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Environmental and Energy Sustainability: An Approach for India

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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.

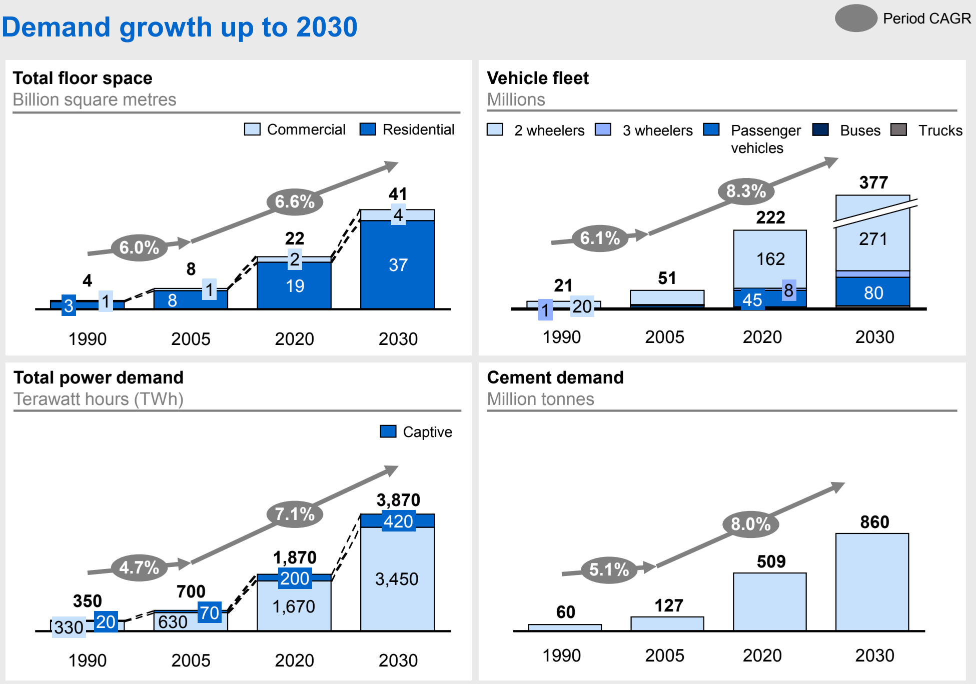
Economic growth will drive up demand in all sectors. Demand for power is likely to increase more than five-fold, from 700 terawatt hours (TWh) in 2005 to 3,870 TWh[13] by 2030. Demand for building stock and infrastructure is expected to grow at the same rate, increasing annual demand for cement to 860 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.

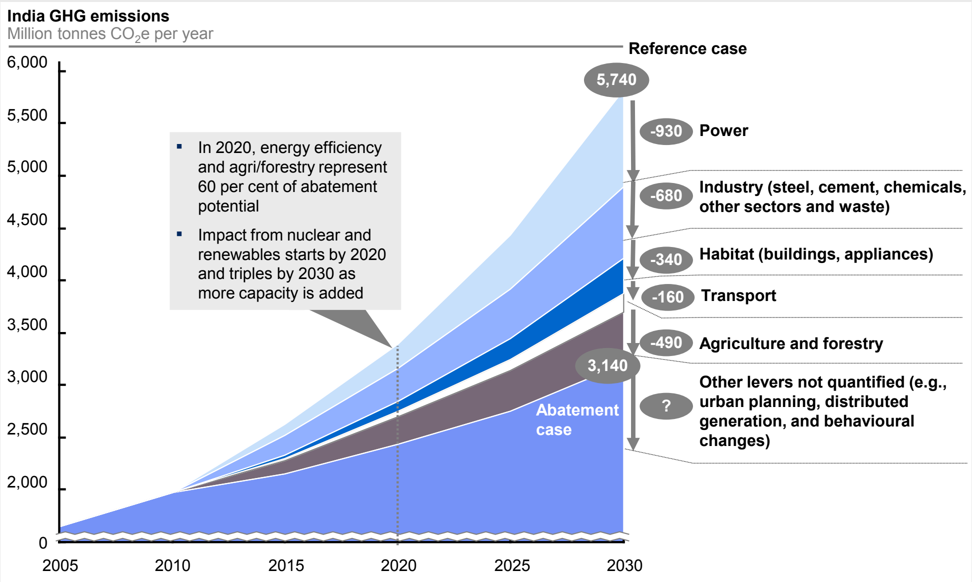
To develop the abatement case, we assessed about 200 opportunities that reduce energy consumption and carbon emissions in the 10 largest consuming and emitting sectors in India.[19] For each opportunity, we analysed the abatement potential (emission reduction potential) and the cost of abatement (for 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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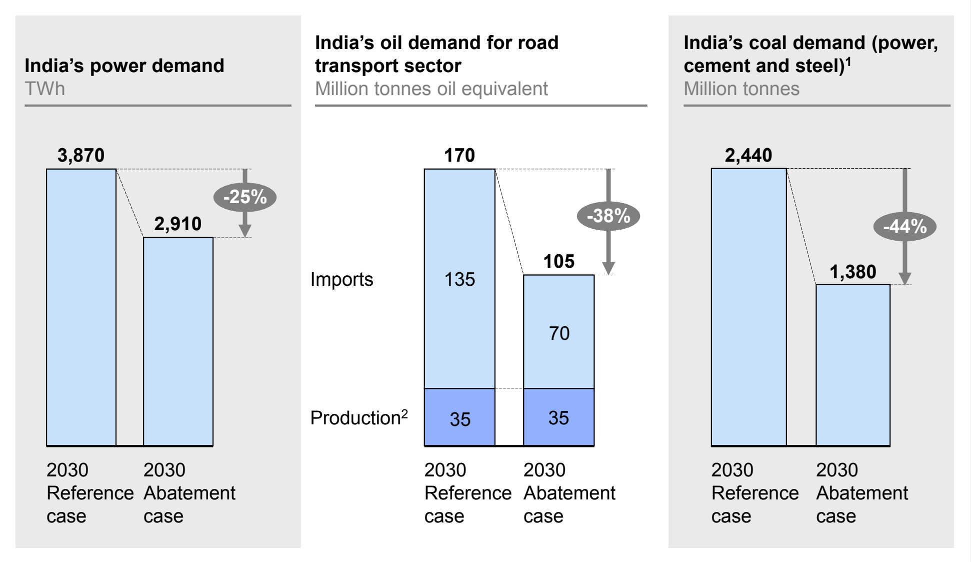
[24] Heating, ventilation and air-conditioning.

[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

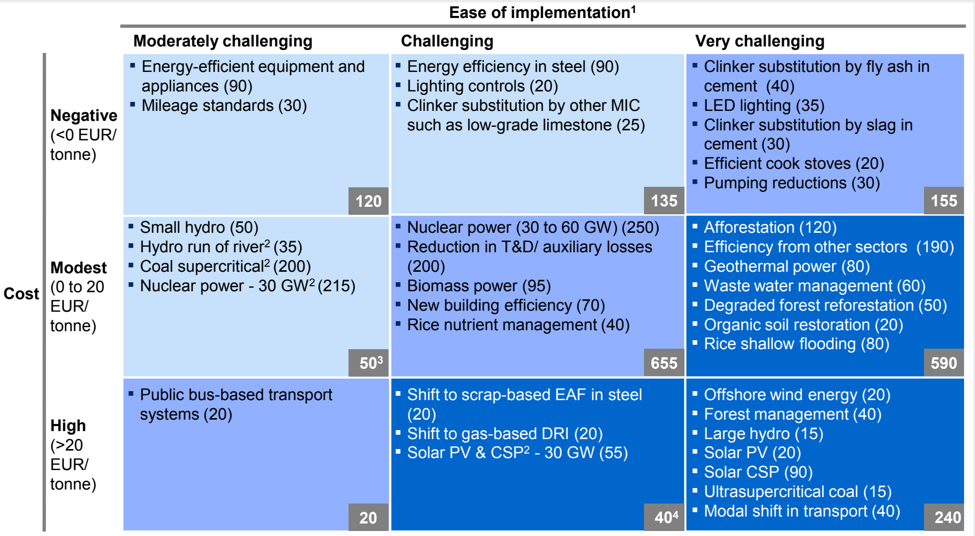
Analysis suggests that only 10 per cent of the additional abatement potential identified is readily achievable (Exhibit 4). Moreover, in thinking about tackling the challenges involved, it is important to recognise that long-term planning and timely action will be critical.

Exhibit 4

Feasibility of capturing abatement potential

Abatement potential in million tonnes CO_2e, 2030

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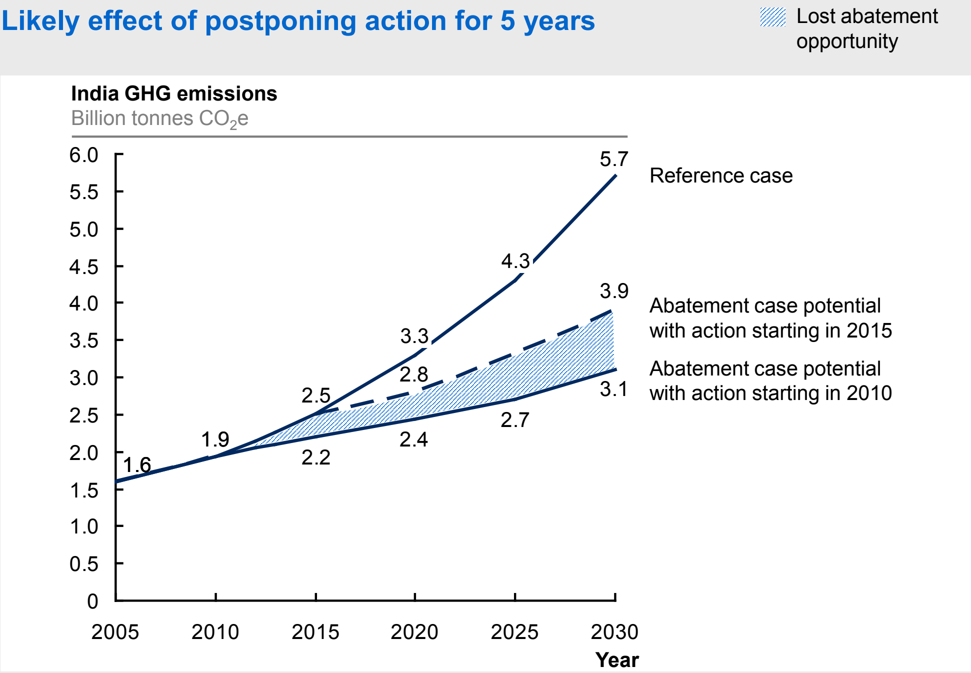
[27] These additional funding estimates do not include taxes and subsidies or transaction costs and are calculated at a societal discount rate of 8 per cent, which means the actual cost of implementation will be higher.

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.

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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.