Turning a Liability into an Asset: Landfill Methane Utilisation Potential in India

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International Energy Agency

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- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

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Introduction

Solid waste disposal sites are not often seen as opportunities for energy solutions. The waste that is disposed in open dumps and landfills generates methane and other gases as it decomposes, causing concerns about explosions, odours, and, increasingly, about the contribution of methane to global climate change. However, the liability of landfill gas (LFG) can be turned into an asset. Many countries regularly capture LFG as a strategy to improve landfill safety, generate electricity, reduce greenhouse gas emissions, and to earn carbon emission reduction credits (e.g. 40% for the United States, 25% for Australia). Many projects in developing countries are taking advantage of the United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) to earn carbon credits by capturing and combusting methane (e.g., the Sudokwon Landfill in Republic of South Korea, the Bandeirantes Landfill in Brazil and the Nanjing Tianjingwa Landfill in China). These Landfill Gas to Energy (LFGE) projects provide a valuable service to the environment and a potentially profitable business venture, providing benefits to local and regional communities.

This International Energy Agency report aims to show that LFGE is a viable source of electricity for India and presents an opportunity to turn a liability into an asset. India does not currently have operational LFGE projects, several projects are now in the initial stages of planning and testing. This study concludes that appropriate landfill management practices and government subsidies will be required to take full advantage of the LFGE resource. Section I outlines the current situation in India regarding energy, waste management practices and climate change. Section 2 explores the possibilities and barriers for planning, funding and running LFGE projects, with an emphasis on potential mechanisms that may be needed to start this new industry in India. Section 3 concludes with recommendations for future action.

IEA Energy Sector Methane Recovery and Use Initiative

In July 2005, the G8 heads of state asked the IEA to map out a “clean, clever and competitive energy future.” The IEA responded with a broad array of initiatives including:
- Alternative energy scenarios and strategies
- Renewable energy
- Enhanced international cooperation

The IEA’s Energy Sector Methane Recovery and Use Initiative relates to these G8 initiatives by helping to reduce short-term greenhouse gas emissions in a cost-effective manner. It also fosters international coordination on research and development, and promotes sound energy policies and practices on a global scale.

For more information, visit www.iea.org/textbase/subjectqueries/methane.asp.

Section 1

Benefits of capturing methane from landfills

Landfill gas can be captured and utilised in a number of ways. LFG contains between 40-60% methane, which is a useful fuel. It can used to drive a gas turbine to generate electricity. It can also be used directly in boilers of nearby industry to provide heat or to power mechanical processes. It can also be purified and fed into the local natural gas distribution system.

Management of LFG has other local benefits. LFG is a cause of unpleasant odours, and creates a fire and explosion risk. There are cases of buildings near landfill sites being destroyed by explosions when methane concentrations exceeded dangerous levels. At the Hyderabad site in India (see section on current projects in India) evidence of fires was visible. In addition, collecting and combusting LFG reduces the risk of contamination of local water supplies via leachate runoff.

The challenge of climate change is one of the most serious problems facing the world today. Methane is the second most important greenhouse gas (GHG) after carbon dioxide; the main sources to the atmosphere are naturally occurring wetlands, agriculture, the energy sector, and landfills and waste (see section on GHG emissions below). Methane from waste management activities is a relatively small contributor to global warming (around 3% of the total anthropogenic GHG emissions (IEA 2008)), but the nature of the climate change issue is that all viable avenues to reduce emissions should be taken. In addition, with appropriate frameworks in India, near-term reductions of methane have the potential to be profitable.

Waste collection and disposal practices in India

An important factor determining the viability of LFGE projects is the way in which municipal solid waste (MSW) is collected, sorted and processed. In rural areas, a majority of solid waste is recycled, with most of the biodegradable material used as animal feed or fertilizer for farms. In India's urban areas the situation is the reverse, where a large majority of MSW is dumped in non-managed open dumps. Between 50-90% of the 42 million tonnes of urban waste produced in India each year is collected and dumped into uncontrolled open landfill sites without sorting, with the remainder left to decompose in streets and drains or dumped illegally in unmanaged sites (Zhu et al. 2007). Around 50% of the MSW is biodegradable (Table 1). Generation of MSW is around 0.2 kg/capita/day in low population density areas, and 0.6kg/capita/day in large urban areas (data from CPCB and NEERI). With the rapid increase in the population living in urban areas, the volume of MSW is likely to increase considerably. (Zhu et al. 2007)

Due to a high proportion of food scraps, and the warm, wet climate, the rate of MSW decomposition in India is faster than in landfills in developed countries (e.g., the United States, Australia and the United Kingdom). The rates of methane flow can therefore be expected to peak shortly after a landfill is closed, and afterwards rapidly decrease. Due to the high rate of MSW decomposition, only large landfill sites will be able produce methane at a high level over a long period of time to be able to support a power generator. At smaller sites, if appropriate industry in located nearby, direct use of LFG in boilers or other equipment is likely to be a better option.

TABLE 1: PHYSICAL COMPOSITION OF MSW IN URBAN AREAS (%)

Type	1996	2005
Biodegradables	42.2	47.4
Paper	3.6	8.1
Plastic/rubber	0.6	9.2
Metal	0.5	0.5
Glass	0.6	1.0
Rags		4.5
Other		4.0
Inert	45.1	25.1

Source: Improving Municipal Solid Waste Management (Zhu et al, 2007)

Organic waste dumping ban in India

In 2000, recognizing the environmental problems associated with MSW, the Ministry of Environment and Forests notified a new set of rules under the Environment Protection Act 1986, (the Municipal Solid Waste Rules 2000) governing MSW collection, transport, processing and disposal. The rules require a major restructuring of waste collection and processing. The rules require that all organic waste be sorted and processed separately and not be dumped into landfills, with the goal of reducing methane production in landfills. To date, few municipalities have made significant progress in implementing the new rules (Ministry of the Environment and Forests, 2000).

Further, the experience from other similar countries shows that even with advanced MSW collection and processing, considerable amounts of biodegradable material continue to be dumped into landfills (M2M national reports). Recognising the difficulties in monitoring and enforcing this ban, the Ministry is considering revising the rule. Even if future MSW is less rich in organic material, current landfills sites rich in organic material will continue to generate methane for considerable time (10-30 years), although the methane production decreases significantly with time, meaning the potential for methane capture will remain for at least one or two decades.

Opportunities and challenges for LFGE in India

LFG can be captured by a system of vertical wells drilled into the landfill or open dump, connected to a blower which creates a partial vacuum to draw the LFG out of the landfill before it escapes to the atmosphere. The wells are connected by pipes that bring the LFG to a central point. The LFG is then dried and cleaned before being used to drive a generator to create electricity, to fuel local industry, or purified further and used as natural gas. Any excess gas produced should be combusted using an enclosed high temperature flare. Some smaller CDM projects use flaring only, which reduces greenhouse gas emissions, but does not produce useful energy.

There are some risks when building and running an LFGE project, such as the potential for exposure to high concentrations of methane at the well heads during construction, or for accidents related to the electricity generation and flaring equipment. However, with proper management procedures, these risks can be kept to a minimum and do not detract from the overall benefits.

Ideally, it is best to plan for LFG capture in the original design of the landfill by sealing the base of the landfill, filling the landfill cell by cell, and capping each cell as it is filled. However, due to the current MSW disposal practice in India of utilising open dumps, the LFGE candidates are sites that are either already closed or close to reaching their capacity. Therefore, the LFG flow rates are close to their peak and it is important that LFGE projects are started with the minimal delay after the closure of a site to maximise the energy generation and GHG emissions reduction.

An important step to determine the viability of a LFGE project is to find an appropriate end-user. The most cost-effective use of the LFG is direct use in industry to run a boiler or other equipment. If an appropriate site is not nearby, or if the volume of LFG produced is very high, then the LFG could be converted to electricity and fed to the power grid. This requires that a power substation is also nearby to minimise the cost of building and maintaining power lines.

Once an end user is identified, a pre-feasibility study should be carried out. The amount of LFG that will be emitted by a particular landfill is difficult to estimate and depends on many factors, including:

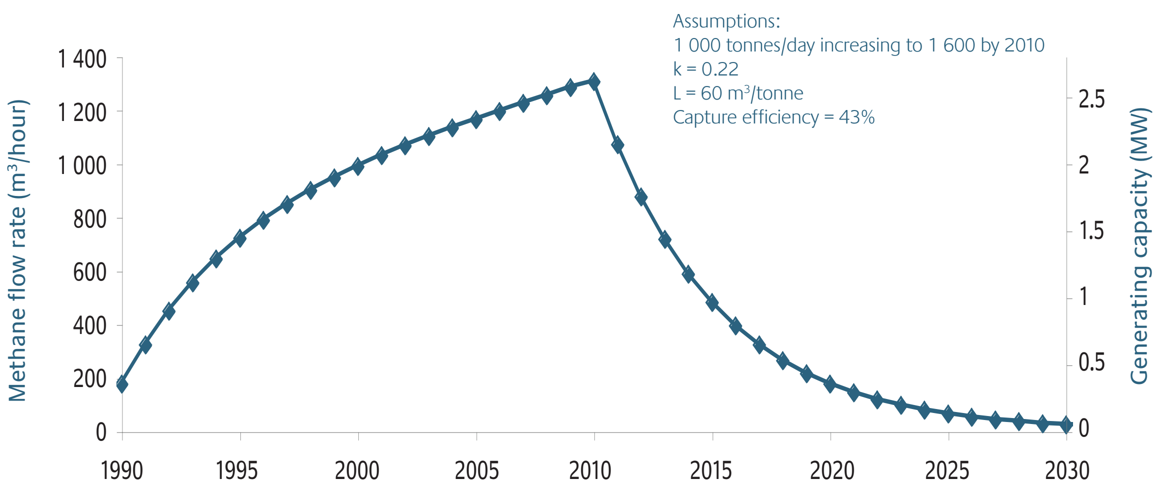
- the history of MSW dumping (tonnes per day);
- MSW composition (% fast, medium and slow biodegradable content);
- the depth of the disposal site; and
- climate, including average temperature and precipitation (IPCC, 2006)

LFG models use a first-order decay relationship and estimate emission paths such as that in Figure 1. In this example scenario we have assumed:

- A landfill site opened in 1990;
- receiving 1 000 tonnes/day increasing to 1 500 tonnes/day by 2010;
- closing in 2010 after receiving 9.4 million tonnes;
- 43% of methane is assumed to be captured (this could be higher with best practice retrieval as well as operations and management techniques); and
- we assume 500 m^3 methane/hour is required per MW of electricity generating capacity.

These assumptions yield an L0 (the methane potential) of 60 m^3/tonne. This generation rate is lower than the typical value of 80 m^3/tonne used in developed countries due to the higher portion of fast decay material in the landfill and shallower depths of the landfills. They also produce a “k rate” (speed of decomposition) of 0.22, which is faster than the typical values used by authorities like the United States Environmental Protection Agency (EPA), due to the higher temperature and rainfall rates in India.

FIGURE 1: ESTIMATED GENERATING CAPACITY BASED ON A FIRST ORDER DECAY MODEL FOR A CITY GENERATING 1000 TONNES MSW A DAY.



The figure shows that the methane flow and potential generating capacity rapidly increases until the landfill is closed, and then rapidly declines. This shows a key issue with LFGE projects – they need to be flexible to cope with changing gas flow. The flaring system needs to have the capacity to be able to destroy excess methane, and the generating capacity should be modified with time as the gas flow increases or decreases. Ideally, modular generators could be moved to a new site as the flow declines at the closed site.

If the pre-feasibility study estimates suggest that enough LFG will be produced, a pump test should be carried out to confirm the model estimates. This involves drilling test wells in a limited area, monitoring the gas flow for a period of time and extrapolating the results for the whole waste disposal site. Details of such drilling tests can be found in the pre-feasibility reports on the **Methane to Markets** website (www.methanetomarkets.org, see reference section for direct links to individual reports).

Table 2 shows the total MSW produced per day from the 10 largest cities in India. Recognising that not all MSW is collected and dumped at landfill sites, a large percentage of all the waste would need to be collected and dumped at one central landfill to make the 10th largest city (Surat, 1000 tonnes MSW/day) viable for an LFGE project with electricity generation. Depending on the distribution of the landfill sites (fewer and larger sites being preferable for LFGE) Delhi could potentially support 25 MW of new electrical generation capacity if managed appropriately.

TABLE 2: TEN LARGEST MSW PRODUCING CITIES IN INDIA

City	Waste generation (kg/cap/day)	k tonnes per year	Tonnes per day
Delhi	0.57	2 161	5 920
Greater Mumbai	0.45	1 941	5 320
Chennai	0.62	1 108	3 035
Kolkata	0.58	968	2 650
Hyderabad	0.57	798	2 185
Bangalore	0.39	609	1 670
Ahmedabad	0.37	475	1 301
Pune	0.46	428	1 172
Kanpur	0.43	401	1 098
Surat	0.41	365	1 000

Source: FICCI Environment Conclave 2006, New Delhi.

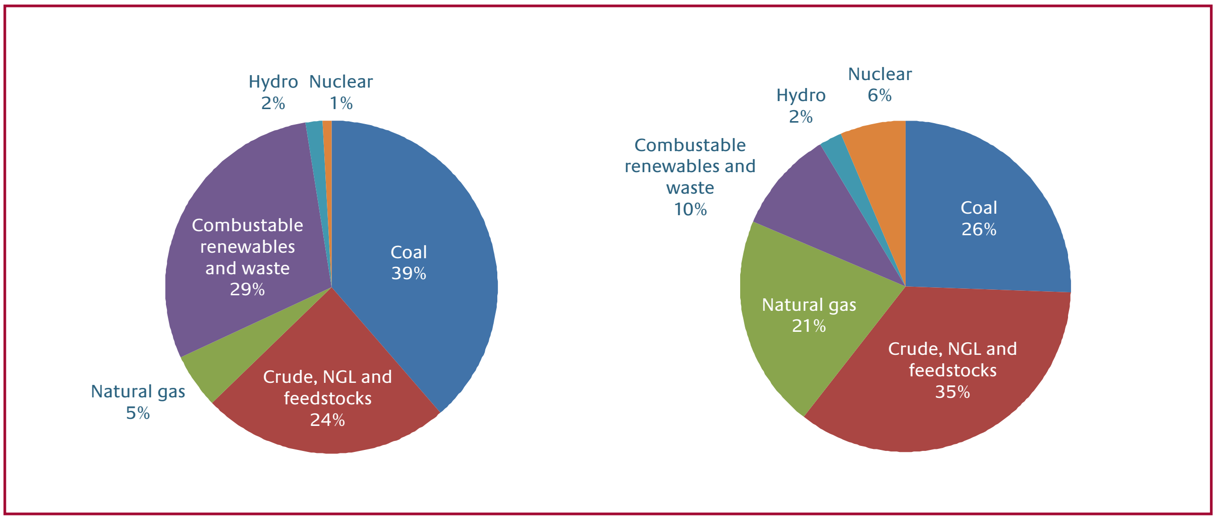
Energy in India

LFGE projects cannot be considered in isolation; other countries have learned that the national and state/provincial energy policies – including grid access, tariffs, and incentives – play a critical role to the success of LFGE projects. This section provides background on these policies in India.

The primary energy consumption in India is significantly lower than the global average in per capita terms, the average habitant using only 0.36 tonnes of oil equivalent (toe) per year compared with the global average of 1.75 toe (IEA, 2007). As the Indian economy continues to grow and the average wealth increases, it is inevitable that per capita energy consumption, and therefore total energy consumption, will increase. A relatively large proportion of India’s energy is derived from coal and from combustible renewables and waste (Figure 2). There are clear benefits of developing renewable energy in terms of environmental factors and energy security.

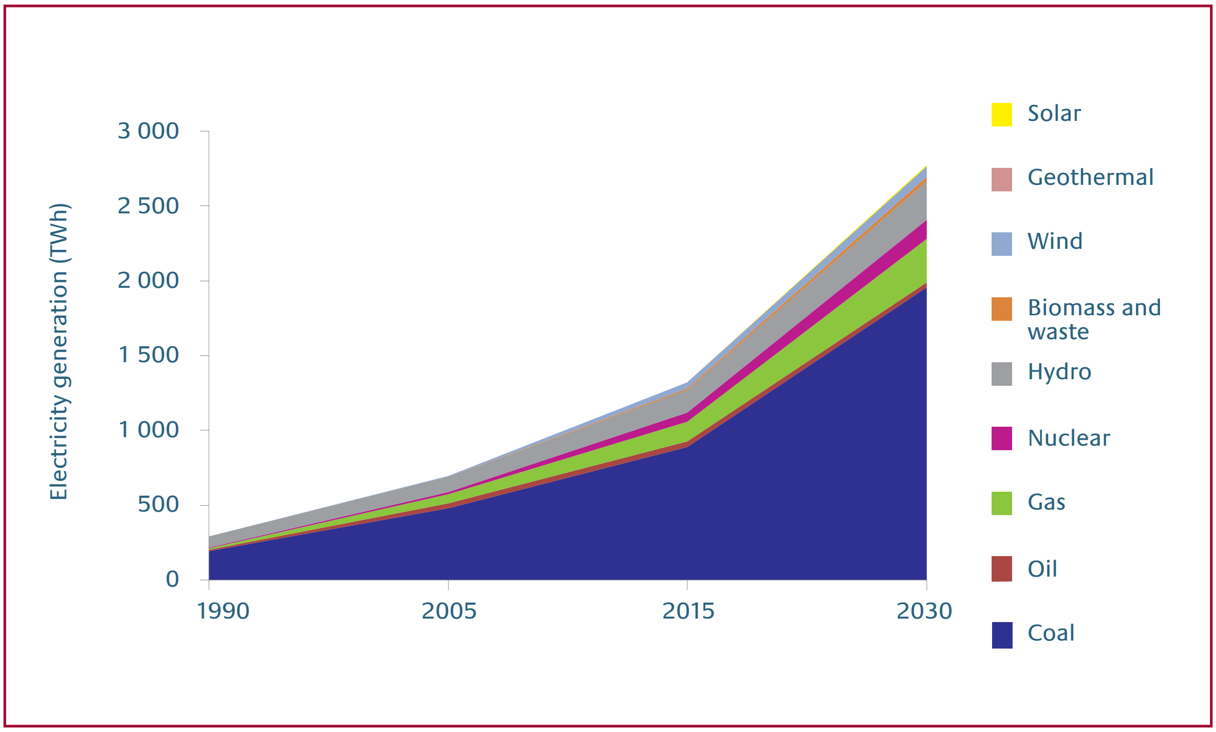
The IEA’s projections to 2030 show a significant increase in electricity generation in India (Figure 3, IEA 2007). However, due to a number of factors, the role of renewables is projected to remain small. Coal is currently the dominant source of electricity and India has large coal reserves. Therefore, coal is likely to be the most cost effective choice for electricity generation, contributing to large carbon emissions. To change this will require proactive policies to encourage renewable energy projects.

FIGURE 2: ENERGY CONSUMPTION BY FUEL TYPE FOR INDIA AND THE WORLD (2005)



Source: IEA, 2007

FIGURE 3: PAST AND FUTURE ELECTRICITY GENERATION IN INDIA BY FUEL TYPE (WEO BASELINE SCENARIO)



Source: IEA, 2007

Electricity markets in India

Demand for electricity has increased dramatically since independence in 1947, and while generating capacity has also increased, average electricity consumption in India is only 694 kWh per person per year (compared to the global average of 2 800 kWh). Around 37% of the population (412 million people) has no access to electricity, primarily in rural areas. Given the expected 7 to 9% economic growth in the coming years, the demand for electricity will continue to grow rapidly (IEA, 2007)

The electricity transmission and distribution system is old and poorly maintained, and efficiency losses are around 25%. Significant investment in the transmission network is required to create an efficient national grid. 73% of the generating capacity is state owed (IEA, 2007), and private investment is difficult to encourage as the regulation of tariffs make it difficult to make a profit. Problems include (IEA, 2007):

- Black outs are common, averaging 15% of the time.
- Loss of electricity due to theft and inefficiencies is high (32-35%)
- Electricity subsidies and theft cause the State Electricity Boards (SEBs) large financial losses
- Tariffs are higher for industry than for domestic users even though the costs of supplying industry are cheaper due to connection direct to high voltage. Large industry operations often generate their own electricity such that the SEBs lose key customers who actually pay their bills.

The Indian Government recognises these problems and the Electricity Act of 2003 (Ministry of Law and Justice, 2003) addresses many of these issues. The Act has a goal of making a minimum of 1kWh/day available to every person in the country. Significant efforts are underway to electrify rural areas and SEBs are required to provide an electricity supply to every village. The tariff structure is being rationalised, and SEBs are being restructured with the generation, transmission and distribution sectors being unbundled. There are some success stories, with the Gujarat electricity board (Gujarat Urja Vikas Nigam Ltd (GUVNL)) restructuring its business and turning a Rs.2 500 crore (650 M USD) loss in 2000-01 into a Rs.220 crore (55 M USD) profit in 2006-07. The turnaround was achieved through strong political direction, retraining of most of the 50 000 employees, and was done without requiring a large increase in tariffs. The GUVNL received recognition as a winner of the London School of Economics 2007 Case Study Development Initiative. (Business Standard, 2008)

With the goal of providing clean energy, some Indian states have set targets for renewable energy consumption, ranging from 0.5% in Madhya Pradesh and 1% in Gujarat, to 5% in Andhra Pradesh, Karnataka, Kerala, Maharashtra and Uttar Pradesh, and 10% in Tamil Nadu. The states have also set tariffs for purchase of renewable energy. The renewable targets and tariffs for biomass energy are in Table 3.

TABLE 3: RENEWABLE ENERGY TARGETS AND ELECTRICITY TARIFFS FOR BIOMASS BASED RENEWABLE ENERGY

State	Minimum renewable target (target date)	Biomass based energy tariffs
Andhra Pradesh	5% (2007-2008)	Fixed cost Rs. 1.61/ kWh in 1st year decreasing to Rs.0.87 in 10th year. The variable cost for 2004-05 is Rs.1.27 escalating to Rs.1.54 in 2008-09
Gujarat	2% (2008-2009)	
Karnataka	5%	Rs. 2.93/ kWh in 1st year escalating to 3.10 in 10th year
Kerala	5% (2006-2009)	
Madhya Pradesh	0.5% (2004-2007)	
Maharashtra	5% (2008-2009)	Rs. 3.04/ kWh in first year escalating to 3.34 in 10th year
Tamil Nadu	10% (2006-2009)	Rs 3.15 / kWh
West Bengal	0.95 – 3.8% (2007-2008)	

Note: Other tariffs exist for wind and small hydro plants which are comparable to the tariffs

Source: Various SEB tariff orders

Other renewable energy sources in India

India has 8.5% of the world's installed wind power capacity (8 000 MW) and the sector is rapidly expanding. Hydro power is a significant contributor and the capacity for growth, especially in the North East (an area where electricity access for the poor is very low), is high. India has large solar potential and would be viable for concentrating solar power projects (IEA 2008). Generation of electricity from biomass (combusting rice husks, bagasse, cotton stalks to drive a generator) currently makes up a small component of total generation, but is forecast to grow to be around 12 GW by 2030 (IEA 2007, WEO Alternative Policy Scenario).

Many renewable energy and emission reduction projects in India are made financially viable by CDM credits being awarded and sold. To date, India has avoided more than 42 million tonnes of CO_2 eq through the CDM scheme, and is forecast to earn over 31 million CERs per year in the near future through its 346 registered projects (an average of 90 000 CERs per year per project).

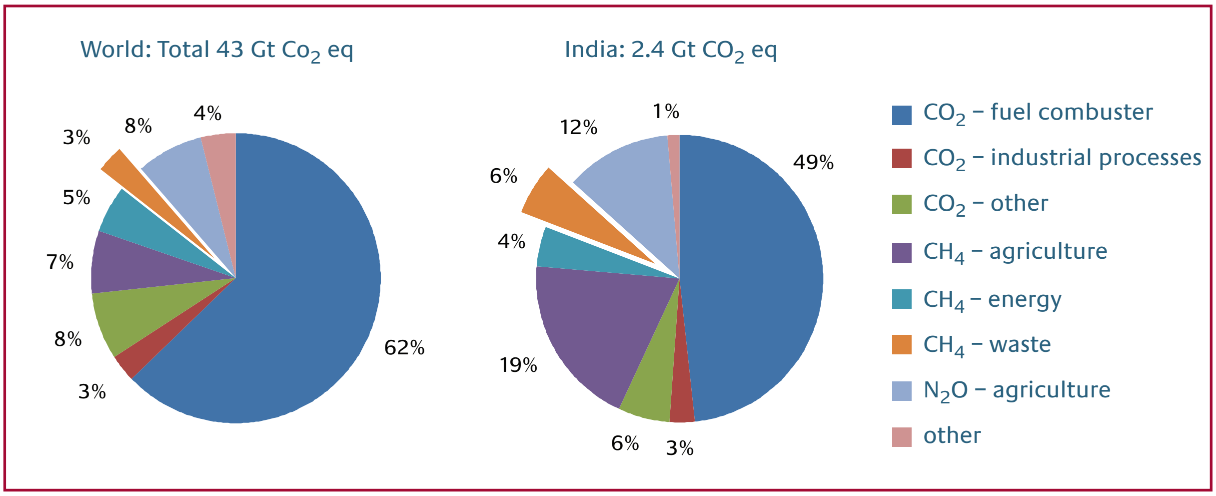
GHG emissions

Methane makes up around 29% of the total Indian GHG emissions, while the global average is 15% (Figure 4). This is primarily due to the large amount of agricultural methane emissions (from rice and ruminant livestock). However, emissions from waste (6%) are also proportionally higher than the global average (3%).

By virtue of its large population, India is one of the world's largest emitters of methane from solid waste disposal, currently producing around 16 Mt CO_2 eq per year, and predicted to increase to almost 20 Mt CO_2 eq per year by 2020 (IEA 2008). A study using the Integrated Assessment Model for Developing Countries (Garg et al, 2003) projects a much larger increase to 48 Mt CO_2 eq by 2020 and 76 Mt CO_2 eq by 2030 (Figure 5). The same study shows that landfills are the second-fastest growing source for methane emissions in India after coal mining. The growth in methane from landfills is largely due to the rapid urbanisation of India, with many people moving from rural areas into the cities resulting in an increase in the amount of MSW produced per person.

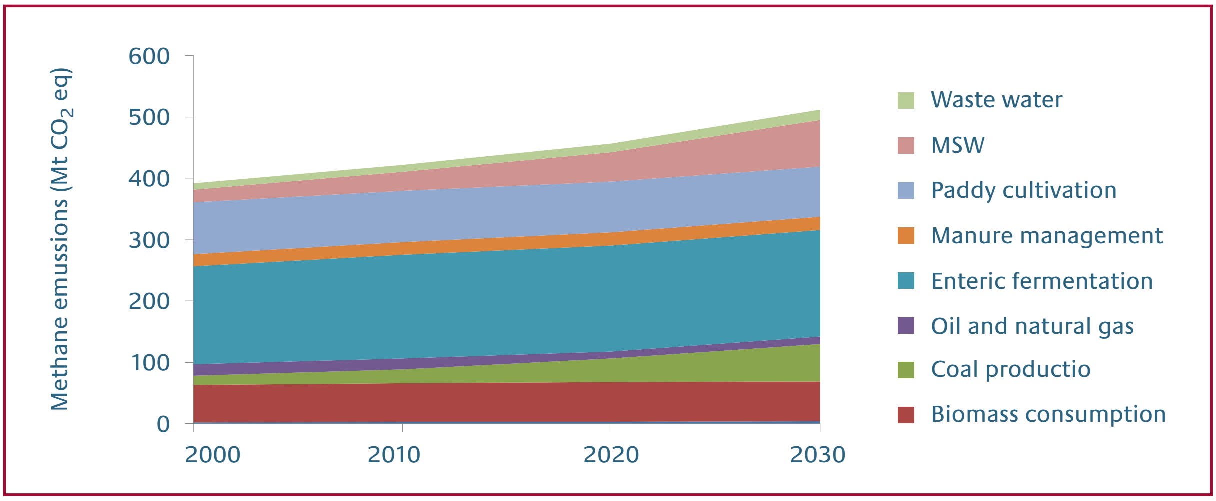
Presently, virtually none of the methane emitted from solid waste disposal sites in India is captured and utilized. If 25% of the methane produced in landfills could be captured and utilised for electricity generations, around 90 MW[1] of capacity could be created (assuming 30% efficiency in the conversion process).

FIGURE 4: GREENHOUSE GAS EMISSIONS FOR THE WORLD AND FOR INDIA (2005).



SOURCE: IEA, 2008

FIGURE 5: METHANE EMISSION PROJECTIONS IN INDIA



SOURCE: INTEGRATED ASSESSMENT MODEL FOR DEVELOPING COUNTRIES, GARG ET AL. (2002).

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1. 90 MW is considerably lower than estimates produced by the MNRE. The estimate here uses typical international conversion and efficiency rates, and is conservative.

Government stakeholders relevant for LFGE projects

There are a number of government actors who will likely play a role in India's LFG to Energy development, including local municipalities, and the Ministries for Environment and Forests, New and Renewable Energy and Urban Development. In India local municipalities have the overall responsibility for the MSW management. They implement laws created by the Ministry for Environment and Forests.

Ministry for Environment and Forests

The Ministry created the Municipal Solid Waste Management and Handling Rules 2000. It governs the Central Pollution Control Board, which is responsible for the oversight of the 2000 Rules. The Ministry supported the Federation of Indian Chambers of Commerce and Industry (FICCI) "Sustainable Waste Management" Workshop in Delhi, 2006 where international companies currently running LFGE projects presented their work to local businesses.

Ministry of New and Renewable Energy

This Ministry covers both renewable energy and new fossil fuel technologies. The ministry is leading the project on Development of High Rate Biomethanisation Processes, which is being implemented and partially funded by the United Nations Development Programme (UNEP) and the Global Environment Facility (GEF). A suspension by the Supreme Court on subsidies to waste to energy projects has been lifted and 5 biomethanisation (see box below) pilot projects currently receive subsidies. The Ministry has recently indicated that it is willing to consider making subsidies available to LFGE projects.

Ministry of Urban Development:

This ministry is a nodal Ministry overseeing urban development in India. The Ministry's Central Public Health and Environment Engineering Organisation (CPHEEO) guides the states and municipalities on technical aspects of solid waste management. As such, CPHEEO is conducting data collection on methane extraction potential from landfills in the country.

Section 2

Current status of LFGE development in India

The practicalities of running a LFGE project mean that only those sites that are closed or about to close are being considered for LFG capture. In the future, with the development of sanitary landfills, LFG management should be considered at the design stage as a way to minimise odours, maximise safety risks and generate revenue through LFGE. Currently, several LFGE projects are in the feasibility stage.

- In **Delhi**, the World Bank is working with the Municipal Corporation of Delhi to carry out pumping tests at the three main dump sites in the areas surroundingthe city (Okhla, Gaziapur and Bhalswa). Reports from these tests should be finished in September 2008. An initial assessment of the **Okhla Landfill** indicates that the site will be closing in 2008 (the site received around 460 000 tonnes of MSW in 2007). The LFG could initially produce around 2.5 MW of capacity, but this would likely fall to 1 MW by 2016. The report (US EPA 2007a) shows that a financially viable LFGE project could be developed, especially if a local user for the LFG can be identified.

- The US EPA is working with the local government testing the LFG flow at the **Deonar Landfill site in Mumbai**. The detailed report from the pump test (US EPA 2007b) indicates that the site, which currently receives 3 000-4 000 tonnes of MSW per day, and will stop receiving organic material in 2010, will generate enough LFG to power two 820 kW generators until 2016, and one 820 kW generator until 2022. Assuming a price of emission reduction credits of 8 to 10 USD/tonne CO_2 eq, and sales of electricity to the grid at the renewable energy tariff of 0.058 USD/kWh, and capital costs of 3 million USD for the extraction equipment and 2.5 million USD for the generators, the project is economically feasible. The returns range from 20 to 100% depending on price assumptions and investment scenarios. Much of the return comes from the sale of the emission credits.

- A pre-feasibility and pump test has also been commissioned by the US EPA at the **Pirana Landfill in Ahmedabad** (US EPA 2007c). This site will close soon having received around 4.6 million tonnes of MSW since 1980. Gas flow models and pump tests suggest a flow rate of around 1 100-1 700 m^3/hour, enough to support a 1.3 MW power plant initially and 700 kW from 2016. Economic modelling supports the alternative of direct use of LFG by local industry, as this avoids the cost of installing generators. This assumes that a local plant is available to take advantage of the LFG.

- In **Mumbai**, USAID India is working on a pre-feasibility study on the **Gorai landfill** site which is anticipated to generate 4 MW of electricity capacity. Data collection is being done through the IL&FS (Infrastructure Leasing and Financial Services, a private entity).

- In **Hyderabad**, an assessment (US EPA 2007d) of a landfill site that closed in 2005 came to the conclusion that the site was unlikely to be viable for capture as the flow rates were too small and declining. This landfill site is relatively shallow and there was evidence of fires. The report highlighted the fact that a large percentage of the biodegradable material in typical Indian landfills is food scraps which decay quickly, especially when the site is not capped effectively. It is therefore desirable to install LFG capture projects in currently active landfill sites, and to caps cells as they are filled to maximise the methane capture.

- The landfill site at **Pune** will be running a pump test in May 2008. Details will soon be available on the M2M website.

Biomethanisation in India

While collecting methane directly from landfills is still in the early stage of development in India, biomethanisation is already being used at the demonstration stage in some industries. Biomethanisation is the process where biodegradable waste is treated and placed in large tanks to encourage anaerobic conditions favourable to methane production, which is captured to generate electricity or used to run boilers. In this process the waste is treated where it is produced, i.e. at a farm, pulp mill or tannery, and the electricity or heat produced is used in the running of the operation, or if the scale is large enough, the electricity is sold to the grid. Note that biomethanisation is primarily used on waste from industry where the companies can easily control the collection and segregation of large quantities of biodegradable material. The process may not be as easily utilised on domestic waste, given current collection and sorting practices.

At least 14 demonstration projects exist (most in production mode as of April 2006) ranging from small projects of 100 m^3 of gas per day up to large projects of 15 000 m^3 per day (generating 35 000 kWh/day). The industries with the largest operations are the pulp and paper mills, sugar mills, and processing of agricultural manure. Other industries include tanneries, abattoirs and municipal waste water treatment plants. For the large scale demonstration plants, the plants were economic and paid for themselves due to energy savings and electricity sales within 5 years, in part thanks to significant government subsidies. Subsidies of Rs 2 – 3 crore (500 – 750 k USD) per MW are available from the Ministry of New and Renewable Energy for waste-to-energy plants, including biomethanisation.

Source: see "Green Energy from Wastes" published by the Ministry of New and Renewable Energy (previously the Ministry of Non-Conventional Energy Sources).

Funding for LFGE projects

The financial viability of LFGE projects depends on many factors, including the capital costs for the gas collection system, power generation equipment and/or gas pipelines or power lines, costs of operation and maintenance, the tariffs paid for electricity or natural gas generated, the eligibility for CDM carbon credits (see discussion below), and any capital subsidies available in the form of grants or loans. Experience from the United States shows that even with no "green" tariffs or government subsidies, direct use of LFGE can still be financially attractive when users are located nearby. In less developed markets, initial costs are likely to be high due to the need to import equipment and expertise, and government subsidies will probably be required to establish the industry.

In the current XIth plan (running from 2007-2012), the MNRE recognised the importance of renewable fuels, and budgeted Rs.150 crore (37.5 Million USD) in subsidies for MSW to energy projects, including RDF (refuse derived fuel) and biomethanisation, with a goal of supporting 200 MW of capacity (MNRE, 2006). The subsidies have the aim at increasing renewable energy generation while reducing the amount of MSW that goes to waste disposal sites. The MNRE has recently indicated that it is willing to consider making the subsidies available for landfill gas projects. This is an important and welcome step, as the experience from developed countries has shown that even with sophisticated collection and sorting practices, MSW will continue to contain significant amounts of biodegradable material. Therefore, it is advantageous to extend the subsidies to LFGE projects to aid in the management of future sanitary landfill sites. Energy generation and carbon credits are an additional benefit to this approach.

To aid the MNRE in its calculations for potential subsidies, Table 4 presents an example budget for a medium-sized LFGE project generating electricity, and shows that with CDMs, and favourable tariffs for the sale of electricity, the project can be viable. Raising capital will be a key factor in getting such a project running, and here government subsidies would provide leverage. From international experience, projects are typically run as a partnership between local government, a technology such as an international company with LFGE experience, and financial supporters.

TABLE 4: APPROXIMATE COSTS OF RUNNING A 1.6 MW LFGE PROJECT IN INDIA

Costs	**USD/year**
Financing capital costs (LFG capture system: 2.9M USD, electricity generation system: 2.4M USD, 10% interest)	(400 000)
Operating costs (in addition to normal landfill operations)	(100 000)
Total costs	(500 000)
Income	
Electricity generation (10512 MWh/yr @ 0.05 US cents/kWh)*	525 600
Carbon credits (18 000 tonnes CO_2 eq avoided @ 8 USD/tonne)**	144 000
Total income	669 600
Balance	**169 600**

* Assumes 1.6 MW generators running for 80% of the time.

**Assumes 300 m^3 of LFG per hour, 50% methane content, and a warming equivalent of 21

Compared to developed countries, the capital costs in India may be higher due to costs of importing machinery, but these costs could be offset by lower costs for local labour. But operating costs could also be high if local expertise to run the projects is not available.

The current level of subsidies for biomethanisation projects is Rs 2-3 crore (500 000 – 750 000 USD) per MW. Sales of electricity to the grid from renewable energy attract a higher tariff than for fossil-based electricity. The tariff varies from state to state (Rs.1.6 – 3.5/kWh). Tariffs can be negotiated with the SEBs, but no precedent has been set for LFGE projects.

Capital costs for LFGE projects on the scale of 1.6 MW are around 5.3 million USD (2.9M USD for drilling wells, piping and blower infrastructure, chemical scrubbing, and 2.4M USD for electricity generation, transmission lines etc). In India, the tariffs for sale of electricity to the grid vary from around Rs.1.6 to 3.0/kWh (3.75-7.5 US cents/kWh, Tariffs Orders from various states, Ministry of Power, http://powermin.nic.in/). CDM credits sell at around 8 USD/tonne. Table 4 shows that with these assumptions, the project can generate a small profit, but that the balance between income and capital costs is critical, and that carbon credits or “green” electricity tariffs are required to make the projects viable.

Certified emission reductions

A significant financial incentive for running emission reduction projects in developing countries is the possibility of receiving Certified Emission Reductions (CERs) certificates under the CDM mechanism. The CERs can be purchased by Annex I countries to offset shortfalls in reaching targets in emission reductions under the Kyoto Protocol targets. The CERs can be traded on the carbon credit markets (e.g., the European Climate Exchange). Due to the overly generous allocation of carbon credits for the current commitment period, the value of European Union Allowances (EUAs) and CERs has dropped dramatically. However, with the significant lowering of the caps for EU countries for the 2008-12 commitment period, the futures trading of EUAs is currently at 22 Euros for December 2008 contracts. CERs will continue to trade at lower prices than EUAs due to the larger risks associated, and currently trade at around 8 to 10 USD. Some narrowing of the gap could be expected as the carbon market inefficiencies are reduced and as the markets become more global in their structure. A landfill site such as Deonar capturing and combusting around 7 000 m^3 of LFG per day will save around 18 000 tonnes CO_2 eq per year, worth approximately 180 000 USD per year as CERs (assuming 50% methane content).

A review of the current CDM projects addressing landfill gas shows that globally there are currently 66 UNFCCC registered projects to capture LFG for flaring or electricity generation. The projects range from small (18 000 tonnes of CO_2 eq avoided per year) to very large (1.2 million tonnes CO_2 eq per year). Small projects that generate electricity produce around 1 to 2 MW of capacity, while the largest is a power plant in South Korea, handling 19 000 tonnes of MSW per day that is predicted to generate up to 50 MW of electricity.[2]

To be eligible for CERs, a project must demonstrate that it would not otherwise proceed, i.e. there are no laws enforcing the capture of methane from landfills. It must also establish a baseline for future emissions if the project were not to exist. It can be assumed that LFGE in India should be eligible, as there are currently no laws regulating the capture of LFG. The baseline can be estimated using LFG production models, and can be verified by the actual amount of methane captured and combusted.

[2] For more information, see http://cdm.unfccc.int/index.html.

It should be noted that some of the CDM LFGE projects have overestimated the amount of LFG that the landfills will produce and have earned less CERs than expected. Of the 16 CDM LFGE projects that have been built and have been awarded credits the average emissions avoided are around 40% of those in the original project description. It may be that in the early stages of these projects, gas flow is lower than the projected average for the lifetime of the projects. However, it is clear that it is important to be conservative in LFG generation estimates to avoid overly optimistic gas flow estimations and therefore avoid underestimation of financial returns.

United Nations Development Programme/ Global Environment Facility

Global Environment Facility of the United Nations Development Programme has funded LFG collection projects in Mexico (SIMEPRODESO in Monterey), Uruguay (Las Rosas in Maldonado), Brazil, Latvia, and in China (Anshan, Maanshan, and Nanjing). Funding is typically of the order of 1 to 5 million USD, around 20% of the total project costs. The UNDP/GEF has already provided funding for biomethanisation demonstration projects in India through the Ministry of New and Renewable Energy.

World Bank

The World Bank is currently active in India supporting several pre-feasibility studies on a number of landfill sites in Mumbai and Delhi. The Bank is a key partner in the Methane to Markets initiative. The Bank already supports many renewable energy CDM projects in India, and sponsored the National Strategy Study on CDM in India.[3]

Experiences in other countries

The Methane to Markets (M2M) Partnership is an international initiative with 25 country partners, chaired by the US EPA. The site evaluation reports cited above were commissioned by the M2M Partnership. The Partnership gathers and disseminates information from the partners and facilitates collaboration via several committees, one of which is on the topic of methane from landfills. The M2M website makes available national reports provided by the M2M partners. Many M2M project network companies are looking for international opportunities to utilise their technical experience. Of the countries that have provided reports, the three most advanced counties are Australia, The United Kingdom and The United States. China has also done a lot of work and has several LFGE projects running. Summaries for these countries are below, based on reports on the M2M website[4] and the CDM database.

United States

In the United States, the Environmental Protection Agency has ruled that all landfills must have LFG management, and large landfills must either flare or utilise the gas in boilers or electricity generators. Around 25% of methane produced in landfills is converted to energy and an additional 22% is flared. In 2004

[3] See www.teriin.org/nss/. [4] See www.methanetomarkets.org/landfills/index.htm#profiles.

9 TWh of electricity was generated (0.4% of the total electricity demands, supplying the needs of 1.3 million Americans) along with 200 million m^3 of LFG to end users. As of April 2008, 450 projects currently capture and convert LFG to energy, with an additional 369 flaring the LFG. Another 120 LFGE projects are currently in the planning stages.

United Kingdom

The United Kingdom (Rosevear, 2005) put in place laws in 1994 to ensure the capture and processing of methane from landfills, and currently has a capacity of 600 MW, producing around 3.5 TWh per year. There are more than 250 landfill sites collecting LFG, and around 25% of the capacity comes from just the largest 11 sites. All new non-toxic landfills sites in the UK must be built with LFG capture and conversion to energy. Due to new laws relating to the sorting of waste and the increased use of bioreactors, methane production from landfills is expected to decrease over the next few decades. In the United Kingdom, Renewable Obligation Certificates mean that electricity generated from LFGE projects can be sold onto the national grid at three times the price of fossil fuels, meaning the process is cost effective and profitable.

Australia

Australia is one of the world leaders in methane capture from landfills (Australian Greenhouse Office, 2005), currently capturing around 25% of all methane produced in landfills. Around 40 landfill sites generate electricity from methane for a combined capacity of over 100 MW. Many of the economically viable landfill sites are already employing LFGE technology. Woodland, one of the largest projects currently being developed, will accept around 400 k tonnes of MSW per year to run a 20 MW capacity power plant using bioreactor technology to enhance methane production. With improving landfill design (such as multi-site projects collecting LFG from several landfills and transporting the gas via pipelines to a single power plant) and improved methane recovery through better capping and enhanced methane production, the net methane capture rate is expected to increase to 40%.

In Australia the cost of producing methane from LFG is around 0.06-0.10 USD/kWh compared with 0.04-0.07 USD/kWh for coal powered electricity plants. Leading companies running LFGE projects in Australia are EDL (Energy Developments), Collex, Veolia and LMS (Landfill Management Services)

China

At the end of 2005, China had over 370 landfill sites, and is the world’s second largest emitter of landfill methane, at around 46 Mt CO_2 eq per year, forecast to rise by 8% by 2020 (US EPA). The Chinese government provides an incentive of 0.25 yuan/kWh (3.5 US cents/kWh) for electricity from LFG projects. The LFGE sector is emerging, with 8 CDM projects currently registered on the UNFCCC’s CDM website. To date, China has earned 220 000 CERs with a much larger number of CERs expected to be awarded into the future (over 2 million per year based on the CDM project design documents). The biggest LFGE CDM project is in Guangzhou, which will process 6 800 tonnes of MSW a day and produce up to 19 MW of electricity capacity, avoiding almost 1 million tonnes of CO_2 eq per year. There are several landfill sites that have been evaluated for LFGE potential using the EPA Land GEM model and pump tests, and are seeking investors to fund the projects.

Section 3

Conclusions and recommendations for next steps

Capturing methane from landfills for energy utilisation has been shown to be economically viable in many countries. In India, methane from solid waste disposal is predicted to rise significantly; the current ban on organic wastes is not likely to affect this predicted rise in methane emissions. As such, LFGE appears to be an excellent near-term energy and environmental solution for India, and merits further consideration by the government. The first LFGE projects are likely to be more expensive to run, but given the possibility of CDM credits, government subsidies and "green" electricity tariffs, LFGE should become a more viable industry in India. Local benefits include better managed landfill sites through reduced odours and explosion risks, employment opportunities and increased electricity supply, and reduced GHG emissions.

In summary, the International Energy Agency makes the following recommendations for India:

- Ensure that LFGE projects take advantage of the existing MNRE subsidies that are now available for projects related to energy from MSW.
- Require SEBs and power companies to pay "green" electricity tariffs to suppliers running LFGE projects (and other low GHG emitting energy sources).
- Revise the 2000 MSWM rule banning dumping of biodegradable material in landfills. Sorting, composting and biomethanisation should be encouraged when appropriate, but based on experience from other countries, it is difficult to remove all biodegradable material from MSW. As India moves towards sanitary landfills, the production of methane is likely to increase, and LFG management will become more important.
- Improve MSW collection and management practices, by creating larger regional landfills with liners; installing LFG collection systems as part of a landfill's initial design; filling and sealing cells one by one to maximise methane capture rates; and avoiding leachate leaking into waterways.
- Take advantage of the Methane to Markets and other international networks of expertise, to learn about the latest technologies and practices, as well as strategies for designing LFGE projects with CDM credit potential.

Appendices

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Acronyms

CDM: Clean Development Mechanism (of the UNFCCC)
CER: Certified Emissions Reduction
CPHEEO: Central Public Health and Environment Engineering Organisation
EPA: Environmental Protection Agency
EUA: European Union Allowances
GEF: Global Environment Facility (of the UNDP)
GHG: Greenhouse Gas
IEA: International Energy Agency
IPCC: Intergovernmental Panel on Climate Change
LFG: Landfill Gas
LFGE: Landfill Gas to Energy
M2M: Methane to Markets
MSW: Municipal Solid Waste
RDF: Refuse derived fuel
SEB: State Electricity Board
TOE: Tonnes of Oil Equivalent.
UNDP: United Nations Development Programme
UNFCCC: United National Framework Convention on Climate Change
USAID: United State Agency for International Development
WEO: World Energy Outlook

Units used

kW: kilo watts (1 000 watts)
kWh: kilo watt hours – 1 000 kW run for one hour
MW: Mega watts (1 000 000 watts)
MWh: Mega watt hours.
Rs: Indian Rupees. 1 Rs = 0.025 USD (2.5 US cents)
USD: US dollars. 1 USD = 40 Rupees
Crore = 10 000 000
Lakh = 100 000
m^3 – cubic metres. 1 m3 = 35.3 ft3
Mt CO_2 eq: Mega tonnes of CO_2 equivalent. GHGs are measured by their relevant strength compared to CO_2.
Methane is 21 times more powerful at absorbing radiation than CO_2, so 1 mega tonne of methane = 21 Mt CO_2 eq

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