McKinsey&Company

Environmental and Energy Sustainability: An Approach for India

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Preface

India is already one of the largest economies in the world, and will continue its rapid urbanisation and economic development over the next two decades. This is a cause for celebration, but one tempered by the recognition of the challenges this growth presents: rising consumption and demand for energy, increasing greenhouse gas emissions[1], and constraints on critical natural resources such as land, water and oil. Like all other countries, India needs to find a way to ensure energy and environmental sustainability without compromising its economic and social development.

In 2008–2009, McKinsey & Company undertook a study to identify and prioritise opportunities for India to meet the closely linked challenges of energy security and environmental sustainability that come with growth. This report is a result of that effort. Its core purpose is to illustrate which measures have the greatest potential to reduce emissions, and correspondingly energy use, and which are the most feasible given the substantial challenges in funding, regulation, technology, capacity and market imperfections. The report aims to facilitate the definition and prioritisation of economically feasible solutions to the challenges of energy security and environmental sustainability that India faces. It primarily optimises economic factors to identify the lowest cost technology solutions for abatement. Prioritising on other dimensions such as adaptation or developmental benefits might yield another sequence of technologies. Therefore, our findings provide one important lens on the approach to abatement and have to be balanced against the priorities of development and adaptation.

The study methodology is built on McKinsey's research into greenhouse gas (GHG) abatement over the past three years in 18 countries. This research is marked by the development of a global cost curve and national cost curves that assess the potential and cost of a range of abatement opportunities for each country. In developing the cost curve for India, we first estimated emissions growth as a result of economic growth in five areas: 1) power; 2) emissions-intensive industries (including steel, cement and chemicals); 3) transportation; 4) habitats (including rural and urban residences, commercial buildings and appliances); and 5) agriculture and forestry. In addition, we assessed existing and planned measures to reduce these emissions. Taken together, these are defined as the **reference case** in this report.

Next, we studied the potential to further reduce emissions over the reference case. To this end, we assessed over 200 practices and known technologies that reduce emissions and increase energy efficiency. The technologies have a predicted cost and development path. To build a comprehensive perspective, we also sought the views of more than 100 experts in government, business, academia and society in India and across the world. Based on this, we estimated the **feasible technical abatement potential** of each practice and technology for a given period with respect to a reference practice or technology. We have defined this as the **abatement case**.

In this report, GHG emissions are used as a consistent metric for evaluating the impact of the full range of different practices and technologies studied, from supercritical technology for coal-

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[1] Greenhouse gases (GHG) include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from human activity in our estimates.

based power plants to LED lighting. In many areas of uncertainty, sensitivity analyses were done to illustrate alternative outcomes.

There are four main boundaries to our analysis. First, the cost analysis is done from the societal perspective and therefore considers only capital, operating and maintenance costs, and excludes taxes, tariffs and subsidies. All abatement costs and capital expenditure estimates are incremental to a current technology such as LED lighting compared to incandescent lighting. Positive or negative social factors (e.g., unemployment or public health benefits), administrative costs, transaction costs associated with switching to new technologies and communication costs are not included. Neither have we assumed any "price for carbon" (e.g., a carbon tax) that might emerge due to legislation, nor the impact on the economy of such a carbon price. In addition, we have assumed a societal cost of capital of 8 per cent in valuing the opportunities.[2]

Second, our focus was on emissions produced and energy consumed by human activity within the borders of India, without a detailed analysis of the impact of "imported" or "exported" emissions or energy. Third, we did not include the impact of abatement options on energy prices and consumer behaviour, or of energy price changes on abatement options adopted. Lastly, opportunities from behavioural changes that could reduce energy consumption and emissions were not included.

The report highlights that there are considerable benefits from reducing emissions—they include improving energy security, promoting inclusive growth, improving quality of life and driving leadership in emerging high-growth business areas. The report also highlights the key challenges of investment, supply and skill concerns, technology uncertainty, regulation and market imperfections. We also discuss the implications of our findings and highlight 10 broad areas for action. The report does not endorse any specific legislative proposals, policies or mechanisms. Neither is its purpose to present opinions or advice on behalf of any party, nor endorse any frameworks for a global agreement on climate change.

We would like to thank our sponsor organisations for providing their expertise and financial support: ClimateWorks Foundation, International Finance Corporation, Larsen & Toubro, Mahindra & Mahindra, Nand and Jeet Khemka Foundation and Tata Power. We would also like to thank members of our Academic Review Panel: Dr. Ambuj Sagar (Indian Institute of Technology, Delhi, India), Professor Dilip Ahuja (National Institute of Advanced Studies, India), Dr. Jayant Sathaye (Lawrence Berkeley National Laboratory, USA), and Dr. Ritu Mathur (The Energy and Resources Institute, India). We also acknowledge the inputs provided by Mr. Jamshyd Godrej (Vice President, WWF-International) in completing this study. Our research has been greatly strengthened by the contributions of these experts and organisations (who may not necessarily endorse all aspects of the report).

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[2] The societal discount rate is based on India's cost of capital in global capital markets and is used to calculate the broad cost to Indian society of making changes. The actual costs faced by individual businesses or households will differ from those faced by Indian society as a whole.

Finally we would like to thank our many McKinsey colleagues who have helped us with advice and support, including Eric Beinhocker, Jaidit Brar, Jens Dinkel, Rajat Dhawan, Per-Anders Enkvist, Thomas Netzer, Jeremy M Oppenheim, Venkatesh Shantaram, Vipul Tuli and Adil Zainulbhai. We would also like to thank the working team, particularly the project managers Sushant Mantry and Rahul Sankhe.

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Director	**Director**	**Partner**

Executive Summary

As India continues to develop, it has choices on how to accomplish its twin objectives of sustainable development and inclusive growth. India could choose to increase its focus on clean and efficient technologies and practices to meet these objectives.

By 2030, India is likely to have a GDP of USD 4 trillion and a population of 1.5 billion. This will swell demand for critical resources such as coal and oil with a parallel increase in greenhouse gas (GHG) emissions. Considering that 80 per cent of the India of 2030 is yet to be built, the country may have a **unique opportunity to pursue development while managing emissions growth, enhancing its energy security and creating a few world scale clean-technology industries.** This would require that India leapfrog inefficient technologies, assets and practices and deploy ones that are more efficient and less emission-intensive. To achieve all this will be challenging, including funding an incremental investment amounting to 1.8 to 2.3 per cent of GDP between 2010 and 2030.

This report presents five key conclusions:

1. **GHG emissions would increase from roughly 1.6 billion tonnes carbon dioxide equivalent (CO_2e)[1] in 2005 to 5.0 billion to 6.5 billion tonnes CO_2e[2] in 2030 in our "reference case".** This is an estimate of India's emissions by 2030, based on demand growth in key sectors such as power, industry and transportation, at a GDP growth rate of 6 to 9 per cent, reasonable assumptions about improvements in energy efficiency and the provision of clean power, and the assumption that all energy demand will be met.

2. India could make a step-change in its efforts to **lower emissions by 30 to 50 per cent to approximately 2.8 billion to 3.6[3] billion tonnes CO_2e a year by 2030, in our "abatement case".** This represents the feasible technical potential for further reducing energy consumption in five sectors of the economy. In this scenario, energy consumption could be reduced by 22 per cent, from 1.8 billion tonnes of oil equivalent (btoe) in the reference case to 1.4 btoe in 2030.

3. **Maximising India's energy and carbon productivity in this way would have several benefits** for India's society and economy. Implemented well, these opportunities could increase India's energy security through a reduction of over 100 million tonnes in metallurgical coal imports[4] and around 60 million tonnes of oil imports, a 20 per cent reduction in power capacity and about a 45 per cent reduction in coal use, over the amounts that would be needed in the reference case. Realising the abatement case could also spur innovation, increase environmental sustainability and open up new business opportunities.

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[1] CO_2e stands for "carbon dioxide equivalent" and is a standardised measure of greenhouse gases. Emissions are measured in metric tonnes of CO_2e per year, i.e., millions of tonnes (megatonnes) or billions of tonnes (gigatonnes). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from human activity, in our estimates.

[2] Range due to assumption of 6 to 9 per cent GDP growth.

[3] At an annual GDP growth rate of 7.5 per cent; range is due to the uncertainty about measures implemented.

[4] Quantity is in terms of Indian coal equivalent, representing Indian coal with a gross calorific value of 4,500 kilocalories per kg, 30 per cent ash and 7 per cent moisture.

4. **Making this step-change will present many challenges.** A large amount of incremental investment will be needed in sectors such as road transport, power, and buildings and appliances. Our analysis suggests that incremental capital[5] of about EUR 600 billion to EUR 750 billion would be needed between 2010 and 2030, even after accounting for steep declines in the cost of emerging technologies such as solar power. Over 60 per cent of the additional abatement opportunities impose a net economic cost, and would require an annual funding of EUR 18 billion, on average[6], between 2010 and 2030. The challenge is heightened by the need to fund abatement actions while meeting India's aspirations of high growth and inclusive development. Equally substantial challenges include supply and skill concerns, technology uncertainty, market failures and the need for regulation to stimulate change. **As a result, only 10 per cent of the total opportunity in the abatement case is readily achievable.**

5. **India could consider adopting a 10-point agenda for carbon- and energy-efficient growth** while also containing emissions. This would entail accelerating and expanding existing programmes to increase energy efficiency, developing clean sources of power generation, building a more responsive power sector, creating energy-efficient infrastructure (e.g., green cities, logistics networks), and making improvements in agriculture and forestry. Many of the actions described could be started (and some completed) within about 18 months. Additionally, state and local governments could develop and begin executing their own "carbon-efficient" growth plans.

Key figures

Factor	Unit	2005	2030 Reference case	2030 Abatement case
GDP growth	Per cent		7.5[7]	7.5
Population	Billion	1.10	1.47	1.47
Energy demand	Btoe	0.5[8]	1.8	1.4
Power demand[9]	TWh	700	3,870	2,910
Power capacity[10]	Gigawatts	150	760	640
GHG emissions	Billion tonnes CO_2e	1.6	5.0 to 6.5 (5.7)[11]	2.8 to 3.6 (3.1)[12]

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[5] Additional upfront capital expenditure required to achieve the abatement case over that needed to achieve the reference case.

[6] Without transaction costs and taxes, and at 8 per cent discount rate; adaptation cost not considered.

[7] For the period 2005 to 2030.

[8] Denotes actual supply.

[9] Includes captive power demand.

[10] Includes spinning reserves and captive power supply.

[11] Based on GDP growth range of 6 to 9 per cent; for our analysis assumed at 5.7 billion tonnes CO_2e at 7.5 per cent GDP growth rate.

[12] Based on range of improvements; for our analysis, assumed at 3.1 billion tonnes CO_2e.

THE CHALLENGE OF RISING EMISSIONS: THE REFERENCE CASE

India's economy has been growing fast and must continue doing so to ensure inclusive growth. At a likely GDP growth rate of 7.5 per cent a year, real per capita GDP is expected to reach USD 2,700 by 2030, a five-fold increase over the 2005 level. This growth will be accompanied by increased urbanisation, with well over half a billion people living in India's cities two decades from now.

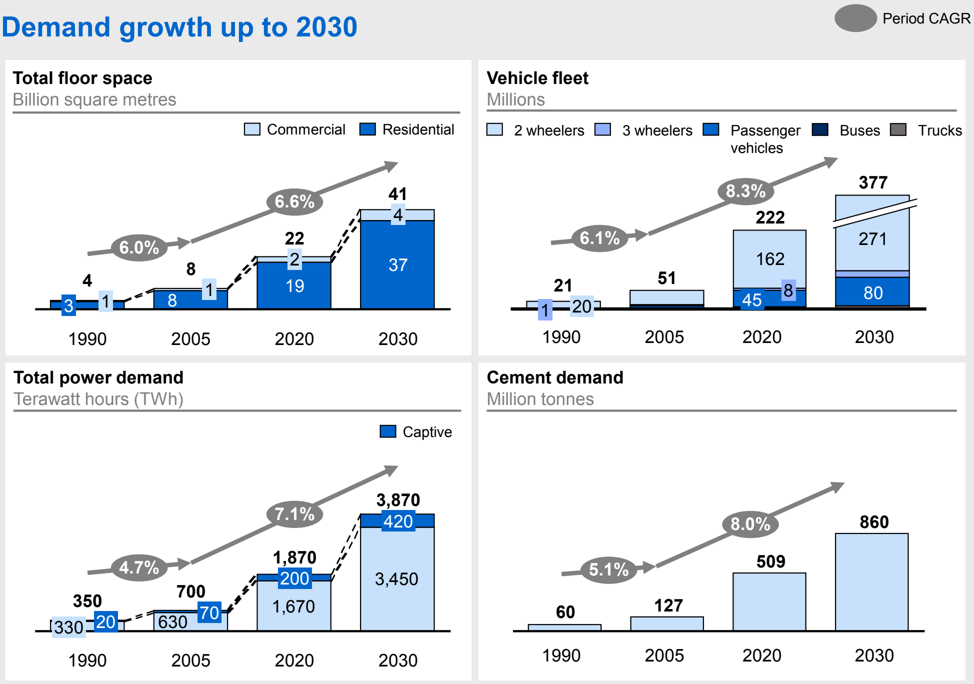
Economic growth will drive up demand in all sectors. Demand for power is likely to increase more than five-fold, from 700 terawatt hours (TWh) in 2005 to 3,870 TWh[13] by 2030. Demand for building stock and infrastructure is expected to grow at the same rate, increasing annual demand for cement to 860 million tonnes and for steel to around 300 million tonnes by 2030. The vehicle fleet is likely to grow seven-fold to about 380 million vehicles, including two-wheelers (Exhibit 1).

With this growth, India's total energy demand is likely to reach around 1.8 btoe a year in 2030, up from 0.5 btoe in 2005, even after assuming efficiency improvements that could occur in the normal course. This would make India the third largest energy consumer in the world, after the United States and China. Meeting this demand would mean that India's share of world energy consumption would nearly double, and thus India would have to find and secure energy resources much faster than other countries. That itself is going to be a challenge for India.

This demand growth will greatly increase energy requirements. India's coal demand by 2030 is likely to be 60 per cent higher than the projected domestic production of about 1.5 billion tonnes

Exhibit 1

Demand growth up to 2030



SOURCE: McKinsey analysis

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[13] Including captive power demand.

per annum by the same year.[14] This shortfall would likely have to be met with equivalent coal imports. Further, given India's limited oil reserves, more than 10 times India's domestic supply of oil may have to be imported. Such a high level of energy imports would have implications for India's energy security. There would also be the challenge of expanding coal mining in India more than three times to reach approximately 1.5 billion tonnes of coal production per annum.

Growth in energy consumption and the resulting increase in fossil-fuel supply would increase India's GHG emissions. In the reference case, by 2030, India's emissions could reach between 5.0 billion and 6.5 billion tonnes CO_2e depending on GDP growth (6 to 9 per cent) and the implementation of initiatives that are planned or likely in the course of business. For our analysis, we have assumed annual emissions of 5.7 billion tonnes CO_2e by 2030 at a GDP growth rate of 7.5 per cent a year between 2005 and 2030.

In the reference case, the power sector will be the biggest emitter, generating more than 50 per cent of emissions, i.e., 2.9 billion tonnes CO_2e by 2030, as over 60 per cent of power capacity is likely to remain coal-based. This level of emissions is likely after assuming improvements such as building power plants with more carbon-efficient supercritical technology, increasing solar power capacity to 30 GW by 2030, reducing technical transmission and distribution (T&D) losses[15] from around 15 to 19 per cent currently to 12 per cent by 2030, and lowering auxiliary consumption in power plants.[16] The reference case also accounts for improvements in other sectors. In buildings, the reference case assumes successful implementation of energy-efficiency initiatives such as the Bureau of Energy Efficiency's (BEE) "Star Labelling" programme for appliances and Bachat Lamp Yojana for promoting compact fluorescent lighting (CFL). In transportation, the reference case assumes mandatory fuel-efficiency norms for vehicles. In forestry, it takes into account continued afforestation at historical rates. In heavy industries such as steel and cement, it assumes continued reductions in energy consumption in line with current trends.

Realising the improvements assumed in the reference case is a challenging task, requiring considerable effort and difficult investment choices. For example, installing 20 GW of solar power would mean increasing current capacity 4,000 times.[17] While a better solution from the environmental and energy security perspective, it is also a difficult investment choice. Building solar capacity requires much more capital expenditure than adding oil-based capacity: the current cost of installing 1 MW of solar power capacity is around 5 to 8 times that of adding 1 MW of oil-based generation.

THE OPPORTUNITY FOR INDIA: THE ABATEMENT CASE

Our analysis reveals that India has the potential to further lower its energy- and carbon-intensity beyond what could be achieved in the reference case. Energy consumption could be

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[14] Source for production data: *Integrated Energy Policy*, Planning Commission, Government of India.

[15] Losses during transmission or distribution (e.g., at transformers) that are not commercial in nature. The number for actual technical losses is not reported, though experts currently estimate these at 15 to 19 per cent. Hence we have assumed 17 per cent in our analysis.

[16] The power used in running a plant.

[17] India's current installed and grid-connected solar capacity is around 5 megawatts (MW).

lowered by about 22 per cent, to around 1.4 btoe[18], and emissions by almost half, amounting to 3.1 billion tonnes CO_2e a year by 2030. We call this scenario the "**abatement case**". This represents feasible technical potential rather than a target.

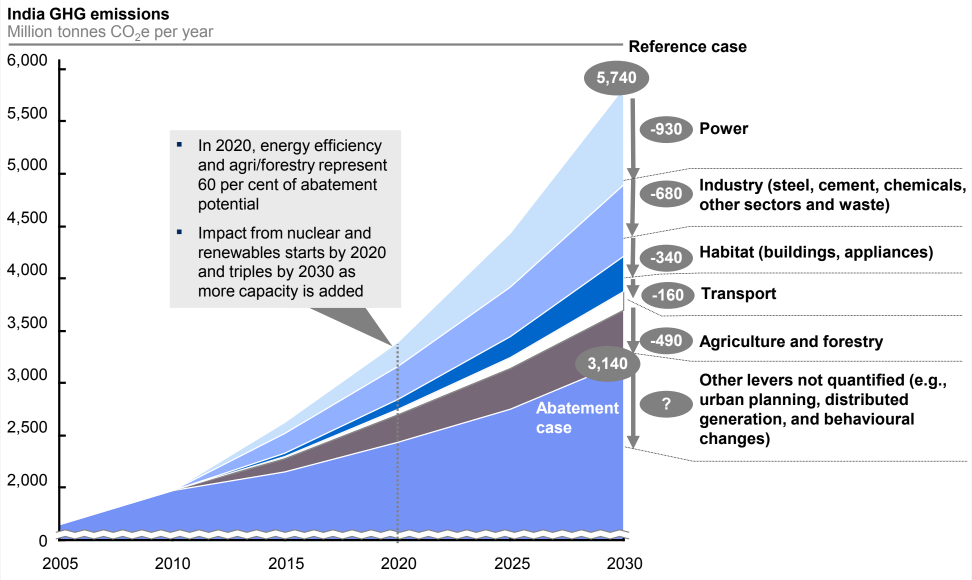
To develop the abatement case, we assessed about 200 opportunities that reduce energy consumption and carbon emissions in the 10 largest consuming and emitting sectors in India.[19] For each opportunity, we analysed the abatement potential (emission reduction potential) and the cost of abatement (for every tonne of CO_2e). Further we assessed the effort and investment required to implement each opportunity to develop a prioritised set of opportunities.

Achieving the potential identified in the abatement case would require substantial acceleration of current programmes for energy efficiency and clean power infrastructure. It would also require investing in new technologies such as LED lighting and ultrasupercritical power plants, and ensuring an efficient transport infrastructure and a widespread improvement in agricultural practices. As in the reference case, there will be many challenges in realising these additional abatement opportunities. These are described in the section "Challenges in realising the abatement case" below and detailed in chapter 4 of this report.

The additional abatement opportunities are concentrated in five areas: clean power, energy-efficient industry, green transportation, sustainable habitats, and sustainable agriculture and forestry (Exhibit 2).

Exhibit 2

Composition of abatement case over time



- In 2020, energy efficiency and agri/forestry represent 60 per cent of abatement potential
- Impact from nuclear and renewables starts by 2020 and triples by 2030 as more capacity is added

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

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[18] Decrease in energy consumption in sectors discussed in this report. This does not include direct energy savings from efficiency opportunities in other industrial sectors (except steel, cement, chemicals and refining).

[19] There are additional opportunities beyond those outlined in the abatement case that are difficult to quantify but could further reduce emissions. They include encouraging behavioural changes among consumers such as car pooling. These have not been included in our study.

Clean power

Clean power provides the biggest opportunity to reduce emissions beyond the reference case and lower India's reliance on coal for meeting its power needs. In the reference case, emissions from this sector would reach 2.9 billion tonnes in 2030. They could be reduced to 1.9 billion tonnes CO_2e by 2030 through three main actions described in the abatement case:

Optimising power demand: Reducing demand, including changing peak demand e.g., by using water heaters that operate during the night and store water for use during the day, would have the maximum impact. On the consumption side, power demand could be reduced in buildings, industry and agriculture through energy-efficiency initiatives. In addition, power demand could be lowered in the power sector itself by reducing auxiliary consumption and lowering technical T&D losses. The demand profile could be made flatter through measures such as time-of-day tariffs, which would reduce the need for oil- and gas-based peaking power plants. This could forestall 120 GW of capacity addition, equivalent to about 20 per cent of the 2030 capacity estimated in the reference case.

Making power generation "cleaner" and better matched to demand: Today, 80 per cent of the power capacity under construction is coal-based. Further, the reference case assumes 60 per cent of coal-based generation capacity in 2030. Besides being a major driver of growth in emissions, a coal-dominated power mix—good for running plants at constant loads—would not be the best fit with India's power demand profile. Generally, only 60 per cent of total capacity is required to meet base load demand (needed throughout the day and year). The rest represents non-base or peak demand and is usually required during parts of the day such as evening, when lights and appliances are used simultaneously, or some seasons such as summer when more power is needed for cooling. With the continued dominance of services in India's economy, and increasing urbanisation and affluence, peak demand is likely to grow faster than base-load demand, as more air-conditioned buildings come up and more households own and use more appliances.

Three major shifts would be required to attain a cleaner power mix that is better matched to demand. The first would be aggressively expanding nuclear energy as a substitute for coal-based power from an expected level of 30 GW in 2030, in the reference case, to 60 GW in 2030 in the abatement case. The second would be increasing solar power as a replacement for peaking oil and gas from an expected level of 30 GW in 2030 in the reference case to 56 GW in the abatement case. The third shift would be to use a higher proportion of reservoir hydro power to serve peaking demand, i.e., 55 per cent (25 GW) in the abatement case instead of 20 per cent (5 GW) in the reference case.

Using cleaner coal technologies: Increasing the efficiency of subcritical coal plants and using more efficient coal technologies such as supercritical[20] and ultrasupercritical could increase the efficiency of coal-based power generation and thus reduce emissions. Our analysis does not include estimates of the potential impact of implementing IGCC or CCS[21], primarily because of

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[20] For our analysis, we have assumed that all supercritical capacity will come online in the reference case.

[21] IGCC: Integrated Gasification Combined Cycle; CCS: Carbon Capture and Storage.

the uncertainty around the commercialisation of these technologies and the potential energy penalty[22] CCS imposes. We have also not assumed any early retirement of existing coal plants.

Energy-efficient industry

Energy-intensive industries such as steel, cement, chemicals and oil refining would generate emissions of 1.7 billion tonnes of CO_2e by 2030 in the reference case.[23] The abatement case identifies the potential to reduce emissions from this level to approximately 1.0 billion tonnes CO_2e, based on a detailed analysis of two major energy consuming sectors, steel and cement.

Abatement could be achieved through the use of energy-efficient technologies and processes in steel production such as improved motor systems and top-pressure recovery turbines, and enhanced processes such as pulverised coal injection and coke dry quenching. Newer steel-making technologies such as direct smelt reduction could reduce energy demand. Using fly ash from coal plants and alternative fuels such as solid waste and biomass for cement production could also reduce emissions. Many of these measures involve improving energy efficiency and substituting lower energy materials for higher energy ones, and hence represent net economic savings.

Green transportation

The abatement case identifies potential to reduce emissions from this sector from 681 million tonnes CO_2e in the reference case to 519 million tonnes CO_2e by 2030.

An expected seven-fold increase in India's vehicle fleet by 2030 would correspondingly increase demand for petrol and diesel. We estimate that the introduction of mileage standards and emission norms would lower oil demand growth for the transport sector, which could reach 170 mtoe by 2030 in the reference case, or five times the consumption in 2005. The measures suggested in the abatement case could reduce this figure by 40 per cent, i.e., to around 105 mtoe by 2030. Increasing vehicle efficiency could reduce oil demand in the transport sector by up to 15 per cent.

Ways to increase vehicle efficiency include lowering kerb weight, reducing friction, and improving fuel combustion. Using biofuels such as ethanol could also reduce oil consumption in the sector by another 5 per cent. Oil demand could be reduced by another 20 per cent by shifting more freight to rail and coastal shipping and increasing public transport in tier I, II and III cities. This would require integrated planning across transport modes and within cities as transportation infrastructure is built. This would also reduce road congestion and pollution in urban areas, and could effectively increase average vehicle speeds in cities by up to 15 per cent.

Sustainable habitats

India is one of the warmest countries in the world. As affordability and power supply increase, a steep rise in demand for air-conditioning is likely. By 2030, over 60 per cent of commercial

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[22] To produce the same output, about 30 per cent more energy is consumed to run a typical CCS plant.

[23] Other industry sectors would add another 1 billion tonnes CO_2e by 2030 through their electricity consumption.

space is likely to be air-conditioned and 4 in every 10 urban households are likely to have an air-conditioner. This increase in air-conditioning demand, along with increased electrification and greater use of appliances, is likely to increase energy consumption from 140 TWh in 2005 to 1,300 TWh by 2030. There would be a corresponding rise in emissions to about 1.2 billion tonnes CO_2e in the reference case.

The abatement case estimates that demand for power could be reduced by around 390 TWh and emissions by 0.35 billion tonnes CO_2e to about 0.85 billion tonnes by 2030. This could be achieved by reducing HVAC[24] consumption in buildings, using the highest efficiency appliances, and replacing incandescent and CFL lights with LED lighting.

The biggest energy-efficiency opportunities lie in creating highly insulated building envelopes with integrated passive design[25] features such as maximising daylight while minimising direct sunlight, and using insulation to reduce power consumption for heating, cooling and ventilation. In addition, the energy used for home and office appliances could be reduced by 35 to 40 per cent by replacing current appliances with the highest efficiency appliances when upgrading or replacing old ones.

Sustainable agriculture and forestry

Agriculture comprises about a fifth of the Indian economy, and generated more than 400 million tonnes CO_2e or 25 per cent of India's total emissions in 2005. The main sources of these emissions are release of methane from rice cultivation and livestock, and the use of electricity and diesel for farming and irrigation. In the reference case, the sector is likely to generate up to 640 million tonnes CO_2e or 12 per cent of India's emissions in 2030, with potential to reduce them to about 375 million tonnes CO_2e in the abatement case.

Energy demand in agriculture could be reduced by 15 to 20 per cent by using efficient irrigation techniques such as drip irrigation and high efficiency pumps, reducing emissions by 65 million tonnes CO_2e by 2030. In addition, introducing agricultural practices such as improved rice cultivation, and reduced tillage could further reduce emissions by around 200 million tonnes CO_2e. Accelerated afforestation and reforestation could absorb 210 million tonnes CO_2e, as estimated in the abatement case.

BENEFITTING FROM THE OPPORTUNITIES

Apart from reducing emissions, the measures suggested in the abatement case could have additional benefits for India:

Capturing the additional abatement opportunities could greatly reduce India's energy consumption. The efforts described above could collectively shrink India's power demand by a quarter, oil demand for road transport by around 40 per cent and coal demand by about 45 per cent, beyond the reference case (Exhibit 3). Capturing the energy-efficiency opportunities

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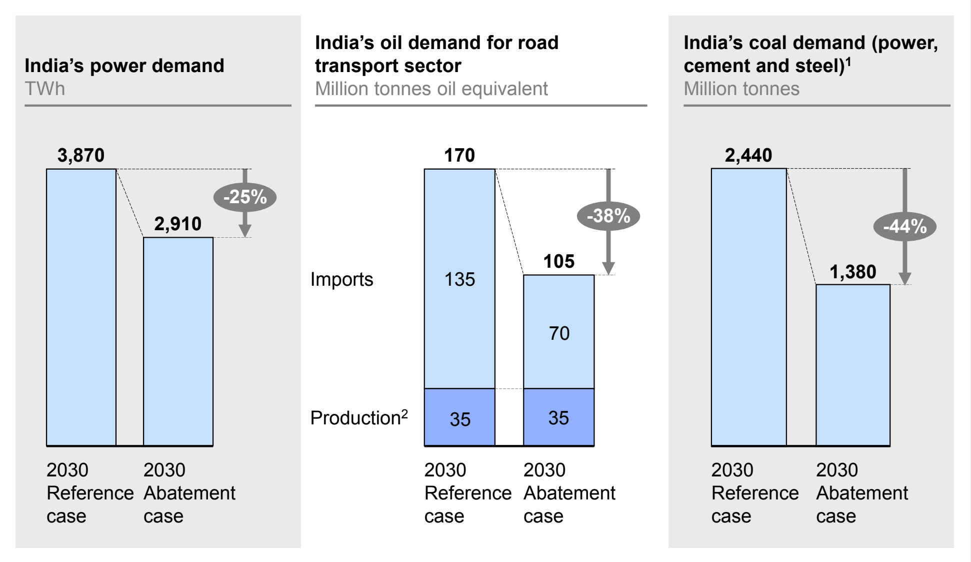
[24] Heating, ventilation and air-conditioning.

[25] Passive design is an approach to building construction that focuses on reducing heating and cooling energy consumption by optimising the insulation, ventilation, orientation and shade of a building.

Exhibit 3

Power, oil and coal demand in the reference and abatement cases



1 Numbers are in Indian coal equivalent assuming average gross calorific value of Indian coal (30% ash, 7% moisture) at 4,500 kcal/kg; includes captive power

2 Production of oil assumed at 35 mtoe in 2030 based on current reserves and discoveries. Production in 2005 was 32 mtoe.

SOURCE: Planning Commission of India; Ministry of Statistics and Programme Implementation, Government of India; McKinsey India Cost Curve model; McKinsey analysis

outlined above could avert the addition of around 120 GW of power capacity, which is 80 per cent of India's capacity in 2005. This could reduce the cost and land requirements of future power projects. In addition, analysis suggests that the lower use of coal for power generation, steelmaking and cement production could reduce coal demand by nearly half and thereby roughly double the life of reserves.

India could increase energy security while reducing emissions. Solutions for reducing emissions would also increase India's energy security, e.g., a reduction in oil consumption would reduce emissions as well as imports. The combination of reduced demand and a move towards renewable energy would substantially reduce oil consumption. Our analysis indicates the potential for a 40 per cent reduction in oil consumption by road transport, equally reducing India's oil imports and lowering the import bill by around USD 35 billion (at USD 60 a barrel), in 2030. The use of metallurgical coal could also be reduced by about 100 million tonnes. Additionally, less thermal coal and gas would need to be imported.

Realising the abatement case could increase energy inclusion and improve the quality of life. Rural India could see many benefits. For example, distributed biomass-based generation, solar power or mini-hydel generation could provide quicker access to energy. Improved agricultural practices could reduce energy and water consumption, increasing access to these resources. Health and productivity could improve due to the introduction of safer, more efficient cooking stoves and reduced overall pollution. In urban India, the quality of life could improve as a result of better transport infrastructure, greater power availability, reduced road congestion and lower vehicular pollution.

India could take the lead in a few clean-technology industries. India could aspire to leadership in a few clean-technology products and services. Investments in clean technologies in several countries to increase energy security and reduce carbon intensity indicate a global market potential of over EUR 1 trillion in clean technologies between 2010 and 2030.[26] With inherent advantages including engineering talent and low-cost manufacturing, India could focus on R&D and be at the centre of intellectual property creation and a leader in manufacturing. Areas of opportunity include clean coal technology, solar technology and efficient building technologies. Emerging areas such as smart grids and low-carbon products such as LED lighting and electric two-wheelers also present opportunities.

India could consolidate its lead in energy and carbon efficiency. Realising the abatement case could further lower energy and carbon intensity from the levels India has managed to achieve so far, making it a leading energy- and carbon-efficient large economy. Per capita emissions, which are likely to grow by two-and-a-half times their 2005 levels to 3.9 tonnes by 2030 in the reference case, could be reduced to around 2.1 tonnes per capita in the abatement case.

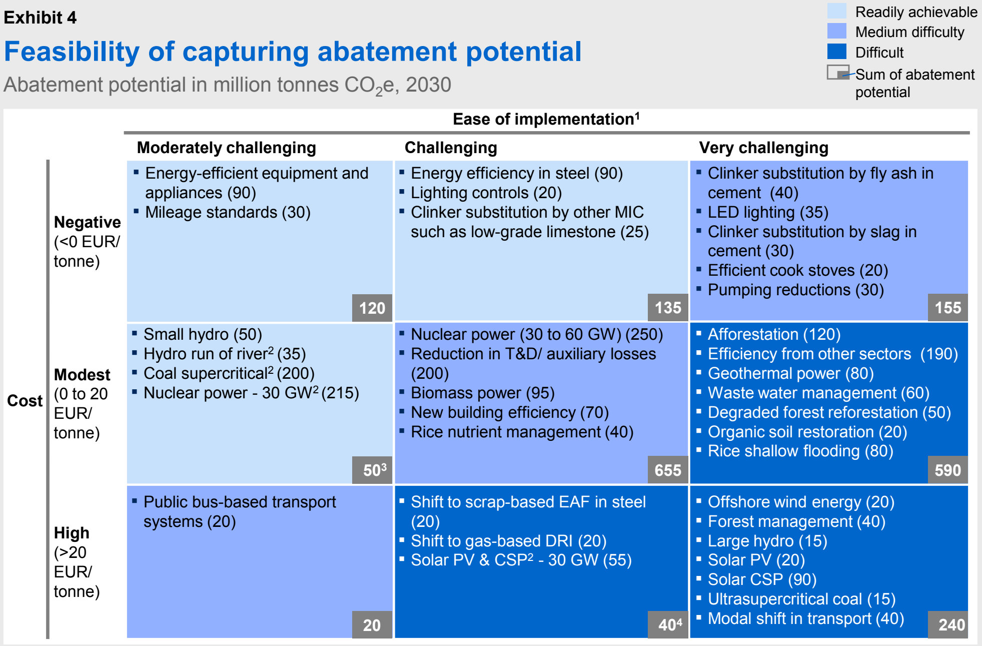
CHALLENGES IN REALISING THE ABATEMENT CASE

Analysis suggests that only 10 per cent of the additional abatement potential identified is readily achievable (Exhibit 4). Moreover, in thinking about tackling the challenges involved, it is important to recognise that long-term planning and timely action will be critical.

Exhibit 4

Feasibility of capturing abatement potential

Abatement potential in million tonnes CO_2e, 2030



Cost		Ease of implementation[1]: Moderately challenging	Challenging	Very challenging
	Negative (<0 EUR/ tonne)	▪ Energy-efficient equipment and appliances (90) ▪ Mileage standards (30) 120	▪ Energy efficiency in steel (90) ▪ Lighting controls (20) ▪ Clinker substitution by other MIC such as low-grade limestone (25) 135	▪ Clinker substitution by fly ash in cement (40) ▪ LED lighting (35) ▪ Clinker substitution by slag in cement (30) ▪ Efficient cook stoves (20) ▪ Pumping reductions (30) 155
	Modest (0 to 20 EUR/ tonne)	▪ Small hydro (50) ▪ Hydro run of river[2] (35) ▪ Coal supercritical[2] (200) ▪ Nuclear power - 30 GW[2] (215) 50[3]	▪ Nuclear power (30 to 60 GW) (250) ▪ Reduction in T&D/ auxiliary losses (200) ▪ Biomass power (95) ▪ New building efficiency (70) ▪ Rice nutrient management (40) 655	▪ Afforestation (120) ▪ Efficiency from other sectors (190) ▪ Geothermal power (80) ▪ Waste water management (60) ▪ Degraded forest reforestation (50) ▪ Organic soil restoration (20) ▪ Rice shallow flooding (80) 590
	High (>20 EUR/ tonne)	▪ Public bus-based transport systems (20) 20	▪ Shift to scrap-based EAF in steel (20) ▪ Shift to gas-based DRI (20) ▪ Solar PV & CSP[2] - 30 GW (55) 40[4]	▪ Offshore wind energy (20) ▪ Forest management (40) ▪ Large hydro (15) ▪ Solar PV (20) ▪ Solar CSP (90) ▪ Ultrasupercritical coal (15) ▪ Modal shift in transport (40) 240

1 Ease of implementation based on financing issues, regulatory support, agency issues, entrenched behaviour, supply constraints and technological readiness
2 These levers are assumed to be implemented in the reference case
3 Without reference case additions; 500 million tonnes after accounting for reference case actions
4 Without reference case additions; 95 million tonnes after accounting for reference case actions
Note: Only key levers listed in the matrix above (covering about 80% of potential)

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

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26 Source: *The Business Case for a Strong Global Deal*, Project Catalyst, ClimateWorks Foundation, 2009.

The six main challenges are as follows:

Incremental upfront capital required: Estimates indicate that achieving the abatement case would require incremental capital of EUR 600 billion to EUR 750 billion between 2010 and 2030, equivalent to 1.8 to 2.3 per cent of GDP between 2010 and 2030. These estimates are based on assumptions about cost reductions in emerging technologies such as solar power, and the extent to which energy efficiency potential is realised. Capital requirements increase, for example, by EUR 40 billion if the cost of solar power decreases at only half the rate assumed. About 40 per cent of the EUR 600 billion would be needed to capture "negative cost" opportunities, those offering a net saving. The balance would be required for realising "positive cost" opportunities, or those with a net economic cost. Most of the incremental capital would be required for clean and renewable power (EUR 135 billion), energy-efficient buildings and appliances (EUR 170 billion), and an oil-efficient transportation infrastructure (EUR 130 billion). The majority of incremental capital would be required between 2020 and 2030; only 30 per cent would be required between 2010 and 2020.

Additional funding for opportunities with a net economic cost: To make them viable, positive-cost opportunities would require annual fund flows of EUR 18 billion on average over the next two decades. Annual fund flows of around EUR 13 billion per annum would be required between 2010 and 2020, and around EUR 23 billion in the next decade.[27]

Supply and skill concerns: India would need to build new end-to-end supply chains (e.g., nuclear forgings, solar manufacturing) to capture these opportunities at scale. Further, capacity created for technologies that are no longer a priority could be "stranded" (e.g., coal-based power equipment manufacturing capacity as the power mix shifts towards nuclear and renewable energy). In addition, realising the abatement potential hinges on the availability of skills at a substantial scale in areas such as nuclear power design, energy auditors, energy engineers and green building architects.

Technology uncertainty: A number of the opportunities identified in the abatement case are based on technologies that are still emerging, e.g., solar thermal with storage and LED lighting. Their application is complicated by high upfront cost, untested efficacy and a paucity of early adopters. However, our analysis assumes that several emerging technologies will be widely commercialised by 2020, depending on factors such as supporting policy, stimulated adoption (e.g., the government introduces LED lighting for street lights) and local supply.

Market imperfections: Energy efficiency is often the casualty of "principal-agent" failures, as in energy-efficient buildings, where developers may be reluctant to take action because the immediate benefit of lower electricity bills will go to tenants not them. New business models, e.g., Energy Service Companies (ESCOs) would be needed to address these challenges.

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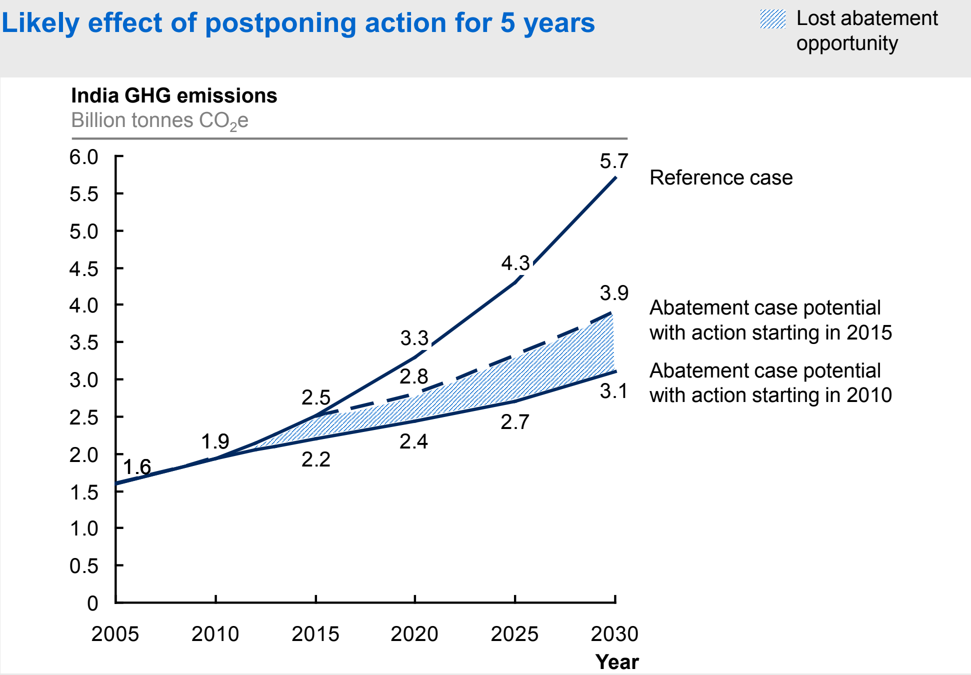
[27] These additional funding estimates do not include taxes and subsidies or transaction costs and are calculated at a societal discount rate of 8 per cent, which means the actual cost of implementation will be higher.

Changes to regulatory and institutional frameworks: Significant regulatory changes such as framing new regulation and amending existing regulation would be required to capture these opportunities. Policies would need to change in many parts of the economy including the power sector, buildings, appliances, agriculture and water use. All levels of governance would need to be addressed—central, state and district—and the government would need to set up institutions and procedures to monitor implementation,.

Timely action would be critical since India is making irreversible investments in infrastructure right now. Even a five-year delay could mean the loss of almost a quarter of the potential identified in the abatement case (Exhibit 5). Long-term planning is equally important. Many of the initiatives required such as clean power that would realise most of the abatement potential between 2020 to 2030 need to be planned for now.

Exhibit 5

Likely effect of postponing action for 5 years



SOURCE: McKinsey India Cost Curve model; McKinsey analysis

A PROPOSED 10-POINT AGENDA

This report does not recommend regulations or policy changes. Instead, our intention is to provide the fact-base needed to weigh the opportunities and challenges for sustainable, inclusive growth and greater energy productivity. In that vein, India could consider the following agenda, perhaps implemented over the next 18 months, which would address over three-fourths of the potential in the abatement case.

1. **Catalyse energy-efficiency programmes in appliances, buildings, industry, transport and agriculture**: To accelerate energy efficiency in key sectors, India could 1) introduce technical norms and standards for buildings, appliances, agricultural pumps and vehicles; 2) provide incentives for adoption of energy-efficient equipment; 3) introduce tradable energy certificates for industry; 4) promote new business models such as Energy Services Companies (ESCO); and 5) implement time-of-day tariffs to shift peak power demand. The Bureau of Energy Efficiency's current programmes could be expanded and accelerated towards this end.

2. **Accelerate the addition of nuclear capacity**: This requires standardising nuclear reactor design, securing fuel supply early, and localising supply chains (e.g., for castings and forgings). Additionally, tariffs would need to be rationalised for building nuclear power to scale. The Indian government could also consider allowing private participation in nuclear generation projects. Managing time delays, which is a major risk in nuclear energy projects, would be crucial.

3. **Encourage the addition of peaking hydro power capacity**: Hydro power capacity additions could be accelerated by following the model used for ultra-mega power projects: developing hydro projects and bidding them out, and addressing resettlement and rehabilitation. In addition, stable and higher paying markets to serve peak demand would be needed to compensate for the higher cost of stored hydro power.[28] Finally, typical delays in construction would need to be managed.

4. **Scale up the addition of renewable energy (particularly solar energy)**: The momentum achieved in developing onshore wind power could be repeated in solar power. Support could include regulatory change (procurement obligations), financial incentives (feed-in tariffs), demonstration projects and infrastructure development (e.g., solar generation parks). This would also require exhaustive resource mapping and support for local R&D and manufacturing.

5. **Develop a more responsive power sector**: The abatement case aims to achieve a better matching of peak power demand and supply and more power savings. This would require continued action to reduce technical T&D losses complemented with efforts to ensure more efficient and cleaner coal generation. Also, multi-year differential time-of-day tariffs would be needed to encourage the addition of peaking power capacity while reducing peak demand. There has to be an emphasis on prioritising allocation of gas for peaking needs and developing innovative gas-based solutions for efficiently meeting peak power requirements (e.g., distributed generation).

6. **Build energy-efficient freight transportation infrastructure**: India could develop an integrated multi-modal logistics policy to leverage rail and coastal corridors for long-haul loads, which interconnect with roads for shorter hauls. This would shift a much higher share of

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[28] Peaking hydro power requires large storage or higher dams, which entails significant resettlement costs. Also greater generation capacity is needed to serve peak requirements although it is used for less time. This raises the cost of such power.

freight traffic to rail and maintain the share of water transport despite freight growth, reducing costs and energy consumption.

7. **Promote energy-efficient urbanisation**: To transform India's cities, urban planning could incorporate climate change objectives including energy efficiency, walk-to-work and public transport. In addition, mechanisms to induce behaviour change would be needed, such as a congestion charge on driving cars in the central business district to encourage people to use the public transport that is being provided.

8. **Improve agricultural practices and technology**: India could improve yields, use less resources and increase abatement through better management of croplands such as conservation tilling and residue management, enhanced agronomy practices such as systemic rice intensification and drip irrigation. This would require sustained educational programmes, low-cost solutions and easy availability of concessional credit for financing these investments.

9. **Promote afforestation/reforestation and forest management**[29]: Forest cover and forest density could be improved through forest management programmes and the promotion of afforestation through well designed community-based programmes.

10. **Proactively create intellectual property in "clean technology"[30] and build manufacturing capability**: India could consider creating a fund to support R&D in multiple areas of clean technology (e.g., solar energy, high efficiency appliances, and energy for rural India). The focus could be on seeding companies in these areas and supporting technologies related to energy efficiency.

* * *

Actions by the central government could be initiated (and in many cases completed) in about 18 months. Additionally, the success of the initiatives described above would hinge on the support and participation of state and local governments, which could develop their own carbon-efficient growth plans within this period. Over time, the institutional capability needed to implement and monitor these initiatives would also need to be created at all levels of governance.

There is a considerable effort in achieving a more energy- and carbon-efficient economy. But it is one worth making in view of the potential outcome: a cleaner, greener India on a sustainable and inclusive growth path.

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[29] Potential actions in agriculture and forestry need to be developed further; the sector has not been studied in detail for this report.

[30] Clean technology refers to a range of products and services that use renewable materials and energy, curtail the use of natural resources and cut emissions and waste.

1. The Challenge of Rising Emissions: The Reference Case

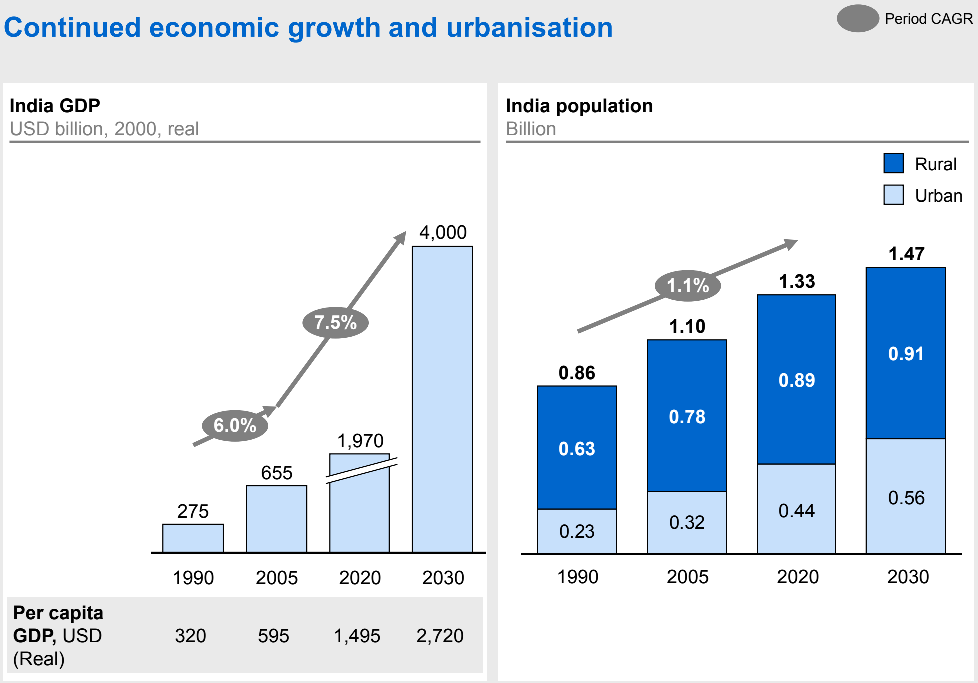
India faces the enormous challenge of maintaining high economic growth with limited energy and other resources while simultaneously containing greenhouse gas (GHG) emissions to mitigate the impact of climate change. This chapter describes the reference case: an estimate of India's annual emissions by 2030 based on assumptions about improvements in energy efficiency in various sectors and the provision of clean power. In this case, India's emissions would grow 3 to 4 times from 1.6 billion tonnes CO_2e[1] in 2005 to 5.0 billion tonnes CO_2e to 6.5 billion tonnes CO_2e, depending on the GDP growth rate.

RAPID ECONOMIC GROWTH WILL INCREASE DEMAND

The Indian economy is likely to grow between 7 to 8 per cent a year for the next two decades (Exhibit 1.1). Over the same period, India's population is likely to reach 1.5 billion. This population expansion will be accompanied by increased urbanisation, with about 550 million (40 per cent) of India's people living in cities by 2030. This shift towards a more urban economy will expand demand for services such as housing, power and transport.

Exhibit 1.1

Continued economic growth and urbanisation



Per capita GDP, USD (Real)	320	595	1,495	2,720

SOURCE: MGI – Oxford Economic Model; National Commission on Population, Office of Registrar General for Census of India; WMM Global Insight; McKinsey analysis

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[1] CO_2e stands for "carbon dioxide equivalent" and is a standardised measure of greenhouse gases. Emissions are measured in metric tonnes of CO_2e per year, i.e., millions of tonnes (megatonnes) or billions of tonnes (gigatonnes). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from human activity, in our estimates.

Consumption levels are relatively low in India today but will rise faster in the next two decades as a result of economic growth. Our analysis shows that this will lead to a dramatic growth in demand in the energy-intensive sectors listed below (Exhibit 1.2).

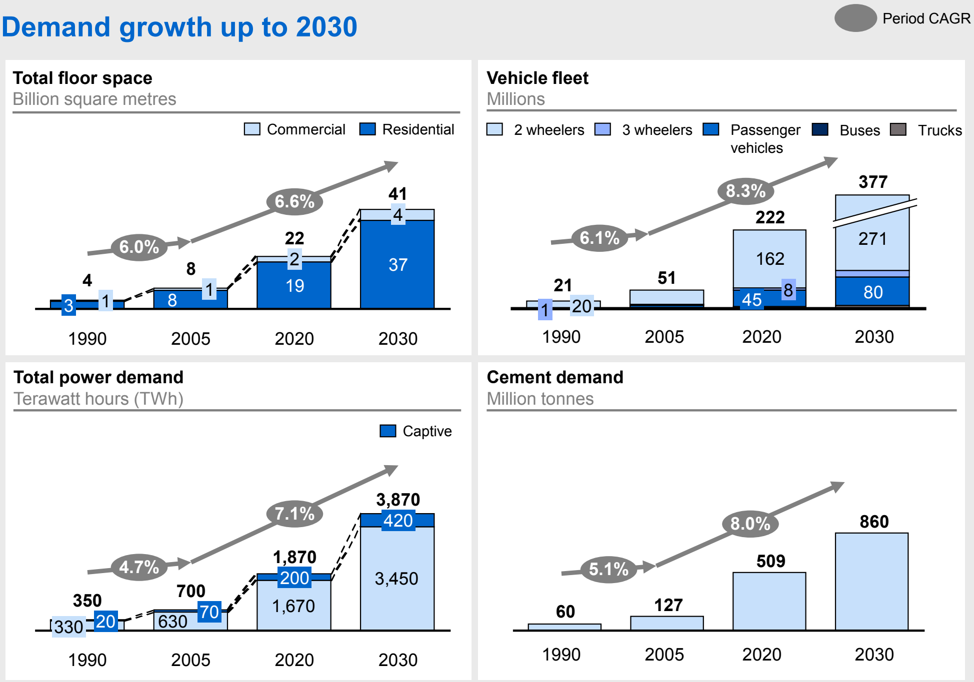
Power: Demand for grid power is likely to increase five-fold from 630 terawatt hours (TWh) to 3,450 TWh by 2030. In addition, India is likely to see another 420 TWh of captive consumption in large industries, taking overall demand to 3,870 TWh. Peak demand in India will also rise due to the increasing affluence of households and the use of more appliances and air-conditioning. Our analysis suggests that more than 40 per cent of demand will be for non-base load or peak power.[2]

Buildings and appliances: Building stock is likely to grow more than five-fold, taking total floor space from 8 billion square meters in 2005 to 41 billion square meters by 2030. The energy-intensity of commercial buildings and households will also increase as more buildings are air-conditioned, more houses are electrified and consumers start owning and using more appliances.

Basic materials: Demand for steel and cement is likely to increase six- to seven-fold by 2030 mainly due to the growth in building stock and increased investment in infrastructure. India's total cement demand is likely to reach around 860 million tonnes per annum by 2030. Consumption of

Exhibit 1.2

Demand growth up to 2030



SOURCE: McKinsey analysis

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[2] Base-load power is required throughout the day and throughout the year. Non-base-load power, otherwise known as peak demand, is required during parts of the day, e.g., the evening when many lights and appliances are used at the same time, or during certain seasons such as summer when more power is required for cooling.

steel is likely to grow nine-fold from the 2005 level to reach about 300 million tonnes per annum by 2030.

Transportation: The vehicle fleet is expected to increase from a little over 50 million today to about 380 million by 2030. With increased private ownership of vehicles and the energy needs of freight transport, oil consumption by the transportation sector is likely to increase to 170 million tonnes of oil equivalent (mtoe) by 2030, five times the 2005 level.

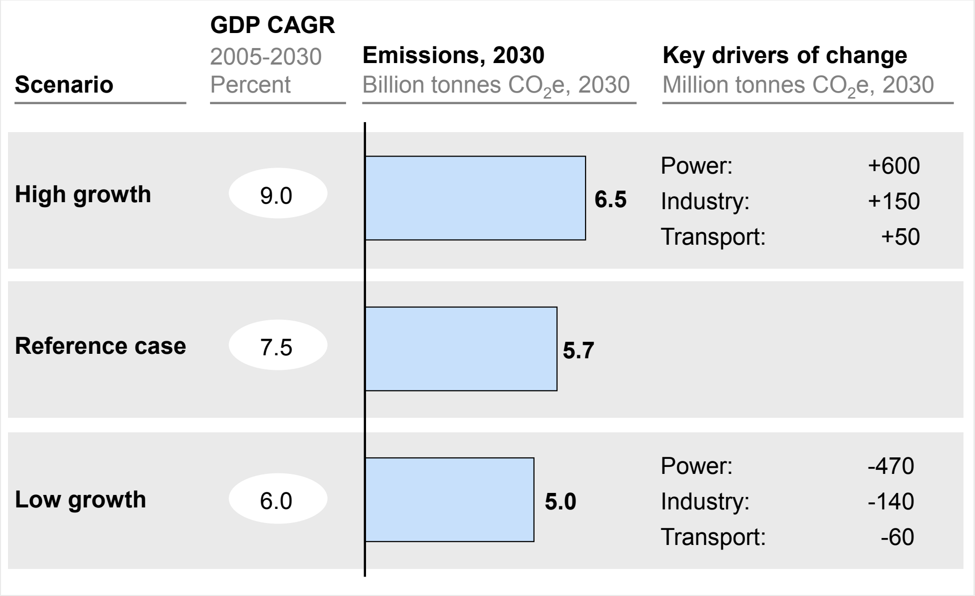
EMISSIONS WILL RISE IN LINE WITH INCREASED PRODUCTION AND CONSUMPTION

We have extensively studied different sectors of the Indian economy and the research findings of leading Indian experts to complete a sector-by-sector analysis of GHG emission projections till 2030.

In our analysis, we defined a "reference case", reflecting our estimate of GHG emissions by different sectors based on 1) demand growth projections; 2) our assumptions about the impact of government programmes and industry initiatives to reduce emissions; and 3) our assumption that all energy demand will be met (see box "Summary of current and planned measures that would reduce emissions"). Based on this analysis, we estimate that total emissions in the reference case would range between 5.0 billion tonnes to 6.5 billion tonnes CO_2e in 2030, up from 1.6 billion tonnes CO_2e in 2005. Emissions in the reference case will depend on GDP growth rates (Exhibit 1.3).

Exhibit 1.3

Reference case emissions by GDP growth rate



SOURCE: McKinsey analysis

Summary of current and planned measures that would reduce emissions

The National Action Plan for Climate Change (NAPCC), released in 2008, outlines policies and programmes aimed at addressing adaptation and mitigation in the face of expected climate change. In addition, several other government and industry initiatives are in place to reduce energy demand and optimise supply, as summarised below.

Reducing T&D losses in the power sector: The Restructured Accelerated Power Development and Reform Programme launched in 2007 aims to reduce aggregate technical and commercial (ATC) losses from 30 to 15 per cent by 2020 by strengthening the sub-transmission and distribution network and adopting IT solutions through central government support of INR 500 billion (USD 10 billion to USD 11 billion).

Increasing the use of clean coal technology: The NAPCC recommends that, in view of the major role of coal-based power generation in the next few decades, “supercritical boilers” be used in the immediate future and “ultrasupercritical boilers” when the commercial viability of the technology under Indian conditions is verified.

Increasing clean and renewable power in India’s power mix: Current policy drafts of the National Solar Mission suggest increasing solar power to 10 GW by 2020. Nuclear capacity would increase to 20 GW by 2020, as announced by government agencies.

Lowering electricity consumption in buildings and appliances: A variety of measures have been initiated by the Bureau of Energy Efficiency (BEE), including the Bachat Lamp Yojana to promote compact fluorescent lighting, the Star Labelling programme to increase self-selection of high-efficiency appliances through energy performance labels on appliances and agricultural pump sets, and the Energy Conservation Building Codes to prescribe minimum efficiency standards for commercial buildings.

Increasing fuel efficiency in road transport: The Petroleum Conservation Research Association (PCRA) and BEE are expected to launch voluntary labelling of cars in 2009, and plan to make fuel-efficiency norms mandatory for all passenger vehicles by 2011-2012.

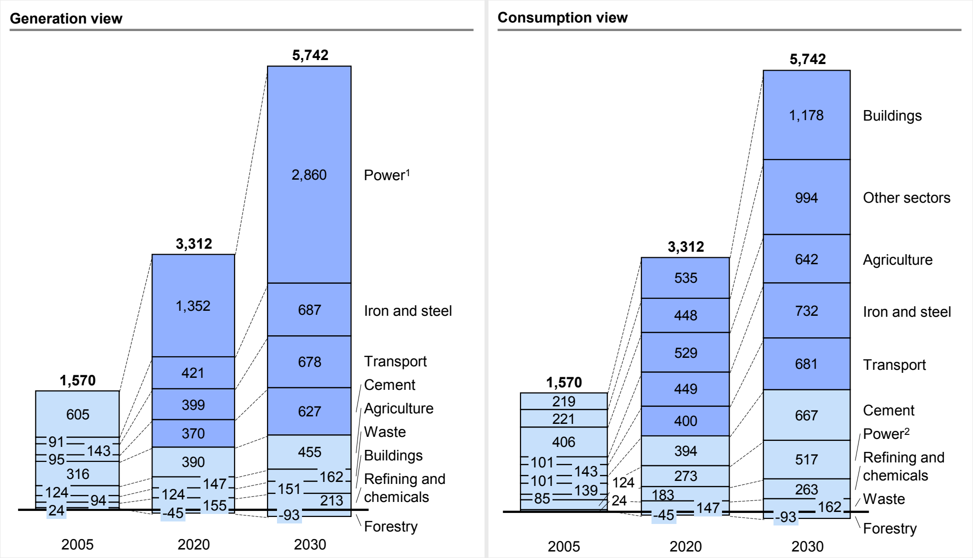
Improving energy efficiency in steel plants: Changes in technology (e.g., direct casting), larger blast furnaces and continuous improvement efforts by steel manufacturers have already reduced energy consumption by about 1 per cent per annum over the last several years.

Expanding forest cover: The National Forest Policy, released in 1989, aspires to bring 33 per cent of India under forest cover. Other programmes for enhancing forest cover include the National Forest Action Plan and Joint Afforestation Programme.

Exhibit 1.4

GHG emissions by different sectors

Million tonnes CO_2e



1 Power sector estimates include auxiliary and T&D losses in generation view
2 Power sector represents auxiliary and T&D losses in consumption view
Note: The generation view shows direct emissions from each sector; consumption view shows both direct and indirect emissions

SOURCE: McKinsey India Cost Curve model

We have conducted a detailed analysis of five key sectors that drive GHG emissions: power, industry, transportation, buildings, and agriculture and forestry. Our estimates suggest that these sectors would remain the largest contributors of India's GHG emissions, as described below and in Exhibit 1.4.

Power: The power sector would be the largest source of emissions in the reference case, accounting for 2.9 billion tonnes CO_2e, or roughly half the total emissions by 2030. Eighty per cent of these emissions are represented by power consumed in sectors such as buildings, industry and agriculture. The rest are represented by power lost in generation, transmission and distribution (the emissions would nevertheless be generated).

Our estimates for power sector emissions in the reference case assume the following improvements in the generation and distribution of power:

- Implementation of the Restructured Accelerated Power Development Reforms Programme (R-APDRP) would reduce technical transmission and distribution (T&D) losses[3] from approximately 15 to 19 per cent currently to 12 per cent by 2030.

- Fifty per cent of new coal-based generation would be based on supercritical technology, with the rest still based on subcritical technology.

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[3] Losses in transmission or distribution (e.g., at transformers) that are not commercial in nature. The number for actual technical losses is not reported, though experts estimate them at 15 to 19 per cent currently. Hence we have assumed 17 per cent in our analysis.

- Gas-based power generation capacity would increase to around 48 GW, if the planned gas supply comes on line. We assume that gas-based generation will increase substantially in order to better match the peak load requirement, which a coal-dominated power mix is not well positioned to do.[4] The remaining peak demand would have to be met by reservoir hydro or oil-based generation.

- The share of clean power in the energy mix would be increased:

  - Nuclear power: Capacity addition in the next decade would reach 20 GW by 2020[5], and 30 GW by 2030

  - Solar power: The aspiration of 10 GW by 2020 would be achieved thanks to supporting policies and incentives, to reach 30 GW by 2030

  - Hydro power: Around 60 GW of hydro power capacity (out of a total potential of 150 GW) would be realised by 2030; of this, about 10 GW would be used to meet non-base demand

  - Wind energy: 35 GW of capacity from high potential sites[6] would be realised by 2030.

- As better technology becomes available, more efficient subcritical coal-fired plants would be set up, increasing efficiency from 31 per cent to 33 per cent.

Energy-intensive industry (including iron, steel, cement, chemicals and refining) would be the second largest emitting sector, with emissions of around 1.7 billion tonnes CO_2e. This is based on estimates that modernised new capacity in steel increases efficiency at the rate of 0.75 per cent per annum including deployment of cogeneration in all new steel capacity from 2020. In cement, we assume that all older wet and semi-dry kilns used in the cement industry would be retired.

Buildings and appliances: Buildings and appliances would account for about 1.2 billion tonnes CO_2e by 2030 based on the following assumptions:

- With the implementation of the Bachat Lamp Yojana, compact fluorescent lighting would replace 50 per cent of incandescent lights by 2020 and 90 per cent of incandescents by 2030 in residential buildings.[7]

- Implementing BEE's labelling programme for appliances would lead to 10 per cent penetration of highest efficiency air conditioners and refrigerators and 100 per cent penetration of labelled appliances by 2030. We also assume that technology improvements will raise the benchmarks, with today's 3-star level becoming the minimum level by 2030.

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[4] A coal plant works most efficiently when run at a constant load. To meet non-base-load demand, it has to be cycled at different loads, which makes it inefficient, or run at higher constant loads, which is wasteful as this generates more power than required during non-peak hours.

[5] Around 8 GW of capacity exists or would come up before 2010.

[6] These sites offer a higher plant load factor (a measure of average capacity utilisation) due to favourable wind patterns including longer lasting winds.

[7] For commercial buildings, we assume that 90 per cent of the lighting will be CFLs and LFLs (tube-lights) by 2010 and almost 100 per cent by 2020.

- Making the improvements suggested in BEE's Energy Conservation Buildings Codes would increase the efficiency of HVAC[8] systems in commercial buildings by 0.8 per cent per annum.

Transportation: The transportation sector would account for 12 per cent of GHG emissions or about 680 million tonnes CO_2e by 2030 in the reference case. Our estimate assumes that the share of higher tonnage vehicles in total commercial vehicles would rise to around 31 per cent by 2020 and to 37 per cent by 2030, going by the growth rate of higher tonnage vehicles since 2000. We have also assumed that expected technology advancements in two-wheelers and cars would increase the average fuel efficiency of petrol cars to 12.5 kmpl, of diesel cars to 16.1 kmpl and of two-wheelers to 58 kmpl by 2030.

Agriculture: Emissions from agriculture would reach around 640 million tonnes CO_2e[9] by 2030, assuming increased efficiency of pumps and an improvement of 2 per cent a year in dairy yields, in line with historical rates. We have assumed a total increase of 15 per cent in the overall efficiency of electric and diesel pumps over the next 20 years based on successful implementation of the BEE programme for labelling water pumps. In addition, we have assumed that rice cultivation will remain at current levels and current rice cultivation practices will be continued.

Forestry: Around 25 per cent of India's land is under forest or tree cover. However, 40 per cent of Indian forests are degraded. The stated aspiration in the government's forest policy released in 1989 is to bring a third of India's land under forest cover. In the reference case, we have assumed that India's historical afforestation rate would be maintained, which would bring another 7.5 Mha of land under forest cover. We have also assumed that forest restoration initiatives would reforest around half of the degraded forests in India by 2030. These assumptions indicate that the forestry sector would become a net carbon sink, sequestering 93 million tonnes CO_2e by 2030 in the reference case.

In view of the assumptions made in constructing the reference case, outcomes would depend on several factors such as the pace of execution, technology improvements and introduction of supporting policy. We have therefore estimated emissions in two scenarios: a "conservative case" where the initiatives detailed above are partially implemented, and the reference case, where the full potential of all initiatives detailed above is realised. As Exhibit 1.5 shows, emissions in the reference case could range from 5.7 billion tonnes to 6.4 billion tonnes CO_2e, depending on improvements achieved, at a GDP growth rate of 7.5 per cent. Emission reductions are most sensitive to initiatives in the power sector, with over half the reductions coming from this sector.

INCREASING OIL AND COAL DEMAND LIKELY TO PUT PRESSURE ON ENERGY SECURITY

A faster expansion of the economy will increase energy consumption correspondingly. Even after assuming that current initiatives and plans would lower consumption to the full potential of the reference case, our analysis shows that India is likely to need a primary energy supply of 1.8 btoe

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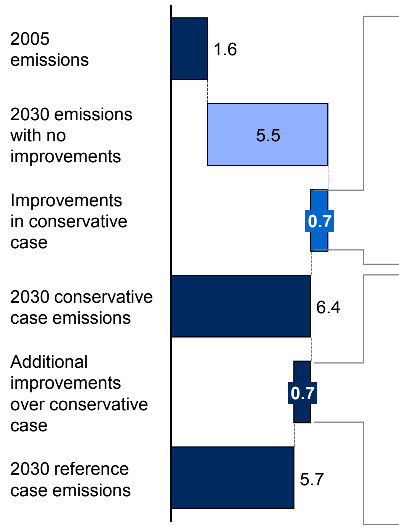
[8] Heating, ventilation and air conditioning systems.

[9] Includes methane and nitrous oxide emissions from rice cultivation.

Exhibit 1.5

Range for emission reductions in reference case

Overall GHG emissions – 2005-2030
Billion tonnes CO_2e



Major sources of improvement in reference case
Million tonnes CO_2e of incremental reduction from improvements

Conservative: Slower progress
Power: Clean coal technologies – supercritical[1] (200)
~36-37% efficiency subcritical coal plants (30)
Auxiliary improvements of 1% (30)
20 GW of gas CCGT for peaking power (60)
Technical T&D losses reduce from 20% to 15% (140)
Industrials: Energy efficiency in steel ~0.3% p.a. (100)
Buildings: 50% CFLs; 10% efficient appliances & HVAC (50)
Forestry: 1 Mha of afforestation and 20% reforestation (40)
Other sectors: 0.25% p.a. efficiency increase (80)

Reference case:
Power: Clean coal technology – ultrasupercritical[1] (60)
~38-39% efficiency of subcritical coal (40)
Auxiliary improvements of up to 3% (50)
48 GW of gas CCGT for peaking power (90)
Technical T&D losses reduce from 15% to 12% (70)
Industrials: Energy efficiency in steel ~0.7% p.a. (100)
Buildings: 90% CFLs; 16% efficient appliances & HVAC (30)
Forestry: 3 Mha afforestation and 50% reforestation (70)
Other sectors: 0.5% p.a. efficiency increase (150)

1 Conservative case assumes 145 GW of generation with supercritical coal plants; reference case assumes 145 GW and 8 GW of generation with supercritical and ultrasupercritical coal power plants respectively

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

by 2030, an over three-fold increase over the 537 mtoe[10] it consumed in 2005. This would nearly double India's share of world energy consumption and make India the third largest consumer of energy in the world after the United States and China. As a result, India would need to find and secure energy resources much faster than other nations—a challenge in itself.

Based on these demand projections:

- **By 2030, India is likely to need almost 760 GW to 790 GW of installed power capacity**[11] to meet the five-fold increase in power demand. Capacity would need to be expanded by almost 30 GW a year, meaning that power plants would have to be added about six times faster than they were between 1990 and 2005.

- **India may have to import about 40 per cent of its coal needs by 2030**. Around 60 per cent of power capacity by 2030 could be coal-based. Running these plants, including captive power plants in other industries, would require approximately 2 billion tonnes of coal by 2030.[12] Thus in the reference case, India's overall coal demand is likely to cross 2.4 billion tonnes per annum by 2030, including demand from the steel and cement sectors. This is about

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[10] World Energy Outlook, 2007, International Energy Agency.

[11] Including 5 per cent of spinning reserves and 80 GW of expected captive power capacity.

[12] The quantity is in terms of Indian coal equivalent, representing Indian coal with a gross calorific value of 4,500 kilocalories per kilogram, 30 per cent ash and 7 per cent moisture.

60 per cent higher than the projected domestic capacity of 1.5 billion tonnes per annum by that period.[13] This shortfall may have to be met with coal imports, which implies that India may have to import 40 per cent of its coal demand by 2030.

- **India could need to import 10 times its own production of oil by 2030.** Driven by increasing use of vehicles, demand from the transport sector is expected to almost quadruple to 170 mtoe by 2030. Overall oil demand is likely to touch 380 mtoe by that period. India's supply, on the other hand, is expected to stagnate at current levels of around 30 mtoe to 35 mtoe, because of its limited reserves. To meet its total oil demand, therefore, India may have to import over 300 mtoe to 350 mtoe of crude oil by 2030.

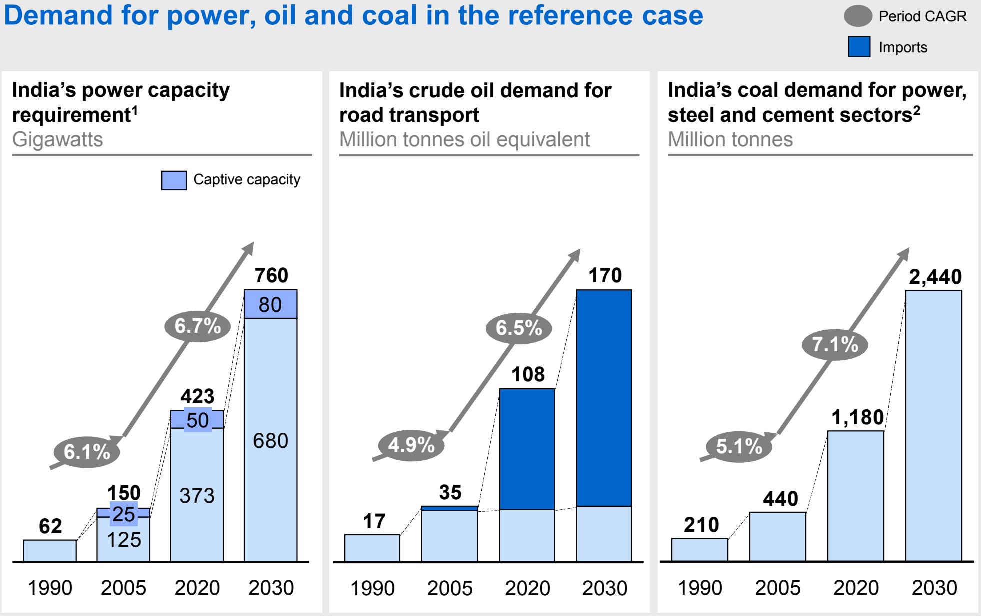
Exhibit 1.6 depicts likely demand by 2030.

THE REFERENCE CASE IS AN ACHIEVABLE BUT STRETCH TASK

The improvements envisaged in the reference case could be achieved but would require a large effort including considerable capital investment and capacity creation, a continued reform and policy push, large-scale adoption of technology and institutional support.

Exhibit 1.6

Demand for power, oil and coal in the reference case



1 Assumes supply meets projected demand by 2030
2 Includes demand for captive power for all sectors; estimates are in Indian coal equivalent assuming average gross calorific value of Indian coal (30% ash, 7% moisture) at 4500 kcal/kg

SOURCE: McKinsey analysis

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[13] *Integrated Energy Policy*, Planning Commission, Government of India, 2007.

Making the improvements encompassed in the reference case would require a large amount of capital. For example, building clean power infrastructure such as nuclear energy and supercritical coal plants would require an incremental investment of EUR 30 billion. Investing in energy-efficient transport such as better highways, public transport systems and rail freight corridors could require another EUR 150 billion to EUR 200 billion. The investment choices would be quite difficult. For instance, while solar power is a better solution from the environmental and energy security perspective, adding this capacity requires a capital expenditure 5 to 8 times that of other alternatives such as oil-based generation.

Considerable capacity creation challenges would also be involved. For instance, in the power sector, the rate of capacity addition would need to increase six-fold over the historical rate of 4 GW to 5 GW a year. Installing 20 GW of solar power would mean increasing current capacity 4,000 times.[14] India's ability to build 30 GW of nuclear power and 60 GW of hydro-based generation capacity by 2030 is also in question considering that there are no precedents. Similarly, a six- to eight-fold expansion of steel and cement capacity in the next two decades is a tall order. It would require a strong implementation thrust from both the private sector and the government and the resolution of issues relating to mining leases and rights, land acquisition and rehabilitation.

Many of the reference case initiatives would also require enabling regulation and institutions to ensure successful execution. Increasing energy efficiency in industry, buildings, transport and agriculture would require shaping regulation and creating monitoring infrastructure. For example, to mandate building codes, regulation would have to be integrated with the construction by-laws of individual states and cities, architects and enforcement officers would need to be trained and a network of monitoring and certification organisations would have to be set up.

Another imperative would be adopting technology, especially in areas such as reducing T&D losses, building ultrasupercritical coal plants or promoting efficient irrigation. To illustrate, reducing T&D losses would require IT systems to detect pilferage, high-voltage transmission lines and more efficient transformers.

Finally, India would also need to develop specialised skills to implement many of the initiatives, for instance, to design and build nuclear power plants. This will be difficult in view of existing skill shortages.

* * *

India is already focused on finding an ecologically sound development path that will maintain rapid economic growth and preserve energy security. The reference case described in this chapter could partly achieve this objective. The good news is that India has the opportunities to do much more, as the next chapter will show.

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[14] India's current installed and grid-connected solar capacity is around 5 megawatts (MW).

2. The Opportunity for India: The Abatement Case

We believe that there is a unique opportunity for India to lower its energy and carbon intensity beyond what could be achieved in the reference case. Our analysis suggests that there is feasible technical potential to reduce India's emissions by 30 to 50 per cent, that is, to 2.8 billion to 3.6 billion tonnes CO_2e[1] by 2030, using technologies commercially available today. This could also bring several economic and social benefits to the country. It would require substantially accelerating current programmes and taking some new initiatives to optimise energy demand and supply. We call this the "abatement case".

In developing the abatement case for India, we assessed about 200 opportunities to reduce energy consumption and carbon emissions in the country's 10 largest consuming and emitting sectors. For each opportunity, we analysed the abatement potential (emission reduction potential) and the cost of abatement (for every tonne of CO_2e). Finally, we also assessed the effort and investment required to implement each opportunity. This yielded a prioritised set of opportunities as arranged in the cost curve for India (Exhibit 2.1).

The cost curve indicates the potential and cost of different opportunities to reduce emissions by 2030.[2] The least expensive opportunities have a "negative cost", that is, they save money when considering the combined operational expenditure (opex) and capital expenditure (capex) requirement. A negative cost opportunity is not necessarily easier to implement, but represents opportunities that have an economic benefit.

The cost curve indicates that:

1. Over 90 per cent of the additional emissions reduction potential represented in the abatement case (2.2 billion tonnes CO_2e) could be captured at an incremental cost of less than EUR 100 per tonne CO_2e (cost of abatement).

2. Negative-cost measures make up 37 per cent of this abatement potential, at societal costs, not including transaction costs and taxes.[3]

The abatement cost curve for India indicates that five areas offer the maximum potential to reduce emissions: power, energy-intensive industry, transport, habitats (including buildings and

---

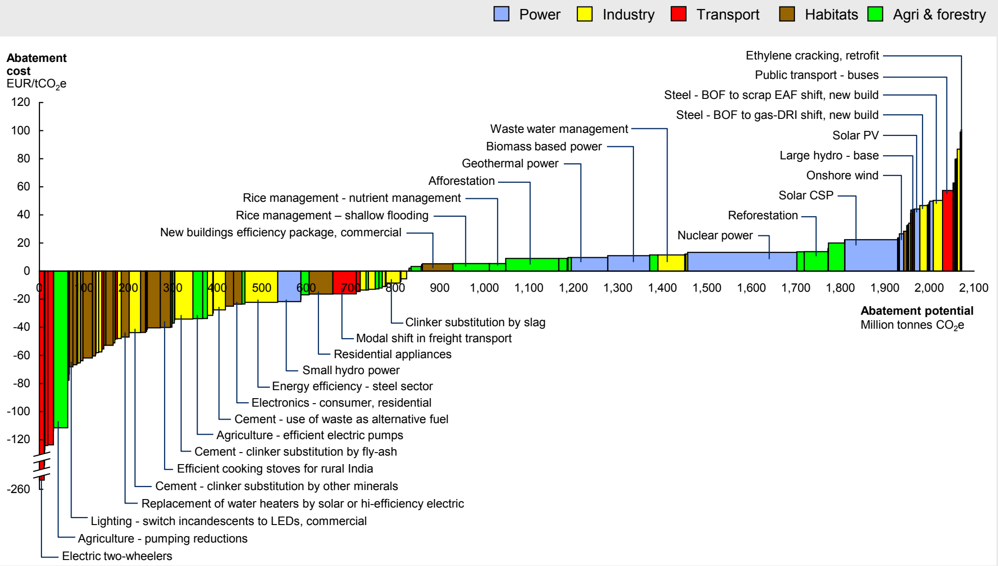
[1] CO_2e stands for "carbon dioxide equivalent" and is a standardised measure of greenhouse gases. Emissions are measured in metric tonnes of CO_2e per year, i.e., millions of tonnes (megatonnes) or billions of tonnes (gigatonnes). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from human activity, in our estimates.

[2] The cost and emission reduction potential for each abatement opportunity is plotted from left to right in ascending order of the incremental cost of abatement. Each abatement opportunity forms a rectangle: its height denotes the cost and its width the quantity of the abatement potential.

[3] The net resource costs of an abatement option were estimated by examining incremental initial investments needed, operating and maintenance costs, replacement costs and costs avoided due to energy efficiency or other benefits. An 8 per cent discount rate was applied to account for the difference in time between the initial investment and the resulting savings.

Exhibit 2.1

India's abatement cost curve for 2030 (cost below EUR 100/tonne)



Note:

1 This curve highlights 2.1 billion tonnes CO_2e of potential. Additional potential below Euro 100/tonne includes reduction in technical T&D losses (190 million tonnes CO2e (mt), auxiliary consumption (~50 mt), efficiency improvement in other sectors (~200 mt), improved urban planning (~30 mt), and distributed generation using combined heat and power (CHP) (~15 mt)

2 Levers costing above EUR 100/ tonne (not included in the cost curve) have a total abatement potential of 80 mt. Important levers are public transport infrastructure (metros) (7 mt), electric vehicles and full hybrids (6 mt)

3 8% discount rate assumed for the cost curve analysis, based on benchmark yield for long-term Indian government bonds

SOURCE: McKinsey India Cost Curve model

appliances), and agriculture and forestry. Clean power offers the biggest abatement opportunity, of around 0.9 billion tonnes CO_2e or 35 per cent of the total potential in the abatement case, and so opportunities in this sector are described in detail below. Reducing the consumption of coal and other fuels in industry through energy efficiency and using less energy-intensive materials offers a further abatement potential of 0.7 billion tonnes CO_2e over the reference case. The remaining potential lies primarily in sustainable habitats (0.3 billion tonnes CO_2e) mainly through energy efficiency in buildings and appliances, green transport and transportation infrastructure (0.2 billion tonnes CO_2e), and sustainable agriculture and forestry (0.5 billion tonnes CO_2e) (Exhibit 2.2).

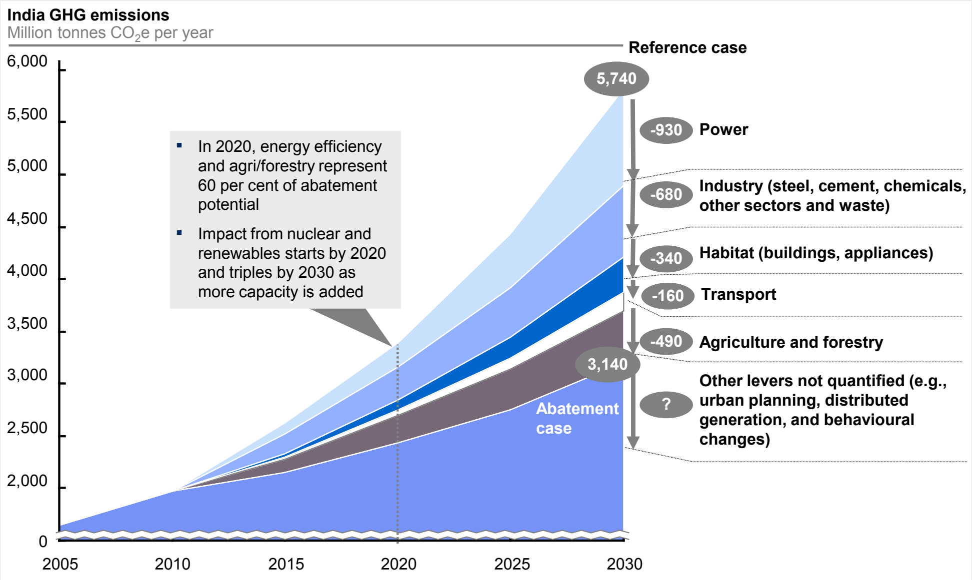
The abatement case rests on a number of assumptions, as described in each section below. If these are partly borne out, the abatement estimates would change accordingly. For example, emissions in the abatement case would range from 2.8 billion to 3.6 billion tonnes CO_2e depending on the extent to which solar and nuclear power are deployed and the extent of afforestation and reforestation. Changes in other variables such as the extent of efficiency improvements would also affect the abatement case (Exhibit 2.3).

CLEAN POWER

The power sector presents the largest opportunity to lower emissions. We have made four assumptions in defining the optimal power capacity to meet India's needs in the most carbon-efficient manner. First, we have assumed that demand will be met completely by 2030 in both

Exhibit 2.2

Composition of abatement case over time



- In 2020, energy efficiency and agri/forestry represent 60 per cent of abatement potential
- Impact from nuclear and renewables starts by 2020 and triples by 2030 as more capacity is added

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

Exhibit 2.3

Abatement case sensitivities

Abatement technology (unit)	Reference case value	Abatement case value[1]	Sensitivity value	Change in abatement case emissions Million tonnes CO_2e
▪ Solar power (GW)	30	56	80	- 135
			45	+70
▪ Nuclear power (GW)	30	60	80	- 165
			45	+130
▪ Forestry sector				
– Afforestation (Mha)	8	28	16	+70
– Reforestation (Mha)	12	25	15	+30
▪ Energy efficiency improvements (percent)	NA	25	20	+200
Sensitivity range				**- 300** **+500**

Possible range for abatement case 2.8 to 3.6 billion tonnes CO_2e on a base value of 3.1 billion tonnes CO_2e

[1] Abatement case value represents the total, including reference case value

SOURCE: McKinsey India Cost Curve model; McKinsey analysis the reference and abatement cases. Second, for both cases, we have defined a capacity mix that matches the demand profile as effectively as possible, i.e., base demand is met through base supply sources and non-base or peak demand is met through peak supply sources, as described below. Third, the abatement case incorporates improvements in power consumption in other sectors, lowering demand by about 25 per cent.[4] Fourth, we have assumed that coal capacity will be added in India through more efficient technologies, to varying degrees in the reference and abatement cases.

With these assumptions, emissions from the power sector could decline from around 2,860 million tonnes CO_2e in the reference case to around 1,930 million tonnes CO_2e in the abatement case. Coal consumption for power generation in such a case would be half of what would otherwise be needed by 2030. Finally, with peak-load technologies serving peak-load demand, the power capacity mix would better match demand.

Reference case: likely mismatch between power capacity and demand profile

A country's demand profile varies over time, on a daily and seasonal basis. In the first place, there is a constant base level of demand throughout the day and the year (base load). Second, there is variable demand, referred to as non-base or peak demand. Daily demand peaks are caused when people turn on their water heaters at more or less the same time in the morning or their lights in the late evening. Similarly, afternoon peaks occur in urban areas as more and more commercial buildings are air-conditioned. Seasonal variations are caused, for example, by increased cooling needs in the summer.

Different technologies are needed to serve base and non-base demand. The technologies suitable for serving base-load demand are coal-based generation, nuclear power, run-of-the river hydro power, gas-based generation using geothermal energy and biomass-based generation. Non-base or peak demand should ideally be met by reservoir hydro as these plants can be turned on or off quickly, solar power as solar generation coincides with the day-time peak, and gas-based combined cycle gas turbines (CCGT) because these plants can "cycle", i.e., operate efficiently even at lower loads.[5] If supply through these sources does not suffice, peak demand would have to be met by cycling coal plants[6] and open cycle gas- and oil-based generation.[7]

Mapping supply to base and peak demand constrains the deployment of technology. For example, solar power is a non-base technology (as it cannot supply power throughout the day), and so can only replace cycling coal or gas- and oil-based capacity required to meet peak demand. This could cap the amount of solar energy that can be deployed, without making aggressive assumptions about storage.

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[4] Demand-side management to reduce peak demand has not explicitly been considered as an abatement opportunity as it implies behavioural changes.

[5] We have not considered open cycle gas turbine generation (OCGT) in the mix as it would be suboptimal to run lower efficiency OCGT plants in a gas-constrained scenario.

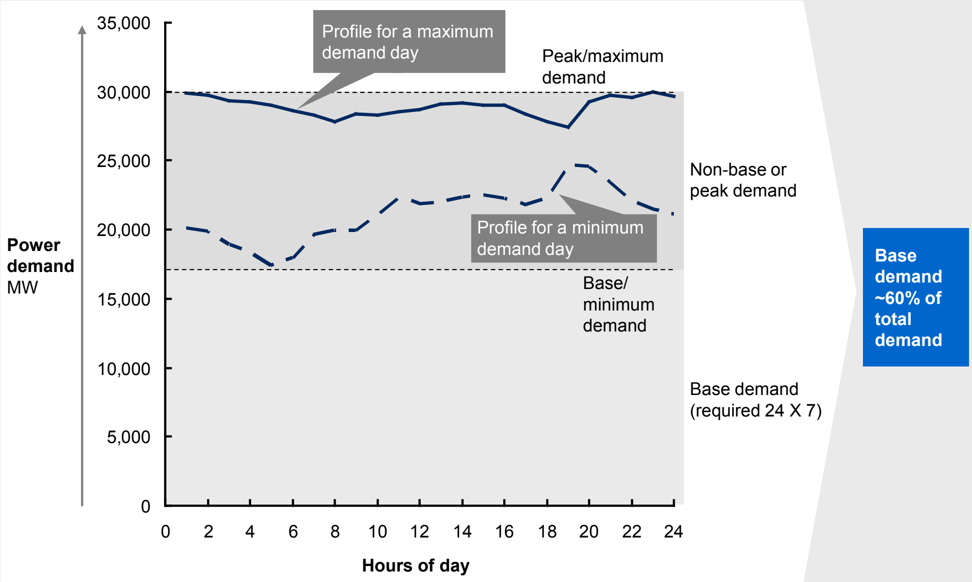
[6] Operation with low plant load factors of coal plants, usually higher cost or older coal plants used for meeting seasonal variations.

[7] Both diesel generators and fuel oil boilers.

Exhibit 2.4

India power demand profile

Based on 2008 demand curve data for northern region[1]



1 Due to lack of data, power demand has been extrapolated from the regional load curve for north India

SOURCE: Northern Regional Load Distribution Centre; McKinsey analysis

In order to determine India's base and peak demand, we used the load curve for India's northern region[8], which, due to a lack of other data, we assume represents India's current demand profile (Exhibit 2.4). Going by this load curve, in 2007, India's apparent base demand was about 60 per cent of total demand in capacity terms. The actual proportion might have been lower if all peak demand had been met. However, for the purposes of this analysis, we have assumed that base demand will still be around 60 per cent of total demand by 2030, for both the reference and the abatement case, based on load curves of some developed countries. India's load curve, combined with the total energy consumption, indicates a power demand of about 630 GW[9], with 380 GW as base-load and 250 GW as peak demand.

The question, then, is how will this grid demand be served in the reference case? A McKinsey report, *Powering India: The Road to 2017*[10], indicates that India could be base-load surplus in capacity but remain substantially short of capacity to meet peak demand by 2017 (Exhibit 2.5). This base-load surplus will be due to the large coal-based capacity addition underway—representing 80 per cent of capacity under construction. Assuming that this trend continues in the reference case, 79 per cent of power generation in 2030 is likely to be coal-based.

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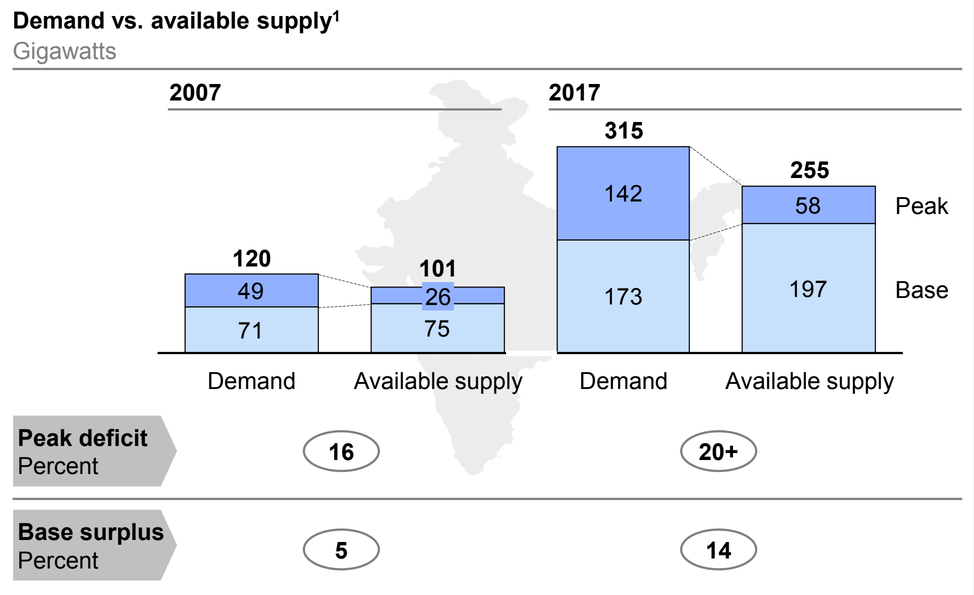
[8] Regional load curves indicate loads every hour.

[9] Equivalent to total grid demand of 3,450 TWh using an energy-to-peak ratio of 0.74 , excluding additional captive demand from industry, which we estimate at approximately 420 TWh by 2030. This figure does not represent the required installed capacity to serve this demand.

[10] *Powering India: The Road to 2017*, McKinsey & Company, 2008.

Exhibit 2.5

Power demand and supply, 2007- 2017



1 Including captive demand and supply

SOURCE: Powering India: The Road to 2017, McKinsey & Company, 2008

Even though around 30 GW of additional hydro capacity is expected to come up by 2030, in the reference case we have assumed that current tariff policies would largely lead to low-capacity, low-storage base-load plants instead of the high-capacity, high-storage facilities needed to meet increased peak demand. Therefore, of the approximately 60 GW of installed hydro capacity in 2030 in the reference case, it is likely that only 10 GW would serve non-base power demand.

Hence, in the reference case, base-load demand would be met primarily by coal-based generation, hydro (both reservoir and run-of-the-river) and nuclear power. Sources for meeting non-base demand such as solar energy, peaking storage hydro[11] and gas CCGT[12] would supply only about 80 GW of the estimated 250 GW of grid non-base demand. Assuming that all of India's power demand will be met, suboptimal sources of peaking power such as cycling coal- and oil-based generation would have to be used. Exhibit 2.6 depicts the technologies that meet base and peak demand in the reference case.

With this capacity mix for meeting the 630 GW of demand (including captive), India would need an installed capacity of 760 GW to 790 GW in 2030 (Exhibit 2.7).

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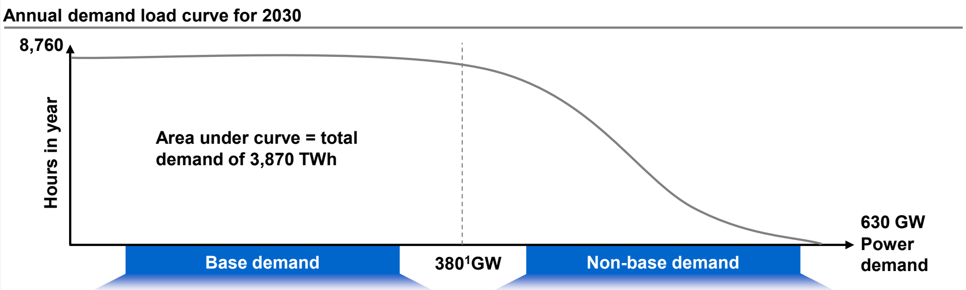
[11] Reservoir hydro capacity assumed to be capped at 25 GW due to environmental constraints and challenges of building dams, of which 5 GW serves peaking needs and 20 GW meets base-load demand.

[12] In the reference case, gas-based CCGT capacity is constrained at 48 GW (assuming the availability of a maximum 120 million metric standard cubic meter per day (mmscmd) of gas for the power sector and a 55 per cent plant load factor). Current gas supply is around 40 to 50 mmscmd, which is expected to increase to 210 to 280 mmscmd by 2020. Supply estimates for 2030 based on supply additions of 80 to 120 mmscmd from the Reliance KG Basin, 10 to 40 mmscmd from ONGC and about 70 mmscmd from current and upcoming LNG terminals.

Exhibit 2.6

Reference case: 2030 power supply



Technology	2030 base capacity (GW)
Coal (sub)[2]	233
Coal (super)	155
Coal (ultra-super)	8
Nuclear	30
Hydro (run-of-river)	28
Hydro (reservoir)[3]	20
Biomass	4
Total base	**478**

Technology	2030 non-base capacity (GW)
Coal (cycling)	60
Hydro (reservoir)	5
Gas (CCGT)	48
Wind (onshore)	35
Solar	30
Small hydro	5
Oil (peak generation)	44
Oil (backup)[4]	55
Total non-base	**282**

[1] 380 GW pertains to actual demand in base; installed capacity has to be higher to account for plant availability factors

[2] Including 74 GW of captive capacity and 5% spinning reserves. Capacities assume average coal fleet PLF of 87% in 2030. Installed capacity required would be higher if actual PLFs are lower

[3] Assumed that 80 per cent of reservoir hydro capacity of 25 GW in 2005 continues to be used as base load capacity in 2030

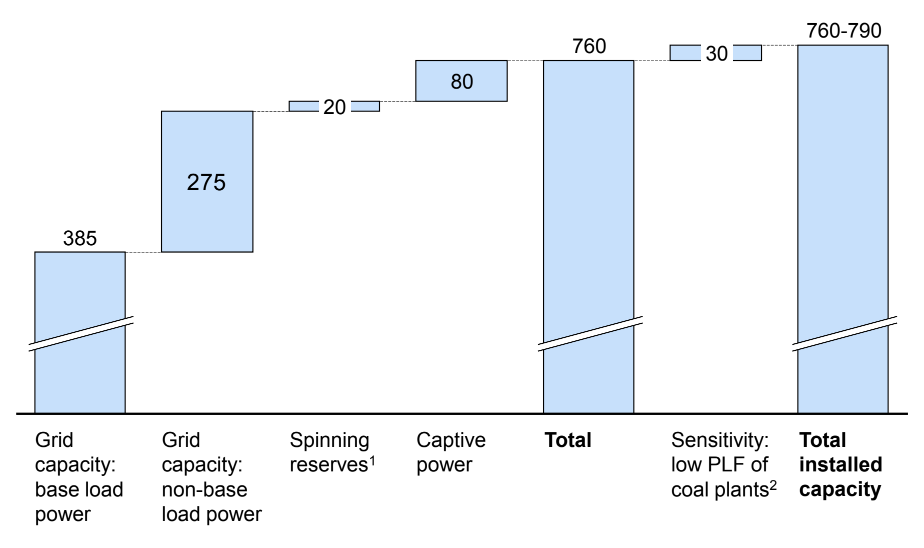
[4] This is capacity required to back up infirm sources like wind and solar

SOURCE: McKinsey India Cost Curve Model; McKinsey analysis

Exhibit 2.7

Installed power capacity in reference case (2030)

Gigawatts



[1] Spinning reserves are reserves to allow for exigencies

[2] Assuming coal plant load factor at 80% instead of 87% assumed for estimating reference case installed capacity

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

Abatement case: energy-efficient consumption

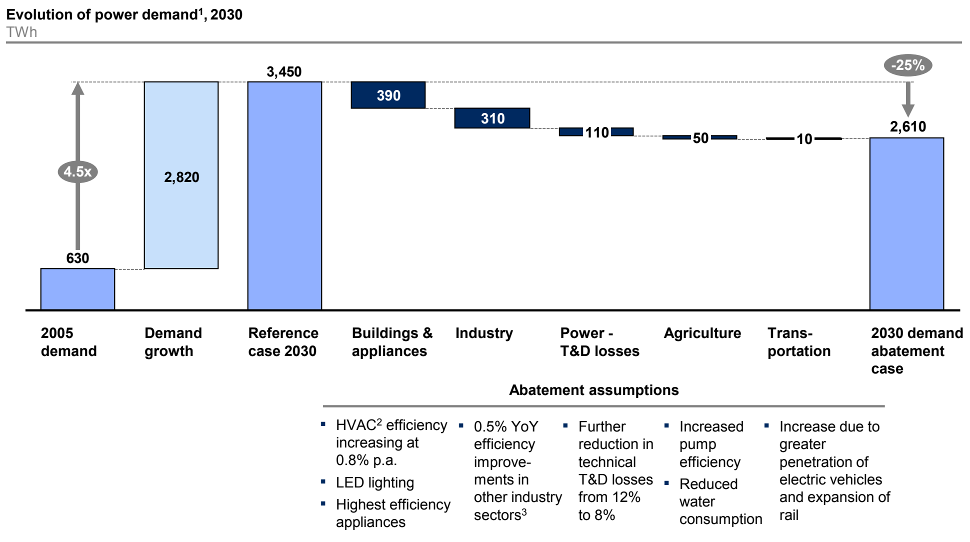
We estimate that increasing efficiency across the power generation-to-consumption chain could reduce electricity consumption by as much as 25 per cent, relative to the reference case (Exhibit 2.8). This could be achieved by reducing auxiliary consumption[13] in power plants, further lowering technical transmission and distribution (T&D) losses, and increasing energy-efficiency in consuming sectors such as industry, buildings and agriculture.

India's generation losses through plant auxiliary consumption, estimated at about 7 per cent, and T&D losses, estimated at around 17 per cent[14], are higher than the global benchmarks of 4 to 5 per cent and 8 per cent respectively. The abatement case assumes that deploying existing technologies such as better quality transformers and introducing new technologies such as smart grids could further reduce losses over those achieved by the reference case. Auxiliary power consumption could be reduced from around 6 to 8 per cent in the reference case to 5 per cent in the abatement case. Technical T&D losses could be lowered from around 12 per cent in the reference case to about 8 per cent in the abatement case.

Energy efficiency could also be increased in consuming sectors. Our analysis suggests that electricity consumption in sectors such as buildings and agriculture could be reduced by a

Exhibit 2.8

Potential reduction in power demand through energy efficiency



1 Excluding captive power demand
2 Heating, ventilation and air conditioning
3 Except cement, steel, refining and chemicals

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

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[13] The power consumed by plant systems including for material handling, pumping, cooling, instrumentation systems.

[14] Losses in transmission or distribution (e.g., at transformers) that are not commercial in nature. The number for actual technical losses is not reported, though experts estimate them at 15 to 19 per cent currently. Hence we have assumed 17 per cent in our analysis.

further 20 per cent over that envisaged in the reference case. In buildings, this could be done by increasing the efficiency of air-conditioning systems, replacing inefficient incandescent lighting with LED lighting and using the highest efficiency appliances (Exhibit 2.8). In agriculture, increasing the efficiency of water pumps and reducing water consumption through efficient irrigation techniques could lower consumption. Energy efficiency could also be increased in industries such as chemicals and other manufacturing sectors that use electricity, e.g., by using higher efficiency motors.

To estimate the net power savings, we have also accounted for increased use of power in some sectors. While this would increase overall energy efficiency, it would also increase electricity use, e.g., in case of a modal shift in transport from road to rail. Exhibit 2.9 illustrates the power savings potential in buildings as an example.

Abatement case: cleaner power generation, better matched to the load profile

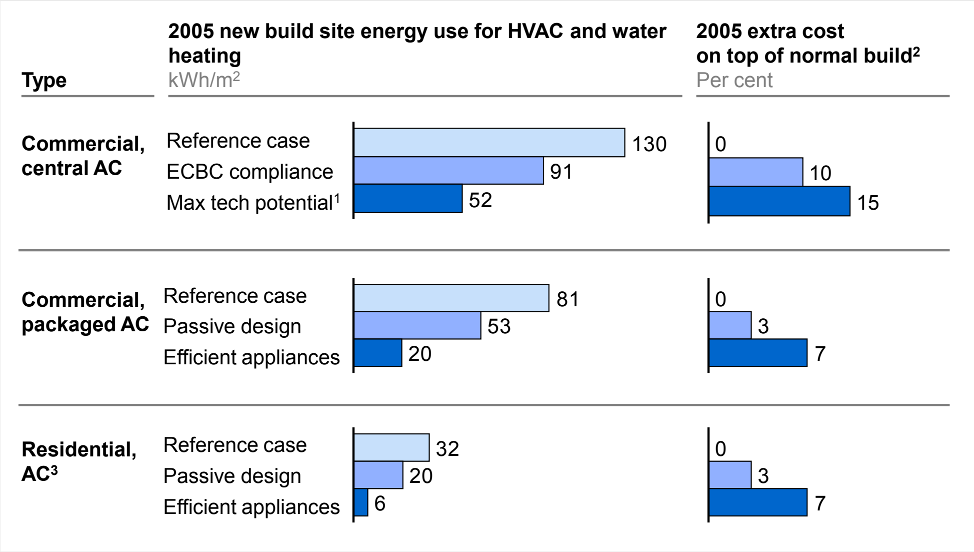
We have defined the abatement case power capacity for a lower demand profile (due to energy efficiency gains), to optimally serve base and non-base demand, keeping in view constraints such as the limited supply of some fuels.

Three major shifts occur in the abatement case. First, coal-based power generation for meeting base load demand is replaced with nuclear energy and to a limited extent, biomass, wind and geothermal energy. Second, cycling coal and gas-based generation is replaced with solar energy to meet non-base demand. Third, a much higher proportion of reservoir hydro power is deployed

Exhibit 2.9

Energy efficiency in buildings

EXAMPLE



1 Maximum technical potential is around 61% with current technology (Source: NREL)
2 Normal cost of commercial buildings assumed: central AC – INR 2,400/square foot (sf), room AC – INR 1,500/sf; residential – INR 1,200/sf
3 Actual power consumption in air-conditioned space of residential buildings is assumed at 113 KWh/m2; 30% of space is assumed to be air-conditioned

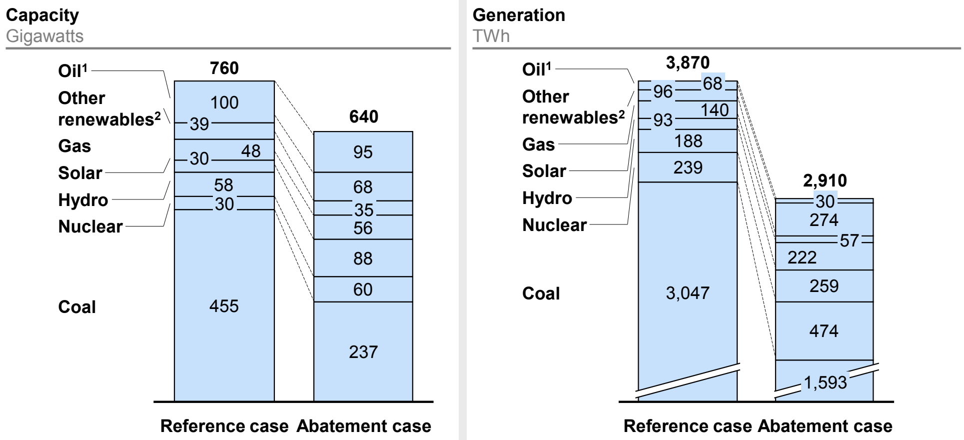
SOURCE: Passive House Institute; UNEP; WBCSD; RSMeans; interviews with experts; McKinsey analysis to serve peaking needs (55 per cent in the abatement case, compared to 20 per cent in the reference case). As a result, generation through clean sources such as nuclear, renewables and hydro increases from about 15 per cent in the reference case to over 40 per cent in the abatement case (Exhibit 2.10).

Despite this, **coal-based generation** would constitute 55 per cent of total generation, continuing to dominate the power generation mix up to 2030. This is because the abatement case assumes a minimum amount of coal-based generation, about 240 GW[15] (including captive capacity), in view of the current momentum of capacity addition. This momentum would lead to the construction of coal-based capacity at the rate of 15 GW to 20 GW a year for the next 10 to 12 years. The abatement case suggests minimising coal-based power capacity beyond 2020. This would require a shift from developing coal-based power plants to establishing cleaner power-plant development capacity. This comes with the challenge of longer lead times for such capacity creation. Also, power engineering, construction and equipment capacity created to build coal-based plants in the next 10 years could become redundant.

The abatement case also assumes that **nuclear capacity** would be enhanced to 60 GW by 2030[16] (Exhibit 2.11). This doubling of installed nuclear capacity over the reference case would be challenging. One option could be to accelerate development of the four identified sites of

Exhibit 2.10

Power mix 2030



Share by fuel type (per cent) – Capacity

	Reference case	Abatement case
Coal	60	37
Other fossil fuels	19	20
Hydro and nuclear	12	23
Renewables	9	20

Share by fuel type (per cent) – Generation

	Reference case	Abatement case
Coal	79	55
Other fossil fuels	6	3
Hydro and nuclear	11	25
Renewables	4	17

1 Oil-based generation is used both for peaking supply and as backup for infirm sources of power like wind and solar. 55 GW for backup and 25 GW for peaking in reference case and 70 GW of backup and 20 GW of peaking power in abatement case. PLF of backup oil is assumed to be minimal
2 Other renewables include wind, biomass and geothermal based generation; small hydro included under "hydro and nuclear" category

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

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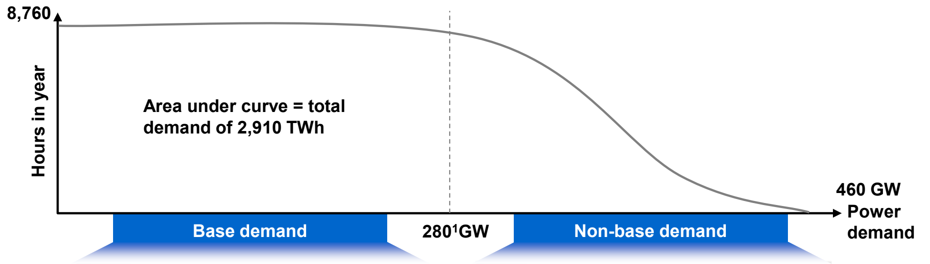
[15] Estimated based on capacity additions already underway and in the pipeline, not including retirement of plants over 30 years old.

[16] Around 8 GW of capacity is existing or would come up around 2010.

Exhibit 2.11

Abatement case: 2030 Power supply

Annual demand load curve for 2030



Technology	2030 base capacity (GW)
Coal (sub)[2]	124
Coal (super)	78
Coal (ultra-super)	16
Nuclear	60
Hydro (run-of-river)	28
Hydro (reservoir)[3]	20
Biomass	16
Geothermal	10
Total base load	**352**

Technology	2030 non-base capacity (GW)
Coal (cycling)	20
Hydro (reservoir)	25
Gas (CCGT)	35
Wind	42
Solar	57
Small hydro	15
Oil (peak generation)	25
Oil (backup)[4]	66
Total non-base load	**285**

1 280 GW pertains to actual demand in base; installed capacity would be higher to account for plant availability factors
2 Including captive capacity of 60 GW and 5% spinning reserves
3 Assumed that 80% of 2005 reservoir hydro capacity of 25 GW continues to be used as base load capacity in 2030
4 Capacity required as backup for infirm sources like wind and solar

SOURCE: McKinsey India Cost Curve Model; McKinsey analysis

10 GW each. This would require streamlining project clearances, securing fuel supply and executing projects faster.

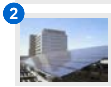
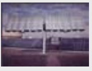
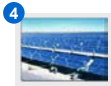
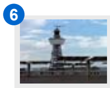
Solar power represents an alternative for peak power supply by 2020 as increasing global demand rapidly drives down costs. Available for around 9 hours during the day, and up to 16 hours with storage, solar energy could, over time, replace conventional sources of peaking power, typically diesel and gas.

Solar power is generated through two technologies: solar photovoltaic (PV) and solar thermal (also known as Concentrating Solar Power or CSP). Exhibit 2.12 summarises the range of photovoltaic and thermal technologies available. Solar PV has seen greater cost declines as economies of scale have increased efficiency and lowered manufacturing costs. These have fallen by about 22 per cent for every doubling of capacity in the past (Exhibit 2.13). If the cost of solar PV continues to decline by approximately 18 per cent for every doubling of capacity, it could fall from EUR 3.0 per peak watt (Wp) in 2005 to EUR 0.7 per Wp by 2030. The capital cost of CSP is assumed to decline at a slower rate of roughly 4 per cent a year from EUR 4.5 per Wp in 2005 to EUR 2.5 per Wp by 2030. For our analysis, we have assumed CSP with 8 hours of storage translating into a 73 per cent plant load factor (PLF) by 2030. The capital cost assumptions include the extra cost of storage.

This decline in solar equipment costs could reduce the cost of solar electricity generation, making solar power a cost-effective source for peak power, substituting diesel generation that today

Exhibit 2.12

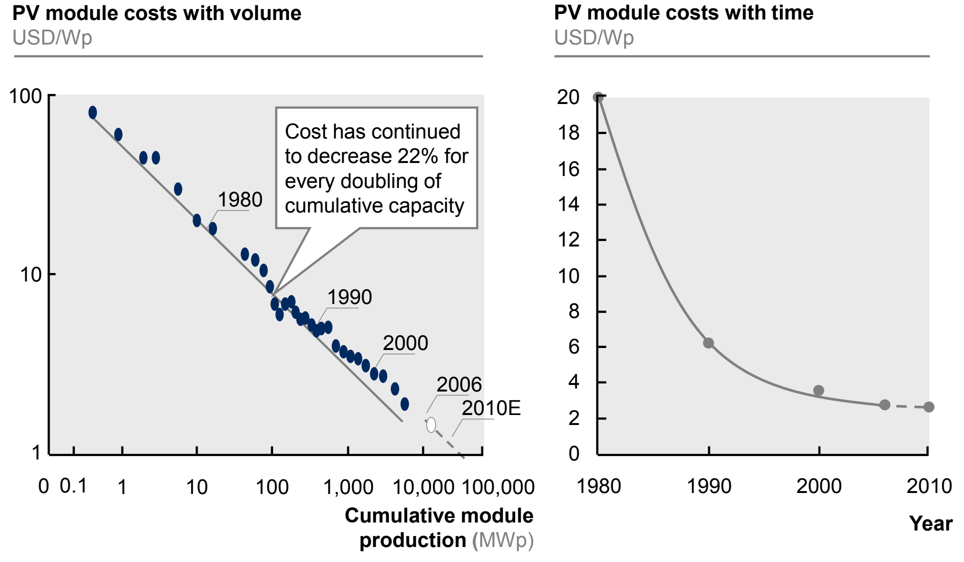
Six key solar technologies

	Key technologies	Sub technologies	Description	Development
Photo Voltaics (PV)	1  **Wafer-based PV**	▪ Mono-crystalline ▪ Poly-crystalline	▪ Uses solar cells combined into modules to generate electricity	Commercial
	2  **Thin film**	▪ Amorphous silicon (a -Si) ▪ Cadmium Telluride (CdTe) ▪ Copper Indium Gallium Selenide (CIGS)	▪ Thin layer of glass, steel, and semiconductor material used to convert light directly into electricity	Commercial
		▪ Nano ▪ Organic dye	▪ Mixture of flexible polymer substrates with nano materials ▪ Flexible PV using plastic as substrate	Laboratory phase
	3  **Concen-trating PV**	▪ N/A	▪ Mirrors used to concentrate light onto cells to increase effectiveness	Pilot
Solar thermal	4  **Parabolic trough**	▪ Without storage or hybrid fossil ▪ With storage ▪ With storage and hybrid fossil	▪ Parabolic mirrors concentrate sunlight on a tube filled with heat transfer fluid ▪ Heated fluid powers steam turbine	Commercial
	5  **Dish-stirling**	▪ N/A	▪ Solar energy converted to heat in a dish collector drives stirling engine, a heat engine that does not require water supply	Pilot
	6  **Power tower**	▪ N/A	▪ Sun-tracking mirrors focus sunlight on a receiver at the top of a tower, which heats water to produce electricity	Pilot

SOURCE: Research reports; web searches; team analysis

Exhibit 2.13

Cost reduction in solar PV technology by capacity and time



SOURCE: European Commission DG JRC; IEA; EPIA; McKinsey analysis costs INR 12 to INR 15 per unit. Solar power could become even more attractive if the prices of oil and gas rise. We have assumed that around 56 GW of solar power—30 GW of CSP and 26 GW of PV—could replace fossil fuel-based generation for meeting non-base demand by 2030 in the abatement case.

For **hydro power**, we have assumed that about 90 GW of India's total potential of 150 GW is captured by 2030 in the abatement case. This takes into account the constraints in realising this potential as highlighted by experts. These include the risk of flooding in some terrains, difficulties in connecting some sites to the grid and the challenge of rehabilitation for populations likely to be displaced. We have also assumed that a higher share of reservoir hydro capacity would be used to serve peak demand—55 per cent (25 GW) vs. 20 per cent (5 GW) in the reference case, to match the demand profile better.

To further augment clean power generation, the abatement case assumes an increase in **wind power** capacity to 42 GW. It also assumes that 16 GW of biomass-based power could be added, consistent with government estimates of the availability of agro residues and waste. We have not considered additional biomass potential from plantation-based biomass due to constraints on land availability.

Therefore, we assume that estimated base demand of about 280 GW would be met through coal, nuclear, run-of-the-river hydro, biomass and geothermal power in the abatement case. Non-base demand of about 180 GW would be met through the usual storage hydro, gas, solar energy and other power sources. This leaves a small amount of non-base demand to be met by cycling coal plants and oil-based generation. A fair amount of oil-based capacity would remain in the system to back up more uncertain sources of power such as solar or wind (Exhibit 2.14). This demand translates into an installed power capacity (grid and captive) of 640 GW to 660 GW for India, in 2030, versus 760 GW to 790 GW in the reference case (please refer to Exhibit 2.7). This capacity mix would further reduce emissions by 650 million tonnes CO_2e beyond the reference case.

Abatement case: using cleaner coal technologies

Coal would remain a significant source of power for India, with around 79 per cent of generation in the reference case and 55 per cent in the abatement case being coal-based by 2030. In view of this, making current and new coal plants more efficient provides an opportunity to extract more power from a given amount of coal, reducing coal consumption and emissions.

India has already taken steps in this direction, with a planned move to supercritical and ultrasupercritical (USC)[17] technologies. Based on these plans, we assume an even split between subcritical and supercritical technology in coal-based capacity additions till 2030, in the reference case, with supercritical plants beginning to come online after 2010.

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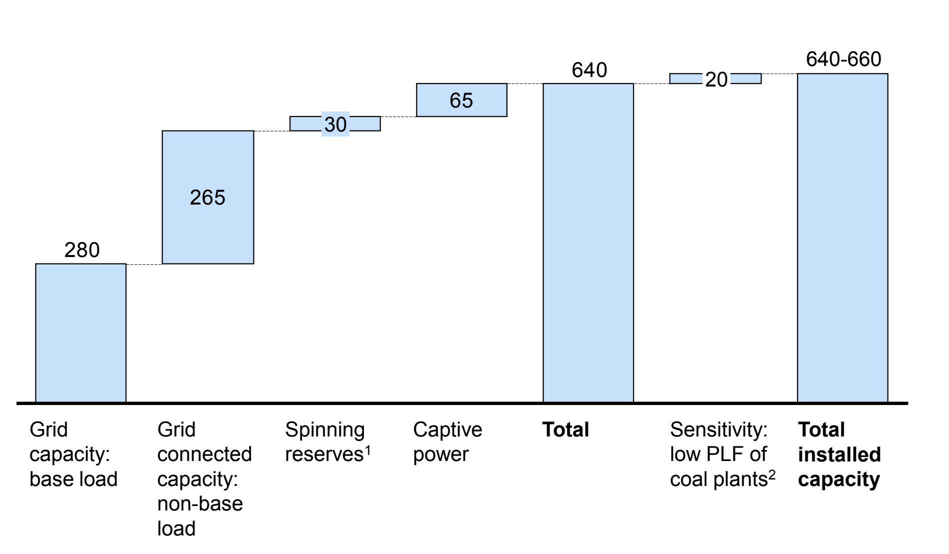
[17] Subcritical, supercritical and ultrasupercritical technologies refer to the temperature and pressure conditions of coal combustion, with higher temperatures and pressures resulting in more efficient combustion (43 per cent for ultrasupercritical compared to 36 per cent for subcritical).

Exhibit 2.14

Installed power capacity in abatement case (2030)

Gigawatts



1 Spinning reserves estimated at 5 per cent of total capacity
2 Assuming coal plant load factor at 80% instead of 87% assumed for estimating reference case installed capacity

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

The abatement case assumes USC capacity of 16 GW, because of its higher efficiencies. Using this technology would further reduce emissions by 14 million tonnes[18] CO_2e by 2030 over the reference case.

Another opportunity is to use the emerging Integrated Gasification Combined Cycle (IGCC) technology. Pilots of IGCC[19] are planned by 2017. However, in view of the technical challenges expected in using Indian coal for IGCC, we have assumed that no IGCC-based capacity will be commercialised by 2030. Several countries are also examining abatement through Carbon Capture and Storage (CCS). We have assumed that CCS is unlikely to play a major role in India's power supply mix till 2030 since uncertainty about the technology could persist for the next 10 years, the period when India would add most of its coal capacity in the abatement case.

ENERGY-EFFICIENT INDUSTRY

The majority of the additional abatement potential in industry lies in the steel and cement industries in the form of energy efficiency and the use of less energy-intensive materials.

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[18] Abatement due to the addition of 8 GW of USC capacity, as 8 GW already assumed as installed in the reference case.

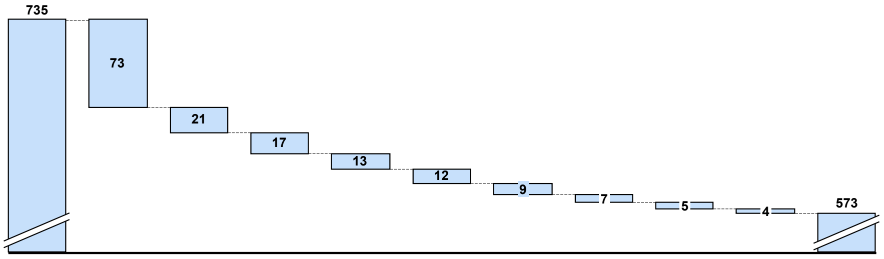
[19] Integrated Gasification Combined Cycle, a technology that turns coal used for generation into gas, which is more efficient and reduces sulphur dioxide, particulate and mercury emissions.

Exhibit 2.15

Emissions and abatement potential for India’s steel sector

Annual emissions and abatement potential, 2030

Million tonnes CO_2e per year



	Reference case 2030	**Energy efficiency-process**	**Shift to scrap-based EAF**	**Shift to gas-based DRI**	**Energy-efficient technologies**	**Bigger blast furnaces**	**Coke Substitution**	**Direct Casting**	**Cogeneration**	**Smelt Reduction**	**Abatement case 2030**
Abatement assumptions		Improvement of 0.5% p.a. through levers like improved motor systems, pulverised coal injection, etc.	5% shift from BF/BOF to scrap-based EAF	7% shift from BF/BOF to gas-based DRI followed by EAF	Four mature technologies: coke dry quenching, TPT, EOS and waste heat recovery from BF stoves	Bigger size furnaces (~3 mtpa) consume less energy	Replacing 10% coke as the primary blast furnace fuel with charcoal, waste plastics, etc.	Move to near-net-shape casting technique for after treatment of steel	Use waste heat in BF exhaust gases to generate heat and electricity	Reduce energy intensity by eliminating the need of coke-making through technologies like COREX in 25% of new builds beyond 2020	

Note: Improvements from material enrichment not included

SOURCE: McKinsey India Cost Curve model

Energy-efficiency in steel

In the steel industry, GHG emissions could be reduced from 735 million tonnes CO_2e in the reference case to 573 million tonnes CO_2e in the abatement case by 2030 (Exhibit 2.15). This could lower the emission-intensity of the steel sector from 2.7 tonne per tonne of liquid steel (tls) in 2005 and 2.0 tonnes CO_2e per tls in the reference case by 2030 to 1.5 tonnes CO_2e per tls in the abatement case. Two types of abatement opportunities exist:

- **Energy-efficiency measures** could reduce emissions by around 70 million tonnes CO_2e by 2030. These include: 1) making processes more energy-efficient, for example, by using improved motor systems or improving process control systems; and 2) optimising energy use through processes such as pulverised coal injection and coke dry quenching, and recovering waste heat from various processes. Challenges of financing and implementation would need to be resolved as well as practical issues such as plant shutdown to upgrade or replace equipment.

- **Technology changes, recycled raw materials and alternative fuels** could reduce emissions in the steel sector by around 42 million tonnes CO_2e by 2030. These include:

  — **Smelt reduction through technologies such as direct smelting**, which eliminate the need for coking plants. We assume that in the abatement case direct smelting will substitute BF/BOF[20] plants in 25 per cent of total capacity added beyond 2020, allowing

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[20] Blast furnace/blast oxygen furnace.

the production of 30 million tonnes of steel a year using direct smelting technologies by 2030. This would hinge on the resolution of issues with direct smelt technologies; they have been on the anvil, with only a few commercialised (e.g., Corex[21]) and none implemented on a large scale.

- **Moving to scrap-based steelmaking**, which requires one-third the energy consumed by the standard blast furnace using iron ore. We have assumed that around 5 per cent of total production could use scrap-based technology by 2030 in the reference case. The abatement case assumes an increase in scrap penetration to 10 per cent of total production. This implies recycling roughly 70 per cent of the approximately 50 million tonnes of scrap India would generate from 2025 onwards. This would represent an economic cost given the high price of scrap. Also, scrap collection systems would need to be set up.

- **Gas-based Direct Reduced Iron (DRI).** We have assumed that gas-based DRI would account for up to 7 per cent of production in the reference case, assuming gas would be available to steel plants by 2020. The abatement case assumes a doubling of gas-based DRI production to 14 per cent of total production. Gas supply would remain an issue, particularly to the iron ore-rich locations. However, coal-bed methane and gas freed up from power generation averted in the abatement case could fill the gap.

Emissions reduction in cement

India is the second largest producer of cement in the world, and over 95 per cent of its plants use the most energy-efficient dry kiln technology. Nonetheless, there are opportunities to further reduce emissions. In the cement sector, using less energy-intensive raw materials and alternative fuels could reduce emissions from 665 million tonnes CO_2e in the reference case to 522 million tonnes CO_2e by 2030 (Exhibit 2.16).

- **Blending cement with less energy- and carbon-intensive raw materials**, that is, using 30 per cent of fly ash or 60 per cent of blast furnace slag could reduce emissions by 98 million tonnes CO_2e in the cement sector.[22] Substituting clinker with fly ash or blast furnace slag helps reduce the energy-intensity of cement production. These materials are by-products of other processes and therefore require no extra energy to produce. In contrast, making clinker requires burning coal and generates carbon dioxide. We have estimated blending potential after taking logistics constraints into account, mapping blending material availability with cement production centres, and keeping in mind economically feasible transport distances. Nevertheless, realising even this potential would be a challenge.

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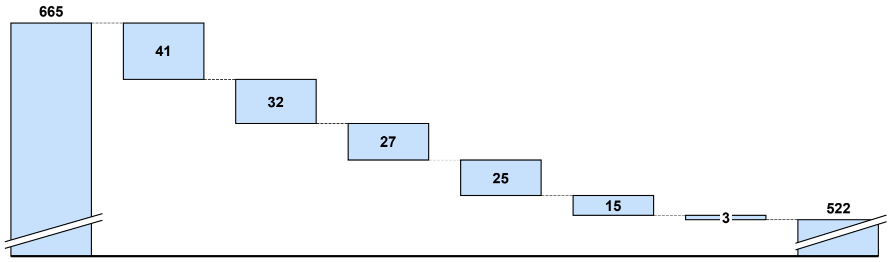
[21] Corex is a direct smelting technology in commercial use at this time. In Corex, non-coking coal is directly used for ore reduction and melting, eliminating the need for coking plants. The use of lump ore or pellets also dispenses with the need for sinter plants.

[22] Based on estimates of material availability, we assume the potential for blending up to 30 per cent of fly ash in 12 per cent of total cement production and blending up to 60 per cent of slag in 10 per cent of total cement production.

Exhibit 2.16

Emissions and abatement potential for India's cement sector

Annual emissions and abatement potential, 2030
Million tonnes CO_2e per year



	Reference case 2030	**Clinker replaced by fly ash**	**Clinker replaced by slag**	**Alternative fuels - waste**	**Clinker replaced by other MIC**	**Alternative fuels – bio-waste**	**Waste heat recovery**	**Abatement case 2030**
Abatement assumptions		30% blending of fly ash reducing clinker production	60% blending of blast furnace slag reducing clinker production	Alternative fuels like pet-coke and shredded tyres replace coal	10% blending of low-grade limestone or calcined clay reducing clinker production	Bio-waste replacing coal as the primary fuel	Cement kiln exhaust at a temperature of around 200-300 C to generate electricity	

SOURCE: McKinsey India Cost Curve model

- **Using alternative fuels to reduce emissions**. Blending coal with alternative fuels such as bio-waste, agri-waste and other combustible solid waste could reduce emissions by 42 million tonnes CO_2e. The main impediment to such a shift would be the lack of bio- and agri-waste for cement producers in view of competition from other end users of these fuels such as biomass-based power plants and farmers.

GREEN TRANSPORTATION

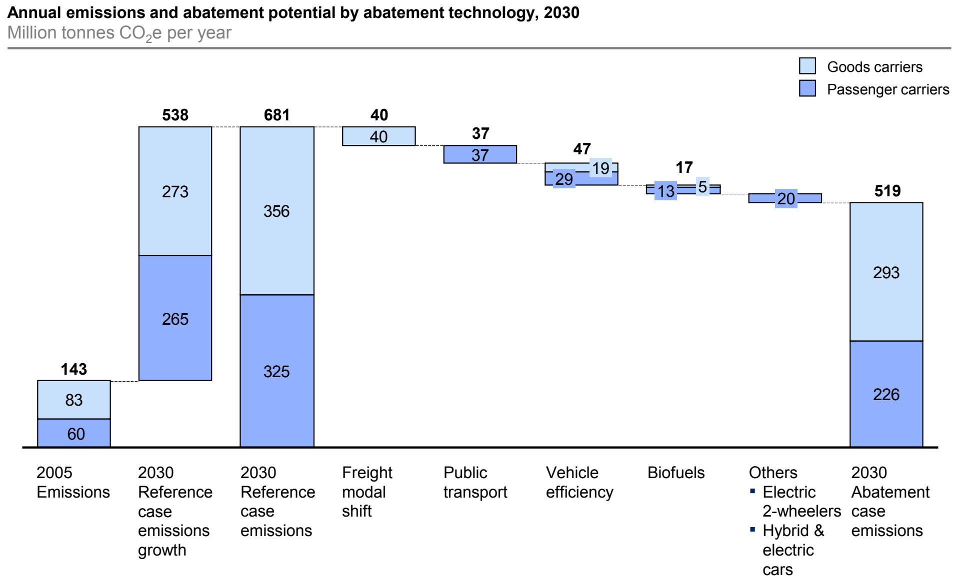
An expected seven-fold increase in India's vehicle fleet by 2030 would correspondingly increase demand for petrol and diesel. If expected efficiency improvements through initiatives such as mileage standards and emission norms are achieved, we estimate that emissions from this sector could be further reduced from 681 million tonnes CO_2e in the reference case to 519 million tonnes CO_2e in the abatement case (Exhibit 2.17).

The key opportunities in the transport sector include improving vehicle efficiency in cars and commercial vehicles, strengthening transportation infrastructure and using alternative fuels such as electricity and biofuels, as described below.

- **Developing more fuel-efficient cars and commercial vehicles**: A series of technical improvements to reduce tyre and engine friction, improve power trains, lower vehicle weight, and increase aerodynamic efficiency could significantly improve fuel efficiency in cars and commercial vehicles. Our analysis shows that making these improvements by 2020 could

Exhibit 2.17

Emissions and abatement potential for India's transport sector



SOURCE: McKinsey India Cost Curve model

increase the fuel efficiency of petrol cars by 33 per cent, diesel cars by 31 per cent and commercial vehicles by 30 per cent. Even if applied only to all new vehicles coming onto the roads in 2015, these measures could reduce emissions by 47 million tonnes CO_2e.

- **Strengthening transportation infrastructure**: Two major shifts in transportation infrastructure—a balanced modal mix with more rail and coastal shipping, and increased use of public transport—have the potential to reduce diesel consumption in the transport sector by 23 per cent.

  India currently has an expensive and inefficient freight transportation system, with 57 per cent of its domestic freight transported by road (in tonne-km terms). Road transport is more expensive and carbon-intensive than rail or coastal shipping, especially for carrying bulk freight over long distances. With road quality improving rapidly and last-mile connectivity issues with rail transport, the share of rail in transporting freight is likely to decline further, to around 30 per cent of the total by 2020. In comparison, China transports 47 per cent of its domestic freight through rail and 31 per cent on coastal or river waterways.

  Our analysis suggests that there is potential to ship more than half of the total freight in India through rail and coastal shipping. Rail could carry up to 46 per cent of total freight and coastal shipping around 7 per cent. Such a balanced modal mix could reduce diesel consumption in the country by almost a quarter or 24 million tonnes, and related emissions by around 40 million tonnes CO_2e.

Implementing this concept is not without its challenges. It would require an integrated freight logistics policy involving a number of ministries, a shift in investment across modes (e.g., to rail) and within modes (e.g., in road transport and building last-mile road-rail connectivity).

- **Increased use of public transport**: A lack of efficient and convenient public transport in most Indian cities, except a few metros, causes people to use personal vehicles and intermediate public transport such as three-wheelers and taxis, adding to traffic congestion. The ratio of buses to the population in India is a tenth of that in some developed cities of the world. Expanding public transportation through metros in high-population cities (more than 5 million people) and bringing bus-based public transport to all tier I, II and III cities could reduce the use of cars and two-wheelers by about 30 per cent and reduce fuel consumption further by easing congestion. This could reduce emissions by 37 million tonnes CO_2e over the reference case by 2030.

- **Introducing hybrid cars and electric two-wheelers**: India is one of the largest markets for two-wheelers and these vehicles consumed 37 per cent of the total petrol used in the country in 2005. Shifting to electric two-wheelers would convert oil demand into electricity demand, which could be met through more efficient sources. If every two out of five two-wheelers in India were electric by 2030, emissions could decrease by 11 million tonnes CO_2e. A shift to hybrid and electric cars could reduce emissions by an additional 9 million tonnes CO_2e over the reference case. Challenges of technology development and diffusion would need to be resolved to realise this potential.

- **Blending of biofuels**: Biofuels could be a carbon-efficient and renewable way of partly replacing petrol without compromising vehicle performance. The Indian government is already planning for 5 per cent ethanol blending in petrol. We assume that up to 18 per cent of gasoline could be replaced by bioethanol, derived in equal parts from sugarcane, sweet sorghum and lingo-cellulosic biomasses, and up to 8 per cent of diesel could be replaced by biodiesel by 2030. This would further reduce emissions over the reference case by 17 million tonnes CO_2e. However, this opportunity is small because of constrained land availability; land used for food crops is unlikely to be diverted to this purpose.

SUSTAINABLE HABITATS

India will see a massive expansion of buildings and increased use of appliances up to 2030 and beyond. If critical decisions about design and energy efficiency are not made now, India risks locking in inefficient buildings for the next 30 years or more. With 80 per cent of the buildings and appliances of 2030 yet to be built or bought, India has a unique opportunity to ensure energy-efficient buildings and appliances from the start.

As one of the warmest countries in the world, India has more than 3,000 cooling degree days—a measure of the energy required to cool a home or building. This is twice the cooling degree days of Mexico and about the same as those of the Middle East. As affordability and power availability increase, demand for air-conditioning will rise sharply. Our analysis assumes that, by 2030, over 60 per cent of commercial space would be air-conditioned and about 4 in 10 urban households would have one air-conditioner. Along with higher use of appliances, this would increase electricity consumption in buildings from 140 TWh in 2005 to around 1,300 TWh in 2030.

We believe that there is further energy-efficiency potential in buildings, appliances and lighting that could reduce electricity demand from this sector by more than 30 per cent and resulting emissions by about 340 million tonnes CO_2e by 2030 (Exhibit 2.18).[23] Approximately 80 per cent of this potential could be captured by ensuring efficient building envelopes for new buildings, high-efficiency appliances and electronics, and energy-efficient lighting:

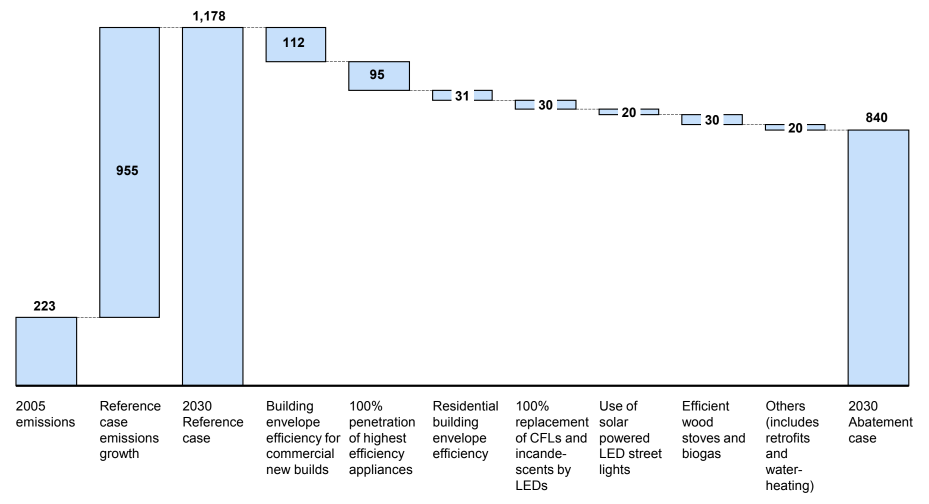
- **Efficient building envelopes:** In India, cooling generally uses the most energy in air-conditioned buildings, accounting for up to 55 per cent of the total electricity consumed in centrally air-conditioned commercial buildings. Passive design alone (to optimise the insulation, ventilation, and lighting of a building) could reduce 15 to 20 per cent of the requirement and along with high efficiency HVAC and insulation could reduce emissions by 140 million tonnes CO_2e. Changing (and in many cases establishing) building codes across the states and many urban centres would be required.
- **High-efficiency appliances and electronics**: Appliances and electronics account for around 40 per cent of the electricity consumed in households, and around 25 per cent in

Exhibit 2.18

Emissions and abatement potential for India's buildings sector

Annual emissions and abatement potential by abatement technology, 2030

Million tonnes CO_2e per year



SOURCE: McKinsey India Cost Curve model

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[23] It is important to note here that the buildings and appliances sector in India differs significantly from those of other countries. Heating and cooling is primarily through electricity, whereas in other countries oil, gas and coal are also used for heating. Any reduction in power use will reduce the need for expensive power plants in India.

commercial buildings, especially IT offices that are set to continually increase in India. Using the most efficient appliances and electronics available today would further reduce emissions over the reference case by about 95 million tonnes CO_2e by 2030. Standards mandating the use of such appliances or fiscal incentives to encourage adoption would help but would need careful management, not only in this area but in all areas driven by standards.

- **Energy-efficient lighting**: Emerging alternatives for lighting such as LED offer significant electricity savings over traditional incandescent lighting, while emitting light of the same level. A technology expected to mature in the next five years, LED lighting is likely to be 6 times more efficient than incandescent lamps and 1.25 times more efficient than CFLs. India's residential sector still predominantly uses incandescent lighting because of the low upfront costs, while many commercial establishments have shifted to compact fluorescent lighting (CFL) due to the higher cost of electricity for commercial purposes. We assume that with current programmes to make CFLs cheaper, the residential sector could also reach a 90 per cent penetration of CFLs. Replacing incandescent lamps and CFLs with LED lighting could reduce emissions by about 30 million tonnes CO_2e by 2030.

A big win for rural India

Efficient stoves and biogas are opportunities unique to India that would not only reduce emissions by up to 30 million tonnes CO_2e by 2030, but also save over 80 million tonnes of biomass. If used in wood gasifiers, the biomass saved could generate up to 50 TWh of electricity, enough to light around 35 to 40 per cent of rural households in 2030. Efficient wood stoves could be a big win for India as they would also increase health and productivity in Indian villages. These stoves nearly eliminate the emission of suspended particulate matter, the largest cause of respiratory diseases in rural areas, particularly for women.

SUSTAINABLE AGRICULTURE AND FORESTRY

Improving practices in agriculture and forestry provides further potential to reduce emissions, from 550 million tonnes CO_2e in the reference case to 150 million tonnes by 2030. In addition, fuel and electricity consumption could be reduced.

Agriculture: Abatement opportunities in this sector include the following:

- **Efficient irrigation techniques and high efficiency pumps**: The agriculture sector in India is estimated to account for 23 per cent of the electricity and 15 per cent of the diesel consumed in the country.[24] Low mechanisation, years of poor water supply and provision of free electricity have prevented the use of more modern techniques or reduced the incentive to do so. India has among the highest diesel and electricity consumptions per hectare of agricultural land in the world, even at lower yields. Water used in some agricultural practices is double the optimal need, which is not only a waste but also reduces yield.

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[24] Some of this is likely to be misclassified as agricultural use, as is being discovered with the separation of agricultural power feeders.

More efficient irrigation techniques, such as drip and sprinkler irrigation, and the use of efficient pump sets could reduce the sector's water needs by up to 25 per cent and its electricity and diesel consumption by 15 to 20 per cent. This would require changing entrenched behaviour and motivating farmers to invest in better pumps.

- **Improved cropland management in rice cultivation**: India is the world's second largest rice producer. Flood irrigation is used for about half of the land under rice, which causes anaerobic decomposition in fields, releasing methane. In 2005, a fifth of India's emissions were from this source. Our analysis suggests that preventing anaerobic decomposition in flooded paddy fields through shallow flooding and the use of non-nitrogen fertilisers has the potential to reduce emissions by 120 million to 150 million tonnes CO_2e.
- **Other improvements** in agriculture practices such as conservation tillage (reduced-till and zero-till) and crop rotation, which adds natural nutrients to the soil, improving its productivity while reducing fertiliser use, could potentially reduce emissions by up to 60 million tonnes CO_2e.

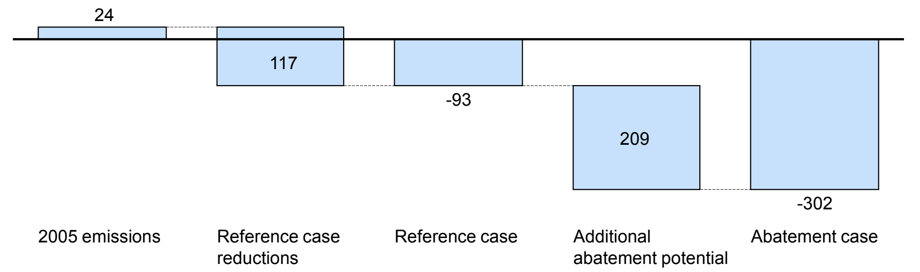
Improvements in agricultural practices offer cross-sector abatement opportunities as well. For instance, better agronomy and irrigation practices would not only increase yield and reduce emissions but also reduce electricity and fertiliser consumption.

Forestry: While we have assumed historical rates of afforestation in determining the reference case, our analysis suggests that the forestry sector has the potential to further sequester

Exhibit 2.19

Emissions and abatement potential for India's forestry sector

Annual emissions and abatement potential
Million tonnes CO_2e per year, 2030



Abatement assumptions

- **Afforestation of 7.5 Mha** based on average annual afforestation rates (3.8 Mha of forests & 3.7 Mha of tree outside forests)
- **Reforestation** of degraded forests: 50% of degraded forests are reforested (15.5 Mha)
- **No net deforestation** in future

- **Afforestation** of additional **20 Mha** of open forests (from wastelands and marginal croplands) to reach stated goal of 33% forest cover for India
- **Reforestation** of degraded forests: 100% of degraded forests are reforested (remaining 15.5 Mha)
- **Forest management** applied to open forests (29 Mha) with 10% to 40% crown density

SOURCE: Houghton (rev. 2005); "Forest conservation, afforestation and reforestation in India: Implications for forest carbon stocks", Current Science, July 2008; National Forest Commission Report; McKinsey India Cost Curve model almost 210 million tonnes CO_2e by 2030 in the abatement case (Exhibit 2.19). The abatement opportunities in this sector are as follows:

- **Further increasing forest cover through afforestation and reforestation**: This could reduce emissions by around 150 million tonnes CO_2e by 2030. In estimating this potential, we assume that India could meet its stated aspiration of having a third of its area under forest cover. This would mean bringing around 20 Mha of additional land under forests, which could potentially come from the 70 Mha of culture-able wasteland available in India.

- **Better forest management**: Forest density could also be increased through practices such as introducing grass and tree species that grow faster, applying fertilisers and organic amendments such as chicken manure, sawdust, compost or leaves to hasten stock growth, and preventing loss of trees through forest fires. We assume that enhanced forest management along with reforestation of degraded forests could increase carbon sequestration and hence abatement by 53 million tonnes CO_2e by 2030.

Due to the large number of stakeholders involved, acquiring land and changing land use to forestry is a big implementation challenge. Such a programme would require, among other things, a uniform incentive structure for owners and stakeholders of these land parcels.

* * *

While additional abatement potential is available in key sectors of the Indian economy, we recognise that realising it will be a challenge. The next two chapters cover the benefits of realising the abatement case and the implementation challenges involved.

3. Benefitting from the Opportunities

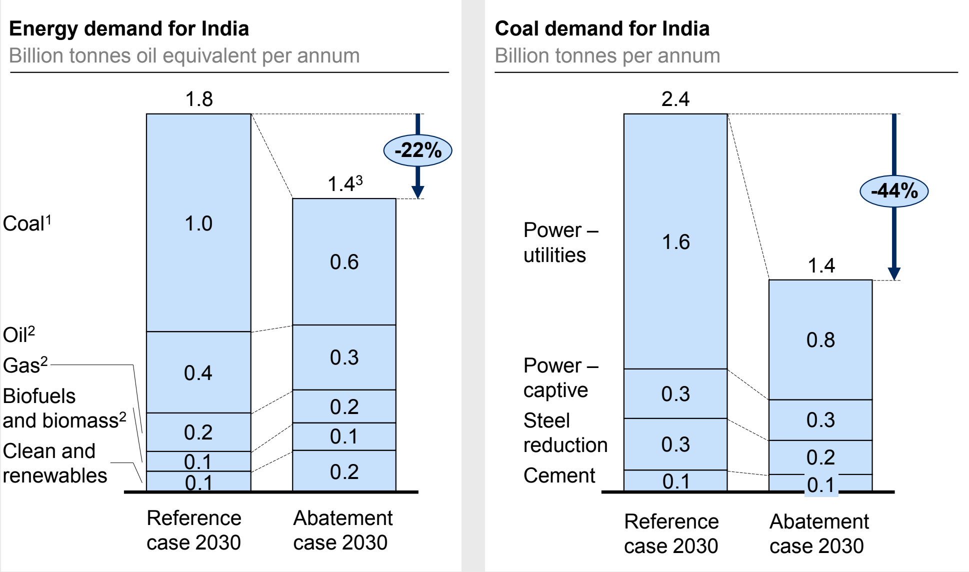
An increase in efforts to reduce emissions could improve energy security, have a positive impact on the Indian economy including creating leadership in new industries, and enable India to become one of the leading energy- and carbon-efficient large economies of the world.

INDIA COULD REDUCE ITS ENERGY DEMAND AND HENCE COSTS

If all the potential identified in the abatement case is realised, India's energy demand could decrease by about 22 per cent, from 1.8 billion tonnes of oil equivalent (btoe) to 1.4 btoe by 2030 (Exhibit 3.1).[1] Our analysis suggests this would reduce the requirements of power, coal and oil—commodities already scarce in India (Exhibit 3.2):

Exhibit 3.1

Energy and coal demand in reference and abatement cases



1 1 tonne coal = 0.41 mtoe; all coal demand figures in Indian coal equivalent; coal demand estimates for power, steel and cement sectors
2 Demand for oil and gas in reference case estimated at historical elasticity with GDP (only road transport sector consumption modeled bottom-up); demand for biomass, kerosene and LPG extrapolated from historical trends based on NSSO data for these fuels
3 Reduction in oil estimated for road transport and agriculture; reduction in gas estimated for power sector; reduction in direct energy demand of oil and gas for other industry sectors not estimated

SOURCE: Integrated Energy Policy; Planning commission of India; NSSO; McKinsey India Cost Curve model; McKinsey analysis

- **Less power demand:** The biggest reduction in primary energy demand in the abatement case would occur in the power sector, where energy efficiency improvements across sectors would significantly reduce demand. The estimated 25 per cent reduction in demand could avert the addition of around 120 GW of power capacity, or 80 per cent of India's power

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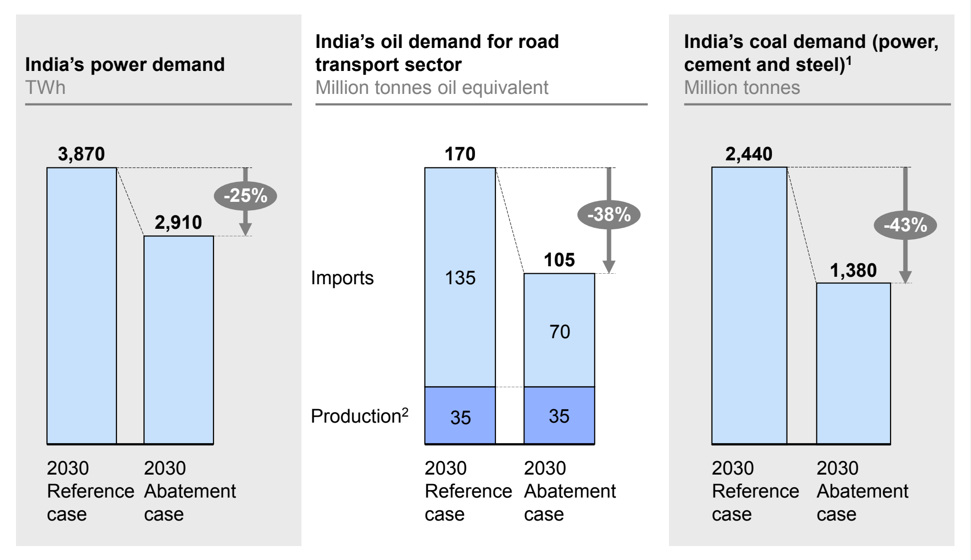
[1] Decrease in energy consumption in sectors discussed in this report. This does not include direct energy savings from efficiency opportunities in other industrial sectors (except steel, cement, chemicals and refining).

Exhibit 3.2

Power, oil and coal demand in the reference and abatement cases



1 Numbers are in Indian coal equivalent assuming average gross calorific value of Indian coal (30% ash, 7% moisture) at 4,500 kcal/kg; includes captive power

2 Production of oil assumed at 35 mtoe in 2030 based on current reserves and discoveries. Production in 2005 was 32 mtoe.

SOURCE: Planning Commission of India; Ministry of Statistics and Programme Implementation, Government of India; McKinsey India Cost Curve model; McKinsey analysis

capacity in 2005, without affecting end-users. One in five plants would no longer be needed. As a result, India could bridge the power demand-supply gap faster.

- **Reduced coal demand:** Averting power capacity and increasing the share of clean and renewable energy in India's power mix in the abatement case could also reduce coal consumption in the power sector. Our analysis suggests that coal use by this sector could be halved by 2030 if the opportunities in the abatement case are captured. The demand for metallurgical coal could also fall by about 100 million tonnes per annum by 2030 if opportunities in the steel sector are captured (please see exhibit 3.1). Accelerating nuclear and renewables supply so rapidly would be a big challenge, but one worth taking on for the significant benefits of reduced pollution and reduced imports.

- **Reduced oil demand:** Oil demand could be reduced by improving the efficiency of passenger and commercial vehicles, moving to a balanced modal mix for freight transport, and encouraging greater use of public transport. As suggested in the abatement case, these measures could shrink oil demand from India's transport sector by about 40 per cent by 2030.

A 22 per cent reduction in total energy demand also augurs well for the economy. The cost savings would lower the cost of production in industries, making them more competitive. Reduced energy expenditure in the overall economy would translate into savings or reinvestment.

INDIA COULD ENHANCE ITS ENERGY SECURITY

Solutions for reducing carbon emissions described in the abatement case could reduce India's reliance on oil and coal imports and thus enhance its energy security. Our projections of oil demand in the reference case show that India may need to import more than 10 times its oil production, which could increase its oil import bill to over USD 150 billion[2] by 2030. The suggested opportunities could reduce oil consumption in transportation and agriculture by about 40 per cent, translating into a reduction of 20 to 25 per cent in overall consumption. India's import bill could thus be reduced by around USD 35 billion (at USD 60 a barrel) by 2030, roughly India's total import bill in 2005.[3]

Using more efficient technologies for manufacturing steel would also reduce the use of imported metallurgical coal.[4] Our analysis suggests that using technologies such as smelt reduction would reduce the use of metallurgical coal and thus its import. This would amount to a saving of around USD 8 billion (at USD 80 a tonne) by 2030.

Besides saving foreign exchange, reducing oil and coal imports would limit the country's exposure to price increases and supply shortages in these commodities due to globally rising demand. It would also have a stabilising effect on global prices of commodities such as coal, where demand from India is a determinant of global prices. In addition, with a more diverse energy supply, e.g., substituting coal-based power with nuclear power and gas-based power with solar power, India could reduce imports of gas and thermal coal and reduce pressure on domestic production.

INDIA COULD INCREASE ENERGY INCLUSION AND IMPROVE THE QUALITY OF LIFE OF ITS PEOPLE

Realising the abatement case would make India's growth more energy-inclusive by increasing access to resources for a larger number of people. For example, power generated from saved biomass or animal waste through the use of efficient cooking stoves or biogas could provide more people faster access to electricity. Similarly, distributed solar generation could increase energy inclusion, as has been the case so far in some pockets of the country. Better irrigation practices would improve crop yields and reduce water and diesel consumption in agriculture, enabling better distribution of these scarce resources. Large-scale use of safer and more efficient cooking stoves would also eliminate the health hazards of inefficient burning of wood.

In urban India, the quality of life could improve as a result of better transportation infrastructure, greater power availability and reduced road congestion and vehicular pollution. Addressing problems such as massive traffic jams and pollution would not just make India's cities more habitable and pleasant, it would also improve the health and productivity of residents.

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[2] At an assumed oil price of USD 60 per barrel.

[3] India spent around USD 38.77 billion on oil imports in 2005 (Ministry of Petroleum and Natural Gas).

[4] Steel making requires a specific type of coal with high calorific value and less ash content, which is not available in India and hence has to be imported.

CAPTURING BUSINESS OPPORTUNITIES COULD BOOST THE NEXT WAVE OF ECONOMIC GROWTH

The abatement case also presents an opportunity for India to take the lead in developing “clean-technology” products and services. Investments in such technologies are likely in several countries worldwide with the dual purpose of increasing energy security and reducing carbon emissions. Global investments in clean energy in 2008 amounted to EUR 112 billion[5], and are expected to continue their high growth in the next decade.[6] The global market potential in clean technologies is expected to be more than EUR 1 trillion between 2010 and 2030 and offers a potential revenue pool of EUR 50 billion to EUR 70 billion annually in clean energy and clean fuel solutions and services.

While there are opportunities in many areas, a few are particularly attractive given their large global potential and India’s inherent advantages in the areas. These are:

- **Solar power generation and equipment manufacturing**: Solar energy has massive potential in India as well as globally and is one of the most promising technologies for renewable energy. Installed solar capacity worldwide grew at 25 per cent per annum, on average, between 1994 and 2007 and is expected to grow to anywhere between 20 and 100 times its current size by 2030. More than EUR 60 billion was invested in the solar industry between 2005 and 2008. With its abundant solar resources and low-cost manufacturing base, India has the potential to be a leading player in the industry. Steps have already been taken in this regard. The Special Incentive Package Scheme encourages investment in new semiconductor and solar manufacturing in India. It has attracted over EUR 10 billion in proposed investments, of which over 60 per cent is related to solar energy.

- **Smart buildings, smart grids and other green technology solutions**: Smart buildings and smart grid solutions are among the largest and most attractive opportunities in energy efficiency. They have well-commercialised technologies, enjoy supporting regulation in many countries and are economically viable. Of particular interest is the EUR 45 billion (by 2020) opportunity in the information, communication and technology sector, with opportunities in hardware for controlling and optimising energy use, software for systems implementation and integration, and energy management services. As a leading provider of software services to the world, India could capitalise on its large skilled workforce and knowledge in the IT sector to capture the related opportunities.

- **Electric two-wheelers**: India represents 20 per cent of the world’s two-wheeler market and had 49 million two-wheelers in 2005; it is expected to have five times more by 2030. Cleaner, quieter and lighter, electric two-wheelers would be an energy- and carbon-efficient replacement for conventional two-wheelers (with an internal combustion engine). Several East Asian countries are moving fast to adopt electric two-wheelers and China already has

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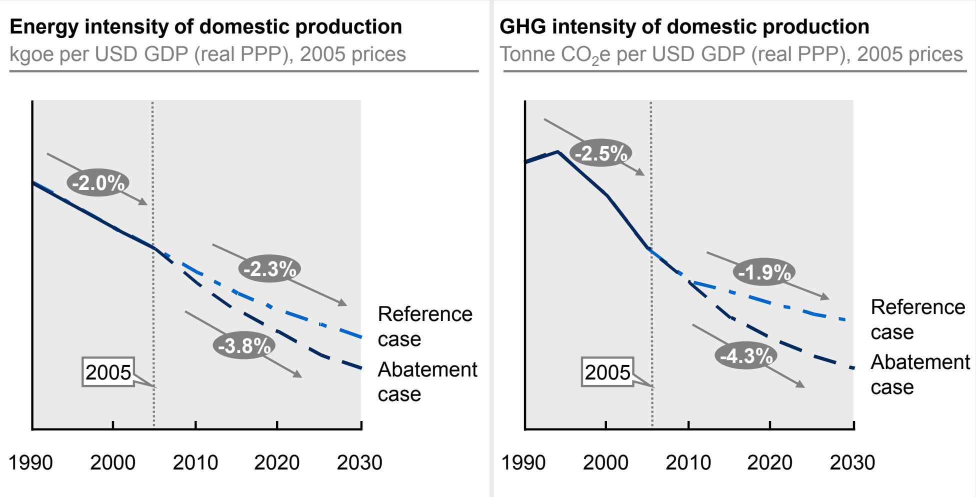
[5] Source: *The Business Case For A Global Deal;* Project Catalyst, ClimateWorks Foundation, 2009.

[6] While investment in clean technology has slowed down in 2009 because of the economic crisis, major banks project it will pick up again with general economic growth, and accelerate further if the risks of regulatory unpredictability are reduced through coherent, long-term policy action.

Exhibit 3.3

Energy and carbon intensity in India



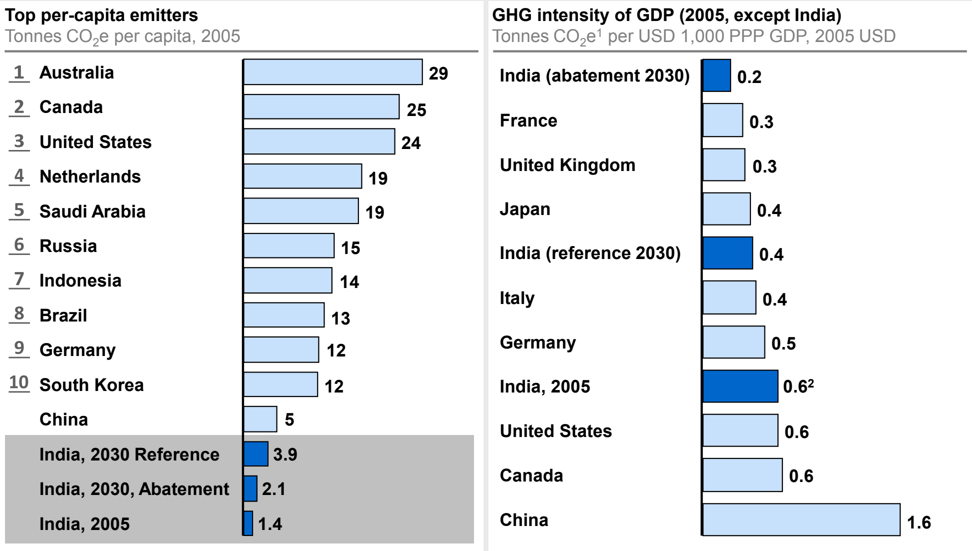
Energy intensity of domestic production
kgoe per USD GDP (real PPP), 2005 prices

GHG intensity of domestic production
Tonne CO_2e per USD GDP (real PPP), 2005 prices

SOURCE: WMM Global Insight; Integrated Energy Policy, Planning Commission; India's Initial National Communication to UNFCCC; Greenhouse gas emissions from India: A perspective, Subodh K Sharma et al, Current science, vol. 90, no. 3, 10 February 2006; McKinsey India Cost Curve model; McKinsey analysis

Exhibit 3.4

Per capita emissions and GHG-intensity of domestic production



Top per-capita emitters
Tonnes CO_2e per capita, 2005

GHG intensity of GDP (2005, except India)
Tonnes CO_2e[1] per USD 1,000 PPP GDP, 2005 USD

1 Includes emissions associated with deforestation and land-use changes. Includes selected countries with annual GHG emissions greater than 250 million tonnes CO_2e

2 Calculated using real PPP data from Global Insight, at USD prices for 2005 to retain consistency in GDP PPP with other countries; PPP GDP data for India may be different from other sources

SOURCE: UNFCCC; IEA; EPA; Global Insight; McKinsey analysis

90 per cent of all electric two-wheelers in the world. India could be a leading promoter and manufacturer of these vehicles thanks to its well-developed two-wheeler industry, associated expertise in two-wheeler design and manufacturing, and a large local and export market base.

- **LED lighting**: LED lighting could replace incandescent lights and compact fluorescent lamps (CFLs) in the future. LED lighting globally has a huge market potential of about EUR 100 billion. The current supply of LEDs is quite limited and therefore India could garner a part of the opportunity by investing early in LED manufacturing.

INDIA COULD CONSOLIDATE ITS LEAD IN ENERGY AND CARBON EFFICIENCY

India has historically been an energy-efficient nation owing to its relatively early stage of economic development, services- and agriculture-based economy, and limited domestic resources. Its growth in the last two decades has also been relatively energy- and carbon-efficient: India's energy intensity[7] declined at 2 per cent per annum between 1990 and 2005 and carbon intensity[8] at 2.5 per cent per annum in the same period. Our estimates suggest that both will fall further at similar rates in the reference case due to assumed efficiency improvements and the addition of clean and renewable power. In the abatement case, energy intensity could decline even faster, by around 3.8 per cent per annum, and carbon intensity by 4.3 per cent per annum (Exhibit 3.3).

Per capita emissions in India are estimated at 3.9 tonnes CO_2e by 2030 in the reference case. This is lower than those of most leading economies of the world. If the potential in the abatement case is achieved, per capita emissions could decline to around 2.1 tonnes CO_2e by 2030. In this scenario, India's carbon intensity could fall to around 0.21 tonnes CO_2e per unit of GDP in terms of purchasing power parity (Exhibit 3.4).

* * *

The benefits of achieving the abatement potential go beyond helping make India a leading energy- and carbon-efficient large economy. They include inclusive growth, greater energy security, a better quality of life and leadership in new business areas for India.

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[7] Energy used to create 1 unit of GDP, expressed as kg oil equivalent per USD 1,000 of GDP.

[8] CO_2e emissions per unit of GDP on a purchasing power parity basis. CO_2e stands for "carbon dioxide equivalent" and is a standardised measure of greenhouse gases. Emissions are measured in metric tonnes of CO_2e per year, i.e., millions of tonnes (megatonnes) or billions of tonnes (gigatonnes). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from human activity, in our estimates.

4. Challenges in Capturing the Abatement Potential

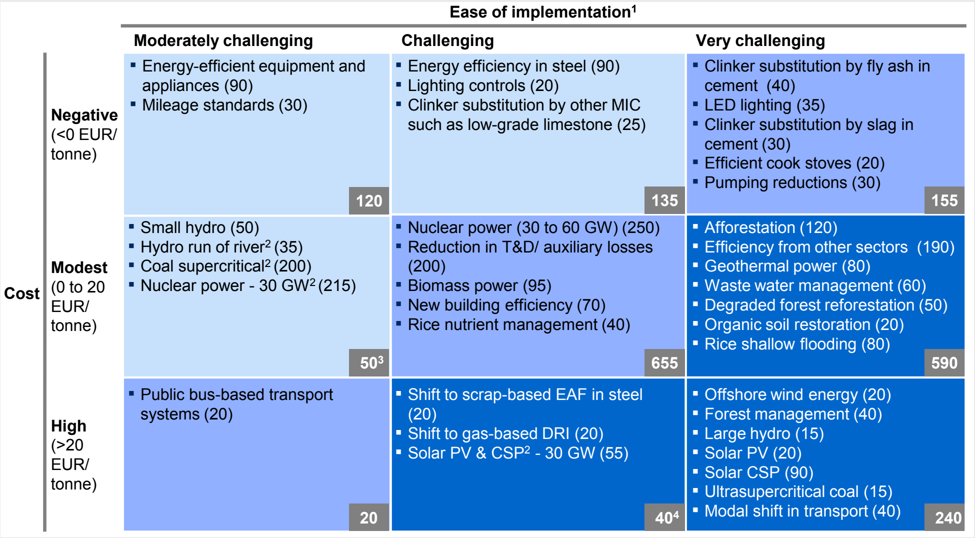
While capturing the additional abatement potential is feasible, not all of it will be easy to capture. The abatement opportunities vary widely in cost and ease of implementation. An analysis of the opportunities on these dimensions shows that only about 10 per cent of the abatement potential is readily achievable (Exhibit 4.1).[1] Most of these opportunities lie in energy efficiency in appliances, buildings, industry, and transport. The majority of the clean power, industrial technology and green transportation opportunities are difficult to implement.

Exhibit 4.1

Feasibility of capturing abatement potential

Abatement potential in million tonnes CO_2e, 2030

□ Readily achievable
▨ Medium difficulty
■ Difficult
▣ Sum of abatement potential



Ease of implementation[1]

		Moderately challenging	Challenging	Very challenging
Cost	**Negative** (<0 EUR/ tonne)	□ Energy-efficient equipment and appliances (90) Mileage standards (30) ▣ 120	□ Energy efficiency in steel (90) Lighting controls (20) Clinker substitution by other MIC such as low-grade limestone (25) ▣ 135	▨ Clinker substitution by fly ash in cement (40) LED lighting (35) Clinker substitution by slag in cement (30) Efficient cook stoves (20) Pumping reductions (30) ▣ 155
	Modest (0 to 20 EUR/ tonne)	□ Small hydro (50) Hydro run of river[2] (35) Coal supercritical[2] (200) Nuclear power - 30 GW[2] (215) ▣ 50[3]	▨ Nuclear power (30 to 60 GW) (250) Reduction in T&D/ auxiliary losses (200) Biomass power (95) New building efficiency (70) Rice nutrient management (40) ▣ 655	■ Afforestation (120) Efficiency from other sectors (190) Geothermal power (80) Waste water management (60) Degraded forest reforestation (50) Organic soil restoration (20) Rice shallow flooding (80) ▣ 590
	High (>20 EUR/ tonne)	▨ Public bus-based transport systems (20) ▣ 20	■ Shift to scrap-based EAF in steel (20) Shift to gas-based DRI (20) Solar PV & CSP[2] - 30 GW (55) ▣ 40[4]	■ Offshore wind energy (20) Forest management (40) Large hydro (15) Solar PV (20) Solar CSP (90) Ultrasupercritical coal (15) Modal shift in transport (40) ▣ 240

1 Ease of implementation based on financing issues, regulatory support, agency issues, entrenched behaviour, supply constraints and technological readiness
2 These levers are assumed to be implemented in the reference case
3 Without reference case additions; 500 million tonnes CO_2e after accounting for reference case actions
4 Without reference case additions; 95 million tonnes CO_2e after accounting for reference case actions
Note: Only key levers listed in the matrix above (covering about 80% of potential)

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

THE CHALLENGES IN IMPLEMENTING THE ABATEMENT CASE

Several challenges need to be tackled to realise the abatement case. These include the large incremental investment needed, funding requirements for opportunities with a net economic cost, changes in policy and regulation, skill- and supply-related concerns, technology uncertainties, and the need for an institutional framework to support widespread implementation.

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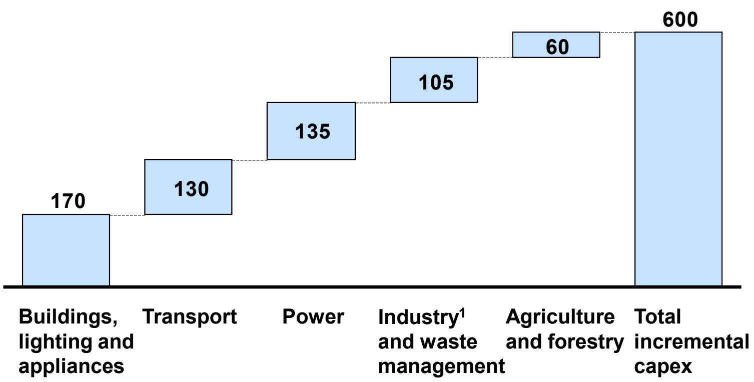
[1] For this analysis, we defined cost as the average cost today of abating each tonne of CO_2e, beyond the reference case. For many new technologies, today's cost is higher than the likely cost in 2030. "Ease of implementation" was defined in terms of the following criteria: i) financing issues such as high upfront capital, long pay-off time, uncertainty about future costs, or difficulty in attracting financing; ii) technology issues such as proven efficacy, high upfront costs and paucity of early adopters; and iii) other implementation barriers such as regulatory and institutional capability, market imperfections, supply chain constraints and talent availability.

Exhibit 4.2

Incremental capital needed by sector

EUR billion

Incremental capex, 2010-2030, abatement case over reference case



Incremental capex sensitivities	Range
▪ Cost reduction in solar PV/CSP at 50% of assumed rate[2]	+40
▪ Cost reduction in nuclear power does not materialize[3]	+17
▪ Lower PLFs for coal and nuclear plants resulting in higher capacity	+25
▪ Reference case improvements: only conservative case achieved	+68

Incremental capex ranges between EUR 600 and 750 billion, excluding capex for abatement improvements in reference case

1 Includes steel, cement, chemicals, refining, and other sectors
2 Assumed rate of 18% for every doubling of global capacity
3 Reduction in costs assumed at 1% per annum between 2010 and 2030
SOURCE: McKinsey India Cost Curve model; McKinsey analysis

Considerable investment required

Our analysis shows that the incremental capital expenditure (capex) required over and above the reference case would be about EUR 600 billion to EUR 750 billion from 2010 to 2030 in the abatement case (Exhibit 4.2). Our estimates of incremental capital are based on assumptions about the declining costs of certain technologies such as solar energy and LED lighting. For example, if solar costs decline at half the assumed rate, incremental capex would increase by EUR 40 billion.

This upfront investment translates into 5.2 to 6.9 per cent of the total additional investment expected in the Indian economy at assumed reinvestment rates of around 35 per cent, or 1.8 to 2.3 per cent of India's total forecasted GDP in this period. To put this in perspective, India's total planned investment in infrastructure in the Tenth Five-Year Plan was around 6 per cent of GDP.

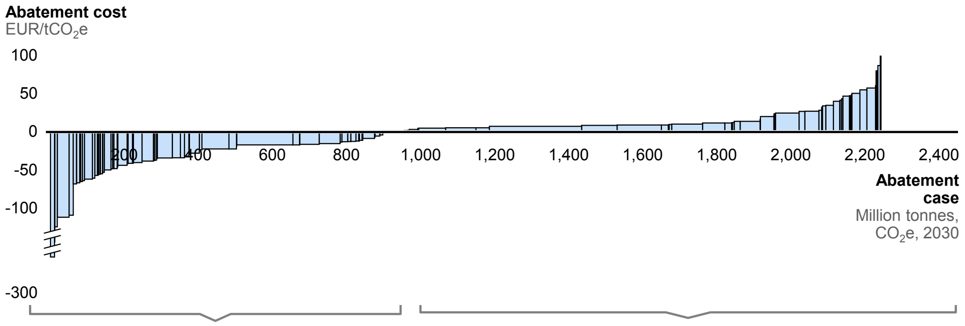
Some of the biggest drivers of the incremental investment are investing in new, more energy-efficient buildings, creating a less oil-dependent transportation infrastructure and building a cleaner power supply based on sources such as solar, nuclear and wind energy. For example, investing in energy-efficient buildings, lighting and appliances would require approximately EUR 170 billion and in clean power approximately EUR 135 billion. Incremental capital of around EUR 130 billion would be needed for setting up less oil-dependent transport infrastructure such as more efficient automobiles and an expansion of railways, and public bus and metro rail systems.

In addition, it is important to understand the timing of the capital requirements. Of the incremental investment of EUR 600 billion, around EUR 180 billion (or about 30 per cent of the total) would be required between 2010 and 2020; the remaining EUR 420 billion would be required between 2020 and 2030. This amounts to about EUR 18 billion annually in the decade starting 2010 and EUR 42 billion in the following decade.

Upfront capital would be required even for opportunities that are “negative cost”.[2] Almost a third of the abatement potential in the abatement case lies in such opportunities. These relate mostly to energy efficiency, and are largely concentrated in buildings, transport, and industry. The fact that these opportunities are potentially profitable to society in the medium to long term does not imply that they are either “free” or simple to capture. Our analysis shows that incremental investment for the negative cost opportunities is likely to be around EUR 230 billion between 2010 and 2030, with the balance EUR 370 billion needed to realise the “positive cost” abatement opportunities (Exhibit 4.3).

Exhibit 4.3

Additional capital need for capturing abatement opportunities by type of cost



Negative cost opportunities

- Upfront capital of EUR 230 billion required between 2010 and 2030
- Implies annual cash inflows of EUR 12 billion[1]
- Largely energy efficiency opportunities in buildings, transport and industry

Positive cost opportunities

- Total additional capex of EUR 370 billion between 2010 and 2030; implies annual cash inflows of EUR 18 billion
- Additional funding of EUR about 26 billion[1] required per year for positive cost levers by 2030
- Renewables, forestry, public infrastructure are key opportunities

1 Excluding taxes, rebates, transaction costs; at 8% interest rate

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

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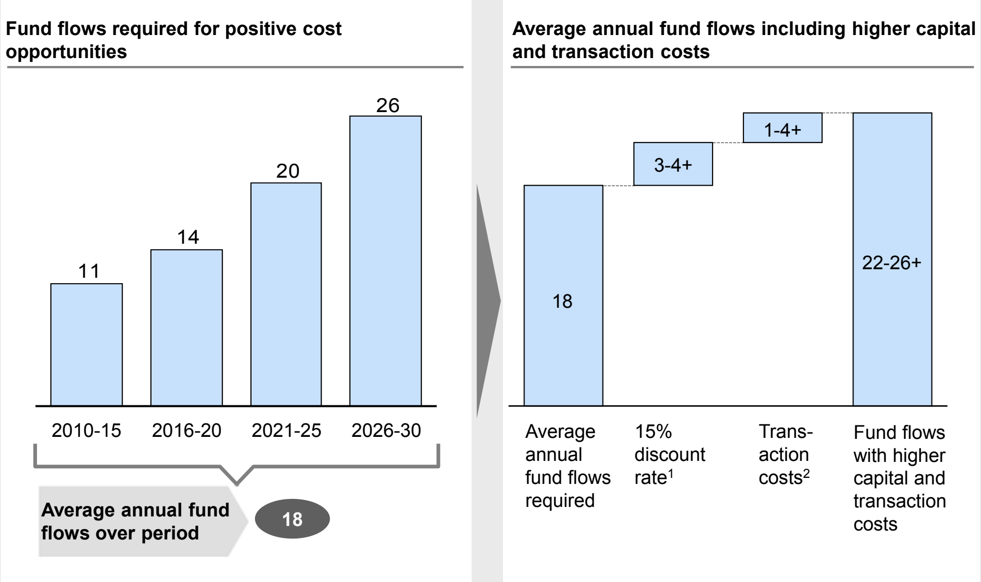
[2] We have classified opportunities into “negative cost” and “positive cost” based on their net project value (NPV) over their lifecycle, using an 8 per cent societal cost of capital. Negative cost opportunities have a positive NPV and therefore result in net economic savings for society. Positive cost opportunities have a negative NPV and therefore require a net investment to be viable.

Exhibit 4.4

Fund flows required for positive cost opportunities

EUR billion p.a.



Fund flows required for positive cost opportunities

Average annual fund flows including higher capital and transaction costs

Note: Cost of adaptation has not been estimated in this study; however, fund flows typically include both mitigation and adaptation.
1 To account for higher cost of capital (societal rate of 8% used)
2 Transaction costs assumed at EUR 1 to EUR 5 per tonne CO_2e of abatement

SOURCE: McKinsey India Cost Curve model; McKinsey analysis

Additional funding for opportunities with a net economic cost

About two-thirds of the abatement potential comes from opportunities that entail a net economic cost to make them viable. These include opportunities such as expanding renewable energy and public transport infrastructure. Making these positive cost opportunities viable would require annual fund flows of EUR 18 billion on average over the next two decades. Fund flows of around EUR 13 billion per annum will be required between 2010 and 2020, and around EUR 23 billion in the next decade. This funding estimate assumes a societal discount rate based on India's cost of capital. However, actual costs would be higher in view of taxes, transaction costs and the actual costs of execution for an individual business (Exhibit 4.4).

Supply and skill concerns

Sourcing the latest technology has been a challenge for India in many areas and the early capacity installation using new technology often ends up being higher cost. Newer technologies will also need to be adapted to Indian conditions. For instance, supercritical coal technologies will need to be adapted to local coal and plants will initially have to be built using more expensive imported equipment and engineering. Furthermore, some technologies attractive in the developed countries could prove unviable for India because of the high cost of capital in the country compared to that in developed economies.

India would need to build new end-to-end supply chains (e.g., nuclear forgings, solar manufacturing) to capture the abatement opportunities at scale. Further, manufacturing capacity created for technologies that are no longer prioritised could be “stranded” (e.g., power equipment manufacturing capacity for coal-based generation). These would need to be re-oriented.

Another barrier to implementation is skill constraints. India will need many more skilled people to implement the abatement opportunities such as engineers and technicians, energy auditors, energy engineers and green building architects. In nuclear power, for example, the needed technical and managerial skills to rapidly construct plants is not widely available in the country today.

Technology uncertainty

The abatement case assumes wide commercialisation of emerging technologies such as solar photovoltaic and CSP[3] and LED lighting, which would reduce their cost. However, these technologies face the typical challenges of uncertainty about adoption and proven efficacy. LED lighting, for example, is an effective replacement for incandescent bulbs and compact fluorescent lighting. The total cost of ownership of LED lighting over 10 years is about 10 per cent[4] of the cost of an incandescent bulb today and is expected to decline further as its luminous efficacy[5] increases and production cost drops through wide commercialisation. However, demand will not pick up till the upfront cost of LED lighting is equitable with other options. At the same time, large-scale commercial production will take place only when large demand exists. In such cases, the government could drive demand, e.g., by using LED lighting for street lights.

Market imperfections

Markets in India and elsewhere in the world do not always have the mechanisms to encourage adoption of climate change imperatives or stimulate the desired behaviour. One issue is that pay-back for such investments could take time, as with the use of high-efficiency automobiles. The cost of buying a more efficient electric or hybrid car, for instance, would be defrayed over its lifetime. Since cars tend to change hands quite fast, people might be unenthusiastic about such an investment when they are unlikely to enjoy the return. Another example of a lack of incentive for investment would be energy-efficient buildings—developers may be reluctant to construct such buildings when tenants, not they, would receive the benefit of lower electricity bills.

Changes to the regulatory and institutional frameworks

A substantial amount of regulatory change would be required to realise the additional abatement opportunities. India would need to carefully weigh these issues and the trade-offs involved. For instance, to realise all the abatement case opportunities, policies would need to be changed for many sectors of the economy including power, appliances, automotives, agriculture, water use and forestry. All levels of government would need to be involved—from central to local.

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[3] Concentrated solar power or solar thermal power.

[4] An LED light consumes about one-tenth the power that an incandescent bulb does while providing the same amount of light, and has a significantly longer lifetime (10 to 15 years) compared to that of an incandescent bulb (typically 1 year). Therefore, even with a high upfront cost, the total cost of ownership of LED lights, including cost of power consumption and cost of replacement, is much lower—around 10 per cent of that of incandescent lights.

[5] Light emitted for every watt consumed.

In some cases, the required regulation is missing or incomplete. As an example, without minimum efficiency standards or incentives for high-efficiency appliances, it is difficult for manufacturers of high-efficiency products to compete with low-cost, inefficient products. After regulation is put in place, a broader institutional framework would be required. The framework would need to ensure consumer awareness of the importance and benefits of high-efficiency appliances, sufficient economic incentive for manufacture of high-efficiency appliances and monitoring of implementation.

Continual increases in energy efficiency in industry, buildings, transport and agriculture would require shaping regulation and creating monitoring infrastructure. For example, to mandate building codes, regulation would have to be integrated with the construction by-laws of individual states, architects and enforcement officers would need to be trained, and a network of monitoring and certification organisations would have to be set up.

OVERCOMING THE CHALLENGES

The challenges described above could be addressed through foresight, conducive policy, and systematic planning. Timely action is critical to maximising impact.

Policy action is required to accelerate impact

Capturing a fair number of the opportunities identified in this study would need to be enabled, even driven, by policy. In many countries, effective policies have helped capture major energy efficiency savings along with economic, energy security and climate benefits. These policies have laid down stringent energy standards for cars, appliances and equipment, strong building codes, renewable portfolio standards and energy-efficiency goals for industry, among other interventions.

In India, policy changes could help overcome market imperfections that impede the realisation of opportunities such as aligning the interests of consumers and companies investing in the opportunities. Technical performance standards and mandatory norms tied to incentives are typically used in many countries as policy instruments to achieve these ends.

A policy on financial incentives could overcome some of the high upfront costs that deter investment in some areas. Policy might also establish institutions or mechanisms to foster the talent needed for the large-scale implementation of many of the opportunities.

A long-term perspective and planning are essential

To achieve the abatement case, India would need to plan now for the long term, as investment choices today in areas such as power and transportation infrastructure will influence its environmental and energy sustainability. For example, with many of the power plants coming up by 2017 already locked-in, there is no latitude to significantly change either the underlying technology or power mix in the short term. Considering that it takes 5 to 10 years to get a power plant from concept to commissioning, depending upon the technology, it is essential to plan now for clean power plants from 2020 onwards. It is also essential to plan for the transition to cleaner energy, e.g., nuclear power, since a supply chain would have to be built from scratch. Also, existing supply chains would have to be designed so that capacity, e.g., equipment for coal-based generation is not "stranded" as capacity creation in these technologies decreases.

Most of the identified potential in the long term, i.e., after 2020, lies in infrastructure projects—clean power sources, new low-energy technologies, efficient public transport and rail-based freight infrastructure. These typically have long gestation periods and many stakeholders. Planning for them could focus on creating the right policy and regulation, and bringing alignment among various stakeholders. It would also be important to integrate these initiatives with current government programmes on infrastructure and development for widespread impact.

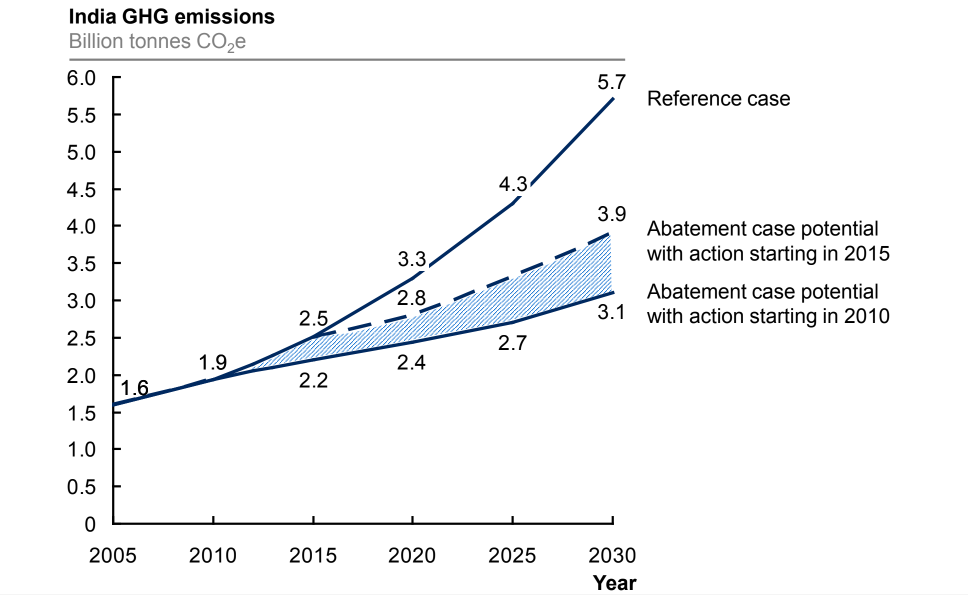
Planning is also required to secure the technology for green energy in the long term. "Seeding" opportunities now, e.g., for emerging technology such as solar energy, LED lighting, IGCC[6], offshore wind power generation, and energy-efficient steel production would ensure that India does not miss the window of opportunity.

Timely action is critical

There is a narrow window of opportunity for capturing the full abatement potential. This is particularly true for buildings, industry and power generation. Over the next 10 years, India will continue to rapidly add to its stock of commercial and residential buildings, expand industrial capacity, and build new power plants. According to current trends, between now and 2020, India is likely to add around 80 GW of coal-fired power plants, 500 million square metres of commercial space and over 25 million cars and 3 million commercial vehicles.

Exhibit 4.5

Likely effect of postponing action for 5 years



SOURCE: McKinsey India Cost Curve model; McKinsey analysis

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6 Integrated Gasified Combined Cycle, a technology that turns coal used for generation into gas, which is more efficient and reduces sulphur dioxide, particulate and mercury emissions.

Most of the energy-efficiency and abatement potential lies in building these assets right in the first place. Retrofitting is difficult and expensive. Acting now rather than five years later could take India onto a different trajectory. As exhibit 4.5 shows, delaying action by five years would add an extra 0.8 billion tonnes CO_2e to India's emissions. In the abatement case described in this report, India's emissions by 2030 would then be 3.9 billion tonnes CO_2e instead of 3.1 billion tonnes CO_2e.

* * *

As this chapter has shown, achieving the abatement case will certainly involve significant challenges. In the next chapter, we explore actions India might consider to minimise emissions.

5: A Proposed 10-Point Agenda

Capturing the abatement potential identified in this report would require action by all levels of government and industry, and by India's citizens. This chapter discusses some of the actions and policies required, although it does not recommend specific ones. There are 10 broad implications for India's leaders—public and private—to consider. In fact, India has already initiated many actions that address some of these implications. The initiatives described in this chapter address opportunities to realise more than three-fourths of the additional abatement potential identified in the abatement case, i.e., a reduction in emissions of 1.5 billion to 2.0 billion tonnes CO_2e[1] by 2030.

While action on several fronts could start with providing enabling policy within about 18 months, much of the execution would be needed in the industries, cities and villages of India. This means that programmes would need to be integrated into the development plans and ongoing programmes of states and cities.

The proposed energy-efficient growth trajectory is as follows:

1. **Catalyse energy-efficiency programmes in appliances, buildings, industry, transport and agriculture**: As mentioned earlier, energy-efficiency measures outside the power sector could collectively reduce electricity demand in India by 20 per cent[2] and oil demand by an equivalent amount, greatly shrinking India's energy bill. Measures in this category could also reduce emissions by as much as 0.8 billion tonnes CO_2e.

   Increasing energy efficiency would require action across a number of areas, many of which are being addressed by government agencies such as the BEE[3], or the Petroleum Conservation Research Association (PCRA).[4] The actions required would include:

   — **Introducing technical norms and standards for buildings, appliances, vehicles and pump sets.** This could include mandating recently launched Energy Conservation Building Codes more widely and integrating them with construction by-laws, implementing fuel efficiency standards for all classes of automobiles, and expanding the scope and coverage of the current labelling programme to all appliances and electronics including electric and diesel pump sets.

   — **Providing incentives for increasing energy efficiency.** Extra floor space for developers or a service tax rebate on leases for certified green buildings are some incentives that

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[1] CO_2e stands for "carbon dioxide equivalent" and is a standardised measure of greenhouse gases. Emissions are measured in metric tonnes of CO_2e per year, i.e., millions of tonnes (megatonnes) or billions of tonnes (gigatonnes). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from human activity, in our estimates.

[2] Efficiency improvements in the power sector such as reducing technical losses and auxiliary consumption would reduce demand by another 5 per cent.

[3] Bureau of Energy Efficiency, Ministry of Power, Government of India.

[4] Under the Ministry of Petroleum and Natural Gas, Government of India.

could motivate the development of more energy-efficient buildings and stimulate demand for them. For appliances, pumps and other equipment, India could also consider tiered excise duty structures to reduce price differentials with less energy-efficient devices.

— **Introducing energy-efficiency targets and tradable energy-efficiency certificates for industry**. Energy-efficiency targets could be mandated for industry and tradable energy-efficiency certificates established as a means of accelerating efficiency in industry.

— **Promoting new business models (e.g., Energy Service Companies or ESCOs) that support energy efficiency and accelerate energy inclusion**. India could adopt ESCO models prevalent elsewhere in the world (e.g., for energy supply and use in buildings, industry and rural areas). This is particularly necessary when market mechanisms fail, e.g., when builders delay investment in energy-efficient buildings because tenants, not they, will receive the benefits, or where widespread adoption is required. It would also help encourage private enterprise to provide integrated energy solutions to rural India across technologies such as efficient cooking stoves, solar energy and biomass-based power.

— **Implementing time-of-day tariffs**. This is another demand-side measure that could shift peak demand to off-peak hours, reducing the need for expensive peaking capacity. If this is done early enough, India's infrastructure and demand patterns will develop accordingly. An example would be using water heaters that work on cheaper power in the middle of the night and store water for use in the morning, thus shifting the time at which power is consumed.

Initiatives across the globe to promote energy efficiency

Many countries have implemented successful energy-efficiency programmes in sectors such as buildings, appliances and transport. The United States (particularly California), Japan, and Singapore are leaders in this regard. Some features of their programmes are:

Demand side management: California's electricity tariff for residential customers has a tiered structure, with the highest consumption tier nearly twice as expensive per kWh as the lowest tier. For commercial customers, California also offers differential rates for peak vs. off-peak consumption.

Incentives for selling energy-efficient products and services: California's residential lighting programme offers rebates to manufacturers and retailers for high-efficiency appliances and electronics.

Exchange programmes: The Spanish government has a programme to provide efficient appliances to households at reduced prices in exchange for their old appliances.

Standards and labelling programmes for appliances: The Japanese government's Top Runner programme obliges manufacturers of appliances and motor vehicles to increase energy efficiency to the level of the most efficient products in the market. As a result, in the last two decades, energy consumption per refrigerator has halved while the average refrigerator size has doubled.

Minimum standards, support and monitoring: The Japanese government has mandated energy audits and disclosures for industry. California has building codes that dictate insulation; heating, ventilation and air conditioning control; windows; lighting and appliance standards. California and Germany provide an interest rate subsidy for certified energy-efficient residential buildings. Japanese government agencies appoint an energy management officer for all large buildings to create an energy rationalisation plan and support/monitor implementation.

Role of utilities: Californian utilities provide training for local code-compliance officials, architects, and engineers to ensure compliance with the state's building standards. They also bear part of the upfront cost by buying energy-efficiency certificates.

Energy service companies: The German government supported the formation of the Berlin Energy Agency, which organises retrofits of large buildings so that building owners face no upfront costs of renovation.

2. **Accelerate the addition of nuclear capacity**: The nuclear capacity envisaged in the abatement case could reduce emissions by about 250 million tonnes CO_2e. Managing time delays, which is a major risk in nuclear projects, would be crucial. Nuclear plant commissioning could be speeded up by:

   — **Standardising nuclear reactor designs and equipment and indigenising supply chains** (e.g., for castings and forgings)

   — **Enhancing engineering and technical skills** by expanding curricula in relevant fields

   — **Considering opening up nuclear generation to India's private sector** as is common in many parts of the world.

3. **Encourage the addition of peaking hydro power capacity**: Hydro power capacity addition in India has generally been slow. It could be accelerated by following the model used for ultra-mega power projects: developing hydro projects and bidding them out. Resettlement and rehabilitation and host-state prerogative issues will need to be addressed. Also, building hydro power that serves peak demand would require stable and higher paying markets to compensate for the higher cost of stored hydro power, as discussed in action 5 below.

4. **Scale up the addition of renewable energy beyond wind power, particularly solar energy.** A greater supply of renewable energy could reduce India's reliance on imported fossil fuel, match power supply to peaking needs and reduce emissions by more than 150 million tonnes CO_2e. The following actions could be considered:

- **Enabling policy for generation**, including regulatory mechanisms, financial incentives and demonstration projects to build momentum. Regulatory procurement obligations (RPO) and feed-in tariffs for renewable power could be considered. Demonstration projects could include a government solar rooftop programme for photovoltaic technology and utility-sized developments for concentrating solar power (CSP) plants. Policies would need to be flexible to adapt to the uncertain technology advancement. Substantial resources would need to be mobilised, perhaps through a sectoral resource-raising effort.
- **Enabling policies for manufacturing**, particularly for solar equipment and installation. Domestic demand could be leveraged to establish a large solar equipment and installation services industry in India. India is well positioned for this skill-intensive manufacturing and could become a major, low-cost global supplier like China.
- **Policies that encourage exhaustive resource mapping** for solar, offshore wind and geothermal energy across the country would enable faster growth of these sectors. The government could consider policies similar to those for mineral exploration and development, besides direct investment in R&D.

Realising India's solar potential

India has abundant solar resources. Harnessing solar power could help India meet daytime power peak requirements and also evening peak demand with three to four hours of storage. India has the potential to create an installed solar capacity of about 60 GW by 2030.

Demand could be stimulated by promoting solar power to three markets—utilities, individuals and organisations (self-consumption and grid-tied rooftop systems for commercial/institutional buildings) and rural areas (rural electrification).

This would require action on the following fronts:

Regulation: Backed by legislation on renewable energy with solar-specific renewable portfolio standards combined with feed-in tariffs to kick-start local demand.

Demonstration projects: Including rooftop programmes to encourage adoption of solar photovoltaic technologies for distributed generation and utility-sized demonstration projects for large-scale technologies such as concentrating solar power.

Physical infrastructure: Including solar generation parks, grid connection priority and insolation data.[5]

Funding: Realising the potential of solar will require huge investment and therefore call for multiple sources of funding.

Manufacturing: Solar manufacturing parks, supported by incentives for both solar photovoltaic and solar thermal technologies.

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[5] Solar radiation energy received on a given surface area in a given time.

5. **Develop a more responsive power sector**: More efficient coal-based generation, distribution reform to cut transmission and distribution (T&D) losses and efficient solutions for peaking power could lower emissions by more than 300 million tonnes CO_2e in the abatement case. The following actions could be considered:

   — **A special focus on "cleaner" coal technologies**: This would require an increase in the efficiency of existing coal-based generation, and ensuring that new plants installed are more energy-efficient. One way of achieving this could be to make this a focus area of one of the NAPCC missions.

   — **Reduce technical T&D losses**[6]: This would require energy accounting to isolate technical losses, separating agricultural feeders, partial or complete privatisation of distribution circles in tier I and II cities, setting multi-year loss reduction targets for distributors and implementing modern technologies such as high voltage DC transmission lines.

   — **New policies that encourage peaking power:** Building power that serves peak demand would require stable and higher paying markets to compensate for the higher cost of peaking power (e.g., gas-based power, stored hydro power or solar power) while reducing peak demand. Such policies could include the creation of a well-functioning wholesale electricity market, with multi-year differential peaking tariffs (time-of-day-tariffs) to encourage capacity creation.

   — **Ensure gas supply for peaking power**: Gas-based plants (closed cycle) are effective for serving non-base demand. Even better at meeting peaking needs are gas engine-based, modular, decentralised plants that provide both electricity and cooling. These could be used for large commercial and industrial installations. Gas allocation for these peaking assets from existing sources, LNG projects and regional pipelines could be prioritised.

6. **Build energy-efficient freight transportation infrastructure**: Increasing the share of rail in freight transport from less than 36 per cent in the reference case to 45 per cent and maintaining the share of coastal shipping at 7 per cent could lower emissions by over 40 million tonnes CO_2e and reduce diesel consumption by more than 20 per cent. This would require a National Integrated Logistics Policy that directs investments into 6 to 8 long-distance water and rail corridors, 15 to 20 interchange points (logistics parks), and many 100 km- to 300 km-long expressways. Several new national projects, across modes, would be needed (e.g., "last mile road", "last mile rail", "tolling standards", "national corridor", "logistics parks"). This entails collaboration across many ministries and may require an empowered inter-ministerial body to ensure implementation.

7. **Promote energy-efficient urbanisation**: A priority could be lowering the emissions-intensity of Indian cities by 150 million to 200 million tonnes CO_2e through:

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[6] Losses in transmission or distribution (e.g., at transformers) that are not commercial in nature. The number for actual technical losses is not reported, though experts estimate these at 15 to 19 per cent currently. Hence we have assumed 17 per cent in our analysis.

- **Integrated urban planning** with sustainability as one of the key design parameters. This could include cluster development, enabling a greater number of people to walk to work; densification of cities through taller buildings that helps reduce the vehicle miles travelled; and implementation of a city-level energy census with incentives linked to improved energy efficiency.

- **Improved city transportation by implementing an integrated public transportation** plan with metro railways for the top-9 cities and bus systems for the top-250, smart traffic management systems that help reduce congestion, and policy, for example, on congestion charges and car pooling.

- **Other actions** such as upgrading power distribution to smart grids that reduce distribution losses and shift peak demand periods, LED street lighting and green buildings that reduce energy consumption at a city level.

8. **Improve agricultural practices and technology**: The adoption of sustainable agricultural practices could be facilitated. Practices such as shallow flooding, reduced tilling, systemic rice intensification and drip irrigation have multiple benefits in improved yield and reduced water consumption and could lower greenhouse gas emissions by over 200 million tonnes CO_2e.

9. **Promote afforestation and deforestation**[7]: To expand the carbon sink by over 200 million tonnes CO_2e, India could improve forest cover and forest quality by promoting successful afforestation and forest management models. One way to do this could be to promote agro-forestry by providing the right incentives to farmers to use marginal wastelands, long fallows and degraded pasturelands for agro-forestry.

10. **Proactively create intellectual property in "clean-technology"[8] and manufacturing capability**: India could consider creating a fund that would support R&D in multiple clean-technology areas including solar energy, energy-efficient appliances and energy for rural areas. There could be a thrust on seeding companies specialising in clean technology and on supporting technologies related to energy efficiency. In addition to the initiatives outlined above, India could aim for global leadership in two to three clean-technology industries. With India's research prowess, manufacturing capabilities and large domestic market, and with the wave of investments around the globe in new clean technologies, India could become the manufacturing or services hub for such technologies. These could include solar energy, LED lighting, electric vehicles and smart grids.

The government could initiate (and in many cases complete) actions described in this chapter within about 18 months. Some of the actions described could be integrated into ongoing programmes. Additionally, state and local governments would need to participate in implementing the agenda. To start with, they could develop their own energy-efficient growth plans within this

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[7] Potential actions for agriculture and forestry need to be further developed. They have not been studied in detail in this report.

[8] Clean technology refers to a range of products and services that use renewable materials and energy, curtail the use of natural resources and cut emissions and waste.

period. For example, a Himalayan state like Himachal Pradesh could choose to focus on energy inclusion in rural areas, peaking hydro-power and clean-technology industry. On the other hand, an industrialised state like Gujarat could focus on solar and nuclear power, leadership in energy-efficient industry and energy-efficient logistics infrastructure. Most states would need to promote initiatives for sustainable urbanisation.

Over time, the institutional capability to implement and monitor plans, which the centre, state and cities would develop, would also need to be created.

* * *

The agenda described in this chapter is an ambitious one and executing it would take significant effort and investment. It promises dividends for India in the form of enhanced energy security, increased environmental sustainability and leadership in select clean-technology industries—aspirations worth pursuing.

Appendix
Scope and Methodology

The purpose of this report is to facilitate the definition and prioritisation of economically feasible solutions to the challenges of energy security and environmental sustainability that India faces.

The study estimates greenhouse gas (GHG) emissions from the 10 largest emitting sectors till 2030 based on assumptions of growth in these sectors. It further assesses over 200 technologies that reduce emissions and increase energy efficiency, with a special focus on five areas: 1) power; 2) emissions-intensive industries (including steel, cement and chemicals); 3) transportation; 4) habitats (including residential and commercial buildings and appliances); and 5) agriculture and forestry.

Our analysis is not intended to serve in any way as a forecast or target for reducing greenhouse gas emissions. The results of our work are based on many underlying assumptions that we have highlighted in the various chapters; whether these assumptions are borne out depends on many external factors.

The report does not attempt to address broad policy questions with regard to the regulatory regimes or incentive structures the Indian government might consider. While we discuss the implications of our findings and a potential 10-point agenda, the report does not endorse any specific legislative proposals or mechanisms to mitigate the impact of climate change. Neither is its purpose to present opinions or advice on behalf of any party, nor does the report endorse any specific proposals or frameworks for a global agreement on climate change.

The study methodology builds on McKinsey's research into climate change abatement over the past three years in 19 countries (Exhibit A1). At the core of this report is an analysis of the potential and the costs of over 200 technologies to increase energy and environmental sustainability. We selected those technologies likely to have the highest impact in India. Our model is a microeconomic model that performs a bottom-up analysis of additional abatement potential of these technologies and aggregates them in order of merit, or increasing order of cost of abatement.

To reconcile the different units of measurement involved in the technologies and develop a consistent view, we adopted GHG emission[1] reduction (abatement) as a proxy for improving energy and environmental sustainability. GHG abatement is measured in tonnes of CO_2e and the cost of reducing GHG emissions in Euros (EUR) per tonne of CO_2e.

Our analysis evaluates each technology / technique in terms of its abatement potential (i.e., how many tonnes of CO_2e emissions it could cut) and abatement cost (i.e., how much it would cost to reduce every tonne of CO_2e). In addition, in some technologies, we also considered the impact of the abatement options on energy, pollution or the ecosystem, particularly when the CO_2e abatement potential or cost alone did not provide the whole picture, e.g., in public transportation. Since it is difficult to quantify such these benefits, we have highlighted them as co-benefits and based our recommendations on both quantifiable and non-quantifiable benefits.

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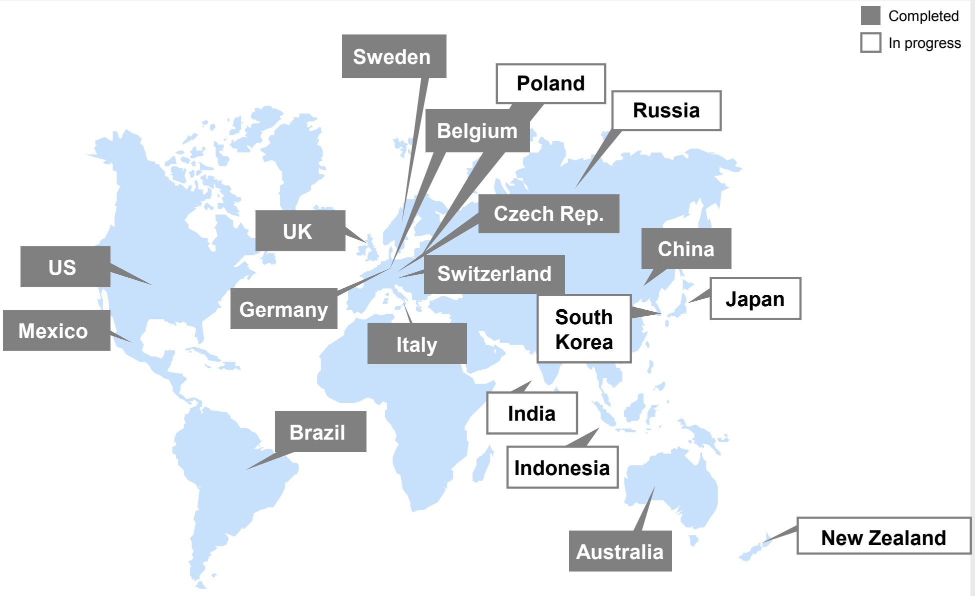
[1] CO_2e stands for "carbon dioxide equivalent" and is a standardised measure of greenhouse gases. Emissions are measured in metric tonnes of CO_2e per year, i.e., millions of tonnes (megatonnes) or billions of tonnes (gigatonnes). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from human activity, in our estimates.

A1: Similar studies are in progress or already completed in 19 countries

AS ON JULY 2009



To estimate the potential and the costs of the various abatement options to reduce or prevent GHG emissions, we defined and quantified two GHG emission scenarios for India from 2005 to 2030: a "reference" case, and an "abatement" case.

The reference case: Building on McKinsey's extensive study of a range of Indian industries and the research findings of leading Indian institutes and experts, the reference case is a bottom-up analysis of GHG emissions sector by sector for the most important sectors: habitats (including buildings and appliances), transportation[2], industries (particularly steel and cement, including oil & gas and chemicals), power, forestry, and agriculture. The reference case assumes reasonable technological development across all these industries and includes a range of mature, proven technologies since we believe that product quality and the efficiency of industrial processes will continue to increase in India in the coming decades.

The abatement case: The abatement case identified additional feasible technical potential up to 2030 based on these technologies, most of which are well understood and likely to be commercially available in the future. It also takes into account the likely evolution of living standards and consumer preferences as income levels rise in India, and does not consider potentially disruptive changes due to concerns about climate change or fuel price changes (Exhibit A2).

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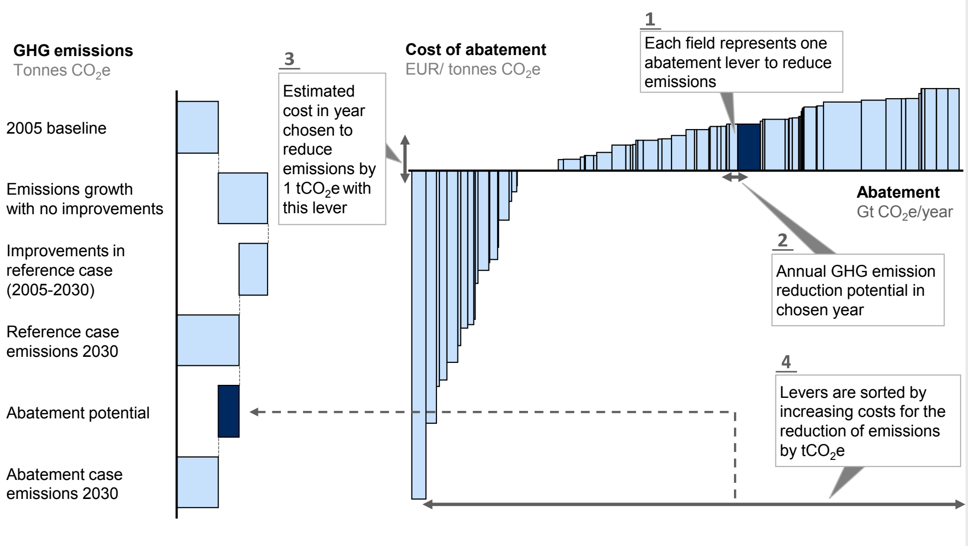
[2] Including emissions from the combustion of oil products in internal combustion engines of road vehicles across all industries, but excluding other energy consumption normally covered in the transportation sector by Indian statistics. Aviation and sea transport not included.

A2: Abatement potential and cost assessed relative to a reference case



SOURCE: McKinsey Global GHG Abatement Cost Curve v2.0

To reach the abatement case, we estimated the technical potential of each additional abatement option to reduce emissions below the reference case figure by 2030, given the right conditions including optimal government support, the applicability and maturity of the technology, and the required supply and talent. We then calculated the incremental resource costs compared with the reference solutions by applying the formula depicted in Exhibit A3.

This cost is incremental to the reference case costs and does not include transaction, and administration costs (Exhibit A4).

Next we quantified the potential and the cost of each option in clusters: clean power, energy-efficient industry (including steel, basic chemicals, cement and refining), green transport infrastructure, sustainable habitats (including buildings and appliances), agriculture and forestry. Additionally, we clubbed together indirect emissions (due to electricity consumption) in other manufacturing sectors not covered under the detailed assessment and made a high-level assessment of the potential to increase electricity efficiency. We refer to this grouping as “other sectors” in our analysis.

A key result of this analysis is the greenhouse gas abatement cost curve for India, which builds on McKinsey’s global cost curve, a technology-by-technology mapping of all major emission reduction opportunities across all relevant sectors and world regions. The curve displays the abatement options from lowest to highest cost and presents each industry’s abatement curve in an integrated fashion to eliminate any double counting. The industry abatement curves represent

A3: Formula for calculating abatement cost

$$\text{Abatement cost} = \frac{[\text{Full cost of } CO_2e \text{ efficient alternative}] - [\text{Full cost of reference solution}]}{[CO_2e \text{ emissions from reference solution}] - [CO_2e \text{ emissions from alternative}]}$$

$$\text{e.g., Fuel efficient vehicle abatement cost} = \frac{[\text{Cost of fuel efficient car + running costs}] - [\text{Cost of standard car + running costs}]}{[CO_2e \text{ emissions from efficient car}] - [CO_2e \text{ emissions from standard car}]}$$

Full cost **includes…**

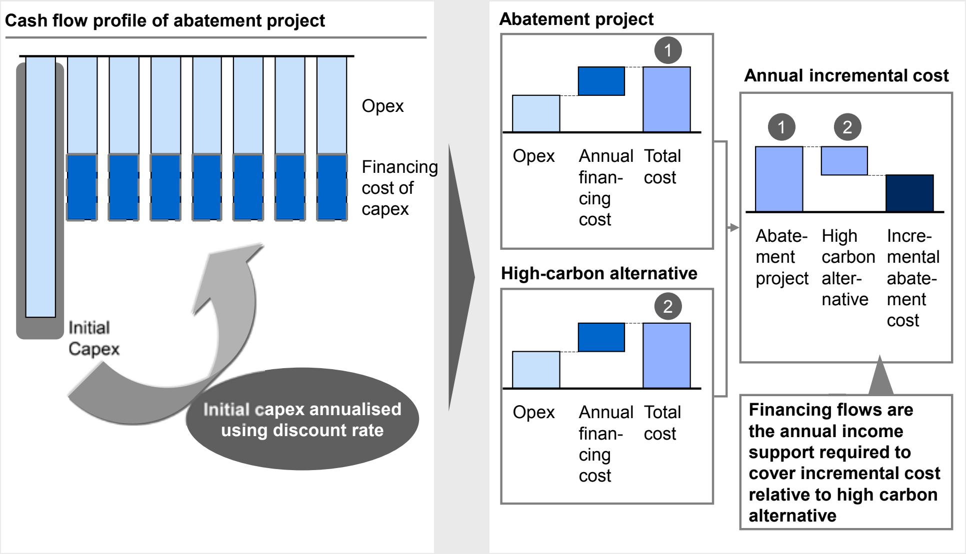
- Investment costs calculated with economic amortisation period and capital costs (like loan repayment)
- Operating costs, incl. personnel/materials costs
- Possible cost savings generated by actions (especially energy savings)

Full cost **does not include…**

- Transaction costs
- Communication/information costs
- Subsidies or explicit CO_2 costs
- Taxes
- Second-order impact on the economy (e.g., how price changes will affect relative sizes of sectors)

SOURCE: McKinsey Global GHG Abatement Cost Curve v2.0

A4: Abatement cost is defined as the incremental, annual cost relative to the high carbon alternative



Financing flows are the annual income support required to cover incremental cost relative to high carbon alternative the estimated feasible technical abatement potential of each option and the realistic resource costs of implementing them. Hence, each abatement curve provides fact-based support to prioritise the various abatement techniques in an industry.

To assess costs on a societal basis, we calculated the net resource costs of an abatement option by analysing incremental initial investments, operating and maintenance costs, replacement costs, leaving out costs relating to energy efficiency or other benefits. To account for the difference in time between the initial investment and the savings achieved, we assumed an 8 per cent discount (on interest) rate. From a "decision-maker's perspective," a higher discount rate would be needed. This would increase the cost estimates of most of the abatement options, particularly those with high upfront capital investment needs.

The additional funding requirements for opportunities with a net positive economic cost of abatement were calculated by comparing the operating and financing costs of individual abatement opportunities and their reference case alternatives. The extra cost, if any, of the abatement opportunities is represented by the difference between the two (Exhibit A4).

Our findings are not meant to be an exhaustive estimate of the GHG emissions abatement potential in India. Rather, they represent the "feasible technical" limit of the potential of the abatement options analysed. There would be additional abatement potential in other sectors of the national economy. Unforeseen new abatement solutions could also emerge in the sectors analysed.

Constraints on our analysis are as follows:

- A focus on emissions produced and energy consumed by human activity within the borders of India, without a detailed analysis of the impact of "imported" or "exported" GHG/energy.

- No assessment of the impact of abatement options on energy prices and consumer behaviour, or of energy price changes on abatement options adopted or included in cost.

- Analysis of technologies with predictable cost and development paths, separating "credible" technological options from "speculative" ones. Our perspective is based on evidence of maturity, commercial potential, and the presence of compelling forces at work in the marketplace:

  — Approximately 80 per cent of the potential identified in the abatement case involves technologies already at commercial scale. Any uncertainty associated with them relates mainly to issues of execution.

  — Technologies providing about 20 per cent of the total potential in the abatement case are likely to reach commercial scale by 2030, based on the views of experts. These include solar PV and CSP, carbon capture and storage, cellulosic biofuels, ICE fuel-efficiency improvement measures, plug-in hybrid vehicles and light-emitting diode lights.

  — Conservative assessments of future technologies. Our analysis does not include the "disruptive" effects of changes such as important breakthroughs in processes and technology, likely in the next 20 to 25 years, or innovation to reduce emissions and conserve energy.

This analysis/model also does not quantify positive and negative externalities including:

- Social costs or benefits associated with increasing energy and environmental sustainability (e.g., the cost of adapting to or the benefits of avoiding the adverse consequences of climate change).
- Environmental and other benefits from the development of a more sustainable economy (e.g., reduced healthcare costs thanks to lower air pollution). These considerations were qualitatively integrated into our findings.
- The social, structural and transactional costs of specific abatement options (beyond direct capital, operating and maintenance costs) as affected by policy. Our focus was on "techno-engineering" or "resource" costs, without any assessment of welfare costs (e.g., due to structural unemployment) or costs related to regulation or compliance.

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