Research on the Application of Japanese Environmental Technologies in India

Research Report
2010

Institute for Global Environmental Strategies

The Energy and Resources Institute

Research on the Application of Japanese Environmental Technologies in India

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Published by
Institute for Global Environmental Strategies (IGES) Kansai Research Centre
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Glossary

AAGR: Average Annual Growth Rate

AC: Air Conditioner

APF: Annual Performance Factor

BAU: Business as Usual

BEVs: Battery Electric Vehicles

BPKm: Billion Passenger Kilometres

CAGR: Compound Annual Growth Rate

CNG: Compressed Natural Gas

COP: Coefficient of Performance

CRDI: Common Rail Direct Injection

DDiS: Direct Diesel injection System

DI: Direct Injection

DOHC: Double Overhead Cam

DRI: Direct Reduction Iron

EAF: Electric Arc Furnace

EER: Energy Efficiency Ratio

EIF: Electric Iron Furnace

ELV: End of Life Vehicle

EP: Electric Propulsion

EPA: Environmental Protection Agency

EVs: Electric Vehicles

FTL: Fluorescent Tube Light

GaInN: Gallium Indium Nitride

GaP: Gallium Phosphide

GDI: Gasoline Direct Injection

GDP: Gross Domestic Product

GHG: Greenhouse Gas

GLS: General Lighting Service

GM: General Motors

GoI: Government of India

HDI: Human Development Index

HEVs: Hybrid Electric Vehicles

HM: Hindustan Motors

HMIL: Hyundai Motor India Ltd.

HSDI: High Speed Direct Injection Diesel

ICE: Internal Combustion Engine

IDI: In-direct Injection

IF: Induction Furnace

IJV: International Joint Venture

IMF: International Monetary Fund

IPR: Intellectual Property Rights

IR: Indian Railways

ITmk3: Iron Making Technology mark 3

JR: Japan Railways

LED: Light-Emitting Diodes

MPCE: Monthly Per Capita Expenditure

MSIL: Maruti Suzuki India Ltd.

MUL: Maruti Udyog Ltd.

Ni-MH: Nickel Metal Hydride

ODC: Oxygen Depolarized Cathodes

PHEVs: Plug-in Hybrid Electric Vehicles

PPP: Purchasing Power Parity

RHF: Rotary Hearth Furnace

RKm: Route Km of Rail

SMC: Suzuki Motor Corporation

SRL: Surya Roshni Limited

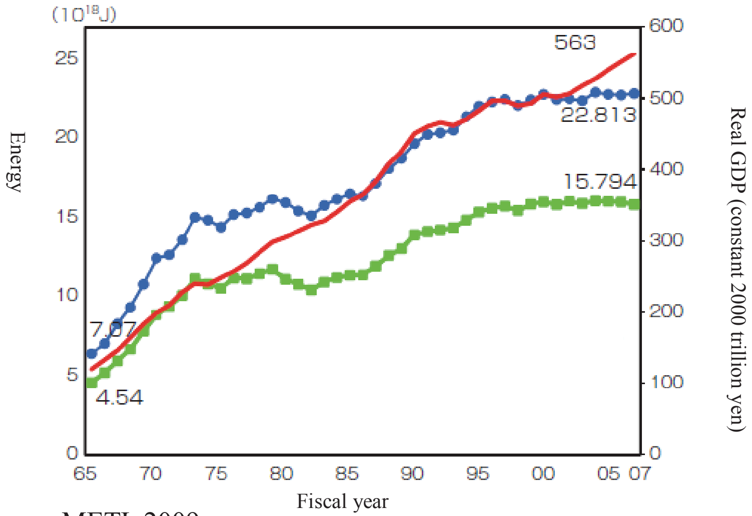
TT: Technology Transfer

Background

The Indian and Japanese Economies

After the World War II, Japan was able to rebuild industries that had been severely damaged during the war. During the period from 1955 to 1973, average annual growth rate was 9.4% and the demand for the final energy consumption grew at 11% (Yamashita, 2009). During the first oil crisis in 1973, the Japanese economy faced problems of a spike in the crude oil prices as well as instability of supply. Since then, Japan has strived to convert itself to an energy efficient society (Yamashita, 2009). For instance, Japan's GDP grew at a rate of 3.3% from 1973 to 1986 while that of total primary energy supply was only 0.7% (Figure 1).

Figure 1: Energy demand/supply trends and GDP growth of Japan: Real GDP (trillion yen) at the top in FY2007, Primary energy supply at the middle in FY2007 and Final energy consumption at the bottom in FY2007.



Source: METI, 2009a

India, after gaining her independence, had a closed economy and had a rate of growth of about 4% (Ministry of Finance, 2008). In the 1990s, after suffering a crisis in the balance of payments, the IMF agreed to extend help to India on the condition that the economy is opened up. In the period of 1993-94 to 2003-04, the rate of economic growth has been approximately 6.25% (Kohli, 2006) and the Indian government "needs to sustain a 8% to 10% economic growth rate over the next 25 years if it is to eradicate poverty and meet its human development goals" (Planning Commission, 2006b). Traditionally, India has exhibited frugal lifestyles and low energy when compared to other economies (Mathur R. and Bhadwal S., 2010). However with rapid economic growth and industrialization, the Indian economy faces the challenge of fulfilling increasing energy requirements in a sustainable manner.

This generates a need to examine the energy efficient technologies in countries such as Japan and their suitability for transfer to India. This project presents a sector-wise review of selected technologies in the Japanese and Indian economies and an overview of the merits and demerits for the transfer of the environmentally sound technologies. The report will also try to identify potential barriers to the transfer of these technologies. Due to data gaps, the report provides indicative savings that could be possible with the application of alternative technologies.

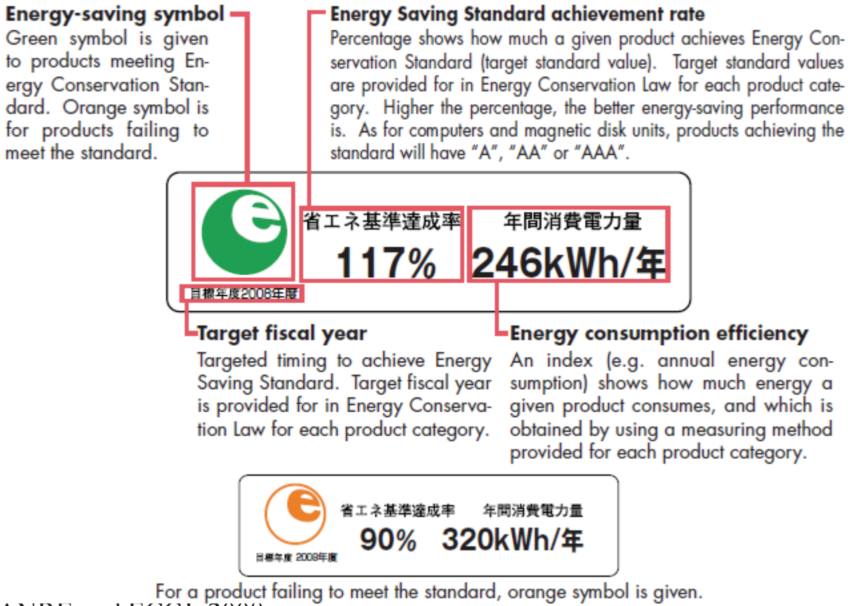
The Japanese Economy – Measures for Energy Efficiency

Although Japan currently has one of the lowest energy intensities in the world in terms of GDP, the economy continues to strive towards even higher levels of energy efficiency through policies such as the Top Runner Program.

The Top Runner Program was introduced in accordance with the revision of the Energy Conservation Law in April 1999 to further improve energy efficiency in machinery and equipments in residential, commercial and transportation sectors. In this program, a high standard is determined based on the best available technology as well as potential technology improvements that may be possible. Manufacturers have to attain that level of efficiency within a given period of time. A company might be banned to ship their product if it is not able to satisfy the standard. Currently, the program has 21 target items ranging from passenger vehicles to electric toilet seats[1]. Furthermore, to provide incentives for manufacturers to achieve Top Runner Standards, in August 2000, the energy saving labelling program was launched. This labelling system will help customers in selecting the energy efficient products. An example of an Energy Saving Label is shown in Figure 2.

[1] The complete range of items include passenger vehicles, freight vehicles, air conditioners, electric refrigerators, electric freezers, electric rice cookers, microwave ovens, fluorescent lights, electric toilet seats, TV sets, video cassette recorders, DVD recorders, computers, magnetic disk units, copying machines, space heaters, gas cooking appliances, gas water heaters, oil water heaters, vending machines and transformers.

Figure 2: An example of Energy Saving Label



Source: ANRE and ECCJ, 2008

Table 1 lists the resultant energy efficiency achieved as against the initial expectation for select items from the Top Runner Program. It is interesting to note that most of the products have increased efficiency even beyond the initial expectation. For instance, electric refrigerators increased efficiency by 55.2% in FY2004 compared to FY1998; this figure is nearly 25% more than the initial expectation.

Table 1: Results of the Top Runner Program

Product category	Energy efficiency improvement (result)	Energy efficiency improvement (initial expectation)
TV receivers (TV sets using CRTs)	25.7% (FY 1997 →FY 2003)	16.4%
VCRs	73.6% (FY 1997 →FY 2003)	58.7%
Air conditioners * (Room air conditioners)	67.8% (FY 1997 →2004 freezing year)	66.1%
Electric refrigerators	55.2% (FY 1998 →FY 2004)	30.5%
Electric freezers	29.6% (FY 1998→FY 2004)	22.9%
Gasoline passenger vehicles *	22.8% (FY 1995→FY 2005)	22.8% (FY 1995→FY 2010)
Diesel freight vehicles *	21.7% (FY 1995→FY 2005)	6.5%
Vending machines	37.3% (FY 2000→FY 2005)	33.9%
Computers	99.1% (FY 1997 →FY 2005)	83.0%
Magnetic disk units	98.2% (FY 1997 →FY 2005)	78.0%
Fluorescent lights *	35.6% (FY 1997 →FY 2005)	16.6%

Note: For the product categories marked with *, energy efficiency standard values are defined by the energy consumption efficiency (e.g. km/l), while those without * are by the amount of energy consumption (e.g. kWh/year). In the above table, values of the “Energy efficiency improvement” indicate the rate of improvement calculated based on each standard. (Example: If 10 km/l is developed to be 15km/l, an improvement rate is calculated as 50% (It is not calculated as the improvement of fuel consumption by 33% from 10 litres down to 6.7 litres for a 100 km drive.); and if 10 kWh/year is developed to be 5kWh/year, the improvement rate is 50%.)

Source: ANRE and ECCJ, 2008

However, it should be pointed out that for a number of sectors the Indian and Japanese economies show a fundamental difference in terms of utilization of resources such as labour and capital. This is a result of the natural resource endowments as well as technological progress taking place within the two countries over time.

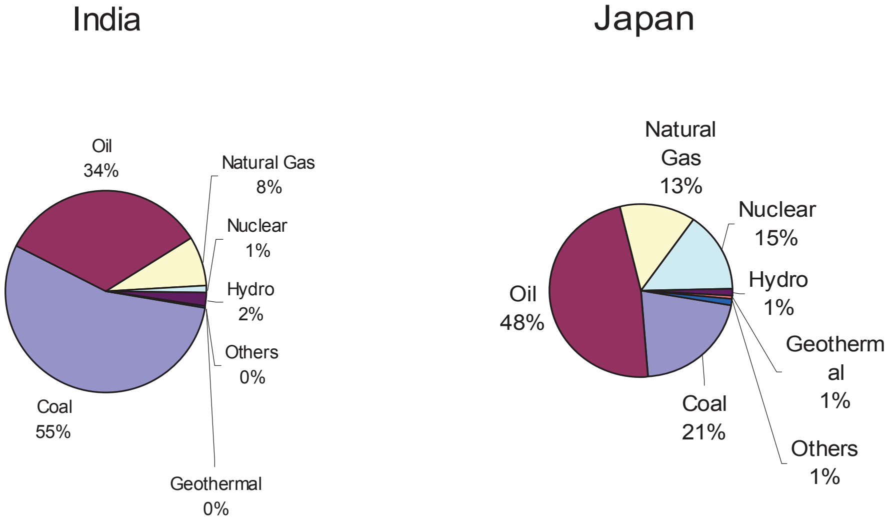
In 2006, India implemented the Standards and Labelling program to provide customers with information on the level of energy saving that is possible with the uptake of certain technologies. However, manufacturers do not face penalties even if they do not comply with efficiency benchmarks. India has also instituted the Bureau of Energy Efficiency to identify technologies and frame policies that promote energy efficiency.

Chapter 1 Overview of the Japanese and Indian Economies

Overview of the Consumption of Energy in the Indian and Japanese Economies

In 2005, the primary energy consumption for India stood at 15,880 PJ[2] and the primary energy consumption for Japan stood at 22,210 PJ (Economic Research Institute for ASEAN and East Asia, 2008). However, there is a significant difference in the proportions of the different fuels that contribute to the primary energy consumption.

Figure 3: Proportion of fuels for primary energy consumption in India and Japan



Source: Economic Research Institute for ASEAN and East Asia, 2008

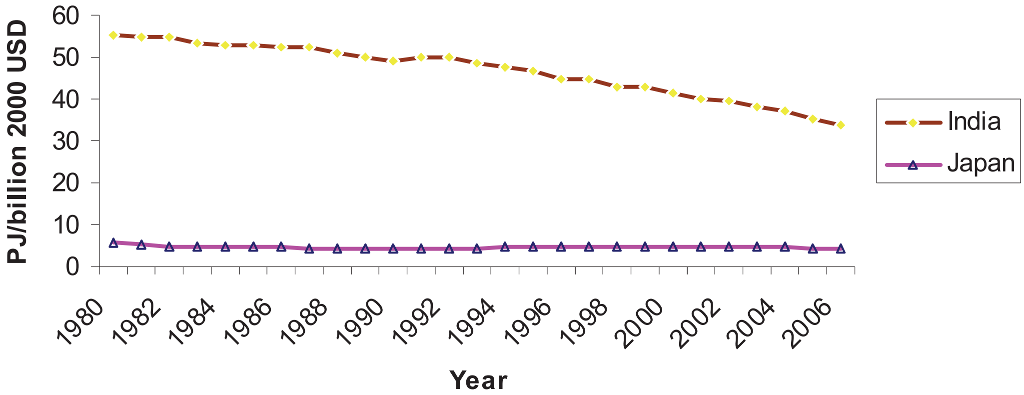
As seen in Figure 3, coal constitutes the bulk of India's primary energy consumption whereas Japan is dependent upon oil for satisfying its energy demands. India has a high reliance on coal based energy – specifically in power generation due to the historical large domestic coal resources. Japan, on the contrary, imports almost all of its energy and has a relatively high reliance on oil, due to several factors including the relatively convenient transportation networks and storing (JIE, 2006). However, since the oil shock in the 1970s, dependence on oil was reconsidered and the portion of other sources such as natural gas became higher (JIE, 2006). In 2006/07, 3,751 PJ of natural gas was used in the Japanese economy out of which 2,107 PJ was used to generate power.

According to projections made by TERI, India's commercial energy requirements could grow at around 7% in a business-as-usual scenario to around 88,886 PJ by 2031-32, with coal meeting 55% of these requirements (TERI, 2006a). Forecasts made by the Institute of Energy Economics, Japan, (2008) in the BAU scenario, indicate that primary energy consumption in

[2] A conversion factor of 1 Mtoe to 41.868 PJ has been taken

India could grow at an AAGR of 6.6% between 2005 and 2030 while Japan is expected to have a 0% rate of growth in the demand for primary energy between 2005 and 2030. Coal is likely to continue playing a dominant role in the Indian economy accounting for a share of around 51.4% of the primary energy supply in India in 2030. Oil is expected to be the dominant fuel in the Japanese economy in 2030, accounting for a share of 38.7% of the primary energy supply[3] (Economic Research Institute for ASEAN and East Asia, 2008).

Figure 4: Energy intensity for India and Japan

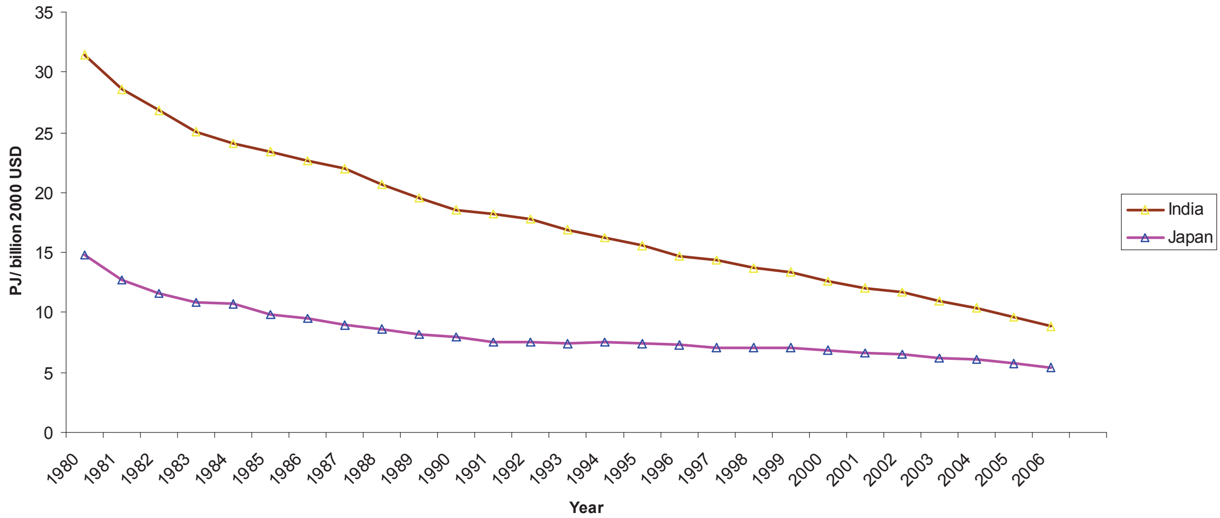


Source: IMF,2010; RBI, 2010; World Bank, 2010; IEEJ, 2008

Figure 4 gives an indication of the progress that Japan has achieved in the field of energy efficiency within its economy. "Japan's energy intensity of GDP is approximately half of that of European countries, and one-eighth to one-ninth that of China and India" (Yamashita, 2009). It is important to note the decreasing trend in energy intensity for the Indian economy from the 1970s up to 2005.

[3] Before the first oil shock, oil accounted for 77% of the primary energy supply in Japan. Since then, Japan has set up a number of coal and gas fired power plants to supply power (Yamashita, 2009).

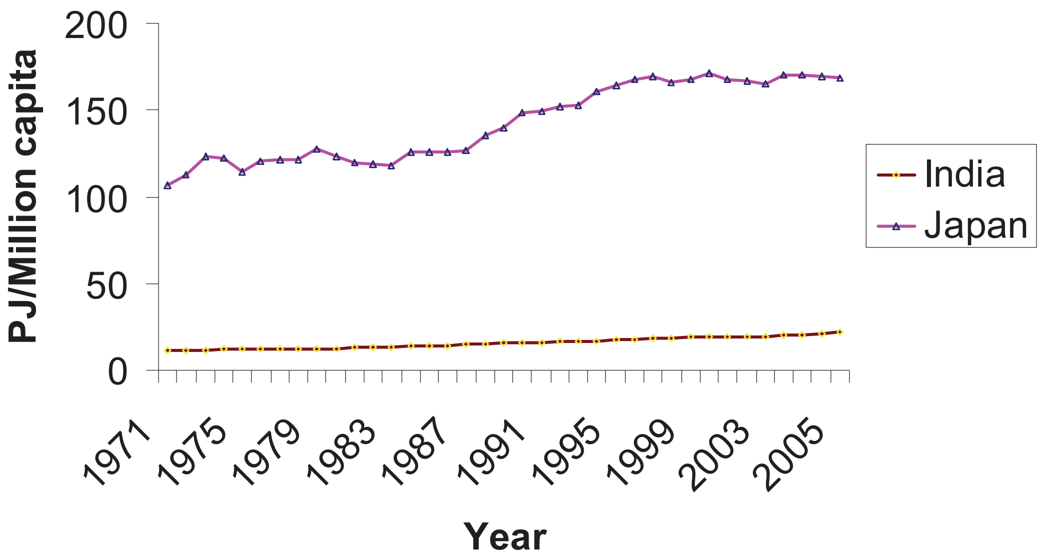
Figure 5: Energy intensity per GDP (in PPP terms) for India and Japan



Source: IMF, 2010; RBI, 2010; World Bank, 2010; IEEJ, 2008

Further, on the basis of GDP in PPP terms, both the economies have experienced a steady decline in energy intensity. In fact, around 2005, both countries attain very similar energy intensity levels.

Figure 6: Energy consumption per capita for India and Japan



Source: World Bank, 2010

As seen in Figure 6, the energy consumption per capita is seen to be rising for Japan due to "upgrading living standards (popularization of household electrical appliances etc) and development of various types of services associated with the maturation of economies" (Yamashita, 2009). Although the energy consumption per capita for India is significantly lower than that of Japan, it is expected that this figure for India will increase as the economy grows and the Human Development Index (HDI) indicators for India improve in the coming decades. However, research has shown that even with increasing incomes and if India was to meet the Millennium Development

Goals, India could still have a lower energy intensity than most of the western countries due to the adoption of efficient technologies (TERI, 2006b). It would hence be important to look at the energy efficient and environmentally sound technologies world-wide and evaluate whether these are applicable for India.

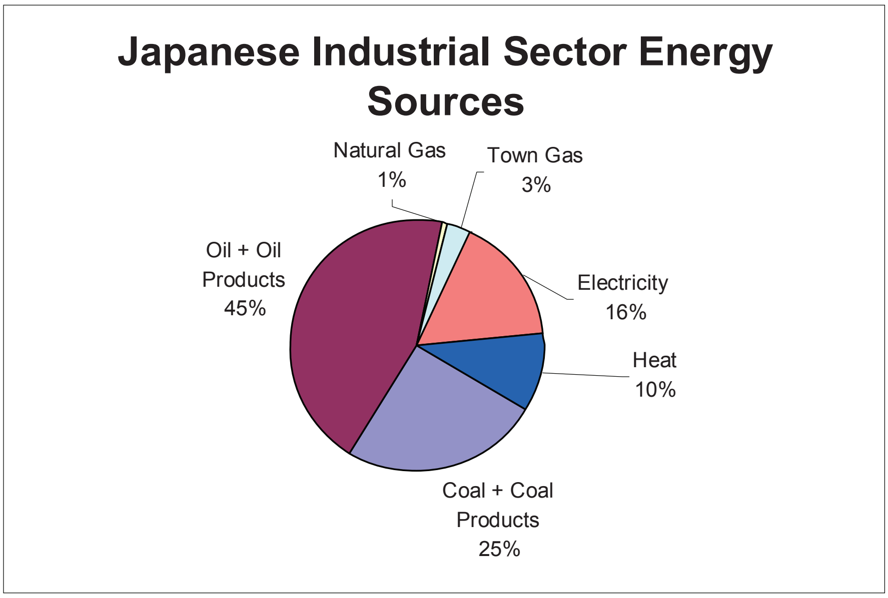
Sector-wise Energy Consumption in India and Japan:

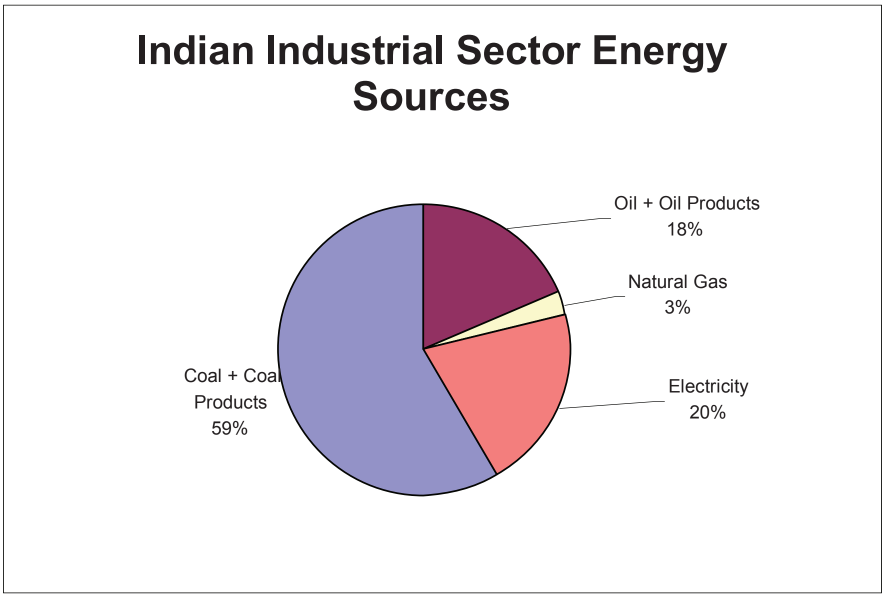
This section aims to provide an overview of some of the technologies in the energy intensive industrial, transport and residential sectors in Japan and India. A case is sought to be made for the selection of sectors where there are differences in the efficiencies between the two economies. Subsequently, the report will try to identify environmentally sound technologies that could be suitable for transfer from Japan to India. Technologies in the residential sector may find application in the commercial sector as well.

The Industrial Sector

In 2006/07, 7,146 PJ of energy were used in the industrial sector in Japan (RIETI and IAA, n.d.) while 4,312 PJ were consumed in the industrial sector in India (TERI, 2009). Figure 7 shows the fuel-wise consumption in the industrial sector in two countries. It is interesting to note that whereas the industrial sector in Japan is highly dependent on oil and oil products, the industrial sector in India is highly dependent on coal and coal related products. It is also important to note that before the first oil shock, Japan was even more dependent on oil for its energy needs in the industrial sector.

Figure 7: Proportion of consumption of different fuels in Japan and India





Source: TERI, 2009; RIETI and IAA, n.d.

The scope for considering application of technology transfer from Japan to India in a number of industrial sectors has been discussed below. Since it was difficult to provide a complete overview of the technological status in all the sectors, selective energy intensive sectors of the Indian and Japanese industry were compared and have been discussed in this report. TERI (2006a) has indicated seven sectors which are energy intensive in Indian economy: these are: i. cement; ii. caustic soda and soda ash; iii. paper and pulp; iv. fertilizer; v. textile; vi. iron and steel; and vii. aluminium sectors. In addition, Garg *et al*. (2006) have examined the cement, fertilizer and iron and steel sectors.

Table 2: Energy consumption in Indian energy intensive sectors in Tg-CO_2

Sector	1985	1990	1995	2000	2005	CAGR % (1985-2005)
Fertilizer	20	22	23	23	24	1.0
Cement	28	43	62	77	98	6.5
Iron and steel	56	74	86	92	103	3.1

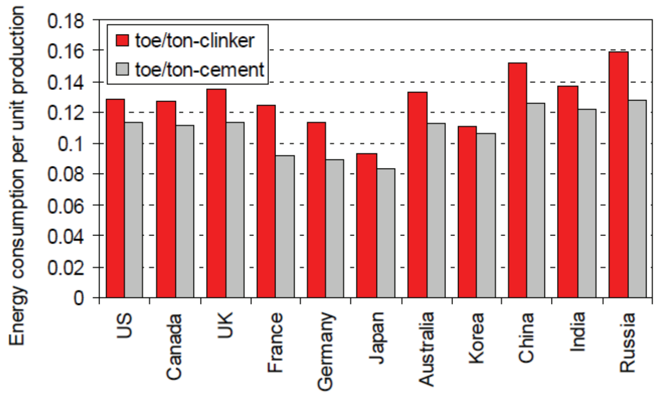
Note: CAGR (compounded annual growth rate)

Source: Garg *et al.*, 2006

The cement industry

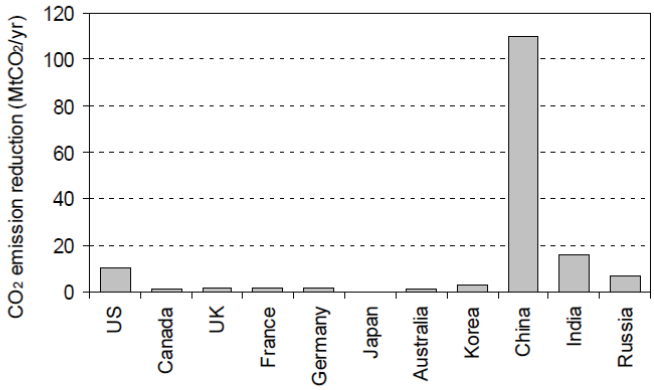
In 2006-07, the Indian cement sector produced 155.66 Mt of cement of which 95.4% was produced by the dry process, 1.2% by the wet process and 3.4% by other methods to produce cement (CMA, 2007). Since the 1960s, there has been a shift in the method of production from the inefficient wet process to the efficient dry process. The dry plants tend to be among the most efficient plants world wide (Sathaye *et al.,* 2005). However, for the sector as a whole, the energy efficiency is not high as the wet and semi-wet cement plants continue to be in operation where the reserves of limestone are small or require benefaction.

Figure 8: Energy consumption per unit cement and clinker production; assuming 1 MWh = 0.086/0.33toe



Source: RITES, 2009

Figure 9: CO_2 reduction potential in the cement sector



Source: RITES, 2009

The caustic soda and soda ash industry

The chlor-alkali sector consists of the production of soda ash and caustic soda. The three main technologies for the manufacture of caustic soda are the diaphragm process, the mercury cell process and the membrane process. Most of the plants in India are based on the membrane process which is the most energy efficient process. India currently has relatively low specific energy consumption in the caustic soda production process and hence has not been included in our analysis (Sathaye *et al.,* 2005). However, the Oxygen Depolarized Cathodes (ODC) technology, which is currently under development could offer significant energy savings in the future (Moussallem *et al*., 2008). The manufacture of soda ash is done by either the Solvay process, the modified Solvay process (or dual process) or the akzo dry-lime process. About 62% of the capacity is based on the standard Solvay process, 34% of the capacity on the modified Solvay process and 4% on the akzo lime process (TERI, 2006a).

In Japan, the production of Solvay caustic soda was discontinued in the mid-1960s. The use of *membrane cell technology* in soda production, which was first commercialized in 1979, had replaced all of the other types of chlor-alkali cells by 1999. Recently, Japan's soda industry is developing a technology of gas diffusion electrodes which should further reduce energy consumption (JSIA, 2010). The annual production of soda products is roughly 360 billion yen in total; however, soda ash industry is relatively minor in Japan compared to that of caustic soda (JSIA, 2010). While there are 30 factories for caustic soda, there are only two factories producing soda ash products in Japan (JSIA, 2010).

The paper and pulp industry

Broadly, there are three different types of raw-materials that can be used to manufacture pulp and paper: wood and bamboo, agriculture residue and waste paper. However, due to the fact that captive plantations are not allowed for paper mills, sourcing raw materials remains a concern for the pulp and paper industry. The Japanese industry is dominated by two major enterprises as a result of saturated domestic market and the consequent alliances amongst the players. Nearly 60% of the market share is dominated by Nippon Paper Group and Oji Paper Company (Sumitomo Trust and Banking, 2002). The Indian pulp and paper plants tend to be significantly smaller in size when compared with those in Japan. Although the industry is contemplating moving to plants of larger capacity, there are a number of considerations such as the provision of resources for making paper as well as the demand for the final product. Based on discussions with experts, it was decided not to consider the pulp and paper industry for further analysis in this study due to the fundamental differences in the structure of this industry in the two countries.

The fertilizer industry

The fertilizer industry is one of the most energy intensive industries in India. The fertilizer sector manufactures phosphorus and nitrogen based fertilizers whereas the entire quantity of potassium fertilizers is imported from abroad. It is expected that as the demand for food in India increases, there will be a corresponding increase in the demand for fertilizers. However, this sector is relatively minor in Japan in terms of market share. To illustrate, the market for fertilizer industry is 320 billion yen (Nihon Nohyaku, 2010), while that of iron and steel sector is more than 21 trillion yen (ARIB, 2009). Therefore, the option of examining technology application from Japan to India in the fertilizer industry has not been considered in this study.

The textile industry

In India, the textile industry can be classified into textile mills comprising of composite and spinning mills in the organized sector and small scale power loom and handloom units in the unorganized sector. The organized sector produces only 4% of the total fabrics produced in the country (TERI, 2006a)[4]. As there is such a wide variety of textile manufacturers in India, technology status is extremely diverse and it would be inappropriate for this project to make recommendations based on the current status of the Indian textile sector.

The iron and steel industry: The Japanese iron and steel sector is one of the most efficient in the world. For instance, while energy consumption per unit production of crude steel (toe/ton-cs) of BF-BOF is 0.59 in Japan, that of India is 0.78 (RITES, 2009).

The iron and steel industry in India consists of a number of integrated iron and steel plants[5], smaller Electric Arc Furnaces (EAF)/Induction Furnaces (IF) and Direct Reduction Iron (DRI) units. The output of crude steel from integrated steel plants in India was approximately 20 million tonnes of crude steel in 2003-04 as compared to 118 million tonnes in Japan (METI, 2009b). India is currently the world's largest producer of DRI based iron with a production of 19.2 MT (provisional) in 2007/08 (TERI, 2009). However, in India, DRI iron is primarily produced using coal as a fuel as compared to gas

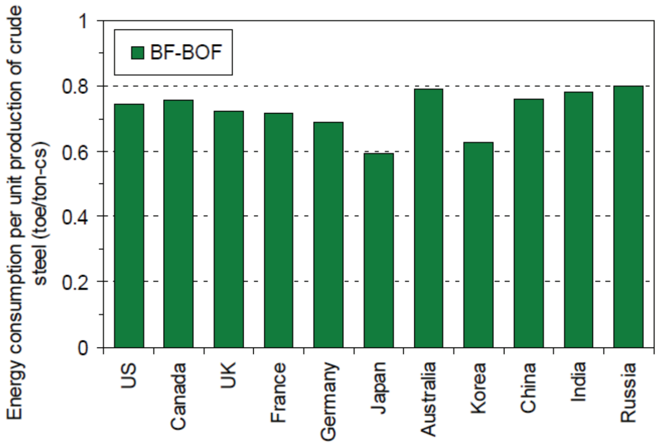
[4] An establishment in the organised sector would necessarily be registered under sections 2m (i) and 2m (ii) of the Factory Act.
[5] There are currently nine integrated steel plants in India, all but one of which are owned by the state. Integrated steel plants use large blast furnaces to produce crude steel. Coke ovens, sinter plants and machinery are generally part of the integrated steel plant

for the rest of the world. There is currently only one COREX plant in India. In Japan, there are currently 26 blast furnaces and five DRI plants. There are no COREX plants in Japan. As Japan has limited resources of both iron ore and energy, most of the ore and energy resources have to be imported from abroad.

Per capita steel consumption in India is much lower than the world average and in 2005 stood at 33 kgs per year (compared to the world average of 157 kgs and Japanese per capita consumption of 610 kgs). It is expected that there will be a sharp increase in the demand for steel in the Indian economy as high levels of growth in the economy are witnessed. The National Steel Policy envisages indigenous production of 100 million tonnes per annum by 2019-20 from the 2004-05 level of 38 mT, implying a compounded annual growth rate of 7.3%. Similarly, projections made by TERI (2006a) indicate that demand for finished steel could rise from 31.4 million tonnes in 2001 to 174.6 million tonnes under the 8% GDP growth assumption till 2021. While the estimates differ based on the assumptions undertaken, it is clear that the iron and steel sector will continue to grow rapidly in India and that there could be significant potential for energy efficiency improvements in this sector.

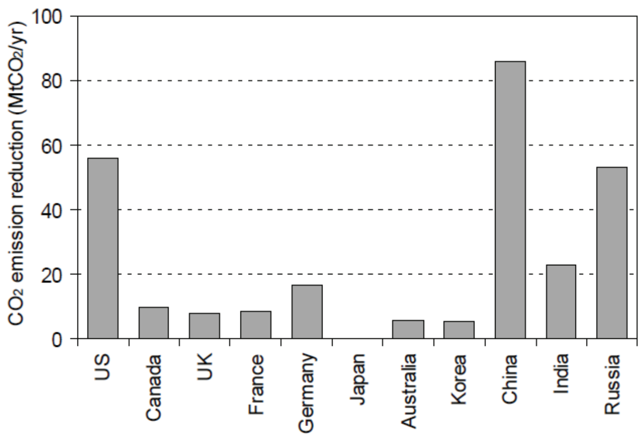
Steel is the 3rd largest emitter of Greenhouse Gases (GHGs) in India. While Indian steel plants are at an average of 2.7 tonne of CO_2/tcs, that of Japan is less than 1.7 tonne of CO_2/tcs (Planning Commission, 2006a; JISF, 2008). India's 11th five year plan has outlined a target for the reduction of specific energy consumption from the current level of 6.45 – 8.5 G Cal/tcs to 5.5-6 GCal /tcs. This is higher than the world best norm of 4.5-5 GCal /tcs (Planning Commission, 2006a). In contrast, the Japanese average is around 0.59 t-oil tcs^{-1}, while that of India is 0.78 t-oil tcs^{-1} (Figure 10) (RITES, 2009). Though Indian emissions and energy consumption per unit of steel produced are better compared to Russia and Australia, its figure is higher than the world average, partially due to the high ash content in Indian coal. Figure 10 indicates reduction potential in iron and steel sector amongst various countries.

Figure 10: Country wise energy consumption per unit of crude steel produced (BF-BOF)



Source: RITES, 2009

Figure 11: Potential for energy efficiency improvement in the iron and steel sector



Source: RITES, 2009

Based on discussions during the study, it appeared that the iron and steel sector is the sector which not only emits the most CO_2 amongst the seven select sectors which were taken up for discussion, but is also the sector which may have the most potential in terms of reduction in CO_2 emission as well. In addition, considering the high efficiency of iron and steel production in Japan, technologies that could make a difference in the energy efficiency in India have been examined in the further chapters.

Cross Cutting Technologies

In the industrial sectors of the Indian economy, there exist a number of cross cutting technologies in Japan that could reduce the energy consumption of various processes. Some of these technologies are in the areas of co-generation at low heat, improved ventilation systems including DC motors and energy efficient combustion. However, it was not possible to evaluate and compare the improvement that these specific technologies could have at a macro level in terms of the economy-wide savings. Accordingly, the scope for energy saving from these technologies and processes has not been further evaluated for the two countries.

The Transport Sector

Population and economic growth combined with structural shifts in the Indian economy have fuelled the demand in transport sector. Currently, the transport infrastructure in India comprises of 3.314 million km of roads, 63,273 route km of rail (Rkm), 12 major and 200 minor ports, 11 international, 89 domestic airports and 14,500 km of navigable inland waterways (TERI, 2008). However, 40% of the Indian population in the rural areas is still not connected by all-weather roads (TERI, 2008). It is expected that with increased incomes especially in the rural areas, the demand for passenger and freight movement will increase in the future. Under the assumption of 8% annual GDP growth rate, road passenger travel demand in India is expected to rise from 1,650 billion passenger kilometres (BPkm) in 2001 to 10,196 BPkm in 2031 (TERI, 2006a).

Road Transport

The share of road transportation in India has increased steadily over the last few years due to the increase in the number of personal vehicles and the shift of freight movement away from rail to road, the latter being more flexible to transportation needs. However, vehicular penetration (vehicles/1000 persons) in India continues to be one-twentieth that of several industrialised countries (JAMA, 2009).

For passenger movement, the energy consumption of road transport is dominated by the use of 4-wheelers for commercial as well as personal use (TERI, 2006a). In 2005, approximately eight million 4-wheeled vehicles (including cars, jeeps & taxi) were estimated to ply on Indian roads (MoRTH, 2008)[6] as opposed to 57 million in Japan (JAMA, 2009). With 25 million small cars, the automobile industry in Japan is dominated by domestic manufactures such as Toyota and Mitsubishi (JAMA, 2009). Due to relatively higher sulphur content in crude oil from the Middle East where Japan is mainly importing its oil (Tokyo Metropolitan Government, 2003) the share of diesel powered 4-wheelers in Japan is only around 4% (JAMA, 2009). In contrast, about 36% 4-wheelers in India run on diesel and the rest run on gasoline (a small percentage of cars run on CNG, LPG and electricity in selected cities). The existing engine technologies are listed below fuel-wise.

[6] Assuming life of vehicles as 12 years

Gasoline

In India, most of the currently existing gasoline models (nearly 70%) use multipoint fuel injection system. Several different models are manufactured by more than 20 companies in India. These models differ in the engine capacity, horse power, size, efficiency and engine technologies. The gasoline engine has more potential for improvements than diesel engine, with the most important direction in these technological advancements relating to multiple valves, variable valve timing and lift systems, gasoline direct injection (GDI) etc (Pundir, 2008). India and Japan follow very different test cycles, due to which the fuel efficiencies for each country are not directly comparable (Table 3). Given the difference, it is known that the 10-15 test cycle followed by Japan is much more stringent than that followed by India. Hence, we can say that the Toyota Vitz with a fuel efficiency of 22.5 on a 10-15 test cycle is much more efficient than the Hyundai Santro in India. Currently the engine technologies for cars plying in India and Japan are as follows:

Table 3: Specifications of gasoline vehicles in India and Japan

	India	Japan
Capital Cost (in Rs)	300,000	496,000
Fuel Cost (in Rs/km)	3-6.5 (City) 5 (MIDC test cycle)	2.58
Seating Capacity	5	5
Fuel Efficiency (in km/ltr)	13.7 (City) 18.4 (MIDC test cycle)	22.5
CO_2 emission (kg/km)	0.12-0.17	0.095

Note:

- Japanese and Indian examples refer Toyota Vitz DBA-KSP90-AHXDK and Hyundai Santro 2000, respectively
- Exchange rate and fuel cost used to calculate the figures were 2.17 JPY/INR (Asahi News Paper dated January 21, 2010) and 125.8 JPY/litre (Jan 17 – 23 2010 average cost; GOGOLabs, Inc., 2010), respectively.
- Price range of an average small car (<1200cc displacement) in India which form majority of the market (Hyundai Santro) calculated using a price of 46 Rs/litre for Gasoline

Diesel

In India, until around 1990, the only technology available in diesel passenger vehicles was the in-direct injection (IDI) diesel engines. In 2000, high speed direct injection diesel (HSDI) engines were introduced in the Indian market. These engines are about 25% to 30% more fuel efficient than the standard PFI gasoline engines and around 10 to 15% more efficient than the IDI engines (Pundir, 2008).

Diesel vehicles are not common in the Japanese market due to the characteristics of crude oil used. Currently, even with the introduction of more powerful Common Rail Direct Injection (CRDI) diesel engines in the passenger vehicle market, we do not envisage an increase in the penetration of diesel vehicles due to reasons mentioned above. Hence, technologies based on diesel are not delved into in this report.

Dual fuel Compressed Natural Gas (CNG) – Gasoline Hybrids

Degrading air quality, concerns over health impacts and increased dependency over fossil fuels in several cities in India led to the introduction of CNG as an alternative fuel. Use of CNG for public transport was made mandatory in Delhi and CNG kits were also made available to convert personal vehicles to CNG-Gasoline hybrid ones.

The high cost of CNG vehicles in Japan makes this an unattractive option from a consumers' point of view. Hence these vehicles have not gained a large market share. Based on discussions regarding application of this option, it is again appeared that CNG was not a priority option for consideration in this study.

Electric

The only electric car plying on Indian roads is a 2-seater car offering a maximum range of 100 miles for an 8 hr battery charging time. The Reva Electric Car Company offers two models in electric vehicles: one that uses Lead-Acid batteries having an expected lifetime of 2–3 years and another with Lithium ion batteries with a longer lifetime of 4–5 years (REVA, 2010). Although the penetration of electric cars in the Indian market is low due to low seating capacity, short battery life and high capital costs, Indian manufacturer's and auto part suppliers are working to overcome these issues.

In Japan, though several electric vehicles are available for corporations, they are not yet available for personal consumers. METI envisages to popularize these vehicles by 2030 and Mitsubishi (i-MiEV) and Nissan (Leaf) have announced that they would make their vehicles available for personal use by the end of 2010 (Yomiuri Shinbun, 2010). There could then emerge a strong market for electric cars in the future.

Table 4: Specifications of electric vehicles in India and Japan

	India	Japan
Capital Cost (in Rs)	349,705 – 428,419	2,177,000
Fuel Cost (in Rs/km)	0.4	1.06
Seating Capacity	2	4
Range (km/charge)	160 – 200	90
Market status	Available	Available
Fuel Efficiency (kWh/km)	0.1	0.105
CO_2 emission (kg/km)	0.16	0.046

Note:

- Japanese and Indian examples refer FHI (Subaru) / STELLA (Plug-in type) and REVA, respectively
- Exchange rate, fuel cost used and specific consumption calculate the figures were 2.17 JPY/INR (Asahi News Paper dated January 21, 2010), 22 JPY/kWh and 0.44 kg-CO_2/kWh (Secretariat of product environmental information providing system, CEIS 2005), respectively.

Two Wheelers

Two wheelers include mopeds, scooters and motorbikes. All the three vehicles differ significantly in technology used and performance output. With a 2 stroke (4 stroke models also available but costlier) 60–75 cc engine capacity, mopeds have a fuel efficiency of around 78 km/litre and the 100–225 cc models that are predominantly 4-stroke have an efficiency of 55–65 km/litre (indiabike.com, n.d.).

The Japanese two-wheeler market comprises of more than 12 million two-wheelers in use in the year 2007 with more than 60% being of less than 51cc (JAMA, 2009). Fuel efficiency for Japanese two wheelers currently is 60 to 110 km/litre for the displacement class of 49 cc, 40 to 60 km/litre for the displacement class between 100 to 175 cc, and around 40 km/litre for the displacement class greater than 175 cc (JAMA, 2009).

The prices of the 2-wheelers increase as the engine size and power increases but still the sale of Mopeds has remained stagnant and motorbike sales have increased in recent years. As there is no significant difference in the efficiency between India and Japan in two wheelers, there does not seem to be scope for discussion of technology transfer in this respect.

Heavy/Medium Commercial vehicles

The Indian truck industry currently carries majority of freight across the country. Factors such as the ability of trucks to carry goods in small quantities and the ability to reach rural and hilly areas have added to the advantages that trucks hold over railways. The vehicles being manufactured as of now are DI diesel engine but due to prolonged use and absence of any scrapping or end of life vehicle (ELV) policies, a large proportion of these vehicles continue to run on indirect injection technology.

The number of trucks on road in 2008 in Japan was more than 17 million of which around 66% have less than one ton of loading capacity (JAMA, 2009).

Although there is a difference in the fuel efficiency between trucks in Japan and India, trucks in Japan are significantly more expensive.

Table 5: Specifications of heavy/ medium commercial vehicles in India and Japan

	India	Japan
Capital Cost (Rs)	1,200,000 – 1,700,000	1,750,000 – 2,120,000
Fuel Efficiency (km/litre)	5 – 6 (fully loaded)[7]	7.3 – 9.6
CO_2 Emission (kg/km)	0.43-0.52	0.27 – 0.36

Note:

- Japanese and Indian examples refer to that of hauling capacity 3 – 4.5 ton and several manufacturers (Ashok Leyland- Tata PRIMA, n.d.), respectively.
- Exchange rate, fuel cost used and specific consumption calculate the figures were 2.17 JPY/INR (Asahi News Paper dated January 21, 2010), 105.3 JPY/litre-diesel (Jan 17 – 23 2010 average cost; GOGOLabs, Inc., 2010) and 2.62 kg-CO_2/litre-diesel (secretariat of product environmental information providing system, CEIS, 2005), respectively.

Energy Consumption

The road transport sector in India accounted for nearly 35% of the total petroleum products in the past decade (TERI, 2008). The diesel consumption has not varied much over the years but the expansion of passenger transport industry in India has caused a rapid growth in the demand for gasoline in recent years (Singh *et al.,* 2008). In 2007, the road transport sector consumed 387 PJ in India, whereas the consumption in Japan was round 2,705 PJ[8].

Rail Transport

Indian Railways (IR) is the world's second largest network with around 63,273 Rkm (in 2006-07). IR operates using a mix of diesel and electric traction with more than 63% of freight traffic being hauled by the electric traction using overhead lines for a single phase 25KV system. More than 80% of the route in the Indian railways is Broad gauge (1.67m) with an average carrying capacity of 53.4 tonnes (MoR, 2007).

An overview of the locomotive technology used by IR and by Japanese rail companies including Shinkansen is given in Table 6.

[7] TERI, 2006a

[8] In India, one-time registration practices, with 15-year validity period have been followed for private modes of vehicles (Singh *et al.,* 2008). Additionally, no records of the scrapping of unused private vehicles have been maintained by vehicle registration authorities. Hence, it is difficult to obtain statistics pertaining to actual number of on road vehicles.

Table 6: Summary of locomotive technology in India

Freight			**Passenger**	
AC Electric			AC Electric	
WAG-5			WAP-4	
HP	3,850		HP	5,000
Hauling Capacity (starting)	33,500 kgf		Axle load	18.8t
Top Speed	80 kmph		Top Speed	160 kmph
Wag-7			WAP-7	
HP	5,000		HP	6,125
Hauling Capacity(starting)	41,000 kgf		Axle load	20.5
Top Speed	100 kmph		Top Speed	160 kmph
WAG-9				
HP	6,125			
Hauling Capacity (starting)	520 kN			
Top Speed	100 kmph			
Diesel			Diesel	
WDG-2			WDP-2	
HP	3,100		HP	3,100
Top Speed	100 kmph		Axle load	19.5t
			Top Speed	160 kmph
WDG-4			WDP-4	
HP	4,000		HP	4,000
Top Speed	100 kmph		Axle load	20.5t
			Top Speed	160 kmph

Source: RDSO Indian Railways, 2010

Table 7: Summary of locomotive technology in Japan

Freight		**Passenger**	
AC Electric		AC Electric	
JR Freight Class EF210		E2 1000 Shinkansen	
Power output	3,390kW (1hour rate)	Power output	7.2 MW (for 8-car train), 9.6 MW (for 10-car train)
Hauling Capacity	199kN 20,300kgf – 1hour rate	Axle Load	12.9 t
Top Speed	110km/h	Top speed	275 km/h (Tōhoku Shinkansen)
JR Freight Class EH500		700 Series Shinkansen	
Power output	4,000 kW	Power output	13.2 MW (for 16-car train), 6.6 MW (for 8-car train)
Hauling Capacity	24,551 kgf	Axle Load	11.3 t
Top Speed	110km/h	Top speed	270km/h(Tokaido) 285 km/h (Sanyō)
JR Freight Class EH200		N700 Series Shinkansen	
Power output	4,520 kW	Power output	17.08 MW
Hauling Capacity	271.8 kN	Axle Load	11.2 t
Top Speed s	100 kmph	Top speed	270km/h(Tokaido) 300 km/h (Sanyō)
Diesel		Diesel	
JR Freight Class DF200		JR DE10	
Hauling Capacity	33,390 kgf	Power output	NA
Top speed	110 km/h	Axle Load	13 t
		Top Speed	NA

Source: Ishizuka, 2010; Morimura, 2010; Japan Railfan Magazine, 2009 and 2007; JRR 2009 and 2006; RFA, 2008; JR, 2006; Japan Society of Mechanical Engineers, 1999; Nishi, 1996; JR Freight Co. website, n.d.

Railways in Japan form a very small chunk of freight movement as the majority of goods are moved by waterways. On the other hand, Indian railways move a large share of bulk commodities such as coal and iron and steel. However, the traction effort of the goods locomotives in both countries is similar. For the case of passenger services, there is a significant difference in the top speed that is achieved. The Shinkansen in Japan is able to achieve a top speed of 300 km/h which is significantly higher than the speed that is achieved by passenger rail transport in India. Technology transfer in this area has been discussed in the next section.

Energy Intensity

With high volumes of passenger and freight movement experienced by Indian Railways (IR), it is interesting to note that the energy consumed per Tkm decreased by half from 0.15 PJ/BTkm in 1979 to around 0.075 PJ/BTKM in 2005. In Japan, railways account for about 28% of the total passenger movement and 4% of the total freight movement. In absolute terms railways accounted for 395 BPkms in the year 2006 in Japan which is only

55% of what the Indian Railways experienced in the same year. In freight movement, Japan experienced 23 BTkms of movement via railways in 2006 which is only 5% of what was experienced by India during the same time period. Analysing the energy intensity (PJ/BPkm and PJ/BTkm) we see that IR consumed around 4195 million kWh and 1 million kilolitre of diesel oil for its passenger movement leading to an energy efficiency of 0.07 PJ/BPkm. The freight services experienced an efficiency of almost 0.25 PJ/BTkm. In comparison a total of 182.6 PJ of energy was needed in order to transport 391,146 MPkm in year 2005/06; thus, resulted in 0.47 PJ/BPkm by the railways system in Japan (MLIT, 2007).

Table 8: An overview of both Indian and Japanese railways

	Indian Railways		Japanese Railways	
	Freight	Passenger	Freight	Passenger
BTkm | BPkm	523	770	22	405
Tonnes | Passengers (in millions)	745	6,219	46	22,976

Source: Indian Railways, 2009; MLIT, 2009

Overview of the Residential Sector

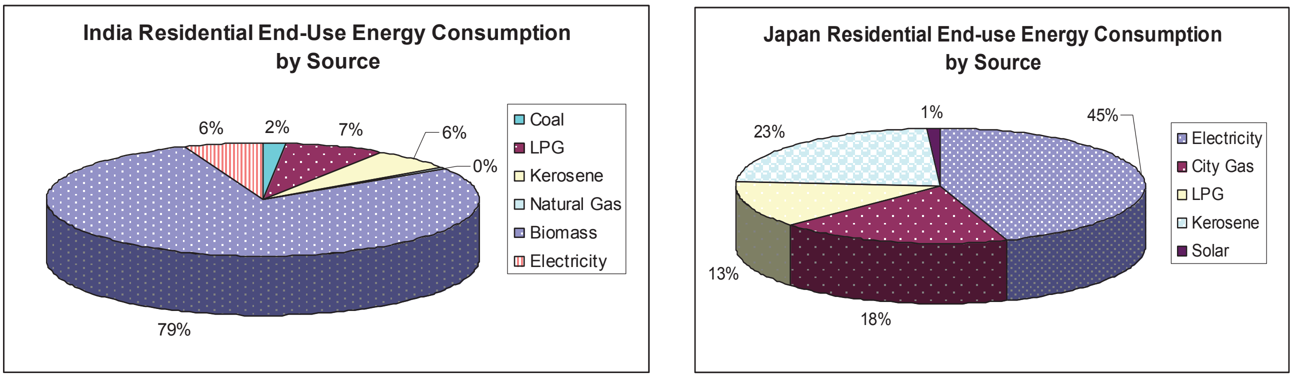
The domestic sector[9] in India consumes 6673 PJ (159.39 Mtoe) of energy that translates to approximately 31.97 GJ per household[10] (TERI, 2009). In comparison, the domestic sector in Japan accounts for 2105 PJ of energy or 44.2 GJ per household (ANRE, 2009) [11].

The domestic sector accounts for 41% of the total energy consumption and 11% of commercial energy consumption by the end use sectors in India[12]. When seen across countries, share of the domestic sector in the final energy consumption is relatively higher in India than in other countries. The energy consumption in the domestic sector as a proportion of the final energy consumption is approximately 12% in Brazil, 18% in USA, 30% in China, 28% in Russia and 13% in Japan (ANRE, 2009; IEA, 2008a; IEA, 2008b). This higher proportion of domestic energy consumption in India can be attributed to inefficient energy sources and end-use technologies in the domestic sector in India. To illustrate, cooking energy in rural India is largely dependent of low-calorific biomass fuels and use of inefficient biomass ‘chulhas’ (cook stoves) with efficiencies of 10-15%. Technologically, therefore, there is a significant potential for improving energy efficiency in the residential sector in India, but there are several barriers, especially the issue regarding affordability and access to modern and cleaner fuels and technologies by the relatively poor households in India.

[9] 154.29 million rural households and 54.44 million urban households (NSSO,2008).
[10] This includes both traditional and commercial sources of energy
[11] This only includes commercial energy sources; however, since traditional energy sources (e.g., woods) are not used extensively, the figures of two countries are comparable.
[12] TERI, 2009

Solid biomass accounts for 79% of the energy consumed in the domestic sector in India. LPG, kerosene and electricity almost equally account for the remaining 20% of energy use. Energy is primarily used for lighting, cooking and space conditioning applications in the domestic sector. Since enabling biomass technology transitions is beyond the scope of the study, the following sections would focus on commercial energy technologies available in India. In Japan, according to ANRE (2009), the energy used in the domestic households is primarily from electric sources (45%), followed by kerosene 23%, city gas 18%, LPG 13%, and solar heat 1%. Figure 12 provides a comparison of residential energy comparison by fuel in the two countries.

Figure 12: Residential energy consumption by source in India and Japan



Source: ANRE, 2009; IEA, 2008b

In the Indian case, an aggregate analysis of energy consumption in the domestic sector is not very appropriate since there are wide differences in consumption patterns between rural and urban areas and between different income groups[13]. Figure 13 depicts the level of penetration of appliances across different fractal group of households, i.e. households classified according to their monthly per capita expenditure (MPCE) in the rural and urban sector[14] and clearly brings out this distinction. The first fractal group shows the ownership pattern of the poorest 20% of the total households, the second group shows the next 20-40% of the total households, and so on.

[13] It is generally accepted that the economic status of the household determines its choice of energy sources. It is more likely for a household in a higher MPCE class to access cleaner and more efficient energy sources (NSSO, 2007 and 2008).

[14] Census of India 2001 defines urban area as:

(a) all places with a Municipality, Corporation or Cantonment or Notified Town Area

(b) all other places which satisfied the following criteria:

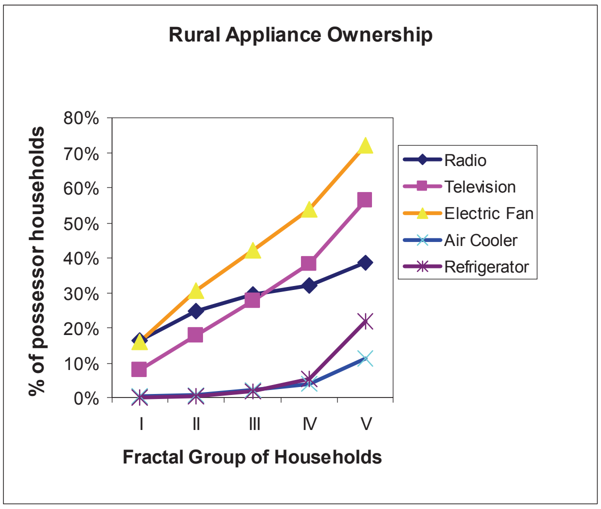
(i) a minimum population of 5,000.

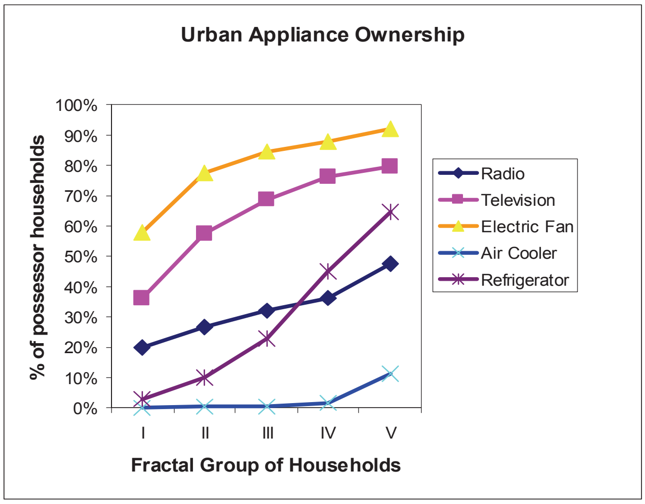
(ii) at least 75% of the male working population was non- agricultural.

(iii) a density of population of at least 400 per sq. Km. (i.e. 1000 per sq. Mile).

The residual area is referred to as rural area.

Figure 13: Percentage ownership patterns across different income groups in India





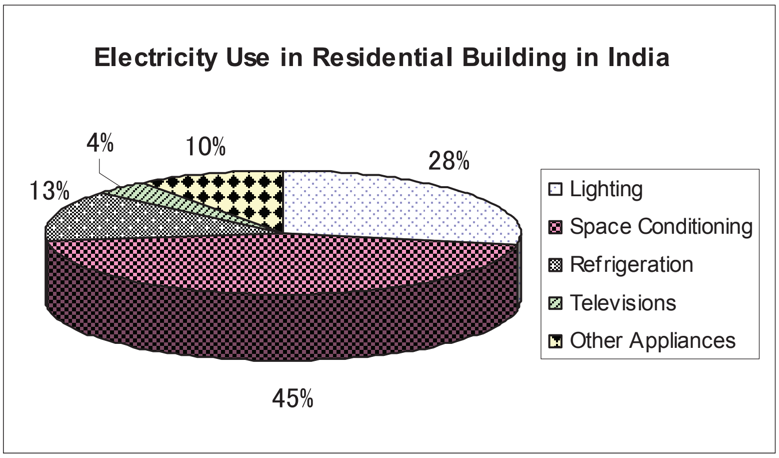
Source: NSSO, 2007

Of the electricity produced by all utilities[15] in India, almost 25% is consumed by the domestic sector in India (CEA, 2009). Over the past two decades, the domestic sector has seen a sharp climb in energy consumption due to a period of steep growth in sales and use of consumer electronics such as air-conditioners and refrigerators in the Indian domestic sector[16]. This growth is being driven by a wide variety of factors such as rapid economic development, industrialization, urbanization and improved lifestyles. In Japan, the domestic sector accounts for 30% of the total electricity consumption by the utilities and this demand is expected to grow by 2% (ANRE, 2008).

As far as electricity end-uses are concerned, lighting and space-conditioning account for the largest proportion of the electricity consumed in residential buildings (Figure 14) and technology differences in these end use sectors have been discussed below. It is however expected with greater development and converging standards of living of Indian households with those of the developed countries (such as US, EU and Japan) the end use patterns may change substantially in the coming decades.

[15] Utilities include Domestic, Commercial, Industrial Power, Public Lighting, Traction, Agriculture, Public Water Works and Sewage Pumping, and Miscellaneous.
[16] McNeil et al. , 2005

Figure 14: Electricity Use in Residential Buildings in India



Source: CMIE, 2001

However, it should be noted that in Japan such stark distinction between the energy patterns of cities, towns and villages does not exist. Additionally, while certain distinctions in the energy consumption levels exist across different income classes, the society is quite homogenous in its choice of fuels. Table 9 presents the diffusion rate of appliances in Japan.

Table 9: Diffusion rates of appliances in Japan

	Diffusion Rate of Appliance (%)			
Income Class	Heater	Air Conditioner	TV	PC
<300 mn ¥	50.1	75.4	97.6	35.3
300-400 mn ¥	60.4	86.2	99.1	64.9
400-550 mn ¥	63.3	87.7	99.1	76.8
550-750 mn ¥	65.9	92.4	99	86.2
>750 mn ¥	70	94.4	99.4	91.6

Note: Since the diffusion rate of refrigerator and washing machines had reached around 99% in 90's, they were taken off from the survey five years before.

Source: ESRI, 2009

Existing Technologies

As indicated in Figure 13, there are wide variations in appliance ownership between rural and urban areas and between the different income groups and not all options may be able to find penetration with Indian households across all income groups. However, a brief overview of the existing technologies for various uses in the domestic sector in India, and the corresponding technologies available in the Japanese market are discussed below.

Lighting

In India, 65.6% households use electricity and 32.9% use kerosene to meet their lighting needs (NSSO, 2007). However, as outlined earlier, the consumption patterns for rural and urban areas differ.

In rural areas of India, only 56.3% of the households report electricity as their primary lighting source. However, even electrified households often use kerosene as a secondary source of lighting because of frequent voltage fluctuations and electricity supply disruptions in rural areas (Planning Commission, 2006b). In urban areas, 92% of households use electricity for lighting and only 7% use kerosene as a main source of lighting. In Japan, almost all households are electrified and electricity is the sole fuel used for lighting (IEEJ, 2005).

The various lighting options available in India are incandescent (GLS) bulbs, CFLs, LEDs and tubelights- T-12 (tubelight with batten and choke), T-8 (tubelight with batten and choke) and T-5 (tubelight with batten and choke). The current Indian market is dominated by GLS and T-12 with only a small penetration (3%) of CFLs (NIES, 2005) largely due to low awareness about CFLs and their higher price. In Japan, the market is currently dominated by fluorescent types of lighting options which enjoys a 48.4% (sales amount) in 2008. This is manufactured by a number of Japanese companies such as Panasonic, Toshiba Lighting & Technology, NEC Lighting, and Mitsubishi Electric Osram (JELMA, 2008).

The popular lighting brands in India are Philips Lighting, Osram India, Crompton Greaves Limited, GE Lighting, Kuber Lighting Pvt Ltd, and Surya Roshni Limited. Surya Roshni Limited (SRL) is the first company in India to launch T-5 (FTLs) lamps which save 81% of energy over an incandescent bulb. Correspondingly, in Japan, some of the different tube lights that are available are as follows: i) fluorescent lamp – circular type; and ii) fluorescent lamp–compact type (plural slim straight tubes combined).

LEDs are being seen as the next big revolution in the lighting industry. Philips Electronics launched India's first comprehensive LED (Light Emitting Diodes) lighting range for the home segment in November 2007; however, LEDs are still not very popular because of their high cost and lack of awareness about them. In Japan, however, currently several percentage of the bulbs sold are LEDs. Panasonic, the top LED lamp maker in Japan, sold products worth 7.3 billion yen in 2007 (Sankei Digital Inc., 2009).

Refrigerators

The refrigerator market in India is currently dominated by Godrej GE Appliances Ltd and Whirlpool India Ltd which account for 55% of the market. The market also has a number of other domestic players such as Voltas Ltd, Videocon Appliances Ltd and BPL Refrigeration Ltd as well as multinational brands such as Electrolux (Sweden), LG (Republic of Korea), Samsung (Republic of Korea) and Daewoo (Republic of Korea). The market is expected to grow at 14 –15% per year over the next few years (STAT-USA, n.d.[17]). In contrast, the Japanese market for refrigerators has been saturated and growth is not expected over the next few years at least. Table 10 shows the market share of different refrigerator manufacturing brands in Japan.

Table 10: Manufacturer-wise ranking of household refrigerator in 2007

	Maker	Share (%)
1	Panasonic Corp.	24.4
2	Sharp Corp.	18.1
3	Toshiba H.A.Corp.	15.5
4	Hitachi Appliances	14.7
5	Mitsubishi Electric	14.6
6	Others	12.7

Source: Nikkei Sangyo Shinbun, 2008

There are two main product classes for residential refrigerators in India: direct cool (manual defrost) and frost-free. Traditionally, direct cool units have dominated the market, but frost-free units are gaining ground. According to a recent survey of Indian refrigerator manufacturers (IMRB, 2004), direct-cool units command 82% percent of the market, with 18% held by frost-free. However, the sales of frost-free units are currently growing at 20% per year[18]. In contrast, in Japan majority of the market has been cornered by frost-free refrigerators. Additionally, in Japan, refrigerators with a number of functions such as deodorization, sanitization, ice making, LED lighting, inverter control are available which have not gained much popularity in India as yet.

For Indian refrigerators currently in the market, the compressor activation rate is 38%. Using this, in combination with the wattage ratings provided for current models (weighted by sales), a baseline refrigerator (165 litre capacity) uses an average of 0.98 kWh per day. Thus, the annual unit energy consumption for the baseline model is 359 kWh per year (McNeil *et al.,* 2005).

Frost-free models, almost all of which are two-door models in India, are much more energy intensive. According to a sample of models tested by manufacturers, the average consumption of a frost-free model is roughly 2.4 kWh/day, or 876 kWh per year (McNeil *et al.*, 2005). The average capacity

[17] STAT-USA Industry Sector Analysis – Refrigeration and Air Conditioning Equipment – India, available at http://www.ic.gc.ca/eic/home.nsf/html/imr-ri.html
[18] Ibid

for frost free models is taken to be around 220 litres. Efficiency for refrigerators in Japan is currently around 210–240kWh/year (75 litre class) for direct cool and is 450–600 kWh/year (300–400 litre class) for frost free refrigerators (ANRE, 2009).

At present, refrigerators have not been able to make inroads into rural markets in India due to irregular power supplies, relatively high costs (i.e. lower disposable incomes in rural areas) and the perception of impracticality[19]. In 2004-05 only 4% of rural households in India owned a refrigerator while ownership was 32% in urban households (NSSO, 2007).

Space Conditioning (Air Conditioners)

In India the fuel generally used for space conditioning is electricity. For Japan, the main fuels are kerosene (67.8%), town gas (19.5%), electricity (10.6%), and LPG (2.0%).

The sales of air conditioners (ACs) to the residential sector in India are growing at 35% annually (STAT-USA, n.d.). Today, there are several domestic and multinational companies in the AC market in India. The multinationals include Whirlpool (USA), Electrolux (Sweden), LG (Republic of Korea), Samsung (Republic of Korea) and Daewoo (Republic of Korea). Locally-assembled ACs are losing market to branded products, since they cost just 10–15% less than the branded products[20], and established brands also provide quality and after-sales service. Further, some brands including LG offer easy financing options making them more appealing to the buyers. The popular brands in Japan include Panasonic Corp., Daikin Industries, Mitsubishi Electric, Toshiba Carrier Corp. and Fujitsu General. The market share of these brands is provided in Table 11.

Table 11: Maker ranking of household refrigerator in 2007

	Maker	Share (%)
1	Panasonic Corp.	23.1
2	Daikin Industries	18
3	Mitsubishi Electric	14.7
4	Toshiba Carrier Corp.	12.2
5	Fujitsu General	9.1
6	Others	22.9

Source: Nikkei Sangyo Shinbun, 2008

The AC market is broadly divided into room ACs and the central AC segments. The room AC segment can be further divided into window ACs and split ACs. The AC market in India has traditionally comprised of window ACs. Split ACs were introduced in India only in the late 1980s but are rapidly finding favour with Indian households. The demand for split ACs is rapidly increasing and their market share is expected to grow in the coming

[19] International Market Research Report (http://strategis.ic.gc.ca/eic/site/imr-ri3.nsf/eng/gr101258.html)
[20] Efficiency of assembled air conditioners is also lower than those of branded air conditioners. Though not much data is available on this, the efficiency has been found to be almost 35% lower for assembled ACs (Frizair, 2009).

years. The popular brands for split ACs are Daikin, Hitachi, Panasonic, Mitsubishi, Carrier, Toshiba and Voltas. Popular window AC brands include Hitachi, Carrier and Whirlpool. On the other hand, the preferred AC type in Japan is split type (separate type) with 99.7% of market share.

The most common capacity class of ACs used in India is the 1.5 ton (or 5 kW) cooling capacity. ACs of capacity 1 and 2 tons account for most of the remainder of the market in India. AC designs tend to be similar across countries, thus the baseline EER (energy efficiency ratio W/W) for the 1.5 ton AC can be taken as 3.0. Japanese ACs are among the most energy efficient in the world and with average efficiency 5.3 in APF[21].

[21] APF = annual total of cooling capacity (kWh) / annual power consumption (kWh)

Chapter 2 Analysis of Suitable Technologies

In this chapter, technologies in Japan that offer improvements in efficiencies over the prevailing technologies in India will be presented along with the disadvantages, if any, of the relevant technologies.

Technologies in the Industrial Sector

FASTMET/FASTMELT process for DRI iron production

The FASTMET process consists of mixing iron ore fines and pulverized coal and consolidating into pellets or briquettes and then feeding into a rotary hearth furnace (RHF) in one or two layers. The CO gas that is generated from the pellets is used as fuel for the RHF. After processing for 6-12 minutes, processed hot iron is derived from the process. The process is designed to make the most effective reduction reaction in the furnace by using the maximum amount of radiant heat (Kuwata, 1998).

The FASTMELT process consists of a FASTMET process for producing iron as well as an Electric Iron Furnace (EIF) to produce hot metal. The hot metal produced is known as FASTIRON®. To produce one tonne of crude steel 29.1 GJ of energy would be used.[22]

The materials that are required for the process can be classified into three categories: metallic oxides or metallic-oxide bearing wastes, reductants (oxide can be reduced) and energy in the form of natural gas and electricity (Kuwata, 1998). FASTMET/FASTMELT plants are extremely efficient at processing EAF dust that has been classified as hazardous and converting this waste product into iron.

The costs of Greenfield site budget for FASTMET plants range from $150 to $200 per tonne of direct-reduced product. FASTMELT plant costs range from $250 – $300 per tonne of hot metal (McClelland and Metius, 2003).

As the industrial advisor to the Ministry of Steel in the Government of India pointed out, the cost of the FASTMELT/FASTMET plant remains extremely high. This is a deterrent to the uptake of this technology in the Indian steel sector as the output of the process is the same as the output from sponge iron plants. Also, as there are already a number of coal based DRI plants in India, the shift to FASTMET/FASTMELT plants could be slow (personal comm. with Mr. ACR Das).

ITmk3 (Iron making Technology mark 3)

The technology developed by Kobe Steel Limited, Japan is used for producing premium grade iron in the form of nuggets (97% iron content) by smelting iron ore fines using non-coking coal. This is done by feeding iron

[22] Steel from FASTMELT case study

ore pellets into a rotary hearth furnace along with non-coking pulverized coal. The furnace is heated to about 1,400°C which results in the iron ore partially melting and the slag separating. After this, the cold nuggets can be shipped whereas the hot nuggets can be used for direct feed into the EAF or the BOF (AllBusiness, 2003). The technology is currently classified as an emerging commercial technology.

The ITmk3 process is able to provide high-quality iron in about 10 minutes whereas the BOF takes about eight hours to produce the iron. At the end of the process, the material is cooled to about 800°C and the iron nuggets are separated from the slag beads. It is expected that if the ITmk3 technology proves successful, then commercialization of the technology could be rapid in India.

Also, as the ITmk3 process does not have a sintering plant or a coke oven, there is a reduction in the amount of NO_x, SO_x and particulate matter that is emitted (Asia Pacific Partnership for Clean Development and Climate, 2007). The capital cost of the ITMK3 process is about half the cost of conventional steel making technologies such as blast furnaces with associated facilities (Business Standard, 2007).

This technology could be especially useful to India due to the fact that it is useful for processing iron ore fines. India currently is the forth largest iron ore producing country in the world; however, 60% of the ore production is limited to fines due to which, 80% of the ore produced is exported (Das, unpublished). In 2007/08, 33,100 thousand tonnes non-agglomerated iron ore fines (62% Fe and above) were exported from India at an export value of Rs. 118,122.1 million (Ministry of Commerce and Industry, 2010). There would be considerable value added to the export of these fines if these were refined before exporting.

Based on discussions, (telephonic interview with Mr. ACR Das, Industrial Advisor, Ministry of Steel, Government of India) the problems that the Indian Steel sector is facing with the uptake of various technologies in the Indian steel sector were sought to be understood. The ITMK3 process has not yet been proven commercially. This was to be accomplished by building a pilot plant in Minnesota, US. However, due to financial difficulties, it was not accomplished. As the technology has not yet been proven at a commercial level, steel plants tend to be hesitant about investing in the technology. However, a number of steel plants in India are interested in the ITMK3 process and the 11^{th} five year plan identified the technology as one of the key technologies to be imported to India. The technology still remains extremely promising to the Indian steel sector. Although the technology uses natural gas which India is not so much abundant in, the makers of the technology have indicated that it may be possible to substitute different fuels. Also, the quality of the output is very high compared to material produced by sponge iron process and other processes.

To sum up, the ITmk3 process can offer a 30% energy savings over integrated steel making and 10% energy saving over the EAF method to produce steel. All the chemical energy of coal and no waste gas is exported from the system, thus the process can reduce emissions by more than 40% as well as reduce the amount of NO_x, SO_x and particulate matter emitted (Asia Pacific Partnership for Clean Development and Climate, 2007) .

A case study of previous transfer of technology from Japan to India and the experiences have been dealt with in further chapters.

Technologies in the Transport Sector

Battery Electric Vehicles (BEVs)

Although battery operated vehicles tend to be more expensive than conventional cars, they offer advantages such as zero-tailpipe emissions and a lower running cost. With these merits, BEVs can help improve air quality and reduce health impacts in major metropolitan cities in the country. However, one of the main disadvantages of electric cars is that they shift the emissions from the tailpipe to the power station. With the greening of grids around the world, battery operated vehicles could offer reductions in the carbon emitted from the operation of vehicles.

Battery operated vehicles contain a battery pack that is charged by plugging it into a socket or other electrical source, such as a solar panel. The energy stored in battery packs is used to power an electric motor which in turn drives the car.

With the introduction of REVA (2 seat battery operated vehicle) in the Indian market, India is ahead of Japan in this technology. However, Mitsubishi is introducing a 4 seat electric vehicle in Japan in 2010 and there is scope that the two countries can learn from each other’s technologies.

The high costs of batteries can be reduced via mass production which can be achieved only if there is enough demand. Further technological advancements can make BEVs as a potential alternative for passenger vehicles.

Mitsubishi i-MiEV: Battery Electric Vehicle

The first model in the i-MiEV series was displayed in 2006. It can travel up to 160 km in a single charge. The i-MiEV uses 88 high capacity lithium ion batteries for storing energy. The full charging time of the battery is 14 hrs in a 100V line and 7 hrs in a 200V line. The maximum power of engine has a maximum power of engine is 63 bhp and the maximum torque is 180 Nm at 2000 rpm. When brakes are applied the energy is not dissipated and instead is converted into electricity and stored in the batteries. Tables 12 and 13 indicate the technological specification details.

Table 12: Specifications of the Mitsubishi i-MiEV

Capital Cost	Yet to be introduced in the personal market
Fuel Cost	0.5 Rs/km[23]
Seating Capacity	4 (Dimensions (mm): 3,395×1,475×1,610)
Range	160 km
Market status	Available
Battery	Lithium ion
Running Coat	1/3rd the conventional gasoline running cost*
Noise Reduction	5dB lower*
CO_2 emission reduction	70% (approx) from conventional gasoline*

* By the manufacturer

Table 13: Charging specifications of the Mitsubishi i-MiEV

	Power Supply	Charging Time
Household Charger System (Full charge)	single phase 200V(15A)	approx. 7h
	single phase 100V(15A)	approx. 14h
Quick Charger system (80% charge)	3-phase 200V 50kW	30min

Source: Mitsubishi Motors Global website, n.d.

Hybrid Electric Vehicles (HEVs)

Hybrid Electric Vehicles combine a conventional internal combustion engine propulsion (ICE) system with an electric propulsion system (EP). The EP systems in these cars provide a better fuel economy than a conventional vehicle. A variety of HEVs exist, and the degree to which they function as EVs varies as well. Mainly there are two variations in HEVs, externally chargeable plug-in hybrid electric vehicles (PHEVs) and HEVs that use power during idling-stoppage time as well as techniques such as regenerative braking to charge the battery which can then be used for additional power during periods of high acceleration.

The hybrid vehicles allow for an optimal use of both combustion engine and energy stored in batteries reducing dependence on each of them. This allows the use of smaller engines and smaller batteries to bring down the cost.

The benefits of hybrid vehicles are the reductions in emissions during the running of the vehicle as well as the reduction in the running cost of the

[23] Cost of electricity assumed as Rs 3 per kWh.

vehicle. The fuel efficiency numbers by the U.S. Environmental Protection Agency (EPA) for various HEVs (such as Toyota Prius and Honda Civic Hybrid) show that the efficiency improvement in these vehicles is around 100% (actual figures depending upon maintenance and driving style could differ). This leads to a 50-70% tailpipe CO_2 emission reductions [24], (ACEEE, 2004). This can also be seen in the fuel efficiency numbers provided by Toyota which are more than 100% efficient than their conventional counterparts. The cost of the battery continues to be a hindrance to the greater uptake of hybrid cars and there continue to be issues of battery performance with respect to range and recharging periods. The technical details of one of the world's most popular hybrid electric vehicle, the Toyota Prius is given in Table 14.

Table 14: Specifications of the Toyota Prius

TOYOTA PRIUS – Hybrid Electric Vehicle	
Price	$ 22,800
Dimensions (h × w × l; in cm)	58.7 × 68.7 × 175.6
Type	Sedan
Technology	Al double overhead cam (DOHC) 16-valve VVT-I 4-Gasoline cylinder + Ni-MH Battery packs
Fuels Used	Gasoline-Electric Hybrid
Mileage (km/litre gasoline)	51/48/50 (City/Highway/Combined)
Battery Type	Nickel-Metal hydride (Ni-MH)
Battery Life	150,000 km (based upon lab testing)

Source: Toyota Prius, 2010

Discussion of BEVs and HEVs

The two major batteries used in P/HEVs and EVs are nickel-metal batteries and the most recent lithium-ion and lithium-metal batteries. Currently Li-ion and Li-metal batteries are preferred for their low cost, low recharging time and high backup in BEVs and PHEVs, although several HEVs use Ni-metal batteries which are relatively safer than the lithium based ones.

HEVs are much cheaper than BEVs (1.5-3 times the cost of their conventional counterpart) but these costs are for sedans and not for small cars; if small cars are hybridized, the cost difference is much higher.

The main deterrent other than high costs and electricity demand of these vehicles is the small battery life. But a lot of research is being carried out to overcome this barrier. Also, India being a predominantly small car market, HEVs may have a limited penetration. Considering these points one of the strategies can be to introduce BEVs with lower costs in small urban cities and HEVs in larger urban areas where the frequency of long distance trips is higher but still not very high. For example the Toyota Prius uses a 5 kWh

[24] The exact reduction caused by the HEVs will depend upon the usage mix of batteries and gasoline in the vehicle. These numbers are evaluated by comparing TOYOTA Prius to TOYOTA Corrolla Matrix 1.8L 4 auto.

batteries giving a range of around 20km from battery and the yet to be launched Chevrolet Volt promises a range of 60-65km with their 16 kWh lithium ion batteries (Toyota Prius, 2010; Chevrolet website, n.d.). No wonder the higher range comes at a higher cost as Volt is expected to be 1.5 times more expensive than Prius. A solution for this problem as adopted by various manufacturers is that the batteries are leased out (instead of being sold) with a nominal monthly or annual charge.

Table 15: Comparison of gasoline, battery and hybrid electric vehicles

	Conventional Gasoline (Small Cars)	**Battery Electric Vehicles**	**Hybrid Electric Vehicles**
Vehicle Cost	Unit cost	4-4.5 times	1.5-2 times
Running Cost	Unit cost	80-90% cheaper	50-60% cheaper
Range	350-450 km with full tank	80-100 km in 1 full 7-8 hrs charge	20-60km per 2-4 hrs recharge + 200-250 km on gasoline
Tailpipe CO_2 Emissions	Unit Emissions	ZERO	50-70% reduction

The introduction of BEVs and PHEVs in India must be accompanied with price control mechanisms to promote these technologies and reduce the payback period for the consumer, greener electricity generation and infrastructure development.

Currently, the Indian Government is aiming towards providing infrastructure for spreading the use of CNG in Indian cities, but considering barriers like restricted domestic supply for CNG, existing bottlenecks for import options, liquefaction and re-gasification of imported gas, energy consumed in drilling etc, the penetration of CNG vehicles in the Indian road transport sector may be restricted. As the domestic supply of natural gas will not be sufficient to support a substantial number of CNG vehicles, importing the gas via pipelines or containers in liquid form will increase India's import dependency. Also, due to competitive uses the fertilizer industry has a preference for natural gas consumption over the transport sector.

Hence, an alternative can be to diversify the transport demand by introducing BEVs and PHEVs that can take some load off from the CNG vehicles and contribute in reducing air pollution, negative health impacts by reduction in tailpipe emissions.

High Speed Rail - The Shinkansen

The Shinkansen network opened in October 1964 to increase the capacity on the saturated Tokyo-Osaka rail corridor. Since then, it has carried over 6 billion passengers without a single major accident. Initially, the trains ran at up to 200km/h, but this has been increased with improvements in infrastructure, signalling and maintenance and now, the maximum speed is 300 kmph with passenger capacity of more than 1,300 (railway-technology.com, 2010). A joint study on the potential of High Speed Railway networks around the globe by Centre for Clean Air Policy and Centre for Neighborhood Technology shows that Shinkansen is much more carbon intensive in terms of amount of CO_2 emitted per passenger kilometre than other railway networks like TGV in France. But even though Shinkansen's CO_2 emission is roughly 15 g-CO_2/Pkm and this figure is more than three times compared to that of regular rails', this is still much more efficient when compared to other transportation means, such as private 4-wheelers which emits nearly 170 g-CO_2 in Japan (NTSEL, 2009) and airlines.

Table 16: Estimated performance characteristics

	Shinkansen	Regular Rails
g-CO_2 / Pkm	15	< 5
Passenger capacity	1,323	varies
Maximum speed (km/h)	300	160

Source: Hokuetsu Express, 2010; NTSEL, 2009; JR Central Japan Railway Co., n.d.

The Shinkansen uses a conventional train design with motors and other equipment mounted on the rolling stock. Electric power is collected from overhead wires. However, there is not much scope for further increasing speed, due to the inherent limitations of the system such as greater size and weight of onboard equipment, difficulty in collecting electric power and reduced adhesion between wheels and rails at higher speeds which may cause wheel slip.

One of the major concerns to IR is that some segments, particularly the short and medium distance passenger business, are facing intense competition from the vastly improved road services. Low cost airlines are giving stiff competition to upper class segments of the passenger business. The rapid growth of the economy, rising industrialization and urbanization and unprecedented growth in inter-city travel has opened possibilities for developing high-speed passenger corridors across India such as in those achieved by the Shinkansen in Japan.

High-Speed Rail requires modern and state-of-the-art signalling / communication and maintenance practices for infrastructure and rolling stock. Such technological know-how and engineering skills would have tremendous spin-offs for India. Apart from reducing the carbon emissions from transportation, the implementation of a high-speed rail will close the technological gap between technology know-how between developing and developed countries.

Indian Railways is planning inter-city high speed passenger railway lines in India for some selected routes with a distance of 500-600 km. RITES, a Government of India enterprise, is carrying out pre-feasibility studies on some of these routes. According to the Working Group committee on Railways, these corridors will see special trains capable of speeds of 250-350 kmph. Some of the corridors identified for the pre-feasibility study are listed in Table 17.

Table 17: Corridors identified for high speed rail in India

Routes	Distance by Road (km)	Distance by Rail (km)
Mumbai-Ahmedabad	545	490
Delhi-Chandigarh-Amritsar	447	500
Delhi-Jaipur	258	307
Chennai-Bangalore	331	361
Chennai-Coimbatore-Ernakulam	670	700
Howrah-Dhanbad-Patna	430	531

Source: Planning Commission, 2006c

Technologies in the Residential Sector

Lighting

Light Emitting Diodes (LED)

LED technologies constitute some of the most promising technologies in the lighting front due to their high efficacy. LED lamps use semiconductors that are crystals comprised of combinations of typically two or three inorganic elements, such as gallium phosphide (GaP) or gallium indium nitride (GaInN). When an electric field is applied to the material, negatively charged electrons and positively charged electron vacancies are produced and exist at different energy levels separated by a "band gap". When these subsequently recombine, the released band-gap energy is converted into a photon of light with a frequency, and hence colour, that is equivalent to the band-gap energy. This results in the emission of light in a very narrow spectrum. Because the light is narrow-band, these are capable of much higher light-emission efficiencies than are incandescent light sources (IEA, 2006).

There are a number of additional advantages of LEDs which include longer lifetime, compact size and flexibility in design, digital control programmability, light output with no ultra violet and infra red radiation and safety of usage and disposal because of low voltage, low heat operation and no mercury usage.

Light from LEDs is monochromatic, which means that immediate processing is needed if white light is to be produced. Additionally, in LEDs heat is concentrated in the emitting device (junction diode) and cannot be easily conducted, radiated or convected away. Therefore, attention is needed in the design and mounting of LED chips so that this heat can be safely dispersed via conduction through the LED base.

As mentioned earlier, Philips Electronics India has recently unveiled their LED range catering to the domestic segment which is a first for India. Details for the product array are given in Table 18.

Table 18: Price of LED devices in India

Item	Price (Rs)
DecoLED	270-475
LED Flash Light	750
LED Candle	350
LED Nitelite	325

Japanese market survey data shows that the leading LED manufacturers are Sharp, Panasonic and Toshiba[25]. The models that were studied for the analysis had lumen outputs that are comparable to 60 W GLS bulbs or higher. On an average, the lighting devices consumed 7.5 W with about 40,000 hours rated life. These bulbs are, however, priced at approximately Rs. 2500 as compared to a GLS bulb that costs only Rs. 11.

Table 19 below shows a comparison of the lighting options that are available in the Indian market. Due to the lack of a developed market for LEDs in India, a comparison of LED has been done against the base option of GLS bulbs.

Table 19: Comparison of GLS and LED bulbs

Option	Capital Cost (Rs.)	Wattage (W)	Life (Hours)	Annual Electricity Consumption (KWh)[26]
GLS Bulb	11	60	1,000	109.5
LED Bulb	2,500	7.5	40,000	13.7

Tubelights

The fluorescent lamp is a very popular lighting device among Indian households. It produces light by creating an arc between two electrodes in a glass tube filled with an atmosphere of low-pressure mercury vapour and inert gas. Light is produced by the phosphorous coating on the inside of the glass, which is activated by the ultraviolet energy of the discharge. In new generation fluorescent tubes, new phosphorous has been used to give better colour spectra and efficiency. The composition of phosphorous determines the quantity and colour of the light emitted.

It is important to include the calculation of ballast losses when comparing consumption and savings for different kinds of lamps. Typical ballast losses are taken as approximately 15% of the lamp wattage. New electronic or solid-state ballasts available in the market save 20%–30% in energy consumption over standard ballasts, at price premiums from 50%–100%[27].

In India, the most common ratings of the fluorescent lamp are 36 W or 40 W. These 36W fluorescent lamps are also popularly known as 'thin tubes' or T-8 lamps. The conventional, 40 W tubes, are also called T-12 lamps. T-5 lamps

[25] Nichia Corporation, Japan is a world leader in the manufacture of LED chips.
[26] Assuming that a light bulb is being used for five hours everyday in households.
[27] TERI, 2004

(28 W) have also been recently introduced in the Indian market. [28] While tubes of 36 W (T-8) use the same fixtures as the conventional 40-W tubes (T-12) and can be easily replaced, T-5 tubes can normally only be used in fittings which have been specifically designed for this type of lamp.

In order to compare the applicability of Japanese tube light technologies in India, data for different manufacturers was collated. These tube lights have a very high lumen output of 3,310 lm as compared to an Indian average of 2,450 lm (T-12 and T-8). Their rated life is also higher (13,500 hours) as compared to an average of 5,000 hours for Indian tube lights[29]. However, these tubelights are 10 times as costly as compared to their Indian counter parts. The costs for the base option (T-12) and the alternatives T-8 (Indian manufacture) and T-8 (Japanese manufacture) are provided in Table 20.

Table 20: Specifications of different types of tube lights

Option	Capital Cost (Rs.)	Wattage (W)	Life (Hours)	Luminosity (Lumens)	Annual Electricity Consumption (KWh)[30]	Efficacy (lumens/watt)
T-12	40	40	5,000	2,450	73.0	61.3
T-8 (Indian)	80	36	10,000	2,450	65.7	68.1
T-8 (Japan)	825	32	13,500	3,310	58.4	103.4

Accordingly, Japanese tube lights appear to be positive cost options as compared to Indian base technologies. The Indian T-8 performs much better as compared to its Japanese counterpart with respect to economics. However, if efficacy (lumen/watt) were considered then Japanese T-8s have a superior performance.

As has been noted earlier, an Indian company, Surya Roshni Lighting, has developed T-5 tube lights for the Indian markets. These bulbs provide similar lighting as the conventional T-8 bulbs but are much less energy consuming (28 watts). While the tube lights themselves are priced approximately equal to the T-8 prices, these bulbs require special fixtures (ballast and holder) for them to operate. Thus, the total system costs would be higher for switch from T-12 to T-5 as compared to a T-8.

Space Conditioning

Following the second law of thermodynamics, the natural tendency of the heat is to flow from the high temperature reservoir to the low temperature reservoir. However, for space conditioning the heat is rejected from low temperature reservoir to the high temperature reservoir. Since this is against

[28] It should be noted that based on the diameter of the tube the lamps may be referred to as T-12, T-8, or T-5. The figures 12, 8 and 5, refer to the number of 1/8th inch in the diameter of the tube. Thus, for instance a T8 tube is in fact 1 inch in diameter. The T-5 tube is 5/8th inch in diameter.

[29] IS:2418 part-1-1977 (amendment no. 3) for 40W tube lights outlines lamp performance till 3500 hours. However, manufacturers report the rated life of tube lights to be higher at about 5000 hours.

[30] Assuming that a light bulb is being used for five hours everyday in households.

the natural flow of heat, some external work has to be supplied to the appliance in order to enable the transfer of heat from low temperature to the high temperature reservoir.

The basic principle of space conditioning equipment is more or less similar. Broadly there are five basic parts in the space conditioning system: (a) Compressor; (b) Condenser; (c) Expansion/throttle valve; (d) Evaporator; and, (e) Refrigerant.

While the system is the same for both air conditioning and refrigeration, the two systems are different with respect to the 'space' conditioned. For refrigerators, an insulated space (refrigerator capacity) is being cooled while for air conditioners the space would be much larger i.e. a room. Moreover, components may be placed externally in the case of a refrigerator, in the case of an air conditioner the components are composed of a packaged unit. However, split units may have the compressor and evaporator segregated.

For space heating, the components of the heat pumps are same as the refrigerator and even they perform the similar functions; the only difference is that in the heat pumps the components work in a reverse manner. The heat pump is the reverse refrigerator.

In the refrigerator the evaporator performs the main function of chilling or freezing, while the condenser performs the function of delivering the heat to the atmosphere. In the heat pump, it is the condenser that performs the main function of heating the room, while the evaporator performs the function of absorbing the heat from the atmosphere.

Refrigerator

Refrigerators are appliances that are used round the year (all seasons) in households and therefore, efficiency is very important in their case. Moreover, due to its perennial application, the performance of refrigerators can be measured in the electricity units consumed by the appliance throughout the year to cool various items stored inside the refrigerator.

Similar to other appliances, a comparison of performance of refrigerator models found in Japan and India was done. However, a cost analysis was not done in the case of refrigerators since it was found that for similar energy efficiency, cheaper models were available in India. In most cases the cost of refrigerators were found to be 1.5-2 times as high as their Indian counter parts with no major increase in efficiency [31,32]. In many cases it was found that for a sub-group, for e.g. 301-350L capacity, the efficiency of refrigerators available in India exceeded those for the Japanese refrigerators.

[31] Details for refrigerators available in India sourced from BEE website (http://www.bee-india.nic.in/) and specific brand websites.
[32] It should be noted that the electricity consumption would depend upon the ambient room temperature as well.

Additionally, a comparison of brands and models available in Japan shows that models with greater rated internal volume (more than 400 litres) were comparatively much more efficient than the smaller capacity ones. The preference of Indian households for larger storage space (more than 400 litres) would be strongly dictated by the prevalent lifestyles [33].

Air Conditioner

Air conditioners (ACs) as well as heat pumps have a seasonal usage. Thus, their power consumption depends upon the duration of their usage as well as the cooling/heating that is required to achieve thermal comfort in a room. The efficiency of heatpumps as well as ACs are therefore measured in COP (coefficient of performance). The unit is defined as the ratio of the desired effect from the appliance (cooling/heating) to the power consumed in its operation.

While data for different AC models is available, the comparison of performance of Japanese ACs against AC available in India is especially difficult since the Japanese ACs provide both heating and cooling services (heat pump technology). Therefore, in this case the appliance characteristics available in Japan and in India are discussed in Table 21.

Table 21: Characteristics of technologies available in Japan and India

	India [34]	Japan		India	Japan	
		Cooling	Heating		Cooling	Heating
Cooling Capacity (kW)	3.5 (~1 ton)	3.6	-	5.3 (~1.5 ton)	5.0	-
Heating Capacity (kW)[35]	-	-	4.2	-	-	6.2
Power Consumption (W)	1,239	1,000	970	1,947	1,619	1,496
COP	2.86	3.63	4.39	2.72	3.15	4.17
Price (Rs.)	20,000	62,203		27,000	79,272	

Japanese AC manufacturers are some of the most efficient manufacturers in the world. As shown above their energy performance with respect to Japanese conditions are superior to those by Indian manufacturers. However, their appliance prices are comparatively three times as high as the prices of ACs available in India. Additionally, their performance may differ in Indian conditions (ambient room temperature, humidity levels, electric voltage and fluctuations etc.) and this would need to be further examined in detail.

Heat Pump (air heating and water heating)

[33] Lifestyles in this context would include usage of packaged and frozen foods, non-vegetarian diets etc.
[34] Details for refrigerators available in India sourced from BEE website, n.d. (http://www.bee-india.nic.in/) and specific brand websites.
[35] Assuming outdoor air temperature to be 7℃.

An outline of heat pump technology that is used for space conditioning has already been discussed earlier in the report. The following section provides details for the heat pump technology that is used in Japan to heat water for domestic use and is marketed as EcoCute. The capital and installation costs of the EcoCute tend to be much higher but the units can boil the same amount of water as compared with conventional electric water heaters with one-third to one-fourth the amount of electricity. However, it should be noted that in the EcoCute, the production of hot water is centralized and hence may be unviable for a direct installation in residential premises in India where the production of hot water tends directly feed into the outlet that it is supplying to. However, the EcoCute mechanism could be used to provide hot water to commercial establishments such as restaurants.

The technology is being successfully used in Japan, US and parts of the Europe. In Europe, heat pumps based on geo-thermal heat currently have 56% of the market [36]. Of the 242,000 heat pumps installed in Europe in 2006, 73,400 were installed in Sweden and 55,000 were installed in Germany. In Japan, 400,000 units were sold of the EcoCute in 2007 [37].

The technology of heat pumps could be applicable to India as it can be used for heating water in the winter months in North India. Also, heat pumps can be used to provide indoor heating and cooling. It has been estimated that it is possible to save up to 6% of CO_2 emissions by using heat pumps world wide.

A draw-back of EcoCute is that the output pressure of hot water from the units tends to be low. However, Hitachi has developed a technology to provide high power to showers. Additionally, the cost of the heater as well as the capacity may prove to be a limiting factor for its popularity. In India, most of the electric geyser market is dominated by 15 and 25 litre models which are preferred by independent flat dwellers. The large capacity of the heater implies in the Indian context that it would find greater usage in institutions or residential housing colonies/apartments that have common water storage systems.

Table 22: Eco Cute Details

	Eco Cute Water Heater
Price (Rs.)	167,648- 188,604
Storage Capacity (Litres)	300-550
Heating Capacity (KW)	4.5 (Summer) 4.5-7.2 (Winter)
Electricity consumption (KW)	0.85
COP	4.2

36 Bosch website, n.d. Details from (http://www.boschthermotechnology.com/sixcms/detail.php/2326073)
37 Climate Success Org website (http://www.climatesuccess.org/uploads/pdfs/68.pdf)

Chapter 3 Barriers to Transfer of Technology to India

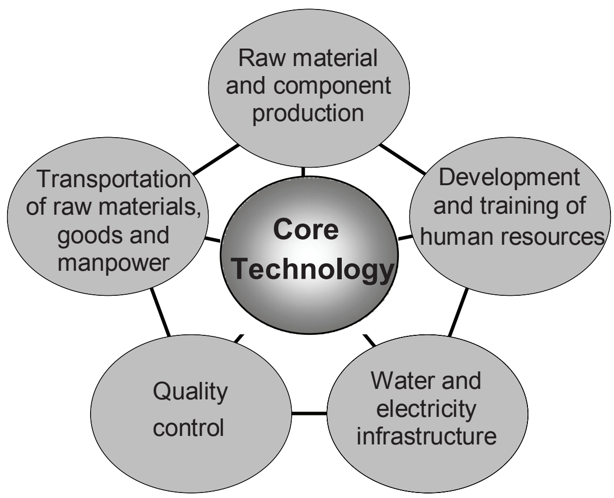
IPCC (2000) contextualizes the argument regarding technology transfer by noting that although the transfer of enhanced skills, capabilities and institutions occurs due to the transfer of technologies, it is important that scientific and technical skills be present in the country that the technology is being transferred to, along with skills to negotiate the financing, marketing, maintenance, service, information dissemination, utility registration, policy development, macroeconomic policy and property rights.

Apart from a lack of understanding of the local market, IPCC (2000) also points out that projects that involve a one-time technology transfer failed to provide incentives structures, failed to demonstrate institutional and commercial viability, failed to account for continuing maintenance requirements, failed to create a maintenance and service infrastructure and in general failed to generate sustainable market for the technology demonstrated.

As IPCC (2000) points out, the need for continuous technology transfers rather than one-off transfers should be considered for a market transformation approach.

Moreover, there is a need to consider the various issues (peripheral issues) which create barriers other than transfer of technology itself, such as infrastructure and cultural differences (JEF, 2010) (Figure 15). These peripheral issues are as important as the technology itself. For instance, while good quality and quantity of water and electricity for industry is easily secured in Japan, these issues might pose a serious problem in India (JEF, 2010).

Figure15: Peripheral issues surrounding the core technology (conceptual diagram)



Source: JEF, 2010, p.30

Financial Barrier

TERI (2009) notes that one of the major barriers to the transfer of technologies is the high upfront cost of several of these technologies. As the adoption of a technology is encouraged through the generation of market demand or by guaranteeing the existence of a future market, there is a significant role that appropriate policies can play regarding the uptake of environmentally sound technologies.

For the adoption of environmentally sound technologies, the profit derived from the adoption of these technologies might be small when compared to the high upfront capital cost. A lack of favourable policies for the uptake of these technologies could be a barrier. In addition, energy costs to the end-users in the transportation and residential sectors in India tend to be subsidized[38] and hence there would be few financial benefits to the uptake of the technologies to reduce the consumption of energy in these sectors. Also, technologies introduced from abroad have the additional disadvantage of having to compete with the domestic technology providers who are already established in the market.

Business Barrier

In Japan, regional differences and income gap in the rural and urban areas are not the major barriers in terms of research, development and production of technology. Public infrastructure such as water, electricity, road transportation is fully equipped. In addition, the distribution of materials and products and securing quality workers are not a major issue in Japan. On the other hand, there are many regions in India where the basic infrastructures, both hard (e.g. equipment and facilities) and soft (e.g., employees' know-how and experience), poses restrictions. It becomes necessary to understand these environmental barriers such as regional and income gap in conducting technology transfer.

In addition, some Japanese companies indicate that lack of qualified local Indian suppliers is one of the barriers to the technology transfer to India (MMRC 2006). However, several Japanese companies have successfully been able to work with local suppliers to acquire parts of the required quality. In fact, 70% of Suzuki Alto is procured domestically in order to reduce cost (Nikkan Jidousya Shinbun, 2000).

Difficulty in sales was considered a barrier for several Japanese companies as well. For example, one of the Japanese home appliance companies had faced issues relating to sales (MMRC, 2006). On this point, Suzuki had advantage of JV with its Indian counterpart, Maruti (Nikkan Kogyo Shinbun, 1998; Nikkei Business, 1997).

[38] In 2007/08, the subsidy provided for petroleum products was Rs 28.2 billion (MOPNG, 2010 from http://petroleum.nic.in/petstat.pdf)

Social and Cultural Barrier

It is important to take note of the differences in society and culture such as work practices and work consciousness, corporate practices, the relationship between enterprises and individual and corporate culture. Additionally, there are several problems related to the employment, such as the training of technical experts, planning a continuous employment skill up of technical experts and a system which prevents job turnover.

Furthermore, there are barriers on cultural aspects such as time perception differences in terms of schedule management. Also the differences in an administrative procedure have been pointed out as issues related to human resources.

Political Institutional and Logistics Barriers

Japanese companies tend to view the tax structure in India as extremely complicated. The different layers of the tax that has to be paid is found to be extremely opaque by Japanese companies. Choudhury (2009) also indicates that Japanese companies tend to view a number of regulations for importing goods to be cumbersome. Choudhury (2009) gives the example of the legislation that the invoice of goods that are being imported have to be registered 24 hours before arrival at the customs office. These cause severe difficulties if the factory is located at a distance from the customs office. In addition, in the case of emergencies, it is impossible to meet the 24 hour period before which the invoice has to be registered.

The bureaucratic difficulties in the Indian system can occasionally result in Japanese companies having to liaison simultaneously with a number of different government departments. Choudhury (2009) conducted a survey with eight Japanese firms that had entered the Indian market and found that six of the eight companies gave "obtaining approvals as obstacles" as the most important or the third most important problem while doing business in India.

Choudhury (2009) also gives a brief case study of a Japanese firm that partnered with an Indian firm. The Japanese firm was in charge of the management and processes in the plant where as the Indian firm was in charge of issues regarding the necessary clearances from the local administration.

Legal Issues

The transfer of technologies suffers from two different types of legal issues. Contract issues refer to enforcing legal obligations with the suppliers/providers of services. Property risks including those related to Intellectual Property Rights (IPR) refer to the risks associated with the asset ownership and corporate risks. Extensive research has been conducted on the impact that IPR has on the process of technology transfer and the role of the companies who hold the patents to these technologies. Although IPR can be a barrier to technology transfer, a discussion relating to IPRs is outside the scope of this report.

Although Japanese companies view the Indian judicial system as an advantage, cases often take a long time to finish which is viewed as a severe disadvantage (Choudhury, 2009). Also, cases are often challenged in higher courts which increase the time that is spent on each case.

Although India ranks relatively low on the corruption index, Japanese companies do not see this as an obstacle, possibly due the prevalence of corruption in the majority of developing countries (Choudhury, 2009).

Technical Barriers

The uptake of new technologies can face stiff resistance in countries especially if these technologies are complex in nature. Additionally, these technologies face the barriers of having to prove themselves as users of older technologies may not wish to upgrade to newer technologies.

Also small companies may not be willing to invest the additional amount to make the technologies suitable for local markets. This additional investment may be quite significant relatively to R&D budgets.

Conclusion

Due to policies that were adopted after the first oil crisis in 1973, Japan has established a number of energy efficiency measures. These have led to its economy having one of the lowest energy intensities in the world. With the growth of the Indian economy, there is a scope for the adoption of efficient technologies across the economy.

This report has examined the various technologies that could be suitable for transfer to India, based on energy saving possibilities. However, some of these technologies are still at the development stage and have not been proven on a commercial scale as yet. Also, a number of the technologies, particularly in the transportation sector, require additional infrastructure to be developed which would result in their own constraints.

As the operating conditions in India tend to be significantly different from those in Japan, additional problems associated with the operation of these technologies in India could also emerge. Also, efficiencies of technologies in India could be significantly different than those in Japan.

Out of the research that has been conducted and the technologies that have been analysed in depth, there are a couple of sector-wise findings that can be learnt. Technologies that have been identified in the domestic sector tend to be costlier than their Indian counterparts. Accordingly, these technologies may not always cater to the needs of the Indian market; for example, Indian customers may not be willing to pay for a number of features in Japanese refrigerators. It should be noted that all technologies that have been identified in this report need to be analysed further with respect to their performance in Indian conditions before a conclusive statement on their applicability can be made. Technologies such as EcoCute and LEDs, though not fully commercialised the world over, may find applicability in India in the future. These technologies do not need massive infrastructure overhaul unlike technologies in other sectors and hence could offer greater efficiency in the short term.

Technologies in the iron and steel sector, such as the ITmk3 may prove to be successful in India if it is proven at a commercial scale. Also, if the technology is adapted to utilize coal, the technology could be especially applicable to India. Although the FASTMET/FASTMELT technology shows a decrease in the energy consumption for the manufacture of steel, there may be a number of hurdles before the acceptance of this technology.

Technologies in the transport sector can be more energy efficient in the future when the issues regarding green sources for electricity generation, electricity demand and high capital costs are dealt with. Till then, there will continue to be concerns raised about the environmental benefits and potential for penetration of such technologies in India. Similar issues also plague the application of high speed railways in India.

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