usually supported on large carved brackets. It is an integral part of the architecture of Rajasthan, Gujarat, Punjab and Uttar Pradesh. In Rajasthan it is used in large scale. They act as heat sinks for the buildings in the hot region of Rajasthan." – Source - http://en.wikipedia.org/wiki/Chhajja

There is a large scope of achieving energy efficiency in refrigeration and air – conditioning through new technologies like vapour compression and absorption system. A vapour compression system absorbs heat by evaporation of liquid refrigerant, raising the pressure of low vapour pressure, through removal of heat from high-pressure vapour and through reduction of pressure of high-pressure liquid. Existing energy efficient vapour compression systems are classified as small, medium and large. Some of the other equipments which could contribute in achieving energy efficiency are cooling tower fan motors, secondary chilled water pumps, dry bulb economizer, enthalpy control measures. Some of the fan systems which are available at the moment in the refrigeration and air – conditioning systems enhancing energy efficiency are – a) Forward – curved fan systems, b) Fans with vortex vanes.

In air conditioners, efficient green chillers are available and they are imported from Europe, Japan and U.S. in many developing countries.. This holds good even for developing countries like India, Srilanka. Some of the companies which have been exporting their technologies and green chillers are – a) Carrier, b) Train, c) York (Blue Star), d) Clivet, e) Voltas and f) Mitsubishi. Window units have centralized chillers. The market for window ACs and centralized chillers are growing in developing countries like India gradually.

Energy efficiency in air – conditioning system in some of the residential buildings in India has been achieved by HVAC plant located in basement. The operation of the plant and the air-handling units are being controlled by microprocessor. The microprocessor control system ensures automatic load management when the building is run on a stand by power generator. This happens when the full plant operation is not possible.

Other than this, Dual Duct Constant Volume Systems, Low Leakage Dampers are also being used for promoting energy efficiency. Heat exchangers, heat pipes, heat recovery wheels could be used for enhancing energy efficiency. Evaporative cooling (evaporative cooler with a 24 inch fan size, 2.5 sq. m pad area), thermal storage systems are also being available for increasing energy efficiency in Refrigeration and Air – Conditioning. Some of the other options which could be used to facilitate energy efficiency are – a) Screw chillers, b) Condensor pumps, c) Microprocessors on cooling tower fans. Volumetric interconnection of floors for passive space conditioning, large cut outs for light and ventilation wells, usage of thermal mass of floor slabs for moderating diurnal swings of temperature. Trombe walls (half trombe, unvented trombe, vented trombe) are also being used for passive heating.

The Makati Stock Exchange Building is an eight-story office building with a total leasable area of around 30,000 square meters, built in 1971 in Philippines. The building retrofit included the following measures for air-conditioning:

- Replacement of the chiller units with more efficient ones.

- Installation of a condenser cleaning system. The system keeps chiller condenser tubes clean and thus increases efficiency.
- Replacement of cooling coils of all the Air Handling Units. This restored the cooling efficiency of the Air Handling Units to their designed efficiency.
- Installation of high-efficiency Air Handling Unit motors. To improve the efficiency of the Air Handling Units, all motors were replaced with high-efficiency units.
- Installation of Variable Frequency Drives (VFDs). VFDs were introduced in all condenser and chilled water pumps to improve efficiency. This has contributed to a grand total energy savings of 129761 Kwh/ year creating monetary savings of USD 17468/ year[37]

Passive design strategies (not necessarily solar alone) such as integration of solar chimneys, earth air tunnels, design strategies to demonstrate stack effect, use of water bodies for cooling, thermal mass, appropriate orientation and building envelope design, green roofs etc. are encouraged and used in order to minimize the energy demand by the building.

Heating and Cooling Systems

District Heating

District heating is commonly found in various places of Europe and specifically in Denmark. The technology used for district heating is largely developed in Denmark. This technology developed in Denmark is widely famous and used all across the world. This is a clean, energy efficient heat generation process in which heat is generated in a centralized location that is then distributed to the residential and commercial buildings of a particular area. The heat is is used for space and water heating in residential and commercial buildings. Generally a combined heat and power system is used for district heating. Such systems generate heat and power simultaneously and the heat from power generation is also used for space heating of residential and commercial buildings of a particular area. In this system, the combined heat and power plant pumps heated water and supplies it to the consumers through the distribution network. The supplied hot water in the residential buildings is applied in the radiators and the water used for domestic purposes is heated. The domestic hot water gets heated through heat exchanger. The supply of heat warms up the water which comes out of the tap. The non warm water from the homes is supplied back to the central heating plant where it is heated up. So the water is circulated in this way through the distribution pipelines. In some cases steam is used as a medium for heating up the water.

[37] http://www.aseanenergy.org/download/projects/promeec/2006-2007/building/ph/PH_Makati%20Stock%20Exchange.pdf, last accessed on 5th Nov 2008

Passive Solar Heating and Cooling

Solar Energy is used in heating up the buildings with the minimum usage of pumps, fans for distribution of heat. Walls, windows, roofs, floors, landscapes are used in controlling the heat generated by solar radiation. Daylighting design is also used in optimizing the usage of natural daylight as a heating option reducing energy consumption and use of any mechanical equipment for heating. High efficiency windows, with an insulation level of R-2000 and air-tight construction are used for passive solar heating. Also a window with a 30 degree south orientation also helps in passive heating of buildings through the use of solar energy. Double and triple glazed glasses are used for solar space heating. Also frames, multiple glazing, low-e coatings, insulating glass spacers, inert gas fills,are also used for space heating purposes. Mass material of heavy nature are also used in the walls for space heating. Some of the other things that are used for space heating are - quarry tile, floor stones in a mortar bed brick or double layers of gypsum board on walls. These helps in absorption of solar energy and subsequent radiation of the sun heat in the room in the absence of sun.

Some other heating and cooling technology that are used are stated below –

Wood Pellet Burning Stoves

These are used at homes for heating purposes.The stove pellets range between .3 – 1 inch in length. They are made from compacted sawdust, bark, agricultural waste, biomass fuels like nutshells, corn kernels, and soybeans

Micro Combined Heating and Power Systems

This would use cogeneration technology in generating heat for residential usage. This technology has been applicable for industrial applications. But now it is being developed in a micro scale to generate heat for residential usage.

Daylighting, Household Appliances, Consumer Electronics and Office Equipment

Lighting

The average electricity consumption for lighting in developing countries like India is around 160 kWh/m^2/annum[38] for residential and commercial buildings respectively. The average electricity consumption for lighting is high (at 160 kWh/m^2/ annum) as the commercial buildings consume more energy for space conditioning and lighting. The table 4, 5 below depicts the energy and carbon emission saving potential through various

[38] TERI Analysis, 2008

energy efficiency options in new residential and commercial buildings in India. The saving potential of each option may vary with typology, climate, space conditioning needs and the initial base design proposed by the client/designer. On an average it is estimated that the implementation of energy efficient options would help in achieving around 30% electricity savings in new residential buildings and 40% electricity savings in new commercial buildings.

Electricity saving potential and corresponding CO_2 emission mitigation by employing the energy efficient measures specified above in case of the upcoming residential and commercial buildings has been estimated and presented in the table below -

Table 2.4 : Cumulative CO_2 emissions mitigation potential of space conditioning and lighting in India in new residential and commercial buildings in India

Year	CO_2 emissions mitigation potential (million tones)		
	Residential buildings	Commercial buildings	Total
2006	0.0	0.0	0.0
2011	5.1	15.3	20.4
2016	13.4	39.9	53.2
2021	26.6	79.5	106.1
2026	48.0	143.3	191.3
2031	82.4	246.1	328.5

Source : TERI PSA Study , PSA/2006/3, National Energy Map for India, Technology; Vision 2030, Office of the Principal Scientific Adviser to the Government of India, TERI

By 2031, it is estimated that a reduction of about 328 million tones of CO_2 emissions can be cumulatively achieved by implementing building design changes and introducing energy efficient lighting in the new residential and commercial buildings.

In lighting, LEDs are available which are coming from Europe, U.S. The companies mainly operating in this segment in India are GE, Phillips. These LEDs are being used for indoor, decorative lighting. Domestic companies like Surya are producing LEDs which are commercially available in India. Induction lamps from Europe are also imported in India and are commercially available. Thorn, Siemens, Phillips, GE have been producing LEDs. Fluroscent lamps are also available. They are used for continuous dimming. The costs are however high due to the usage of different types of ballasts. The CII-Godrej Green Business Center (CII-Godrej GBC) Building is the office of CII-Godrej GBC, a joint initiative of the Government of Andhra Pradesh, Confederation of Indian Industry (CII) and Godrej, with the technical support of USAID and is the first green building in India. It is an unique model of a successful public-private partnership that is dedicated to promote efficiency and equitable growth leading to sustainable development. The building is centered around a circular courtyard, with a series of smaller interior courtyards. Energy-efficiency features of this building include: North light for indoor day-lighting. Almost 90 percent of the interiors are day-lit, with north lighting and

windows facing onto the courtyards. (The site uses north light to minimize heat gain in its tropical location.) In many developing countries like China, LEDs are imported from Europe. In countries like Srilanka, India the entire technology is coming from Europe. In some of these developing countries of South Asia, CFLs are produced locally within the country. The components like filament fibres are coming from Taiwan. They are then assembled to produce cheaper CFLs with the use of the local labour. This has implications on the cost dimensions of CFL. For instance, the cost of a CFL has dropped from an average 12 USD in mid 90s to an average of 3- 5 USD in 2008. In countries like India, components of the CFL are coming from China, Taiwan which are then assembled in India. In comparison to this the cost of commercially available LEDs in the developing countries of South Asia, Latin America, Africa are 4 – 5 times than the price of a CFL. The energy saving potential in new residential and commercial buildings of developing countries under such a scenario is given below -

Energy saving potential in new buildings (in lighting)

In lighting appliances, tungsten halogen type of incandescent lamps are available which are energy efficient. Type R reflector lamps are available for indoor lighting. Parabolic aluminized reflector are used for outdoor flood lighting. Fluorescent lamps with replacement of ballasts and fixtures are available as efficient lighting options. CFLs are also energy efficient sources of lighting in India that saves almost 60% - 75% of energy. The 9W CFLs have been effective in this regard. Energy savings lamps of 36W with fluorescent ballasts could be used. This raises the efficiency of the fixture by 12% - 30%. Another option of energy savings could be through the use of 36 W slim tubelights. The high-pressure sodium lamps are also one of the energy efficient options which could be applied in the residential and commercial sector. Some of the other energy efficient equipments for lighting include the lighting control devices. **The lighting control devices which are available in India include – Snap switches, Photocells, Timers, Occupancy sensors, Dimmers.** Mercury Vapour, Metal Halide and Low Pressure Sodium lamps are some of the energy efficient lighting options for residential and commercial buildings of developing countries like India, China, Brazil, South Africa. High intensity discharge lamps are also energy efficient sources of lighting. High-pressure sodium lamps are used for outdoor lighting. Air heating panels, wooden joineries are also available and being used to minimize infiltration losses to enhance natural lighting. Venetian blinds operated by microprocessor controlled motors tilts the slates at proper angles and helps in distribution of sunlight across the different faces of the building. Motorized louvres are automatically adjusted to reflect sunlight on white painted flat, angled panels of the ceiling. This reduces the energy load for lighting during the daytime and contributes to energy savings.

Energy saving potential in existing buildings (in lighting and space conditioning only)

Existing residential and commercial buildings in India offer energy saving potential through suitable retrofit options. In this case, the energy saving potential for residential buildings is estimated to be around 20% and for commercial buildings around 30%. Linear fluorescent lamps (25 mm diameter, slim 36 W high efficacy tubelights) have been available in the residential and commercial buildings. Compact fluorescent lamps are being used with 20% - 30% of wattage required for incandescent lamps. Halogen spotlights, metal halide lamps for external lighting are also being used in the residential and commercial buildings. In some residential buildings 25 Kwp solar PV power plant is being used at the roof for meeting the energy demands for lighting. Across developing countries, alternative technologies for lighting are being developed with the following criteria in consideration: (i) high lamp life (currently lamps with a life ranging from 10,000-20,000 hrs are available. R&D on increasing the lamp life greater than 40,000 hrs (upto 60,000 hrs) is being targeted, which will significantly reduce the maintenance costs) and (ii) efficiency of the lamp. There are several technologies in the market at various levels of technological development and establishment available. To name a few, they are:

- CFLs and T5: efficient, developed and already established in the market. The costs have reduced considerably (from Rs. 450 in 1990s to about Rs. 120 in 2008).
- LEDs: developed, however not established in the market due to high costs. Currently targeting the street lighting and indoor lighting market. The lamps and fixtures were initially being imported from other countries. But in many developing countries they are now being assembled. Efficiencies and costs of the LEDs may not be available in the market. The main barriers to the extensive use of LEDs are cost (first cost vs. life cycle cost), reliability, convenience of use/maintenance and disposal.
- Induction Lamp: technology is being developed (http://www.nam.lighting.philips.com/us/ecatalog/hid/pdf/P-5502.pdf)
- Sulphur Lamp: technology is being developed

The costs of alternative technologies in lighting in developing countries like India may be reduced by increasing demand in the market, enhancing the manufacturing capabilities of industries in India; producing the goods locally as far as possible; and importing components from countries like China and Taiwan as opposed to other European countries.

Characteristics of the commercially available goods, technologies in India are highlighted below –

Light Sources and Lighting Systems

- Broadly these are GLS (glass shell) incandescent lamps; Tungsten Halogen lamps; Compact Fluorescent lamps; Linear Fluorescent tubes; Gaseous Discharge lamps such as Mercury vapour, Sodium vapour, Metal halide; LEDs etc.

Incandescent GLS Bulbs

- Low luminous efficacy (12 to 14 lumens / watt) and short life (only 1000 burning hours)
- Consists of a gas filled glass bulb with tungsten wire filament which glows when electrical current is passed through it

Tungsten Halogen Lamps

- Tungsten filament lamps same as GLS but with Halogen gas which prevents the vapourized tungsten being deposited on the quartz glass
- The gaseous compound flows back to the filament prolonging the life of the lamp
- The halogen lamp provides more than double the luminous intensity than the incandescent lamp and lasts twice as long
- Compact and with a wide variety from narrow spotlight to wall washers

CFL

- Fluorescent tubes packaged in the compact form
- Save up to 80% electricity for same light out put as the GLS bulb. For example a 20 W retrofit CFL, with integral electronic ballast, will replace a 100 W GLS bulb
    - Because of very long life, (12,000 burning hours from reputed manufacturers) far fewer lamps are required to be manufactured and transported resulting in saving of raw materials, transport and energy.
    - Reduces fire risk

Energy Saving with CFL

- 320 Million GLS points in the country with 25 % of these being replaced by CFL
- Energy savings will equate to
    - Saving 5760 Mw in Generating Capacity.
    - Saving 7884 Million Kwh p.a.
    - Saving 6 Million tons of coal p.a.

Linear Fluorescent Lamps

- Low pressure mercury vapour lamps. When an electrical charge is passed through the mercury vapour in the glass tube, the UV radiation is converted into visible light by the phosphors coated inside the tube.
- In India the 40 W, T-12, (38mm dia.) tubes with electro-magnetic chokes are commercially available. However these became obsolete in the mid 1980s in other countries with switchover to T-8, 36 W (28mm dia.) tubes which in turn are being replaced by tri-phosphor T-5, 28 W (16 mm dia.) tubes with high P.F.
- Has an electronic ballast saving great deal of power usage
- The efficacy of T-12 is approximately 60 lumens per watt against approximately 100 lumens per watt for the T-5 lamp.
- The switchover from T-12 lamp to T-5 lamp will save on average 30 W per lamp.
- There are approximately 240 Million T-12 lamp points in India. If 25 % are replaced by T-5 lamps with electronic ballasts it will lead to a savings of -
    - 2400 Mw of Generating capacity
    - Saving 3285 Kwh p.a. for consumers saving the consumers Rs 986 Crores p.a. in electricity charges.
    - 2.4 Million tons of coal p.a. the burning of which causes Greenhouse gases.

- The life of T-5 lamp is > 20,000 hours against only 5,000 hours for T-12
- The electronic ballast automatically switches off in case of a failed lamp or defective lamp and eliminates the fire risk
- The ECG (Electronic Control Gear)[39] operates at very high frequency (25 – 40 KHz) to ensure smooth flicker free light without stroboscopic effect responsible for eyestrains and headaches associated with the T-12 installations with conventional choke.
- The electronic ballast operates on a wide range of 145 Volts to 285 volts and are ideal for the Indian conditions of wide voltage fluctuations

Super HPS (High Pressure Sodium) lamps

- Has an efficacy of 150 lumens / W
- Allows higher mounting height for street lighting thereby reducing the no. of street light poles / KM (kilometer)with better illumination and uniformity. Leads to savings in new installations with respect to Energy, Capital cost and the running costs can be up to 25 %
- Long life and high luminous efficacy make the super lamps highly energy efficient and most economical

[39] An Electronic Control Gear is a device which controls the flow of electricity by regulating the frequency of the lamps. The electronic control gear could be reused once the integrated fluorescent tubes are not of use.

Light Emitting Diodes

- LED consists of several layers of semi-conductor material
- Forward biased light is generated in the thin layer
- Unlike the incandescent lamp radiating a continuous spectrum of light, an LED emits monochromatic light of a particular colour depending on the material used.
- Efficacy of LED has already reached more than 30 lumens/ watt against a target of 50 lumens/ watt
- Typical size of an LED is a few hundred micrometers mounted in a package for easy electrical contact
- High shock resistance
- Extremely long life, up to 100,000 burning hours
- The more immediate applications include, Instrument panels, Signage, Traffic and Railway signals, Rear and internal lights for cars, Back light for liquid crystal displays, Edge and path lighting, Garden lights with Solar voltaic energy source
- No IR and UV radiation

Solid State (Electronic) Ballasts

- Energy efficient and have power loss of around 2 Watts against approximately 15 Watts for the existing copper/aluminium electromagnetic ballasts which are being used in India with T-12, 40 Watt Tubes
- Automatic shutdown in case of end of life or defective lamp, therefore, virtually eliminating fire hazard
- High frequency operation (25 – 40 KHz) ensuring flicker-free light without stroboscopic effect
- Increases lamp life by 50 %
- Operates on wide voltage range of 145V to 285V
- High power factor > 0.95
- Harmonics within IEC recommendations.
- Fibre Optics
- Electromagnetic ballasts
- Electronic Control Gear
- Variety of Sensors etc.

Amongst the above-mentioned options prioritization has been done for LEDs and gaseous discharge lamps in India. This prioritization has been done by Bureau of Energy Efficiency (BEE) based on the existing market scenario on level of uptake in India. So in lighting applications quite a few commercial goods and technologies are available across developing countries like India, South Africa, Brazil, **China. These technologies include light control devices like Snap switches, Photocells, Timers, Occupancy sensors, Dimmers. It also includes goods like GLS (glass shell) incandescent lamps; Tungsten Halogen lamps; Compact Fluorescent lamps; Linear Fluorescent tubes; Gaseous Discharge lamps such as Mercury vapour, Sodium Vapour lamps, Metal**

halide lamps, LEDs, Linear Fluroscent lamps. Although goods like LEDs are commercially available, R&D is being carried out the same time in developing countries towards developing cheaper long lasting varieties of LEDs.

Energy Efficient Appliances

Application of efficient appliances in residential and commercial sector

Super Market Refrigeration System

Energy efficient motors, refrigerators are commercially available in developing countries like India, Brazil, China. They are produced by domestic companies like Bijlee Bharat, Kirloskar. The technologies are also imported from big players like Dillen, LG, Carrier. These large companies mostly control the 5 star, 4 star, 3 star energy efficient technology market with a significant market share.

Desiccant cooling technologies are also commercially available in developing countries of South Asia, South East Asia. Such technologies involve use of heat pipes, energy recovery wheels. But these goods and technologies are largely being used in centralized air conditioning systems. These technologies help in optimizing and reducing the cooling loads which thereby reduces the energy consumption and carbon dioxide emissions.

Active Collection and Transformation of Solar Energy

Energy saving potential through solar thermal system

Renewable energy particularly solar energy has a large potential in the residential building sector of India. Water heating is the second largest energy use in residential complexes after space conditioning (cooling /heating). Solar hot water systems are estimated to reduce the operating expenses on fuel for water heating to the extent of 70% to 100%[40], depending on the season. The Pearl River Tower, which has been under construction since 2006 in Guangzhou, will be occupied by the China National Tobacco Corporation when finished in 2009. It is designed to be a zero-energy building This building takes advantage of both high energy-efficiency building design and solar and wind power to generate energy for its consumption. Among its features are turbines that turn wind into energy for the HVAC system. Other green features of the building include a solar collector for more power generation, and a rainwater collection system, part of which is heated by the sun to provide hot water. The building is cooled, in part, through heat sinks and vertical vents.

[40] Source - fletcher.tufts.edu/research/2004/Milton-Samuel.pdf

Energy savings through Solar Energy Applications for Lighting, Heating and Cooking

Solar energy could also be used in the residential and commercial sector for energy savings. Different types of solar collectors are commercially available in developing countries of South Asia, Africa, South East Asia which could be used for tapping solar energy in order to contribute to energy savings in residential and commercial building sector. They include – a) Flat Plate Collector (consisting of coated metallic tube, plate arrangements called absorbers, top glass cover, housing with back and side insulation), and b) Parabolic Collectors. Efficiency of flat plate collectors could be increased by evacuated tube collectors in which the absorber is placed in an evacuated cylindrical glass tube. The heat losses are minimized due to the absence of a medium between the absorber and the cover. Some of the other equipments to increase energy efficiency through reduction of heat losses could be achieved through use of compound parabolic concentrator collector and parabolic trough concentrator. The above-mentioned collectors are used in raising energy efficiency in residential and commercial sector by using them for heating, drying. Solar air heaters are being used for drying of yarn, processed and finished cloth in the commercial buildings of the textile industry of many developing countries like India. Solar water heating systems are also being used in residential and commercial building sector to heat of 40000 liters of water per day on an average. This is contributing towards reduction of energy consumption in commercial buildings across developing countries. Solar cookers like Scheffler cookers/steam cooking systems are also being used for increasing energy efficiency in the residential and commercial sector through a reduction in LPG consumption. Solar collectors for service applications till 90 degree Celsius are readily available in India. This includes flat plate and evacuated collectors. At the moment there are 83 manufacturers who are manufacturing solar flat plate collectors as per BIS norms. **Parabolic tough concentrators are commercially available in Israel, U.S and Germany which are being imported in India. There is one manufacturer of parabolic dish concentrator in India at the moment. Solar chimneys also commercially available now**. Solar water heating and solar photovoltaic systems are also in place. Overhangs are also being used to maximize collection of solar energy in winter. In some of the residential and commercial buildings, roof mounted grid – integrated photovoltaic systems are also meeting major part of the building electrical load. Solar Collectors are also being used in developing countries of South Asia to warm air and blower fans are also used in residential buildings to circulate air into the interior spaces

Solar Water Heating

Solar water heating technologies by domestic companies like TATA BP SOLAR are available in developing countries like India, Pakistan, Srilanka. Convection heating technology is also available. Solar chimneys are used for heat gain in residential buildings of many developing countries like India, South Africa, China.

Domestic production of energy efficient technology applications in solar water heating have not gone up in developing countries like India to the extent the building and construction growth has taken place. This has created import dependence for energy efficient technologies for solar water heating.

Solar Photovoltaic

India is the 5th largest producer of solar cells/modules and SPV production has been increasing at an average annual rate of 25% (during what time period). In India, crystalline silicon solar cells are mainly manufactured and commercially available, which constitute more than 90% of the total production in India. **The main contribution to India's solar PV production is due to Tata BP solar, CEL (Central Electronic Limited), BHEL (Bharat Heavy electrical Limited), WEBEL solar etc**. However Indian PV industry consists of -

- Two silicon wafer manufacturers (with equivalent capacity of 4.5 Mw/year)
- 8 solar cell manufacturers (38Mw/year capacity)
- 14 module manufacturers (72Mw/year capacity)
- Around 45 system integrators

Table 2.5 The cell module shipments of different manufacturers in India–

Company	Shipments (Mw)
Tata BP solar	14.1
WEBEL	6
Maharishi	4.5
CEL (Central Electronics Limited)	2.5
BHEL	2
BEL	1
UDHAYA	1

Source : TERI Compilation, TERI Analysis 2008 (Centre for Distributed Generation) (TERI)

Solar Thermal

In India solar thermal systems are used both in the residential as well as commercial and industrial sector. Solar thermal energy can be utilized for various following end uses which are -

- Solar energy for water heating and industrial application
- Solar cooking

It is estimated that approximately 1000 solar domestic water heaters (2000m^2 of collector area) can contribute to a peak load saving of 1Mw. **There are now 79 manufacturers of**

solar flat plate collectors with approval from the BIS (Bureau of Indian Standards) for their product

Solar Cooker

Commercially box solar cookers are available at the moment in residential and commercial building sector in India. Other than this a dish solar cookers, community solar cookers are also commercially available in India at the moment. Such cookers have large automatically tracked parabolic reflector standing outside the kitchen; it reflects the sunrays into the kitchen through an opening in its north wall. A secondary reflector further concentrates the rays on to the bottom of the cooking pot, which is painted black. The solar steam cooking system comprises of automatically tracked parabolic reflectors installed in a series and parallel combination that generates steam for cooking in community kitchens.

CHAPTER 3: Key mitigation technologies/goods subject to R&D but with strong prospects of near to medium term deployment in developing countries

Introduction

As mentioned in chapter 2, there is a wide range of technology, goods which are commercially available in India and other developing countries of South Asia, South East Asia, Asia Pacific, Africa, Latin America. The areas in which R&D is being carried out are – a) Thermal Envelope, b) Daylighting, Household Appliances, Consumer Electronics and Office Equipment, c) Heating, Ventilation and Air Conditioning, d) Active Collection and Transformation of Solar Energy. The segments below emphasize on the R&D being carried out in the following areas.

Daylighting, Household Appliances, Consumer Electronics and Office Equipment

LEDs are already commercially available. R&D is going on in developing countries of South and South East Asia to produce cheaper commercially available LEDs in the next 5 years. Cheaper fluorescent lamps also have a chance of being commercially available. Precisely the R & D has to be done for –

- Development of low-cost light-emitting diode (LED)-based lamps for space lighting.

The Scientific Advisory Committee of the Cabinet (SAC-C) of India has recommended the launch of a national networked initiative for R&D on the development of the next generation of LEDs, particularly white LEDs. Other than this, sensors could also be applied in the residential and commercial buildings in India. The sensors have the following characteristics that are highlighted below –

Some of the products like sensors are already available. But R&D is going on to develop modified, cheaper versions of products like sensors in a large scale in South Asian, Asia Pacific and African developing countries. Some of the characteristics of the products under R&D is mentioned below -

Sensors

- These play a vital role in reducing demand and for security and have become popular in the developed countries.
- The most frequently used are 'Occupancy Sensors'[41] which automatically switch on the lights only when the space is occupied or in use and switch off the lights within a predetermined time (2 to 5 minutes) after the space is rendered empty.
- Likewise the security lights switch on only when some one enters the predetermined restricted area and/or building/house boundary.
- There are also the day-light sensors which permit the lights to switch on only when the illumination level drops below the desired level. These are recommended to be used in conjunction with the occupancy sensors, security lights and near windows to prevent the lights to come on during day time.
- The use of sensors can save 15 to 25 % of the power used for lighting.

Energy efficient appliances

The segments in energy efficient appliances that are undergoing R&D and have a chance of commercially available in next 5 – 10 years are –

- Development of energy-efficient ceiling fans
- Development of very-low-energy-consuming circuits for stand-by power

Some of the other areas of R&D for lighting are –

a. Replacement of inefficient light sources and electromagnetic chokes by long life energy efficient lamps, electronic control gear
b. A shift from conventional energy sources to renewable energy sources and extensive use of day-lighting
c. All the new buildings and houses / apartments may be wired with electronic ballasts with 4-pin sockets for CFL to prevent the use of GLS incandescent lamps
d. Setting up local micro grids in remote areas fed by renewable energy sources

In many developing countries R&D is being carried out to reduce energy consumption in certain consumer appliances which are - refrigerators, washing machines, dishwashers, televisions and videocassette, recorders, and cooking devices. Also R&D initiatives are taken to increase energy savings in computers, disk drives and copiers.

[41] There is a product differentiation in the types of sensors available. Whereas many of the censors are already commercially available R&D is also going on to develop low cost sensors which are high in the technology ladder.

Thermal Envelope

Better insulation technologies, glazing technologies, daylighting control technologies, LEDs, induction lamps with low life cycle costs could also be available through a larger R&D in these areas. Some of the other areas where R& D is required are -

- Development of energy efficient windows
- Development of low-cost insulation material
    - Development of electro chromic glazings
    - Development of simulation software to predict the energy used in buildings

Many of the above mentioned goods, technologies are commercially available. But R&D is still carried out to produce cheaper, long lasting varieties of the above mentioned goods on a large scale in developing countries of South Asia, South East Asia and Asia Pacific. R&D is also being done to develop more cost efficient RC (Reinforced Concrete) system, S (Steel) system, and wooden system in developing countries of South and South Asia, East Asia and Asia Pacific. Development of cheaper low emissivity glazing, vacuum sealing, and combinations for building is also a focus of R&D in many developing Asian countries. R &D is also going on in countries like China, India, and other developing countries of South Asia on developing cheaper total heat exchanger in buildings.

Heating, Ventilation and Air Conditioning System

Hybrid AC system is the one in which research is going on which might be commercially available in next 5 – 10 years. In countries like South Africa, R&D is going on to reduce energy consumption for active space heating. This is being mainly researched by emphasizing on the substitution of some usage of electricity (coming from coal) with electricity (coming from natural gas) for space heating. The active techniques are being focused to a larger extent in comparison to the contribution of passively keeping the house warm. R&D on solar powered absorption air conditioning systems is going on in developing countries of Asia. Solar flat plate hybrid systems for cooling and heating of large scale commercial systems are also an integral component of R&D in developing countries of South Asia, Africa. In some countries of Africa like Ghana, improving the energy efficiency of Air – Conditioners in buildings is the main focus of R&D research. In some countries of South Asia, R&D is being carried on to develop desiccant cooling systems with larger life time, lower maintenance cost.

Active collection and transformation of solar energy

In developing countries like India, South Africa, Brazil , research is going on broadly on

- Material (Thin film development)
- Large-scale manufacturing (processes involved) and PV products

The R&D is focusing on thin film solar cell and deals with pure fundamental research. The major areas of R&D in SPV (Solar Photovoltaic System) are in –

- Development of crystalline silicon thin film layers and low cost substrates for film deposition
- Development of large size solar cells/ modules based on crystalline silicon thin films
- Development of multi junction amorphous silicon solar cells/ modules
- Development of process technology for polycrystalline thin film solar cells/modules
- Development of devices based on new materials/concepts
- Improvement in solar cell efficiency to 15 % at commercial level and > 20 % at research level
- Improvements in PV module technology with higher packing density and suitability for solar roofs
- Development of lightweight modules for use in solar lanterns and similar applications

The table below gives a synopsis of the R&D projects going on in this segment (dealing with solar photovoltaic systems) in India –

Table 3.1: R&D projects in India

University/Institute	Ongoing Research Projects
Center For Materials for Electronics Technology, Pune	Development of phosphorous paste for solar cells to develop a prototype for production of phosphorous paste for use in fabrication of solar cells.
IACS	Development of nano and microcrystalline Silicon based low cost, high efficiency solar cells.
National Physics Laboratory	Development of Injection solar cells utilizing dye sensitized nanocrystalline TiO2 films.
IACS	Plasma enhanced chemical vapor deposition system for deposition of amorphous silicon films and a magnetron sputtering system. (6-7% efficiency achieved)
ACS, Jadavpur University	Deposition of silicon thin films
P.S.G. College of Technology, Kongunadu Arts and Science College	Transport properties of chemical bath deposited copper indium diselenide thin films

University/Institute	Ongoing Research Projects
IACS, Jadavpur	Fabrication of microcrystalline silicon solar cells using VHF PECVD technique (6% efficiency has been reached)
IISc, Bangalore	Development of CIS thin films (small area thin films with 12-14% efficiency have been fabricated)
Coimbatore Institute of Technology, P.S.G. College of Technology	CIS based solar cells prepared by CSVT/Hot wall deposition techniques. (2.8-3.5 efficiency has been reached)
Jadavpur University	Developing Cu based contact for p-CdTe solar cells
Sri Venkateswara University	Physical Properties of thin film CuAgInSe/CdS heterojunction cells. (3.2% efficiency has been achieved)
Coimbatore Institute of Technology, P.S.G. College of Technology	CdSeTe thin film solar cell (2.8%efficiency has been achieved)
IACS	Polymer based cells
IACS, Jadavpur	Application of ZnO as back reflector for the improvement of short circuit current of A-Si:H thin film solar cells. (10.26% - single junction, 10.85% - double junction)
Periyar Maniammai College of Technology For Women, Sree Sevigam Annamalai College, Alagappa University	Electrodeposition of Zinc Selenide thin films
IIT, Delhi	Nano composite copper oxide based thin film solar cells
Benares Hindu University	Pilot scale production of hydrogen by photocatalytic decomposition of water using semiconductor photocatalyst
IACS	CIS thin films using the co-evaporation technique (12%)
IIT, Delhi	CdTe thin films

Source : TERI Compilation, TERI Analysis 2008 (Centre for Distributed Generation ,TERI)

In countries like South Africa, countries of East Asia research is going on to produce more cheaper efficient solar water heaters/ geyser blanket for larger energy efficient water heating. In China, solar thermal utilizations are based on low and medium temperature thermal applications. Largely wafer based solar cells, thin film solar cells are subject of R&D in developing countries of Asia and in China. Solar water heating, building heating, solar drying, solar refrigeration systems and photovoltaic devices are the main areas of R&D research in China. Solar water heaters which exists largely in the Chinese, South Asian and Asia Pacific market are batch, flat-plate, and all-glass vacuum tube type. Solar water heaters comprised of a 10%[42] market share of water heating devices in China. R&D is going on to produce cheaper varieties of solar water heaters to increase the market share. In many countries of South Asia as well as in China R&D is

[42] Technical note solar thermal utilization in China, Renewable Energy 29 (2004) 1549–1556

going on developing cost efficient passive solar house. The passive solar house would reduce the energy consumption for space heating of buildings. Many of them could be already found in Northern China, where winter is extremely cold which leads to huge energy consumption for space heating in the absence of adequate bush, forest and hay. R&D is going on to develop passive solar greenhouses for agricultural production and flower cultivation in a more cost efficient way. The R&D research in this domain includes solar thermal utilization subsystem and a PV (photovoltaic) subsystem for buildings. In Malaysia, a building integrated photovoltaic project has been initiated. As a part of this project research would be carried out to reduce long-term cost of the PV technology. This would entail development of cheaper PV modules and inverters and their integration with building designs and envelopes. The thermal utilization system in these kinds of buildings would provide energy for water heating, space heating and cooling. The PV subsystem would provide energy for lighting and household appliances. R&D is going on in South Asia for large scale commercial application of these technologies in buildings. Most of these kind of buildings are being in a R&D phase in countries like China.

Wide scale commercial application of solar refrigeration is another area of R&D research in countries like China, India, Srilanka, Pakistan and other developing countries of South East Asia and Asia Pacific. Solar solid adsorption refrigeration, solar ice-maker are already being developed in China. But R&D is being carried out to produce large volume of such products on a commercial scale.

CHAPTER 4: Policies for promotion of energy efficiency in residential and commercial buildings

Some of the policies promoting energy efficiency in the residential and commercial buildings of developing countries of South Asia, South East Asia, Africa and Latin America are -

- Expansion of the commercial buildings tax deduction to the end of 2013
- Extension of the tax credit for efficient furnaces, boilers, air conditioners and water heaters; and insulation and window upgrades to existing homes (covering improvements installed in 2009, but not 2008)
- One year extensions for new energy-efficient home tax credit, to the end of 2009.
- Three years of manufacturer tax credits for sales of high-efficiency refrigerators, clothes washers, dishwashers and dehumidifiers (2008-2010)
- New investment tax credits for combined heat and power systems (till 2016)
- Tax credits based on accelerated depreciation norms for smart meters and smart grid systems for residential and commercial buildings
- Laying down of bonding program for green buildings and sustainable design for helping local and state governments to fund energy conservation efforts

In some of the countries, renewable energy usage is also promoted for its use in the residential and commercial buildings and the policies are –

- Extension of investment tax credit for residential and commercial solar installations for eight years (beyond 2008)
- A cap on the investment tax credit for residential solar electric installations placed into service after December 31, 2008
- Allow filers of the alternative minimum tax to claim solar investment tax credits for solar installations in residential and commercial builidings
- Allow public utilities to claim the solar investment tax credits
- Issuance of new clean renewable energy bonds and create a new category of tax credit bonds to finance state and local initiatives to reduce carbon emissions in residential and commercial buildings
- Extend tax deductions for energy efficient commercial buildings

Many developing countries like China, Brazil and countries of South and South East Asia are following practices like –

- public procurement of energy efficient products in residential and commercial buildings

- efficiency labeling and standards for residential and commercial buildings
- support for energy service companies to provide energy efficiency appliances in residential and commercial buildings

For instance in China, the ministry of finance has directed the government agencies to give greater priority in procuring energy efficient products. Energy efficient goods are being procured with a greater priority in commercial government buildings. Labelling and energy efficient standard products are also in the market in developing countries of India and China for its usage in residential and commercial buildings. Many energy service companies of China are providing financing and expertise for energy efficiency projects in residential and commercial buildings. There are close to 100[43] such energy service companies in China that are providing such facilities. The finances and loans are available for energy efficiency projects in residential and commercial buildings of developing countries largely on the basis of the long term cost that could be saved from energy savings in the building sector. One of the key issues for energy savings in the residential and commercial buildings of developing countries is the availability of technology. For that, technology transfer and diffusion has to take place. Some of the key issues that are being faced for technology transfer and diffusion in the residential and commercial building sector are – a) Hindrances from the Intellectual Property Rights regime, b) High applied tariffs on the technologies, c) Favourable policy regimes in developing countries to cover the incremental cost of low emission technologies in residential and commercial buildings of developing countries, d) Designing of subsidy schemes to manage the initial incremental costs of investments in residential and commercial buildings with a check on excess entry of players into the technology markets of residential and commercial buildings of the developing countries, e) Need for insurance and incentive mechanisms to address the technological risks of energy efficient technologies in the residential and commercial building sector of the developing countries. These issues have to be addressed by the policies in the developing countries in for a greater degree of energy efficient technology transfer and diffusion in the residential and commercial buildings of developing countries.

In many developing countries like China, South Africa policies have been framed to launch CDM projects dealing with replacement of incandescent lamps with compact fluorescent lamps in residential and commercial building sector. State policies have been framed in some developing countries to facilitate projects dealing with use of energy efficient appliances in residential and building sector. Policies have been designed to launch these projects in residential and commercial buildings as CDM projects.

[43] Zhao Ming 2006, Zhao Ming, 2006. *EMCA and China's ESCO Industry*. Presentation at the 2006 Conference on Energy Conservation in Buildings, Energy Performance Contracting and Financial Guarantee for Energy Efficiency Projects, Beijing, China, July 25-26, 2006.

So across the developing countries some policies are being developed to address the level of technological progress and diffusion which is being faced and needed by the developing countries. With such a background, the section below also identifies the possibilities of differentiated products and technologies which are commercially available in the developing countries. Many goods and technologies are already commercially available, although R&D is being implemented to produce greater advanced, cheaper varieties of such products.

Conclusion

Energy efficiency in buildings is a key factor towards addressing climate change problem as it contributes to carbon emissions to a great extent. The growing construction boom in various developing countries of South Asia, Asia Pacific, Africa, Middle East enhances the importance of the issue of energy efficiency in building construction. Commercially many technologies are available to improve energy efficiency which would lead to carbon emission reduction. These technology applications deal with reduction of heating and cooling loads, increase in energy efficiency of various appliances, new building designs, use of renewable energies as energy sources for buildings. With respect to reduction of heating and cooling loads, there are already many technologies and goods which are commercially available. These technologies deal with insulation, glazing and shading devices in buildings. Moreover energy efficient lighting devices like CFLs, LEDs are also commercially available in many developing countries like India, China, South Africa. But R&D is still going on in these developing countries towards production of cheaper varieties of LEDs. With regard to application of renewable energy in buildings, solar water heaters, cookers are commercially available in large developing countries like China, India. But R&D is going on in these countries to develop solar thermal refrigeration systems, building integrated PV designs. Currently, carbon mitigation goods and technologies are commercially available in developing countries of South Asia, Asia Pacific, South East Asia addressing thermal Envelope, daylighting purposes, active collection of solar energy in residential and commercial buildings. R&D work is still going on in producing cheaper durable, long lasting lighting applications of LEDs, Sulphur lamps.

Research shows there is a technological ladder which exists for products like sensors for managing cooling, lighting loads. While many countries of Europe and India have already developed certain kinds of sensors (reducing energy consumption of lights in residential and commercia buildings), there is a wide variety of product differentiation in types of censors across the technological ladder of sensors.

R&D is also being carried on in developing more energy efficient chillers, heat exchangers for air – conditioners in residential and commercial buildings. The objective of many of these R&D initiatives have been development of low cost energy appliance options which have been already made commercially available.

Many energy efficient consumer appliances are already commercially available in countries like India, China, Brazil, South Africa. These include products like hard disks, copy drives, computers.

So an analysis of the entire bandwidth of technology applications for residential and commercial buildings of developing countries gives rise to the following highlighted findings –

- Commercially available goods exist in improving the energy efficiency of the thermal envelope of the buildings. This include applications like energy efficient insulation materials, radiant heaters, softwares for managing and optimizing building cooling loads, energy efficient chillers, walking coolers, solar heaters, solar cookers, energy efficient freezers
- Many energy efficient lighting applications like CFLs, GLS are already commercially available in the developing countries of South Asia, East Asia, Asia Pacific and Africa
- Although many goods like LEDs, Sensors are commercially available research is still going on developing cheaper long lasting varieties of LEDs, Sensors in the developing countries
- R&D is being taken to develop integrated façade lighting, electrochromic windows
- R&D is also taking place in developing countries on thermal insulation technologies, reinforced concrete systems, solar thermal subsystems, mean radiant temperature based systems, under floor radiant cooling/heating, refrigeration cycle and leak detection systems, building integrated PV designs, solar air conditioning systems
- Passive design strategies (not necessarily solar alone) such as integration of solar chimneys, earth air tunnels, design strategies to demonstrate stack effect, use of water bodies for cooling, thermal mass, appropriate orientation and building envelope design, green roofs etc. are encouraged and used in order to minimize the energy demand by the building

So many of the above mentioned technologies have a possibility of being commercially available in a span of 10 years. In order to smoothen the process of transition from lab to market for these technologies, it is necessary to have policy incentives, government support in the developing countries along with the able partnerships of private agencies. Reduction of global public liabilities like environmental pollution could happen in a faster way through prioritization of the R&D areas of research reducing heating and cooling loads, managing energy consumption, creating new building designs and enhancing use of renewable energy. This could foster only in the presence of equitable global regime of technology transfer, development research. A result of that could be felt through the reduction of carbon emissions generating global positive externalities across developing and developed countries.

ANNEX I – Tables

Table A1: Climate Mitigation Goods Available on a Commercial Basis

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
	Thermal Envelope	In most of the developing countries of Asia and South East Asia like China, Hong Kong, Thailand and Singapore a large focus has been given on an energy efficient building envelope to achieve energy efficiency in residential and commercial buildings. Technology for efficient insulation, Solar radiation through windows are available in the developing countries of Asia and South East Asia. **Insulation** Insulation technology is commercially available in India at the moment. Under such a category – PUF insulation, extruded polystyrene insulation goods are commercially available. In insulation the following types are there –	The insulation materials reduces the heat flow from the outside to the inside of the building and vice-versa (depending on climate differences)This reduces the cooling or heating loads and helps in reducing energy consumption for cooling within the building. Efficient glazing reduces the lighting load by using passage of natural light within the building that reduces the energy consumption. Efficient double glazed glasses reflects the heat (UV radiation of the sun) which reduces the passage of heat to the inside of the building thereby reducing cooling load and energy consumption.	Europe, Japan, U.S.		

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		Fibrous Insulation The characteristics of this type of insulation are – • Comprises of Rock wool and Glass wool in the form of slabs and rolls of density 24 to 48 kg/m^3 and thickness ranging from 25 to 75 mm • High-density 96 & 144 kg/m^3 rigid slabs and boards are also available. The typical thermal conductivity is around 0.029 W/mk at 10 deg.C mean temp. It is also available as pipe sections in densities from 85 to 144 kg/m^3. Resin Bonded mineral wool confirms to BIS : 3958(Pt.5), ASTM C553, C612 Some of the characteristics of fibrous materials which are used for fibrous insulation are as follows – *Resin Bonded Mineral wool (Rock wool and Glass wool)* • Made from selected siliceous rock melted at 1600 deg C and spun into fibres of diameter 4-5 microns • Confirms to standards IS: 8183, BIS: 3958 (Pt.5), ASTM: C513, C612.			Of rock wool In slabs, sheets or rolls : Ex 6806.10 In other forms : Ex 6806.90	Heading 68.06 : **Slag wool, rock wool and similar mineral wools; exfoliated vermiculite, expanded clays, foamed slag and similar expanded mineral materials; mixtures and articles of heat-insulating, sound-**

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
						insulating or sound-absorbing mineral materials, other than those of heading 68.11 or 68.12 or of Chapter 69. 6806.10 - Slag wool, rock wool and similar mineral wools (including intermixtures thereof), in bulk, sheets or rolls 6806.90 - Other Heading 70.19 : **Glass fibres (including glass wool) and articles thereof (for example, yarn, woven fabrics).** - Thin sheets (voiles), webs, mats, mattresses, boards and similar nonwoven products : 7019.39 - - Other
		Rigid materials The characteristics of this type of insulation are – • Plastic foam materials comprising of rigid polyurethane foam (PUF), polyisocyanurate foam (PIR), perlite			Of glass wool In slabs, sheets or rolls : Ex 7019.39	

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		• PUF confirms to BIS: 5608, ASTM : C 591 and available in densities of 30 kg/m^3 to as high as 300kg/m^3 for pipe supports. • PIR confirms to BIS: 5608 standards and used for insulation applications in ships and also on RCC roof as underdeck insulation Perlite has high thermal conductivity value and is a porous material and confirms to ASTM C610 Some of the rigid materials which are used for rigid material insulation are as follows – *Phenolic Foam* confirms to BIS : 13204 low thermal conductivity *Polyisocyanurate foam* low thermal conductivity, low smoke emission			In primary form (i.e., liquids and pastes, including dispersions (emulsions and suspensions) and solutions; or in blocks of irregular shape, lumps, powders (including moulding powders), granules, flakes and similar bulk forms) : 3909.40 In primary form (i.e., liquids and	Heading 39.09 : **Amino-resins, phenolic resins and polyurethanes, in primary forms.** 3909.40 - Phenolic resins Heading 39.11 : **Petroleum resins,**

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		and low water absorption • confirms to IS:12436, BIS : 5608			pastes, including dispersions (emulsions and suspensions) and solutions; or in blocks of irregular shape, lumps, powders (including moulding powders), granules, flakes and similar bulk forms) : Ex 3911.90	**coumarone-indene resins, polyterpenes, polysulphides, polysulphones and other products specified in Note 3 to this Chapter, not elsewhere specified or included, in primary forms.** 3911.90 - Other
		Cellulose fibre • good thermal insulation material and sticks to any surface configuration such as domes, steel beams, concrete columns • good fire resistance property			In primary form (i.e., liquids and pastes, including dispersions (emulsions and suspensions) and solutions; or in blocks of irregular shape, lumps, powders (including moulding powders), granules, flakes and similar bulk forms) : Ex 3912.90 Monofilament :	Heading 39.12 : **Cellulose and its chemical derivatives, not elsewhere specified or included, in primary forms.** 3912.90 - Other Heading 39.16 :

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
					Ex 3916.90 Monofilament : Ex 5405.00	**Monofilament of which any cross-sectional dimension exceeds 1 mm, rods, sticks and profile shapes, whether or not surface-worked but not otherwise worked, of plastics.** 3916.90 - Of other plastics Heading 54.05 : **Artificial monofilament of 67 decitex or more and of which no cross-sectional dimension exceeds 1 mm; strip and the like (for example, artificial straw) of artificial textile materials of an apparent width not exceeding 5 mm.**
		Other than this, preformed insulation material is used for insulation. Preformed insulation material could be divided further into Expanded Polystyrene slabs, Extruded Polystyrene slab, Polyurethane / Polyisocyanurate slabs, Perlite boards. The characteristics of these materials are given below –				

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		Expanded polystyrene (EPS) • Light weight cellular plastic foam material comprising of carbon and hydrogen and derived from petroleum products • Confirms to BIS : 4671			In the form of plates, sheets, film, foil and strip (other than those of Chapter 54) and of blocks of regular geometric shape, whether or not printed or otherwise surface-worked, uncut or cut into rectangles (including squares) but not further worked (even if when so cut they become articles ready for use). Ex 3921.11	Heading 39.21 : **Other plates, sheets, film, foil and strip, of plastics.** - Cellular : 3921.11 - - Of polymers of styrene
		Extruded Polystyrene • Improved variety of Expanded Polystyrene material and consists of closely linked beads / globules to form rigid slabs and pipe sections to reduce air gap between the beads • Lesser amount of water absorption			In the form of plates, sheets, film, foil and strip (other than those of Chapter 54) and of blocks of regular geometric shape, whether or not printed or otherwise	Heading 39.20 : **Other plates, sheets, film, foil and strip, of plastics, non-cellular and not reinforced, laminated, supported or similarly combined with other materials.** 3920.30 - Of polymers of styrene

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
					surface-worked, uncut or cut into rectangles (including squares) but not further worked (even if when so cut they become articles ready for use). Ex 3920.30	
		Polyisocyanurate / Polyurethane foam slab • Consists of urethane foam insulation materials and has a low thermal conductivity, lesser smoke emission & water absorption properties • Product matches the IS:12436 & BIS 5608 standards			In the form of plates, sheets, film, foil and strip (other than those of Chapter 54) and of blocks of regular geometric shape, whether or not printed or otherwise surface-worked, uncut or cut into rectangles (including squares) but not further worked (even if when so cut they become articles ready for use). Of polyurethanes :	Heading 39.21 : **Other plates, sheets, film, foil and strip, of plastics.** - Cellular : 3921.13 - - Of polyurethanes 3921.19 - - Of other plastics

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		Perlite Boards • organic rigid board insulation consisting of expanded volcanic glass, wood fibres bonded with asphaltic binders and light in weight, stable dimension and larger compressive strength. • low 'R' value, high 'K' value and a tendency to absorb moisture Other than this specific materials are used for duct insulation and the characteristics of such			Ex 3921.13 Of polyisocyanurates : Ex 3921.19 In sheets : Ex 6806.10 In other forms : Ex 6806.90	Heading 68.06 : **Slag wool, rock wool and similar mineral wools; exfoliated vermiculite, expanded clays, foamed slag and similar expanded mineral materials; mixtures and articles of heat-insulating, sound-insulating or sound-absorbing mineral materials, other than those of heading 68.11 or 68.12 or of Chapter 69.** 6806.10 - Slag wool, rock wool and similar mineral wools (including intermixtures thereof), in bulk, sheets or rolls 6806.90 - Other

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		materials are as follows – • Resin Bonded Mineral wool in density 32-48 Kg/m^3 and thickness 25 & 50 mm.			In sheets : Ex 6806.10 In other forms : Ex 6806.90	Heading 68.06 : **Slag wool, rock wool and similar mineral wools; exfoliated vermiculite, expanded clays, foamed slag and similar expanded mineral materials; mixtures and articles of heat-insulating, sound-insulating or sound-absorbing mineral materials, other than those of heading 68.11 or 68.12 or of Chapter 69.** 6806.10 - Slag wool, rock wool and similar mineral wools (including intermixtures thereof), in bulk, sheets or rolls 6806.90 - Other
		• Polyurethane Foam 36 + 2 Kg/m^3 and thickness 30 mm			In the form of plates, sheets, film, foil and strip (other than those of Chapter 54) and of blocks of regular	Heading 39.21 : **Other plates, sheets, film, foil and strip, of plastics.** - Cellular : 3921.13 - - Of

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
					geometric shape, whether or not printed or otherwise surface-worked, uncut or cut into rectangles (including squares) but not further worked (even if when so cut they become articles ready for use). Of polyurethanes : Ex 3921.13	polyurethanes
		• Nitryl Rubber elastomeric close cell material of density 55-70 Kg/m^3 and thickness 13-90 mm			Ex 4002.59	Heading 40.02 : **Synthetic rubber and factice derived from oils, in primary forms or in plates, sheets or strip; mixtures of any product of heading 40.01 with any product of this heading, in primary forms or in plates, sheets or strip.** - Acrylonitrile-butadiene rubber (NBR) : 4002.59 - - Other

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		The materials used for chilled water pipe insulation are as follows – • High density polyurethane foam pipe support of density 90 – 100 kg/m^3 • Thickness, insulation of 30 – 50 mm, length of 300 mm with metal fittings The characteristics of the material used for equipment insulation are – • Expanded Polystyrene slab 20-22 kg/m^3 and thickness 50-75 mm.			Ex 3926.90 In the form of plates, sheets, film, foil and strip (other than those of Chapter 54) and of blocks of regular geometric shape, whether or not printed or otherwise surface-worked, uncut or cut into rectangles (including squares) but not further worked (even if when so cut they become articles ready for use). Ex 3921.11	Heading 39.26 : **Other articles of plastics and articles of other materials of headings 39.01 to 39.14.** 3926.90 -Other Heading 39.21 : **Other plates, sheets, film, foil and strip, of plastics.** - Cellular : 3921.11 - - Of polymers of styrene

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		• Polyurethane Foam slab 36 + 2 kg/m^3 and thickness 50 mm.			In the form of plates, sheets, film, foil and strip (other than those of Chapter 54) and of blocks of regular geometric shape, whether or not printed or otherwise surface-worked, uncut or cut into rectangles (including squares) but not further worked (even if when so cut they become articles ready for use). Of polyurethanes : Ex 3921.13	Heading 39.21 : **Other plates, sheets, film, foil and strip, of plastics.** - Cellular : 3921.13 - - Of polyurethanes
		• Insulation fixed with cold bitumen adhesive			NOTE : Not clear whether the description refers to any material combined with bitumen adhesive or to the expanded polystyrene or	Heading 39.21 : **Other plates, sheets, film, foil and strip, of plastics.** - Cellular : 3921.11 - - Of polymers of styrene 3921.13 - - Of

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
					polyurethane slabs indicated above only. The applicable HS-codes given below concern the latter group. In the form of plates, sheets, film, foil and strip (other than those of Chapter 54) and of blocks of regular geometric shape, whether or not printed or otherwise surface-worked, uncut or cut into rectangles (including squares) but not further worked (even if when so cut they become articles ready for use). <u>Of polystyrene :</u> Ex 3921.11	polyurethanes

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		• Vapour Barrier and Aluminium covering is used			Of polyurethane : Ex 3921.13 NOTE : Not clear whether the description refers to any material combined with aluminium or to the expanded polystyrene or polyurethane slabs indicated above only. The applicable HS-codes given below concern the latter group. In the form of plates, sheets, film, foil and strip (other than those of Chapter 54) and of blocks of regular geometric shape, whether or not printed or otherwise surface-worked, uncut or cut into	Heading 39.21 : **Other plates, sheets, film, foil and strip, of plastics.** - Cellular : 3921.11 - - Of polymers of styrene 3921.13 - - Of polyurethanes

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
					rectangles (including squares) but not further worked (even if when so cut they become articles ready for use). <u>Of polystyrene :</u> Ex 3921.11 <u>Of polyurethane :</u> Ex 3921.13	
		Glazing Glazing technologies are also commercially available. Under glazing technologies, double glazed low emissivity (e) glasses are commercially available. Triple glazed glasses are also used in many windows in Europe. These glasses does not allow heat to pass and provide larger warmth by not allowing the escape of heat. The glasses are warm not only on the edges but also on the entire glass surface that is glazed. In Europe, triple glazed units are available with a U value of .8w/ m2k for the combination of glass and frame. The values could be as low as .5w/m2k		Europe, U.K.	7008.00	Heading 70.08 : **Multiple-walled insulating units of glass.**

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		along with a krypton fill. Triple glazed glasses with argon gases and R- 3 value are available. Also triple glazed glasses with argon gas and R-5 value is available. Multi chambered glasses with high values of R- 12.5 is also available.				
	Heating Systems	In heating systems radiant heaters of small capacity are commercially available. Condensing Boilers • Condensing boilers could capture larger amount of usable heat from the fuel. The operating efficiency of a condensing boiler is increased by the use of dual heat exchangers. The heat exchangers ensure that maximum amount of heat is transferred from the burner. The exchanger also helps in reducing the heat losses in the form of gas. • Condensing boilers are of the following types – a) regular and b) combination. The regular condensing boilers warms up the water through the use of hot water cylinder. The combination condensing boilers doesnot use cylinders for warming water. • The new condensing boilers work with a seasonal efficiency of 88%. The condensing	Used in heating the room during winter. An indirect heating method is being used. Radiant heaters are generally mounted on ceilings. The heat rays from outside meet floors, walls and surfaces. The radiant heater uses this heat to warm up the air in the dwelling zone. Spreads more heat in all corners of a room with lesser energy consumption with a larger use of natural heat.	U.S., Canada, India	NOTE : It is assumed that the commodity at issue refers to a radiant ceiling system (other than mechanical or electrical) which utilizes either hot or cold water in order to heat or cool spaces. These systems come in the form of linear panels, and are made from an extruded aluminium heating strip that provides heat transfer to which copper tubing is attached. Classification	Heading 76.16 : **Other articles of aluminium.** - Other : 7616.99 - - Other

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		boilers use Natural Gas, LPG and Oil as fuel. These boilers have burner control devices. It also includes fans, motors, heaters and other electrical equipments. It generally excludes pumps that are used for water circulation outside the pump. The condensing boilers contain storage combination boilers. The storage combination boilers contain layers of insulation. • The material used to insulate the stored hot water are mineral wool, polyurethane foam and fibre glass. Heating Controls Consists of time programmer and room thermostat. It also often contains a cylindrical thermostat with thermostatic radiator valves.	The thermostat timer switches off the heat once the room temperature reaches at the desired level through heating in cold climate. In this way the timer saves the wasteful use of energy and thereby helps in lowering of energy consumption and carbon emissions.		according to material which gives the whole its essential character : Ex 7616.99	

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
	Cooling and cooling loads	In cooling and cooling loads the technological softwares that are commercially available are – VISDOE, HAP, TRNSYS. Most of these softwares are imported from U.S. and Europe. Duct Sealing A well designed sealed duct system could improve energy efficiency of the buildings. Improved duct systems reduces the loss of the conditioned air within the rooms of the building. This could reduce the energy consumption.	Calculates optimum cooling loads, energy performance for buildings to reduce extra energy consumption of a building. This helps in enhancing energy efficiency of a building. Reduction in the energy consumption through minimization of the air loss could save energy and would help in reducing emissions.	U.S., Europe	NOTE : Software as such is not classifiable in the Harmonized System. The applicable HS-code below refers to software presented on CD-ROM. Ex 8523.40	Heading 85.23 : **Discs, tapes, solid-state non-volatile storage devices, "smart cards" and other media for the recording of sound or of other phenomena, whether or not recorded, including matrices and masters for the production of discs, but excluding products of chapter 37.** 8523.40 – Optical media
	Heating, ventilation and air conditioning (HVAC) systems	High performance chillers with /without variable frequency drives (VFD) are commercially available. These goods are being produced by companies like Trane, Carrier, Denham Bush, Clivet. Also variable refrigerant volume (VRV) and variable refrigerant flow (VRF) systems are commercially available at the moment in India. District Heating This is a clean, energy efficient heat generation process in a centralized location that is then distributed to the residential and commercial	Consumes lesser energy during its usage in the window and centralized AC system of a building. This increases the energy efficiency of a building. Many of these combined heat and power plant in district heating use wood, natural gas and waste and provide a clean	U.S., Canada, Belgium, Denmark, Finland, France, Singapore, United Kingdom.	Window or wall type ('split-system') : Ex 8415.10 Other, incorporating a reversible heat pump : Ex 8415.81	Heading 84.15 : **Air conditioning machines, comprising a motor-driven fan and elements for changing the temperature and humidity, including those machines in which the humidity cannot be separately regulated.** 8415.10 - Window or wall types, self-contained or 'split-system'

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		buildings of a particular area It is used for space and water heating in residential and commercial buildings • Generally a combined heat and power system is used for district heating. Such systems generate heat and power simultaneously and the heat from power generation is also used for space heating of residential and commercial buildings of a particular area. • In this system, the combined heat and power plant pumps heated water and supplies it to the consumers through the distribution network. The supplied hot water in the residential buildings is applied in the radiators and the water used for domestic purposes is heated. • The domestic hot water gets heated through heat exchanger. The heated supply water warms up the water which comes out of the tap. The water from the homes is supplied back to the central heating plant where it is heated up. So the water is circulated in this way through the distribution pipelines. • In some cases steam is used as a medium for heating up the water. Wood Pellet Burning Stoves:	source of heat and power. Recycling of the heat for warming up the water and supplying it to residential places through distribution networks optimizes the usage of energy and help in attaining energy efficiency. Wood Pellet Burning Stoves are considered to be carbon neutral (he biomass used for the stove consumes carbon during its lifetime and the same wood when used in the stove releases some carbon dioxide) and hence are considered to be not a net carbon emitter. In this way they contribute to reduction of enhancement in environmental emissions.			- Other : 8415.81 - - Incorporating a refrigerating unit and a valve for reversal of the cooling/heat cycle (reversible heat pumps)

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		• These are used at homes for heating purposes.The stove pellets range between .3 – 1 inch in length. They are made from compacted sawdust, bark, agricultural waste, biomass fuels like nutshells, corn kernels, and soybeans Micro Combined Heating and Power Systems: • This would use cogeneration technology in generating heat for residential usage. This technology has been applicable for industrial applications. But now it is being developed in a micro scale to generate heat for residential usage. • These systems are used in a large scale in Denmark in distributing heater water in residential complexes • Also some of these are solar energy based hybrid systems of big capacity. Other than this, integrated heat pumps are also used for providing energy services. Combined heating and power systems are used in residential and commercial buildings of	The fuel used in micro combined heating and power systems are cleaner and thereby would reduce the level of energy consumption to generate heat. A reduction in energy consumption would reduce the level of carbon emissions. Also these systems optimize the usage of energy and hence leads to lower emissions through larger energy savings.			

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		various climatic zones. • Technical Characteristics – Integrated heat pumps (Require installation in places within a temperature range of 40 degree f – 90 degree , could be a geothermal heater with efficiencies of 300% - 600% in the coldest of winter nights) Many of these are already available in Europe. But research is going on in developing systems which have a higher efficiency and are available at a lower cost. Passive Solar Heating and Cooling: • Solar Energy is used in heating up the buildings with the minimum usage of pumps, fans for distribution of heat. Walls, windows, roofs, floors, landscapes are used in controlling the heat generated by solar radiation. Daylighting design is also used in optimizing the usage of natural daylight as a	These technologies reduce the use of energy consumption for heating of rooms by using natural energy to a larger extent and hence saves energy consumption and leads to reduction in carbon emissions.			

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		heating option reducing energy consumption and use of any mechanical equipment for heating. High efficiency windows, with an insulation level of R-2000 and air-tight construction are used for passive solar heating. Also a window with a 30 degree south orientation also helps in passive heating of buildings through the use of solar energy. Double and triple glazed glasses are used for solar space heating. Also frames, multiple glazing, low-e coatings, insulating glass spacers, inert gas fills,are also used for space heating purposes. Mass material of heavy nature are also used in the walls for space heating. Some of the other things that are used for space heating are - quarry tile, floor stones in a mortar bed brick or double layers of gypsum board on walls. These helps in absorption of solar energy and subsequent radiation of the sun heat in the room in the absence of sun. • In passive cooling technique ventilators, shading, vegetation, special glazing of windows are used to a large extent to provide cooling within the buildings. External shading devices are used for				

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		reducing space heating within the buildings. Also external heating is reduced by using good insulators, good reflective materials in walls and roofs. Cross ventilation techniques and mechanisms are also used for passage of cool breeze at night. • Buildings use louvres and shutter systems to block the sunrays from entering the room during summer. It is also used to allow the sunrays to come into the rooms of the house during winter. • Large windows facing south and building materials having thermal mass of high density that could absorb and release the heat are used in buildings. • Windows play a major role in passive solar cooling by helping in natural ventilation. • Direct gain systems are used where the sun rays directly heats up the building. The heat is stored in the thermal mass and in the stone floor slabs. The south facing windows provide maximum amount of sun rays during the winter that is absorbed and used for space heating. Similarly the windows would allow least amount of sun rays to pass onto the room in summer. Heat is retained in summer by using internal wall,				

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		floor that would be made of concrete, stone or masonry that might be painted with flat and dark colour. • Sun spaces or solarium are also often used in buildings. In such a system, solar radiation warms up the sun space directly. This then warms up the living space.				
	Building energy management systems (BEMS)	Honeywell and Siemens systems are commercially available. TRNSYS software programs are already available for carrying out simulation of optimal loads of collectors, storage tank, heat exchangers. Some other software programmes which are commercially available are - Ecotect, Lumen designer, AGI 32, Transys, VisDOE, RET screen, Energy plus and Design builder.	Monitors the usage of energy in a building. This reduces the chance of energy consumption in a building over the optimum level.	Germany, United Kingdom, United States, Europe, Belgium	NOTE : Software as such is not classifiable in the Harmonized System. The applicable HS-code below refers to software presented on CD-ROM. Ex 8523.40	Heading 85.23 : **Discs, tapes, solid-state non-volatile storage devices, "smart cards" and other media for the recording of sound or of other phenomena, whether or not recorded, including matrices and masters for the production of discs, but excluding products of chapter 37.** 8523.40 – Optical media
		The softwares are used for quantification of comfort/ discomfort hours, daylight received inside the building, impacts of various shading strategies, sizing for various renewable energy technologies, etc.				
	Active collection	Photovoltaics:	Uses the solar radiation, energy which is stored in the	Germany, Canada	PV modules : Ex 8541.40	Heading 85.41: **Diodes, transistors and**

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
	and transformation of solar energy.	Currently, crystalline silicon solar cells and modules are commercially available in India. Solar Photovoltaic Systems with an installed capacity of 2.9 MW are commercially available at the moment and are installed in the field. Solar power plants are being put up on field sites. Solar power packs are commercially available and are being applied in telecommunication sector. Solar home lighting systems, solar lanterns, solar street lights are also commercially available. Solar Thermal Systems: Solar thermal systems are also being used in the Indian industrial sector within the temperature range of 100 – 250 degree Celcius. This temperature requirement is met through high – temperature pressured water and low pressure steam. Solar Cookers: Other than this concentrating dish type solar cookers, indirect heating type solar cookers with or without heat storage, hybrid type solar cookers, box type solar cookers are also commercially available in India. Other than this concentrating cookers like the parabolic dish	solar cells. This energy is used to generate electricity, for cooking. Thus energy efficiency is attained by use of renewable energy.		Concentrating cookers, of iron or steel : Ex 7321.19	**similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes; mounted piezo-electric crystals.** 8541.40 - Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes Heading 73.21 : **Stoves, ranges, grates, cookers (including those with subsidiary boilers for central heating), barbecues, braziers, gas-rings, plate warmers and similar non-electric domestic appliances, and parts thereof, of iron or steel.** - Cooking appliances and plate warmers :

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		type cookers are also available. The parabolic dish type solar cooker has a concentrator. For high capacity community cooking Scheffler cooker is commercially available in India				7321.19 - - Other, including appliances for solid fuel
	Domestic hot water	Flat plate collector and evacuated tube collector for domestic hot water heating are being commercially available in India. Solar water heaters with 2000 sq. metre collector area are commercially available. Smaller systems are also present that could be applied in residential buildings. The collectors have coated metallic tube, plate arrangements called absorbers, top glass cover, housing with back and side insulation. Efficiency of flat plate collectors could be increased by evacuated tube collectors in which the absorber is placed in an evacuated cylindrical glass tube.	Collects and uses the solar energy to heat water. Reduces the load for water heating within the house.	Germany, U.S.	Flat plate collector (part of a system) Ex 8419.90 Evacuated tube collector (part of a system) Ex 8419.90 Complete system : Ex 8419.89	Heading 84.19: **Machinery, plant or laboratory equipment, whether or not electrically heated (excluding furnaces, ovens and other equipment of heading 85.14), for the treatment of materials by a process involving a change of temperature such as heating, cooking, roasting, distilling, rectifying, sterilising, pasteurising, steaming, drying, evaporating, vaporising, condensing or cooling, other than machinery or plant of a kind used for domestic purposes; instantaneous or storage water heaters, non-electric.** - Other machinery, plant and equipment : 8419.89 - - Other

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
						8419.90 – Parts
	Day-lighting Household appliances, consumer electronics and office equipment	***Continuous control (On/Off) systems*** for dimming, day-linking are commercially available. Ballast type control systems for fluorescent lighting are also commercially available. Such control systems are either tubular or compact. Other than this compatible dimmers and sensors are also commercially available. Aluminium luvers embedded in glasses are also available commercially. Some of the lighting options are as follows -	Adjusts the lighting load within a building based on the availability of natural light. This thereby reduces the loading requirements for lighting within a building. LEDs, fluorescent lamps provide light for a longer time period reducing the energy consumption.	U.S., Germany, U.K., Japan	Dimmer switch : Ex 8536.50	Heading 85.36 : **Electrical apparatus for switching or protecting electrical circuits, or for making connections to or in electrical circuits (for example, switches, relays, fuses, surge suppressors, plugs, sockets, lamp-holders and other connectors, junction boxes), for a voltage not exceeding 1,000 volts; connectors for optical fibres, optical fibre bundles or cables.** 8536.50 – Other switches
		Incandescent GLS Bulbs • Low luminous efficacy (12 to 14 lumens / watt) and short life (only 1000 burning hours) • Consists of a gas filled glass bulb with tungsten wire filament which glows when electrical current is passed through it			Ex 8539.22	Heading 85.39 : **Electric filament or discharge lamps, including sealed beam lamp units and ultra-violet or infra-red lamps; arc-lamps.** - Other filament lamps, excluding ultra-violet or infra-red lamps : 8539.22 - - Other, of a power not exceeding 200

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
						W and for a voltage exceeding 100 V
		Tungsten Halogen Lamps • Tungsten filament lamps same as GLS but with Halogen gas which prevents the vaporised tungsten being deposited on the quartz glass. • The gaseous compound flows back to the filament prolonging the life of the lamp. • The halogen lamp provides more than double the luminous intensity than the incandescent lamp and lasts twice as long. • Compact and with a wide variety from narrow spotlight to wall washers			8539.21	Heading 85.39 : **Electric filament or discharge lamps, including sealed beam lamp units and ultra-violet or infra-red lamps; arc-lamps.** - Other filament lamps, excluding ultra-violet or infra-red lamps : 8539.21 - - Tungsten halogen
		CFL • Fluorescent tubes packaged in the compact form • Save up to 80% electricity for same light out put as the GLS bulb. For example a 20 W retrofit CFL, with integral electronic ballast, will replace a 100 W GLS bulb. o Because of very long life, (12,000 burning hours from reputed manufacturers) far fewer lamps are required to be manufactured and transported resulting in saving of raw materials, transport and energy. o Reduces fire risk			8539.31	Heading 85.39 : **Electric filament or discharge lamps, including sealed beam lamp units and ultra-violet or infra-red lamps; arc-lamps.** - Discharge lamps, other than ultra-violet lamps : 8539.31 - - Fluorescent, hot cathode

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		Linear Fluorescent Lamps • Low pressure mercury vapour lamps. When an electrical charge is passed through the mercury vapour in the glass tube, the UV radiation is converted into visible light by the phosphors coated inside the tube. • In India the 40 W, T-12, (38 mm dia.) tubes with electro-magnetic chokes are commercially available. However these became obsolete in the mid 1980s in other countries with switchover to T-8 , 36 W (28 mm dia.) tubes which in turn are being replaced by tri-phosphor T-5, 28 W (16 mm dia.) tubes with high P.F. • Has an electronic ballast saving great deal of power usage • The efficacy of T-12 is approximately 60 lumens per watt against approximately 100 W for the T-5 lamp. • The switchover from T-12 lamp to T-5 lamp will save on average 30 W per lamp. • Approximately 240 Million T-12 lamp points are there in India. If 25 % are replaced by T-5 lamps with electronic ballasts it will lead to a savings of - 1. 2400 MW of Generating capacity 2. Saving 3285 KWH p.a. for consumers saving the consumers Rs 986 Crores p.a. in electricity charges. 3. 2.4 Million tons of coal p.a. the burning of which causes Greenhouse gases.			Ex 8539.32	Heading 85.39 : **Electric filament or discharge lamps, including sealed beam lamp units and ultra-violet or infra-red lamps; arc-lamps.** - Discharge lamps, other than ultra-violet lamps : 8539.32 - - Mercury or sodium vapour lamps; metal halide lamps

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		• The life of T-5 lamp is > 20,000 hours against only 5,000 hours for T-12 • The electronic ballast automatically switches off in case of a failed lamp or defective lamp and eliminates the fire risk • The ECG operates at very high frequency (25 – 40 KHz) to ensure smooth flicker free light without stroboscopic effect responsible for eyestrains and headaches associated with the T-12 installations with conventional choke. • The electronic ballast operates on a wide range of 145 Volts to 285 volts and are ideal for the Indian conditions of wide voltage fluctuations				
		Super HPS lamps • Has an efficacy of 150 lumens / W • Allows higher mounting height for street lighting thereby reducing the no. of street light poles / KM with better illumination and uniformity. Leads to savings in new installations with respect to Energy, Capital cost and the running costs can be up to 25 %. • Long life and high luminous efficacy make the super lamps highly energy efficient and most economical			Ex 8539.32	Heading 85.39 : **Electric filament or discharge lamps, including sealed beam lamp units and ultra-violet or infra-red lamps; arc-lamps.** - Discharge lamps, other than ultra-violet lamps : 8539.32 - - Mercury or sodium vapour lamps; metal halide lamps
		Light Emitting Diodes • LED consists of several layers of semi-			Ex 8541.40	Heading 85.41 : **Diodes, transistors and**

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		conductor material. • Forward biased light is generated in the thin layer. • Unlike the incandescent lamp radiating a continuous spectrum of light, an LED emits monochromatic light of a particular colour depending on the material used. • Efficacy of LED has already reached more than 30 lumens/ watt against a target of more than 50 lumens/ watt. • Typical size of an LED is a few hundred micrometers mounted in a package for easy electrical contact. • High shock resistance • Extremely long life, up to 100,000 burning hours. • The more immediate applications include, Instrument panels, Signage, Traffic and Railway signals, Rear and internal lights for cars, Back light for liquid crystal displays, Edge and path lighting, Garden lights with Solar voltaic energy source • No IR and UV radiation.				**similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes; mounted piezo-electric crystals.** 8541.40 - Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes
		Solid State (Electronic) Ballasts • Energy efficient and have power loss of around 2 Watts against approximately 15 Watts for the existing copper/aluminium chokes which are being used in India with T-12, 40 Watt Tubes			Ex 8504.10	Heading 85.04: **Electrical transformers, static converters (for example, rectifiers) and inductors.** 8504.10 – Ballasts for

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		• Automatic shutdown in case of end of life or defective lamp, therefore, virtually eliminating fire hazard • High frequency operation (25 – 40 KHz) ensuring flicker-free light without stroboscopic effect • Increases lamp life by 50 % • Operates on wide voltage range of 145V to 285V • High power factor > 0.95 • Harmonics within IEC recommendations.				discharge lamps or tubes
	Consumer Electronics	:Energy efficient computers, disk drives and copiers • Lesser consumption of energy by the processors • Energy efficient chips • Energy consumption in processor, input devices are reduced • Energy consumption in communication peripherals (networks, modems) are reduced • Timers exist to switch to lower power mode • Power management to recognize the resumption of activity			NOTE : As the description is not very specific, HS-codes have been assigned for the following commodities only : Automatic data processing (adp) machines (computers), disk drives and copiers. Copiers : Ex 8443.31 Ex 8443.32 Ex 8443.39	Heading 84.43 : **Printing machinery used for printing by means of plates, cylinders and other printing components of heading 84.42; other printers, copying machines and facsimile machines, whether or not combined; parts and accessories thereof.** - Other printers, copying machines and facsimile machines, whether or not combined : 8443.31 - - Machines which perform two or more of the functions of

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
						printing, copying or facsimile transmission, capable of connecting to an automatic data processing machine or to a network 8443.32 - - Other, capable of connecting to an automatic data processing machine or to a network 8443.39 - - Other
					<u>Adp machines :</u> 8471.30 8471.41 8471.49 8471.50 <u>Disk drives :</u> Ex 8471.70	Heading 84.71 : **Automatic data processing machines and units thereof; magnetic or optical readers, machines for transcribing data onto data media in coded form and machines for processing such data, not elsewhere specified or included.** 8471.30 - Portable automatic data processing machines, weighing not more than 10 kg, consisting of at least a central processing unit, a keyboard and a display

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
						- Other automatic data processing machines : 8471.41 - - Comprising in the same housing at least a central processing unit and an input and output unit, whether or not combined 8471.49 - - Other, presented in the form of systems 8471.50 - Processing units other than those of subheading 8471.41 or 8471.49, whether or not containing in the same housing one or two of the following types of unit : storage units, input units, output units 8471.70 - Storage units
	Refrigeration systems	Walking Coolers, Deep Freezers which are energy efficient to certain extent are available commercially at the moment. 11 kw motors with an efficiency of 86% at given load with a power factor of 88% are used in the refrigeration systems. Uses cooling tower fan motors, secondary chilled water pumps, dry bulb economizer, and enthalpy control measures. Some of the fan systems which are available at	Consumes lesser amount of energy for cooling and freezer systems. This increases the energy efficiency of the equipments.	Germany, U.S., U.K.	Ex 8418.50	Heading 84.18: **Refrigerators, freezers and other refrigerating or freezing equipment, electric or other; heat pumps other than air conditioning machines of heading 84.15.** 8418.50 - - Other

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		the moment in the refrigeration and air – conditioning systems enhancing energy efficiency are – a) Forward – curved fan systems, b) Fans with vortex vanes. Dual Duct Constant Volume Systems, Low Leakage Dampers are also existent in some of them. Some of the refrigeration and ac systems use a) Screw chillers, b) Condensor pumps, c) Microprocessors on cooling tower fans. Trombe walls (half trombe, unvented trombe, vented trombe) are also being used for passive heating in certain refrigeration and air conditioning system.				furniture (chests, cabinets, display counters, show-cases and the like) for storage and display, incorporating refrigerating or freezing equipment

Source – Compiled from TERI Studies, TERI Analysis 2008[44]

Table A2: Climate Mitigation Goods Undergoing R&D

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations

[44] Discussion with technology experts - Mr. Pradeep Kumar, Ms. Mili Majumdar, Dr. Pradeep Dadhich, Ms. Parimita Mohanty have also been useful in this compilation

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
	Thermal Envelope	*Integrated façade day lighting, electrochromic windows for improvement of day lighting and in development of sensors, analysis tools*. Technical Features – • *Integrated façade day lighting (Double Skin Facades, Dependent on Sun Shading which is located between exterior and interior glass façade, solar radiation is blocked before entering the building, absorbed heat by the pane shading system is released in the intermediate space)* • *Electrochromic windows (Low cost fabricating bleaches, upscaled sizes more than 14 by 16 inches for windows divided into small panes*) • *Sensors (Development of photosensors, Presence of timer switches, motion sensors)*	Insulation would allow efficient transfer of heat from outside to within the buildings and would reduce the cooling loads and would reduce power consumption. Sensors would lead to optimum use of light and would reduce additional energy consumption.	U.S., India, Japan, China, Australia, Hong Kong, Singapore, Thailand, Canada, Brazil		
		R& D is going on *thermally broken insulation technology*.				

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		Technical Features – • *thermally broken insulation technology (Uses hollow metal frames, Steel Doors insulated with fibreglass batting)* Developing next generation insulation technologies. In U.S., *insulation technologies are being developed which allows air transfer but does not allow transfer of moisture*. **Technical Features of the DU Pont Insulation Technology is –** • Helps in holding out of bulk water with vapour permeability preventing moisture accumulation in walls • The products are of the following types –				
		• Commercial Wrap (1000 sq. ft area), Stucco Wrap (1000 sq. ft area) • Installation accessories are – Wrap Caps (1000 caps/ box) • The materials used in designing the DU Pont Insulation technologies are –				

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		• Air penetration matches ASTM E 1677, water vapour transmission matches ASTM E 96, water penetration matches AATCC 9 (American Association of Textile Chemists and Colorists) Test Method 127, Weight of the material matches the TAPPI Test Method T – 410 • Air filtration matches the TAPPI Test Method T – 460 • Tensile Strength matches ASTM D822 In *improvement of thermal performance*. Specifically R&D is being carried out to develop – *a) conduction through opaque walls and window glass and b) solar radiation through window glass*.				
		Technical Features – • Opaque Walls (High value of overall thermal transfer value, high energy efficiency of the opaque walls)				

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		Developing insulation in the buildings and to reduce leakage by *developing optimum window areas, floor areas and occupancy spaces to incorporate energy efficiency in buildings*. Development of *specific window types for enhancing energy efficiency through larger ventilation*. In glazing, triple *glazed low e- krypton glasses with plastic at the centre* layer has been the focus area. **Technical Features –** • *triple glazed low e-krypton/argon glasses with plastic at the centre (parallely spaced glazing sheets separated by resilient spacing and sealing assembly, inner space comprises of moisture permeable foam material, separated glazing sheets creating insulated air space which is filled with krypton gas)*				
		Developing *low energy integrated building façade system*. This would				

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		have dimming ballast, optimal space conditioning provisions. Development of *exterior insulation systems, next generation roof and attic system, phase change insulation, better quality foams and dynamic membranes*. **Technical Features –** • *exterior insulation systems (Improvement in the interface detailing for improving the penetration property of exterior wall, improvement in the water penetration resistance of exterior wall for better insulation)* • *Phase Change Insulation (development of phase change materials smoothing out daily room temperature fluctuation, low cost material which is not toxic, corrosive or hydroscopic, melting temperature is above 25 degree Celsius)*				
		Technical Features of dynamic membranes –				

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		• ***Higher durability and better tear resistance property with an UV resistance of 9 months. Have flexible membranes which could be easily installed in different wall assemblies.*** • ***Helps in reduction of air leakage protecting the R value of insulation thereby generating greater energy savings*** **Reinforced Concrete System** Technical Characteristics are – • ***reinforced concrete chimney shell placed over a reinforced concrete foundation*** • ***Structural steel access platforms giving support, lateral restraint*** • ***Reinforced concrete roof slab over structural steel beams*** • ***Insulated stainless steel being used as an input*** • ***Roof drainage system*** • ***and miscellaneous ferrous***				

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		components • ***painting/coating of all structural steel work*** • ***Interior socket outlets***				
	Heating Systems	*R&D is ongoing in the existing heat and cold storage systems in Europe. In these technological systems, heat is captured by pumps for cooling in summer and the heat is stored in the underground and then the stored heat is applied in winter to warm up the temperature of the building. R&D is ongoing in enhancing the efficiency of these systems at a lower cost. R&D is ongoing to create chemical storage of heating in a little space of 1-3 cubic meters. The stored heat during summer generated through some mechanical and chemical* solar thermal utilization subsystem and a PV (photovoltaic) subsystem Technical Characteristics – • *Centralized on medium and low temperature applications* • *Comprises of plates and photovoltaic cells for tapping*	Reduces the energy consumption due to higher efficiency and leads to a fall in fossil fuel consumption.	U.S., China, Europe		

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		solar energy • *Comprises of a PV array and battery subsystem* • *Comprises of solar collector, the storage tank, and the heat exchanger*				
	Cooling and cooling loads	*Fluorescent Refrigerant Leak Detection System* to optimize cooling loads. Developing *solar air conditioners* in Abu Dhabi as a part of the Masdar initiative. Technical Characteristics – *Fluorescent Refrigerant Leak Detection System(Uses ultraviolet blue light inspection lamps, fluorescent dyes which are infused into the air conditioning and refrigeration system)*	Increases the optimum utilization of energy for cooling. Increases the energy efficiency and reduces energy losses. This optimizes energy and fossil fuel consumption. Fluorescent dyes which are used in refrigeration system reduce the CFC emissions and contributes to environmental benefits.	U.S., Canada		
	Heating, ventilation and air conditioning (HVAC) systems	*Mean radiant temperature based systems, under floor radiant cooling/heating, refrigeration cycle. Development of helix condensor for HVAC systems*. Improved airflow and air handling systems. Development of *ventilation models, evaporative cooling and chilled beams for residential and commercial buildings* across various	Optimizes energy usage for air conditioning, heating and refrigeration. Reduces energy consumption for heating and cooling purposes which results in lesser fossil fuel consumption.	U.S., Canada, Europe, Australia	Window or wall type ('split-system') : Ex 8415.10 Other, incorporatin g a	Heading 84.15 : **Air conditioning machines, comprising a motor-driven fan and elements for changing the temperature and humidity, including**

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		climatic zones. Technical Characteristics – *helix condensor (high efficiency evaporative condensor, thin walled helical coils, minimization of air water droplet contact with the helical coils)* *Solar powered absorption air conditioning systems* Technical Characteristics – • absorption chiller uses water and lithium bromide solution			reversible heat pump : Ex 8415.81	**those machines in which the humidity cannot be separately regulated.** 8415.10 - Window or wall types, self-contained or 'split-system' - Other : 8415.81 - - Incorporating a refrigerating unit and a valve for reversal of the cooling/heat cycle (reversible heat pumps)
		Reduction of energy requirement for refrigerants through the *use of monobloc systems to efficiently transfer energy to the point of requirement*. Recovery of *waste heat from refrigeration system for its usage in heating up the building and for recovery of hot water*. Technical Characteristics – Monobloc Systems (Rust free, moulded, quick removal of condensate waters, larger utilization of vibration isolators)		Canada		

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
		Development of geothermal heat pumps are also being developed. In developed countries reduction in the use of synthetic refrigerant by developing secondary loop refrigerant systems that would be integrated with the HVAC system of the buildings and would help in improving energy efficiency of buildings.		Canada, Hong Kong, Brazil	8418.61	Heading 84.18: **Refrigerators, freezers and other refrigerating or freezing equipment, electric or other; heat pumps other than air conditioning machines of heading 84.15.** - Other refrigerating or freezing equipment; het pumps : 8418.61 - - Heat pumps other than air conditioning machines of heading 84.15
		In air-conditioning R&D is being carried out in Hong Kong to develop more energy efficient air conditioners, refrigerators, freezers, air conditioners, incorporating modern ventilation techniques in the residential and commercial buildings. Also for improving indoor air quality of				

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		buildings through ventilation techniques and towards creating clean air conditioning techniques within residential and commercial buildings. Using natural ventilation techniques for improving energy efficiency of residential and commercial buildings. R&D is also being carried on desiccant cooling systems with larger life time, lower maintenance cost. Technical Characteristics – Natural Ventilation (ventilation opening could be small with a floor area between 10% - 15%, medium with a floor area between 15% - 25%, large with an area over 40%)				
	Building energy management systems (BEMS)	*Hybrid ventilation, task ventilation, and demand control ventilation* to build in energy management systems. Technical Characteristics – *Hybrid ventilation (Chemical Dehumidification, Insertion of solid desiccants in rotary heat exchanger)* *Advanced controls, wireless controls, integrated commissioning and diagnostics, information and*	Optimizes the energy loads for ventilation and increases the efficiency of energy consumption. The optimal level of energy usage is managed through monitoring and review by a software system. This optimizes the use of fossil fuel consumption.	U.S., Europe		

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		monitoring diagnostics system, whole building diagnostician software, internal commissioning. Technical Characteristics – Developing tools *like RESFEN and COMFEN, new softwares for creating new types of building geometry*. Development of building *information management, building energy usage analysis through out the life cycle of the building*. Technical Characteristics – *RESFEN and COMFEN, new softwares (new geometry simplification tool based on input from model based CAD, comprises of IDF generator)*				
	Active collection and transformation of solar energy.	Focusing on specific applications for development of solar PVs Technical Characteristics – • Development of crystalline silicon thin film layers and low cost substrates for deposition of films • Large size solar cells/ modules	Uses renewable sources of energy like the solar energy for meeting the energy needs and leads to reduction in fossil fuel consumption. This gives rise to environmental benefits.	Germany		

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		based on crystalline silicon thin films • Large size solar cells/ modules based on crystalline silicon thin films. • Polycrystalline thin film solar cells/modules • PV module technology with higher packing density and suitability for solar roofs. • Lightweight modules for use in solar lanterns and similar applications • Lightweight modules for use in solar lanterns and similar applications				
	Domestic hot water	Integrated solar thermal system for preparing domestic hot water. Low temperature solar thermal systems for integrating it into building system. Technical Characteristics – Integrated Solar Photovoltaic System (silicon thin film layer of crystalline nature, multifunction solar modules of amorphous nature, high density of packing, polycrystalline thin films) ***Solar water heaters/ geyser blanket***	Uses renewable source of energy for heating purposes. This reduces the fossil fuel consumption and leads to environmental benefits.	U.S., Europe, India, China	Ex 8516.10	Heading 85.16 : **Electric instantaneous or storage water heaters and immersion heaters; electric space heating apparatus and soil heating apparatus; electro-thermic hair-dressing apparatus (for example, hair**

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		Technical Characteristics – • wafer based solar cells • thin film solar cells of solar thermal systems				**dryers, hair curlers, curling tong heaters) and hand dryers; electric smoothing irons; other electro-thermic appliances of a kind used for domestic purposes; electric heating resistors, other than those of heading 85.45.** 8516.10 - Electric instantaneous or storage water heaters and immersion heaters
		Solar refrigeration Technical Characteristics – • Absorption refrigeration system based on solar energy for ice plants • Usage of solar energy to remove volatile component from solution and create pressure • Silica gel used as adsorbent			Combined refrigerator-freezers, fitted with separate external doors : Ex 8418.10 Refrigerators, household	Heading 84.18 : **Refrigerators, freezers and other refrigerating or freezing equipment, electric or other; heat pumps other than air conditioning machines of heading 84.15.**

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations
		• Usage of waste heat and generation of hotware/ steam • Stainless Steel and Mild Steel Sheets of different thickness are being used • Solar panel efficiency of 8% - 10%			type : Ex 8418.29 Freezers of the chest type, not exceeding 800 l capacity : Ex 8418.30 Freezers of the upright type, not exceeding 900 l capacity : Ex 8418.40 Other furniture (chests, cabinets, display counters, show-cases and the like) for storage and display, incorporatin	8418.10 - Combined refrigerator-freezers, fitted with separate external doors - Refrigerators, household type : 8418.29 - - Other 8418.30 - Freezers of the chest type, not exceeding 800 l capacity 8418.40 - Freezers of the upright type, not exceeding 900 l capacity 8418.50 - Other furniture (chests, cabinets, display counters, show-cases and the like) for storage and display, incorporating refrigerating or freezing equipment

Sector: Residential and Commercial Buildings	**Technology**	**Technology sub-category and Goods (With Technical Description)**	**Environmental Benefits**	**Country**	**HS-Code/ Ex-out**	**Observations**
					g refrigerating or freezing equipment : Ex 8418.50	
	Day lighting	Glare control of windows and in developing light pipes which would transmit the natural light into the buildings for day lighting. Advanced wireless lighting control systems, development of softwares to optimize the use of day lighting in commercial and residential buildings. Improvement of the energy efficiency of the CFl. Technical Characteristics – Light Pipes for natural light transmission (Directs daylight illuminance levels at 4.6 – 9.1 m from the window aperture with minimum solar heat gains. Computer assistance for sun ray tracing) Cheaper low emissivity glazing Technical Characteristics – • Emissivity levels are low • Lesser allowance of the infra red portion of sunlight	Optimizes the use of natural daylight for day lighting and hence reduces the energy consumption for day lighting. Reduction in energy consumption leads to environmental benefits.	U.S., Brazil		

Sector: Residential and Commercial Buildings	Technology	Technology sub-category and Goods (With Technical Description)	Environmental Benefits	Country	HS-Code/ Ex-out	Observations

Source – Compiled from TERI Studies, TERI Analysis 2008[45], websites mentioned in the references

[45] Discussion with technology experts - Mr. Pradeep Kumar, Ms. Mili Majumdar, Dr. Pradeep Dadhich, Ms. Priyanka Kochhar, Ms. Parimita Mohanty have also been useful in this compilation

Contents

1. Abbreviations and acronyms

UN	United Nations
WCO	World Customs Organization [i]
WTO	World Trade Organization

2. Harmonized System

2.1 Introduction

With a view to facilitating international trade, a commodity classification system was developed by the World Customs Organization (WCO). This system is laid down in the International Convention on the Harmonized Commodity Description and Coding System (done at Brussels, on 14 June 1983), also known as the “Harmonized System” or “HS”. As of 1 December 2008, 135 countries and economic or Customs unions are contracting party to this convention and another 70 countries and economic or Customs unions apply the system on a voluntary basis for Customs tariff and statistical purposes, thus covering over 98 percent of global trade.

Since the Harmonized System is updated on a more or less regular basis – sets of amendments came into force on 1 January 1992, 1996, 2002 and 2007, respectively – users may refer to different editions. Any reference in this paper to HS headings, subheadings and Section, Chapter or Subheading Notes, is based on the fourth edition (2007) of the Harmonized System.

2.2 Application

The Harmonized System is a multi-purpose tool, both in concept and design. Although developed as a Customs tariff and statistical tool, it is also used by governments, international organisations and the private sector for:

- internal taxes
- trade policies
- monitoring of controlled goods
- rules of origin
- freight tariffs
- transport statistics
- price monitoring
- quota controls
- compilation of national accounts
- economic research and analysis

The United Nations (UN) are using HS subheadings as building blocks for its economic classifications. Consequently, the data used for statistical systems such as the Standard International Trade Classification (SITC), the International Standard Industrial Classification of all economic activities (ISIC) and the Central Products Classification (CPC), is based on HS classification.

Also, the World Trade Organization (WTO) and its members use the Harmonized System as a common language for trade negotiations, and tariff concessions schedules of WTO members are based on the Harmonized System. In addition, the HS is also providing a basis for the Harmonization of non-preferential Rules of Origin, currently under development by the WTO.

Other international organisations use the HS as an instrument for monitoring international trade in certain controlled goods, e.g., chemical weapons material, hazardous waste, ozone-layer depleting substances and certain hazardous chemicals. The use of a single, global classification system in these areas has proved to be of great benefit to the implementation of and compliance with the international instruments involved.

Classification in the Harmonized System is also extensively used by individual countries in the application of preferential tariff treatment, in particular for the identification of the goods and for the determination of the origin of the goods.

2.3 Classification principles

The classification of goods in the Harmonized System follows its own rules. The appropriate HS heading or subheading for each commodity has to be determined on the basis of a full description of the goods, in association with the texts of the headings (and subheadings), any relevant Section, Chapter or Subheading Notes, and the General Interpretative Rules. The General Interpretative Rules lay down guiding principles for classification purposes, with a view to arriving at a uniform interpretation and application of the system. For legal purposes, the wording of the headings and any relative Section, Chapter or Subheading Notes, are decisive. Titles of Section or Chapters are for reference only and do not have legal status.

The WCO has published Explanatory Notes to the Harmonized System, which clarify the scope of the headings and subheadings. However, they do not have legal status and cannot change the scope of a heading or subheading.

2.4 Structure

In the Harmonized System, commodities can be grouped together in a “heading”. Such headings are identified by a code consisting of four digits. The first two digits of this code indicate the Chapter wherein the heading appears, while the latter two indicate the position within that Chapter. The two groups of digits are separated by a period. For example, HS heading 84.19 belongs to Chapter 84 and is the 19th heading in that Chapter.

Most of the headings have been further subdivided into two or more one-dash subheadings which, where appropriate, have been further subdivided into two or more two-dash subheadings. Such subdivisions are identified by a unique six digits code, the so-called “HS code”. The first four digits of this HS code correspond to the heading number (but without the period between the first two digits and the last two), whereas the fifth and sixth digits identify the one-dash and two-dash subheadings, respectively. To identify the subheadings, the numbers one to nine are used. If there are no such subheadings, a zero is used. Also, if a heading has not been further subdivided, the last two digits are “00”. The last two digits are separated from the first four by a period.

3. Appendices A1 and A2

3.1 Scope

Appendices A1 and A2 refer to commodities (both consumer goods and intermediates) and to technologies. The HS codes assigned would be applicable when the goods are presented (and, therefore, to be classified) separately. If components which constitute, for example, together a complete power plant, are presented together, the resulting HS code(s) may be different, due to the classification rules.

3.2 Assignment of HS codes

HS codes have been assigned to each of the commodities to the extent possible. In many cases, in particular in Appendix A2, it was not possible to assign an HS code, due to the fact that the description of the commodity at issue was not sufficiently specific in terms of the HS. For example, the reference to “integrated façade daylighting” does not provide a description which can be used to identify the commodity in terms of the HS. In these cases, no HS codes have been mentioned in the Appendices.

3.3 Results

The components listed in Appendices A1 and A2 are classified under 43 different HS codes, divided over 25 headings (see columns (3) and (2), respectively, of the table below). The table also shows the number of “hits” for each of the HS codes (column (4)).

With respect to the number of “hits” the following should, however, be taken into consideration.

First, in several cases no HS codes have been assigned. As indicated above, this is due to the fact that the description provided is lacking information which is needed to allocate a single HS code.

Second, it appears that the majority of the commodities fall within the HS chapters covering mechanical appliances (Chapter 84) and electrical apparatus (Chapter 85).

Finally, a particular HS code may cover a range of products, including the product referred to in one of the Appendices. This results in a so-called “ex-out”, which is identified by using the prefix “ex” in front of the HS code. For example, HS code 8504.10 covers all types of ballasts for discharge lamps or tubes. In Appendix A1 reference is made to “solid state (electronic) ballasts”, which is a particular type of ballast. Since not all ballasts are included in the Appendix reference, the prefix “ex” is used in front of HS code 8504.10.

4. Additional lists

4.1 WTO list and extracted list

In columns (5) and (6) of the table below, reference is made to the "WTO 153-list" and the "43-list", respectively (hereinafter "the lists"). Where there is an overlap between the current document and any reference from the two lists, this is marked with "x" in the appropriate column.

4.2 WTO list

The "WTO 153-list" refers to the list of commodities specified in the Annex to WTO document JOB(07)/54 of 27 April 2007. This document concerns a non-paper by Canada, the European Communities, Japan, Korea, New Zealand, Norway, the Separate Customs Territory of Taiwan, Penghu, Kinmen and Matsu, Switzerland and the United States of America, presented pursuant to the continued work under paragraph 31 (III) of the Doha Ministerial Declaration (reduction of Customs tariff rates for environmental goods). The Annex to this WTO document tables descriptions of commodities as a basis for negotiations within the context of environmental protection, including the following areas:

- air pollution control
- management of solid and hazardous waste and recycling systems
- clean up or remediation of soil and water
- renewable energy plant
- heat and energy management
- waste water management and potable water treatment
- environmentally preferable products, based on end use or disposal characteristics
- cleaner or more resource efficient technologies and products
- natural risk management
- natural resources protection
- noise and vibration abatement
- environmental monitoring, analysis and assessment equipment

4.3 Extracted list

The "43-list" concerns 43 products (derived from the WTO 153-list) that the World Bank identified as being relevant to climate mitigation and was proposed by the United States of America and the European Communities informally at the WTO December 2007. Therefore, an overlap between this document with this list is also an overlap with the WTO 153-list.

4.4 HS codes

It is to be noted that both lists are using HS codes from the HS 2002 edition, whereas this document uses HS codes from the 2007 edition. For this document there is only one difference between the HS 2007 codes in column (3) and those referred to in both lists. This concerns the reference to solar stoves, which are classified in HS 2007 subheading 7321.19 (HS 2002 : 7321.11).

4.5 Scope of descriptions

Appendices A1 and A2 refer to the consumer and intermediate products, while the lists also include complete installations and parts of components. This means that the overlap of HS codes covered in this document with those from the lists, is restricted. On the other hand, all environmental areas covered by the lists have been taken into account when comparing them with the HS codes in Appendices A1 and A2.

5. Table

(1)	HS heading (2)	HS 2007 Code (3)	Frequency (4)	WTO 153-list (5)	43-list (6)
1	39.09	3909.40	1		
2	39.11	Ex 3911.90	1		
3	39.12	Ex 3912.90	1		
4	39.16	Ex 3916.90	1		
5	39.20	Ex 3920.30	1		
6	39.21	Ex 3921.11	4		
7		Ex 3921.13	4		
8	39.26	Ex 3926.90	1		
9	40.02	Ex 4002.59	1		
10	54.05	Ex 5405.00	1		
11	68.06	Ex 6806.10	3		
12		Ex 6806.90	3		
13	70.08	7008.00	1		
14	70.19	Ex 7019.39	1		
15	73.21	Ex 7321.19	1	x	x
16	76.16	Ex 7616.99	1		
17	84.15	Ex 8415.10	2		
18		Ex 8415.81	2	x	x
19	84.18	Ex 8418.10	1		
20		Ex 8418.29	1		
21		Ex 8418.30	1		
22		Ex 8418.40	1		
23		Ex 8418.50	2		
24		8418.61	1	x	x
25	84.19	Ex 8419.89	1	x	x
26		Ex 8419.90	2	x	x
27	84.43	Ex 8443.31	1		
28		Ex 8443.32	1		

(1)	HS heading (2)	HS 2007 Code (3)	Frequency (4)	WTO 153-list (5)	43-list (6)
29		Ex 8443.39	1		
30	84.71	8471.30	1		
31		8471.41	1		
32		8471.49	1		
33		8471.50	1		
34		Ex 8471.70	1		
35	85.04	Ex 8504.10	1		
36	85.16	Ex 8516.10	1		
37	85.23	Ex 8523.40	2		
38	85.36	Ex 8536.50	1		
39	85.39	8539.21	1		
40		Ex 8539.22	1		
41		8539.31	1		
42		Ex 8539.32	2		
43	85.41	Ex 8541.40	2	x	x

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PICTURE: Brick Batt Coba

[i] In 1994, the Customs Co-operation Council adopted the working name “World Customs Organization” to reflect its transition to a global intergovernmental organisation. The Convention establishing the Customs Co-operation Council came into force in 1952. The organisation has 174 members (as per 1 December 2008).