Non Co2 GHGs & Other Short-lived Climate Forces in India:

Status, Abatement Potential and Policy Options

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FOCUS ON THE GLOBAL SOUTH

INDIA PROGRAMME

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Contents

Executive Summary

1. The Study seeks to examine the status, potential for abatement and related policy issues pertaining to Non-CO2 greenhouse gases (GHGs) and other short-lived climate forcers (SLCF) in India which have not received specific attention hitherto. Without taking pre-determined positions, the Study takes a critical look at these SLCFs and their sources, assess various mitigation options, estimate abatement achievable from the best options, and examine policy issues involved. The broad perspective was: knowing that absolute emissions in India were bound to rise in the near term, with a considerable proportion based on fossil fuels for electricity generation, could mitigation of Non-CO2 Forcers help India adopt a fair and equitable low-emissions development pathway? Multi-Criteria Analysis (MCA) was used to compare various mitigation options, looking at co-benefits or penalties from each across 5 criteria namely Mitigation, Economic Growth, Inclusion, Local Environment & Health, and Implementation.

2. After examination of the literature and various data sources, it was decided to use India's official National Communication to the UNFCCC (2011 based on 2007 data) for an Inventory of the Non-CO2 GHGs. This data is read along with the commentaries, discussion and projections in the various sectoral and thematic papers published in 2011-12 by the Ministry of Environment & Forests (MoEF) under its Indian Network for Climate Change Assessment (INCCA). This was felt to be an optimum strategy in order to avoid prolonged and distracting debate as to veracity of data and as the best base from which to engage policy-makers in India effectively.

3. The main findings of the Study are briefly summarized below.

4. Of India's total annual emissions of 1,727,706 kilo tonnes (kt) $CO_{2\text{-eq}}$, Non-CO2 GHGs contribute 621,085 kt or 36% of the total. Within Non-CO2 GHGs, Methane (CH4) contributes 514,046 kt or 83%, Nitrous Oxide (N2O) contributes 70,996 kt or 11% and F-gases contribute 36,043 kt or 6% (all in $CO_{2\text{-eq}}$).

5. Within Methane emissions, enteric fermentation in ruminants (53%), paddy cultivation (18%), wastes i.e., solid wastes and sewage both domestic and industrial taken together (12%), as well as domestic sources chiefly biomass burning in cookstoves (13%), are the four largest sources. However, since we are taking into account co-benefits across five criteria rather than only using mitigation as a yardstick, our analysis did not suggest that these Methane emissions ought to be tackled in their above order of magnitude. Taking all factors into account, the best options for mitigation of Methane were found to be as noted below along with main policy issues.

5.1 Tackling Methane from Rice Cultivation and Wastes (both solid wastes and liquid sewage) emerged as the best options, despite a common perception in official circles in India that emissions from agriculture are a “no go” area. Abatement strategies in Rice Cultivation that do not affect yield would provide co-benefits in conservation of water resources known to be affected by climate change apart from several other co-benefits. Other advantages include simultaneously utilizing the agricultural extension system in tackling other abatement strategies in agriculture such as for N2O discussed below, although this also brings to the fore the biggest implementation challenge, namely the highly eroded institutional capability and reach of the governmental agricultural extension system.

5.2 Wastes are currently the smallest fraction of Methane sources but are responsible for one of the fastest growing emissions in India given rapid urbanization and increase in waste generation. Substantial co-benefits include energy production through Methane recovery and in improved local environment especially avoidance of contamination of groundwater.

5.3 Advantage with both the above is that governmental agencies themselves are among the main stakeholders making implementation less difficult although issues of capacity and technology remain a challenge.

5.4 Ruminants even though a large Methane emissions source is found to be too difficult to tackle given the dispersed cattle population in very small herds, with uncertain returns on mitigation mainly from alternative feeds due to the dominantly foraging and grass-feeding rather than stall-feeding practices of cattle rearing in India.

5.5 Since Domestic biomass burning is a source of methane, N2O as well as Black Carbon, findings are summarized together under Black Carbon.

6. In Nitrous Oxide emissions, Soil/Agriculture are responsible for by far the largest fraction at 58% of N2O emissions, followed by Domestic Energy mostly biomass-burning (15%), Industry (9%) and Wastes (7%). It was found that tackling Soil/Ag and Domestic Waste stream emissions would yield the best results.

6.1 N2O emissions from Soil/Ag are mostly due to over-use of nitrogenous fertilizers and agricultural practices, both of which are amenable to corrective action without yield penalties. Co-benefits are adaptation strategies including changed agricultural practices, shifting towards sustainable agriculture and reduction of input costs for small farmers.

6.2 Domestic Waste has already been discussed above.

7. F-Gas emissions, mostly HFCs from air-conditioning and refrigeration, are only 6% of Non-CO2 GHGs and a mere 2% of all GHGs in India. Yet they have attracted a lot of attention of late due to the high global warming potential of these gases and because of the potential of these user sectors to expand rapidly in coming years. The Study finds that there has been some over-estimation of growth rates in the A/C and refrigeration segments as well as the rise of the Indian middle-class and its purchasing power. Nevertheless, this remains an important sector to tackle, mostly because it is a well-organized and concentrated industry and user-base, and past experience of time-bound

and effective phasing out ozone-depleting CFCs under the Montreal Protocol has shown the way forward for tackling GHGs from this sector. The Study concludes that, given the strong and growing international consensus of tackling HFCs too under the Montreal Protocol, and the pressures the Indian A/C and refrigerator manufacturing industry will feel to come up to international standards quickly, the best route forward for India would be to also take up a time-bound programme for phasing out HFCs, preferably under the Montreal Protocol or under any equally effective mechanism if it can devise one. Efforts already made by several India-based air-conditioner and refrigerator manufacturers to introduce non-HFC or low-GHG emission refrigerants are encouraging signs of the potential for such a course.

8. Black Carbon (BC) is not in the UNFCCC list of GHGs to be controlled and reported on, so there is no official inventory available. The Black Carbon Research Initiative taken up in India is also skeptical of the extent of adverse effects of BC on climate change and of benefits to be gained from BC mitigation. This arises mainly from the release of BC bound together with Organic Carbon (OC) with the latter in much larger proportion in India than generally assumed. Question raised is whether efforts to check BC from such mixed emission sources, such as domestic wood-burning stoves or open field burning of agricultural wastes, would also cut down OC which, like similar aerosols, have a combined "cooling" or negative forcing effect.

8.1 This Study finds that tackling domestic wood-burning cooking is an extremely hard nut to crack as shown by earlier experience of the Improved Cookstove programme in the 1980s. Institutional weaknesses, costs of current-generation improved cookstoves and several factors may weaken the potential of this option. Current high rates of urbanization with attendant shifts to LPG and such shifts already taking place in rural areas quite substantially would also lower the attractiveness of improved wood-burning cookstoves. They may also not yield the desired mitigation as discussed above, even though they will provide much benefit especially to women due to sharp reduction in indoor air pollution. For these reasons, tackling of Methane and N_2O through Improved Cookstoves has been considered a weak option.

8.2 The Study recommends focusing on BC mitigation by checking diesel-engined vehicles, especially trucks and the rising numbers of passenger vehicles (SUVs and cars) clogging the big cities and highways, and Brick Kilns. BC from these sources are not bound with OCs, certainly to much less extent than in biomass burning.

8.3 Newer technologies in brick-making such as zig-zag kilns and vertical Shaft Brick Kilns (VSBK), as well as better material composition and use of internal fuel, would substantially reduce the quantity of coal and biomass fuel used in the industry, and contribute substantially to mitigation of CO_2 besides BC. Huge co-benefits would also accrue from reduced local pollution.

8.4 Mandatory fuel economy standards in mostly outdated technologies in use in India are long overdue, as are tighter tailpipe emission norms. While other known measures to increase fuel efficiency such as changing driving practices and fleet management may not be feasible under Indian conditions, mandatory norms at the manufacturing are less difficult to implement and India has had fairly good experience with them in passenger car emission norms. Political will to push through such regulation will be the big challenge.

9. The study makes quantitative projections of mitigation achievable by 2035 in the identified priority sectors.

9.1 It is estimated that the rate of growth of Methane emissions from Wastes could decline, after a brief period of increase, from the current 7% Cumultive Annual Growth rate (CAGR) down to around 3.5%, delivering around 56% of total Non-CO2 emissions avoided by 2035. Rice Cultivation could decline, after a small period of increase, at a Cumultive Annual Growth rate (CAGR) of around -3.4%, delivering almost 9% of total emissions avoided.

9.2 Similarly, N2O from Soil/Ag could be brought down by -3.4% CAGR, delivering around 4% of Non-CO2 emissions avoided. (Reduction of emissions from Soil/Ag due to Methane and N2O together could amount to 13% of emissions avoided.) Reductions of N2O emissions from Domestic Waste streams could amount to around 5% of emissions avoided.

9.3 If India does not follow the trajectory currently being worked out for phasing out HFCs under the Montreal Protocol and follows some other course, it is estimated that due to industry actions and other regulatory measures, the current 6.6% CAGR could be brought down to 3% contributing 25% of avoided emissions by 2035.

10. All told, total Non-CO2 emissions could amount to as much as 5.819 Giga tonnes CO2-eq.

Climate Works Foundation-Shakti Sustainable Energy Foundation Study on

Non-CO2 GHGs & other Short-lived Climate Forcers in India: status, abatement scenarios and related policy options

Technical Report

1. Introduction/Background

1.1 The beginning This Project began with the idea at Climate Works Foundation and its India partner, Shakti Sustainable Energy Foundation, to take a closer look at the scenario concerning Non-CO2 emissions, otherwise known as Short-lived Climate Forcers (SLCF), in India where it had apparently not received much attention till that time. Whereas some scholars and agencies had done some preliminary work on SLCFs, they had either taken sector-specific views or had arrived at projections based on selected readings or data-sets. There also appeared to be a tacit assumption that reduction of all SLCFs was prima facie a desirable goal, perhaps even a preferred mitigation strategy, whatever be the conditions, perceptions, policy orientations and capabilities in India. Very few such studies, it appeared, had examined the issues involved from a broader perspective taking these and other factors into consideration within a wider policy frame.

1.2 The objectives With this in mind, the Project sought to:

- compile an inventory of non-CO2 emissions in India based on available secondary data from a variety of peer-reviewed sources with broadest possible acceptability, cross-check this information to the extent possible and establish as well as analytically use this data set for studying policy options
- within acknowledged margins of error, assess different policy options based on qualitative and quantitative analysis, and develop a framework within which to examine the comparative effectiveness, feasibility and ability to implement such policies in the socio-economic and political contexts in India, such that this framework can be used to further improve the analysis and recommendations as and when better data becomes available
- thus work out and recommend a desirable set of policy options for mitigation of non-CO2 Forcers under concrete Indian conditions

1.3 Problems Due to some administrative problems in the implementing agency which have been discussed in a separate Narrative Report, major consultative exercises envisaged at the outset could not be taken up and the work had to be completed within roughly half the sanctioned budget. Nevertheless, most substantive research and analytical work has been completed and it is hoped that some outreach work may now be possible outside of the immediate Project framework.

2. Perspective/Approach

2.2 Why look at Non-CO2 gases?

As noted earlier, a great deal of heat has been generated by recent discourse on Non-CO2 Forcers, but unfortunately not too much light has been shone on the main issues.

The background assumption in important strands of the debate is that, since Non-CO2 GHGs and other SLCF such as black carbon have higher global warming potential (GWP), and also stay in the atmosphere for shorter periods than CO2, mitigation of Non-CO2 forcers would yield relatively quicker dividends in checking temperature rise, even if on a short-term basis, than the longer-term and perhaps more difficult mitigation of CO2 emissions.[1] Proponents of this view hold that this would be beneficial, especially in a context where global action on control of all GHGs appears a distant prospect, with action to curb fossil-fuel consumption and hence CO2 emissions seemingly difficult to achieve in the face of political and corporate resistance.

Apart from the merits of the case, from the point of view of developing countries especially India, these arguments trigger a sense of déjà vu. A substantial part of campaigns against Non-CO2 forcers seems to focus on black carbon, especially from biomass combustion, and on methane, notably from paddy cultivation and cattle rearing, both being activities taking place largely in developing countries in general and in Asia in particular. A question that crops up is whether this is a crusade impelled by a need to shift the focus away from CO2 and the fossil-fuel based economy dominated by the global North and the historical emissions from developed countries that are mostly responsible for the climate crisis? This also sounded like a throw-back to a similarly inspired campaign in the early 1990s that sought to blame methane from paddy cultivation in Asia for most of global warming, and which required to be countered by an arduous scientific research programme in India, one of the first from the global South?[2]

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[1] No specific author or campaign is being singled out here, and therefore no reference is being provided. The idea here is mainly to highlight and clarify the perspective of the researchers who have authored this Report.

[2] Dr.A.P.Mitra's researches into methane from rice paddies in India can be seen at Mitra, A.P., 1991, "A preliminary report" in Global Change: Greenhouse Gas Emissions in India, Scientific Report No. 1, NPL, Publication and Information Directorate, CSIR, New Delhi, India; Mitra, A.P., 1992, "1991 Methane Campaign" in Global Change: Greenhouse Gas Emissions in India, Scientific Report No. 2, NPL, Publication and Information Directorate, CSIR, New Delhi, India; Mitra, A.P., 1996. Global Change: Greenhouse Gas Emissions in India, Scientific Report No.10, Centre for Global Change, NPL, New Delhi, India, all cited in numerous articles. See also Jairam Ramesh, Foreword, "Climate Change and India: Towards Preparation of a Comprehensive Climate Change Assessment," Ministry of Environment & Forests, Government of India, 2009. For an interesting discussion of differences in methane emissions from paddies in different parts of India due to variations soil carbon content, see Subhra Priyadarshini, "High carbon in paddy fields questions India's methane emission levels," Down to Earth, June 30, 2007, in http://www.downtoearth.org.in/node/6138

Notwithstanding these pitfalls, and caution could always be exercised to insure against falling into any conceptual or ideological traps, the Research Team of this Project felt that two major propositions justified a closer look at mitigation actions directed at Non-CO2 Forcers in India.

2.3 Perspective for the Study First, whereas many studies had looked at this or that particular Non-CO2 Forcer or their sectors of origin, such as black carbon from brick kilns or from domestic cookstoves, no study had so far looked at Non-CO2 Forcers in India as a whole and examined whether there were any low-hanging fruit that could yield substantial mitigation benefits at relatively low cost and less societal effort or pain.

Second, whether tackling some Non-CO2 Forcers in India could buy some time while CO2 emissions inevitably rose due to essential developmental and poverty removal activities, such as increases in electricity generation and infrastructure. The Research Team, who work with the Delhi Science Forum (DSF)[3], have been deeply involved in climate policy studies, particularly regarding India's domestic policies, strongly advocating that India and other large developing nations, while rightly emphasizing the UNFCCC principle of common but differentiated responsibility (CBDR), also had an obligation to contribute meaningfully to the global mitigation effort by slowing down its currently high emissions growth,[4] an argument also advanced by the IPCC's Fourth Assessment Report[5] but largely and perhaps conveniently ignored. The authors, both singly and jointly, have called for a far more pro-active stance by India in pushing for an urgent, effective and equitable global emissions control regime both on ethical grounds as a good global citizen, and in enlightened strategic self-interest since India is in one of the most badly affected regions from the impacts of climate change.[6]

The on-going collaboration between DSF and the Centre for Science, Technology & Development, Tata Institute of Social Sciences, Mumbai, which has been working for several years on computer models and simulation for an equitable burden-sharing arrangement between nations that could meet the 2°C goal set by successive conferences of the UNFCCC. In this collaboration, DSF-TISS has been working with a carbon budgets perspective and equitable sharing of the remaining carbon budget within an allocation principle of a "fair share" of the total global budget for each nation on the basis of per capita entitlements of the total carbon budget since the industrial era (or any other agreed year) after allowing for historical emissions.[7] Briefly, according to these models, out of a total global carbon budget for 2000 to 2050 of about 1440 Gt CO2, India can avail of around 190-210 Gt CO2 in the period 2010-2050 and would require to peak its emissions around 2040-45 and then start declining.[8] The rise in

[3] See website of the Forum at www.delhiscienceforum.net
[4] See numerous articles by the authors singly or jointly, especially AIPSN (2007), Raghunandan D., IDS Bulletin (2012), Jayaraman T., and Raghunandan D., the Hindu (2009) and numerous articles by Raghunandan in the website of the Delhi Science Forum
[5] IPCC/AR4/WG3-pp.89-90
[6] See articles cited in Footnote 4 above and references therein.
[7] See Kanitkar et al (2011), Jayaraman T., et al (2009) etc
[8] Kanitkar et al (2011) esp. pp 58 and ff

emissions from present levels, albeit at substantially decelerated rates of growth compared to current rates, is necessitated by the poverty and development burden borne by India, particularly the necessity of providing equitable energy access in a context where around 50% of households mostly in rural areas do not have electricity or modern cooking fuels[9], infrastructure, transportation and the millennium development goals, all of which would require considerable energy, a substantial part of which would need to come from fossil sources at least in the medium term.[10]

The intriguing question that struck the Research Team was: *while CO2 emissions would definitely increase in the initial period due to the inevitable reliance on coal and petroleum in the medium term and till renewable energy production kick in, could reductions in Non-CO2 emissions help to reduce total GHG emissions and assist India to remain within the cumulative emissions budget projected*?

If so, which Non-CO2 Emissions could or should be targeted? Are there priorities that could be delineated? What policy instruments would be most effective in achieving the desired goals? And how would one go about answering these questions? It was felt that tackling these questions and providing robust pointers to the way forward was key. For even if one arrived at which Non-CO2 forcer from which sector could yield the maximum mitigation benefit, it did not necessarily follow that this gas or sector would be the easiest to tackle or would actually deliver the desired result which could depend on multiple economic, political, institutional or other factors.

This study sought to emphasize the policy aspect, again because it had scarcely been addressed in so much of the debate which seemed to take for granted that the main goal was to identify the danger posed by this or that Non-CO2 forcer, for example black carbon, and the rest would take care of itself. Our experience on the policy front suggested that this was far from the reality in which interest groups and lobbies, state of the economy, institutional reach and limitations, available and feasible policy frameworks and instruments, trade-offs between benefits and costs (not merely financial but also political and administrative) across sectors, would all have to be factored in before arriving at policy choices. This was our goal in the present Project and the methodology adopted was tailored towards this end.

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[9] The Indian government's rural electrification programme to provide electricity to all citizens, the Rajiv Gandhi Gramin Vidyutikaran Yojana, stated at the time of launch in 2005 that only 44% of households had been electrified at that time (see http://powermin.nic.in/whats_new/pdf/Rajiv_gandhi.pdf). Taking account of progress achieved since then, the Planning Commission put the numbers at 600 million Indians without electricity and about 700 million Indians using biomass as their primary source of cooking energy (see http://planningcommission.nic.in/sectors/index.php?sectors=energy). Allowing for minor variations, and taking into account other official statistics, we are here taking a rough figure of 50%.

[10] Based on the Integrated Energy Policy 2006, it has been broadly estimated that India's commercial energy demand till 2031-32 will rise by around 6.8% per year even while energy use per unit of GDP would reduce by around 20% over the next decade, which would mean "requirement of India's dominant fuel Coal including Lignite will expand from around 500 million tonne in 2006-07 to over 2.5 billion tonnes per annum based on the quality of available domestic coal over a period of 25 years." (see http://planningcommission.nic.in/sectors/index.php?sectors=energy)

2.4 Methodology Clearly, the first step would be to arrive at as accurate an inventory of Non-CO2 emissions as possible.

2.4.1 Inventory From the very outset, it was recognized that a comprehensive And reliable Inventory was well beyond the scope of this study and the resources available in it. There was also a strong intuitive feeling that authoritative data might not be available across sectors over and above what was officially published by government. It was therefore decided to scan the available literature, examine sources other than the government data and assess their reliability including through consultation with sector experts, and then arrive at what could be considered a satisfactory inventory for the purpose of arriving at informed policy choices.

As work on the inventory proceeded, this approach was strongly vindicated on several grounds. The following discussion is based on analysis of various published literature looked at under this Study and which have been listed in ***Annexure-1.***

Literature scanned for Inventory The Indian government had officially submitted two rounds of National Communications to the UNFCCC as required which provided an inventory of GHGs covered under the prevailing international agreement viz. the Kyoto Protocol. NATCOM1 submitted in 2007 was based on 2004 data, and NATCOM2 submitted in 2011 was based on 2007 data. Many experts have questioned the accuracy of these data in different sectors, and several studies have made projections based on perhaps more robust micro-level data within sectors. Our Consultant on Transportation, for instance, presented excellent data and projections for GHGs from this sector. However, for reasons of consistency across sectors and base years, it was virtually impossible to substitute the NATCOM data with any of these data sets for the following reasons:

- academic or industry data used different reference years which made it near impossible to incorporate them into a single data set with a uniform reference year
- much academic data related to micro-level case studies which could not reliably be extrapolated to the national level
- the accuracy of some other data sets, even if based on excellent primary data at the micro or meso level in particular sectors and extrapolated to the national level in some way, could not be definitively affirmed: in that sense, even if several other experts felt some of these projections were quite realistic, there was no scientific or peer-reviewed way in which one could assertively substitute this data set for NATCOM data that had been prepared based on UNFCCC methodology used across nations
- it was strongly felt that impact on policy makers in India required consistent data that could not be easily questioned or challenged, and towards that end, use of NATCOM2 data seemed to be the best bet
- finally, even if there were a, say, ±5% error or variation in any data set chosen, it would probably not make too much of a difference to policy

recommendations which were, in the ultimate analysis, based on fairly broad brush assessments, and variations due to different reference years or differing methodologies could well be of that order or greater

It was therefore decided to accept the NATCOM2 data set for purposes of the policy-level analysis even while acknowledging that it may not be the most accurate for particular sectors or specific reference ears.

Exception had to be made, however, in the case of Black Carbon.

Unfortunately, there is no official data in India on BC inventory. NATCOM does not contain BC inventory data presumably because BC is not one of the GHGs specified under the UNFCCC for monitoring and reporting. The Black Carbon Research Initiative (BCRI) in India sets out a programme and methodology for, inter alia, compiling an inventory of BC emissions from India but does not contain a baseline of any sort.

In this one instance, therefore, this Study had to rely on data from other research, deviating from the principle adopted at the outset to use official Indian data so as to avoid controversy and debates about the data rather than the substantive arguments being advanced for which, so long as data are broadly acceptable, accuracy of data within a very narrow band is not really critical.

After going through various publications, reports, papers and other works by authorities on Black Carbon, it was decided to take inventory data from the USEPA Report on Black Carbon in South Asia which is not original data collection but a compilation of data from various sources.[11]

2.4.2 Policy Choice: Co-benefits approach and Multi-criteria Analysis As briefly mentioned above, the major focus of this Study is to discuss policy choices for mitigation of Non-CO2 forcers as part of a wider mitigation effort in India, itself to be configured within the framework of an as yet unknown equitable and science-based international burden-sharing agreement. Even a cursory look at emissions data seem to suggest that Non-CO2 emissions are large enough to justify specially-directed attention addressing feasibility of efforts to contain or reduce them.

Issues that require closer examination are: which Non-CO2 emissions and source sectors should be targeted and how much emission reduction could reasonably be expected given current and foreseeable emission trends in a business-as-usual scenario as well as if special efforts were put in and improved technologies deployed? If special efforts are to be put in, what questions of prioritization might come into play and what factors could influence policy choices? Quite apart from issues of technology and cost, what other factors would influence policy choices, for example institutional capacities,

[11] "Reducing Black Carbon Emissions in South Asia: Low Cost Opportunities," US EPA, June 2012 available at: http://nepis.epa.gov/Exe/ZyPDF.cgi/P100EF3D.PDF?Dockey=P100EF3D.PDF. It is also gratifying that this Report relies for its Indian data on studies and published articles by C.Venkatraman and M.Reddywho are widely regarded as among the leading authorities on Black Carbon and whose data is not only the most cited but also has not been specifically rebutted or updated even though it is based on research conducted over a decade ago.

resistance from other stakeholders, trade-offs between sectors or other political considerations?

The challenge in this Study was to evolve a robust framework for arriving at such decisions or policy choices, and then use this framework to present an informed "optimum" set of choices for mitigation of Non-CO2 forcers. Outputs of the Study were therefore to be both the recommended choices for mitigation of Non-CO2 forcers but also this decision-support framework and methodology. The idea is that using this decision-support framework, the choices arrived at in the Study could be re-visited if and when better data became available.

To construct this decision-support framework, we decided to adopt a Co-Benefits approach and Multi-Criteria Analysis for both methodological and substantive reasons.[12] Briefly, there are two broad ideas behind this approach.

Before we discuss specifics of the methodology adopted here, a brief discussion on background for adopting this methodology may be appropriate.

A question commonly asked is why we have not used econometric models such as General Equilibrium or their variants, or McKinsey Cost Curves. Apart from the thin data set available as regards future trends, and even with respect to present emissions which are in many sectors "guesstimates," economic models suffer from some basic problems, in our view. Without going into an extensive discussion or critique of equilibrium theory, we may very briefly highlight here major problems due to which we have preferred not to use econometric models and to use Multi-Criteria Analysis instead.

Most economic models are based on several key assumptions on the behaviour of the economy and trends therein, depending upon variations in different parameters in relation to others. While the models themselves and the curves they generate give the appearance of well-defined trend-lines based on hard quantitative data, they are actually projections based on assumptions whose validity is assumed rather than proved in any rigorous sense. Further, and particularly germane to our analysis here, economic models do not lend themselves to comparative analyses of different policy options across sectors. This arises from the difficulty of assigning values to outcomes in given parameters of options within that sector, and even more so in accounting for changes in values of other parameters in other sectors due to inter-related effects of some options across sectors.

Now to specifics as regards why we believe multi-Criteria Analysis is appropriate for the present study and in general for mitigation policies especially in India.

First, given the context in India and other developing countries, decisions on mitigation policy cannot be taken only with emission reductions in mind. Not only are there still unresolved issues with regard to burden sharing among developed and developing countries, there are also pressing issues of poverty removal and development deficit that require to be addressed, all of which often appear as competing or conflicting demands on financial resources and institutional effort. Our

[12] This framework, as evolved in the context of climate policy in India, has been explained in detail in Dubash N., Raghunandan D., and Sreenivas A., in Economic & Political Weekly, 13 June, 2013

approach has therefore been to adopt a co-benefits approach wherein deliverables in mitigation are accompanied by developmental dividends in other spheres.

Secondly, and related to the above, mitigation policies cannot be assessed solely by themselves but must take into account impacts on many different sectors of the economy and social life. Benefits in one area may be offset by disadvantages in another. For instance, high-speed rail might reduce carbon emissions compared to, say, ordinary rail or road transport, but may result in services being priced beyond the reach of lower income groups, thus resulting in a negative impact on equity. Policy choices must therefore weigh outcomes on multiple counts.

A robust decision-support framework based on these core ideas has been adopted in this Study and is briefly explained below.

The National Action Plan on Climate Change (NAPCC) too has invoked the concept of co-benefits, but deals with voluntary mitigation endeavours by India as essentially developmental efforts with accompanying co-benefits in mitigation.[13] While this is an interesting formulation, and in our view a clever inversion of the reality, it is also revealing of anticipated difficulties of "selling" mitigation policies in developing nations and also of problems in dealing with the concept of co-benefits.

Co-benefits and their consideration in policy-making are well known in the literature. But they have often been used for post-facto justification of policy choices or have been cherry-picked to sell policies already decided upon. In other words, co-benefits tend to be reckoned subjectively, somewhat opportunistically and thus ultimately in a rather ad hoc manner.

In our approach, co-benefits to mitigation are simultaneous benefits in other developmental spheres that can be captured well based on referenced peer reviewed research findings and other reliable information. Even if the co-benefits are not quantified, mostly for want of accuracy in translating benefits into financial terms, they can be detailed in such a way as to enable comparison with other comparable policies. As would be seen from the analysis further below, the co-benefits would be delineated based on fairly hard evidence amenable to verification and cross-checks, and in a manner that leaves a clear "audit trail" of reasoning and argumentation. Any conclusions arrived at can be re-visited at a later date if new or updated information becomes available.

In this Study, we have considered co-benefits and outcomes in five categories viz. mitigation, economic growth, social equity, local environment and health, and the degree of ease or difficulty in implementation of the concerned policy. The framework as presented here, only slightly modified from the original technique in the cited reference, provides a structure for systematic, explicated and transparent delineation of co-benefits and trade-offs in these five well-defined categories.

The five categories and the main aspects covered under each are summarized as follows:

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[13] National Action Plan on Climate Change (NAPCC), p2, in http://www.moef.nic.in/modules/about-the-ministry/CCD/NAP_E.pdf

- Growth
  - [Aggregate economic] Impacts on Demand
  - Job creation
  - Energy Security
  - Infrastructure Development
- Inclusion or Equity
  - Positive impacts on poorer and lower-middle class
  - Distributive effect
  - Impact on Access
- Local Environment
  - Air
  - Land/Soil
  - Water
  - Health impacts
- Carbon mitigation
- Implementation[14]
  - Political feasibility
  - Stakeholder/Governmental Resistance
  - Technological and Infrastructure Impediments
  - Conflicts with other policies/development goals

For purposes of comparison and prioritization between options, we have adopted Multi-criteria Analysis as a tool. Briefly, based on the outcomes indicated with reasoning accompanied by references to authorities or literature as required, a score is assigned for each category or criterion on a scale of 1-5, with a low score signifying poor delivery of benefits in that category and a high score signifying maximum benefits. Where necessary, sub-categories are also defined and related outcomes evaluated. These scores are then plotted in a "spider diagram" yielding pentagons enclosing different areas. Obviously, the pentagon with the largest enclosed area would then represent the best choice.

It bears re-emphasis that these scores are not quantitative but qualitative rankings. Of course, the scores have a quantitative aspect in several of the categories, such as "Carbon Mitigation" or "Growth" or even in impacts on local environment and health, in that the scores assigned do convey something about measurable impacts. But it is important to stress that the scores do not inform about absolute values in any sense. For instance, a score of 3 on "Mitigation" for one policy choice and a score of 5 for another do not suggest that the latter will reduce carbon emissions by 40% more than the former. The scores, in fact, better enable comparisons between different

[14] In this Study, this last factor of "implementability" has been treated somewhat differently from the original version of Dubash, Raghunandan and Sreenivas cited above for ease of handling and explication. The original dealt with the other four factors together and implementation separately, then combined the two sets of explanations together, whereas here we have here combined all five factors into a single set.

policy choices on a given issue than between policy choices across issues. For example, scores on policy options regarding different bio-fuels could be compared with each other or with extant policies, but not against, say, inter-modal shifts in transportation. In other words, the scores are relative within a particular policy set but not across sets. An analogy would be student Grade Point scores which rank student performances in a given batch relative to each other, but could not be used to quantitatively compare the performance of students across batches or academic years.

Being a qualitative ranking, the method may be questioned on grounds of subjectivity or bias. However, given the referenced data and evidence-based reasoning, the subjective element gets minimized. The methodology enables corrections or improved reasoning for choices as and when better data is available. Weightages could also be assigned, but this complicates the process and might not yield great advantage.

Further, and importantly, the methodology can and should be used through multi-stakeholder consultations cutting across sectors, disciplines and constituencies or interest groups. This will ensure that a wide cross-section of views is obtained and will result in a balanced assessment of outcomes and assignment of scores, further reducing subjectivity and also promoting ownership of the decision-making process among a variety of stakeholders thus improving the process of policy making and enhancing potential for success in implementation.

The analysis to follow uses the above methodology.

The overall inventory of Non-CO2 sources is presented, priority sectors and Non-CO2 emission sources are identified based on the proportion of total emissions, then each of these sectors and sources are subject to detailed Multi-Criteria Analysis with scores assigned and spider diagrams are drawn. The Spider Diagrams relating to different sources and/or policy options are then compared and the best options selected.

Since the selection has been made on the basis of evaluation across different outcome criteria, these "best options" are not necessarily those that result in the most emission reduction but are those that, while yielding substantial mitigation, *also* yield co-benefits in economic growth, equity, local environment and health, and *also* have better prospects in terms of implementation.

2.4.3 Projected mitigation potential Based on available data on emission trends, a quantitative assessment is then made of potential emission reductions achievable through the identified "best options" in each of the selected priority sectors or sources by 2035.

A clear warning is required here. These assessments of possible emission reductions under "best option" pathways are tentative and somewhat speculative. Reason is that the currently available data are very thin on predictive trends for individual sectors or for individual Non-CO2 emissions. So only some broad projections are made based on current emission growth rates and expected future trends, and the assumptions made are briefly explained. As stated above, the analysis and projections can be improved upon with better data when available, using the methodology delineated here.

The thinness of the Indian data at present, at least as far as individual sectors and predictive trends are concerned, is also in our view a major constraint to extensive use of quantitative analysis.

As explained earlier, our use of qualitative techniques to arrive at "best options," while appearing to be subjective, results in perhaps more robust analysis and recommendations than what appear to be definitive conclusions from quantitative analyses because, while the latter are numerically based, they could well be quite widely off the mark because their data foundations are weak and assumptions based on them are consequently tenuous.

In any case, for each of the preferred policy options emanating from the MCA Analysis outlined above, our quantitative analysis begins with determining peak and trough levels and years for the concerned GHG and sector.

GHG emissions are taken to be directly proportional to the levels of activity or usage of fuels that lead to the emissions. In the case of Non-CO2 emissions, it is observed that the relevant activity levels or usages show a pattern which rises steeply at the start and then flatten out after x number of years. Such behavior can be well-represented by 'S curves' or sigmoid functions.

'S Curves have been widely used in the forecasting industry.[15] They have been used in diverse industries such as electricity generation, renewable energy etc. Such methods are based on the assumption that any industry has a set of competitive pressures – "any growing process is tightly linked with competition for resources."[16] Zit is assumed that industries which produce specific emissions themselves have limits to their rowth, and would therefore have a period in which they would grow and then start to limit themselves based on available spce, market segmentation or carrying capacity. The rate of growth is the steepness of the S-Curve. While the steepness of the curve uses curve-fitting based on existing data, the idea of limits to growth is difficult to estimate in this manner. Here the approach of using causal models, that is, estimating a priori the limits based on resource availability or other considerations, is usually followed.

In this Study, we have used a specific form of S-Curve, but it may be pointed out that any other form too may have led broadly to the same results. The co-efficients used are computed from the trajectory we consider likely from existing data, current trends where available, and conversations with experts with regard to probable saturation level and peaking year.

The problem in using the S-Curve is in estimating in which segment of the curve we are, that is, in the first segment of the curve or in the period of rapid growth before leveling off. Hence the need for some a priori determination of where we are. In the case of F-gases, for instance, according to experts is that we are in the first segment of the S-Curve just before the period of rapid rise. Once this segment is decided, then based on current value, imputed peaking year and peaking value, a sigmoidal curvecan

[15] See for instance Dmitry Kucharavy, Roland De Guio, "Application of S-shaped curves," presented at ETRIA TRIZ Future Conference 2007, Frankfurt,, 7/11/ 2007, http://www.seecore.org/d/2007_02t.pdf)
[16] Ibid.

be fitted. Coefficients were computed using a MATLAB programme created for this purpose.

Based on feedback from experts, and the research carried out in this Study, peaking year and peaking value of all Non-CO2 GHGs emissions in 'business-as-usual' (BAU) scenarios, taking the respective 2007 emissions values as base year, are worked out. Possible reduction trajectories for each of the identified Non-CO2 GHGs by 2035 were then estimated.

Emissions under BAU scenarios and reduced scenarios are represented using the sigmoid function expressed as follows:

$$A + \left(\frac{B}{1 + e^{\frac{-(x - C)}{D}}} \right)$$

Here, coefficient 'D' defines the slope of the curve. For each emission, the coefficients of this function are estimated using a curve fitting package.

Resultant curves and emission reduction values are given in the Results section.

3. Inventory of Non-CO2 Emissions (2007) As explained earlier, after thorough study of various sources including sectoral and sub-sectoral studies, we finally decided to use for our Inventory the official NATCOM2 data with 2007 as base, using updated IPCC methodologies, and published and submitted to UNFCCC in 2011. For purposes of analysis, this data is read along with the commentaries and discussion in the various sectoral and thematic papers published in 2011-12 by the Ministry of Environment & Forests (MoEF) under its Indian Network for Climate Change Assessment (INCCA).

Table 1: Inventory of Non-CO2 Emissions by Sector

GHG	Sector	Annual Emissions (kT)	Annual Emissions (kT CO2-eq)	%age in category
1. CH4				
1.1	Paddy	3327	83,175	16.2
1.2	Livestock/enteric fermentation)	10,100	252,500	49.12
1.3	Biomass/crop residue burn	226	5,650	1.1
1.4	MSW/Landfills	604	15,100	2.94
1.5	Industrial Waste Water	1050	26,250	5.11
1.6	Domestic Sewage, Waste Water	861	21,525	4.19
1.7	Fugitive Gases (Coal, Oil & Gas)	60.4	2,540	-
1.8	Thermal Power Generation	8.14	204	-
1.9	Residential (biomass energy)	2721.9	68,025	13.23
1.10	Road Transport	23.0	575	-
1.11	Manure Management	115.0	2,875	-
	Total	**20,561**	**514,046**	100
2. N_2O*				
2.1	Power Generation	10.66	3,175	4.47
2.2	Residential (Biomass energy)	36.3	10,810	15.23
2.3	Emission from Soils	140.0	41,692	58.72
2.4	Road Transport (Automobiles)	6.0	1,787	2.52
2.5	Aviation			
2.6	Industries (dominantly HNO3)	20.6	6,135	8.64
2.7	Domestic Waste water	15.8	4,705	6.63
	Total		**70,996**	100
3. BC	Diesel automobiles, locos, DG sets, cookstoves, brick kilns, agri-residues burning	N/A	N/A	N/A
4. F-gases	Refrigerants and ACs, Industries		**36,043**	
	GRAND TOTAL (Non-CO2 GHGs)		**621,085**	
	TOTAL (ALL GHGs)		**1,727, 706**	

(* includes indirect N_20 resulting from conversion of Nitrogen Oxides or NOx as per IPCC guidelines)

Again as discussed earlier, many experts and commentators might feel that this or that figure given in this inventory is incorrect, under-estimated or over-estimated. However, as our detailed study of literature showed, there are no authoritative rival projections made by others nor are there comparable economy wide estimates made in other studies either in overall terms or for individual sectors. Even where projections have been made in some sectors, studies on which these are based relate to widely varying base years and thus cannot be used in a single inventory.

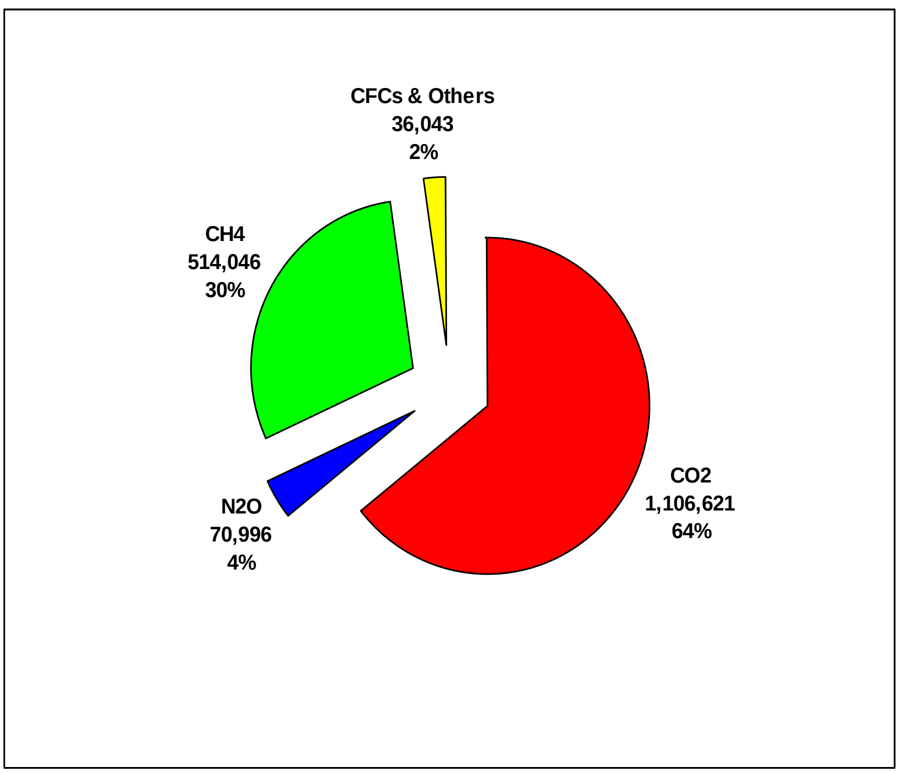
As such, NATCOM2 data remains the only authoritative data set currently available, and this is what we have used for this Study.

Since the NATCOM data sets are prepared for submission to UNFCCC according to its procedures, the inventory does not cover aerosols such as Black Carbon. However, we will cover emission sources such as wood-burning Cookstoves in this Study and will discuss Black Carbon in that connection.

3.1 Break-up of Non-CO2 GHGs

As would be seen from Table 1 above, Non-CO_2 GHGs are a sizeable 35.95% of all GHGs from India which accounted for 1.73 billion tonnes of CO_2 equivalent per year in 2007. It is straightaway clear that Non-CO_2 forcers are not some fringe element in the emissions scenario in India, and deserve special attention in addressing mitigation.

Fig.1: CO_2 and Non-CO_2 Emissions in India

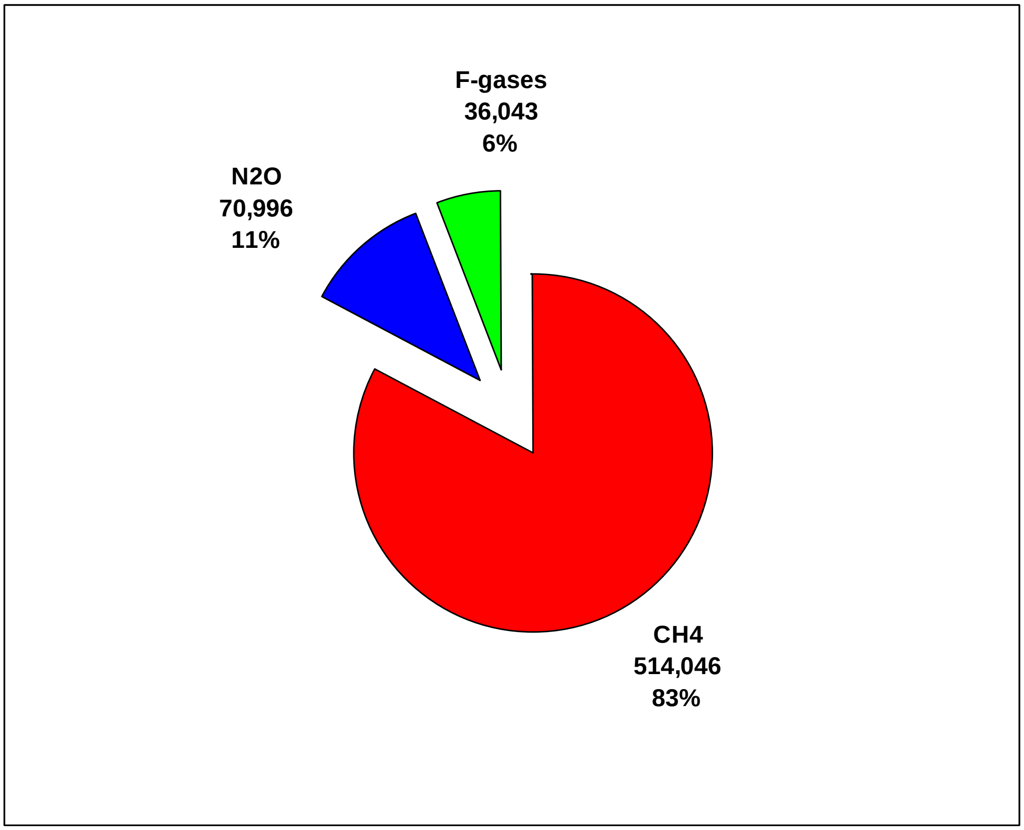


Within the Non-CO_2 forcers, methane (CH_4) is an overwhelming 82.77% of Non-CO_2 emissions (515 million tonnes $CO_{2\text{-eq}}$) and 30% of total emissions in India.

N_2O accounts for 11% of Non-CO_2 forcers and only 4% of total emissions.

F-gases are just 6% of Non-CO_2 emissions and a mere 2% of the total.

Fig 2: Fractions of Non-CO2 Emissions



From these gross numbers themselves, it seems apparent that Methane should be a major focus of mitigation efforts as regards Non-CO_2 GHGs.

Within India's total emissions which grew at 3.8% per year between 2000 and 2007, growth of methane emissions at 1.1% was relatively slower compared to the growth rates of CO_2 at 4.2% and N_2O at 3.2% during this period.[17] This reflects the growth of respective sectors and consequently emissions of the latter GHGs. Sharp increase of CO_2 and N_2O resulted from growth in electricity generation, transportation and industrial production during this period when overall annual economic growth in India was over 8% on average.[18] The relatively higher rates of growth of these GHGs is also reflected in the fact that the share of CH_4 in total emissions dropped from 31% in 1994 to 24% in 2000 down to 21% in 2007, while the share of CO_2 went up from 64% in

[17] NATCOM2, p.80

[18] NATCOM2, p.80

1994 to 67.3% in 2000 to 71% in 2007.[19] The share of N_2O has remained almost the same at around 5%,[20] which we will discuss later.

It should be noted that F-gases, even though they are the subject of much debate in the context of refrigerants and air-conditioning, are quite a small fraction of Non-CO_2 forcers, around 6% at present, and a far smaller proportion of all GHG emissions. However, we must also keep in mind that sectoral trends suggest F-gas emissions are rising rapidly at over 14% CAGR (compound annual growth rate) between 2000 and 2007, their share having doubled from 1% to 2% of total emissions.[21]

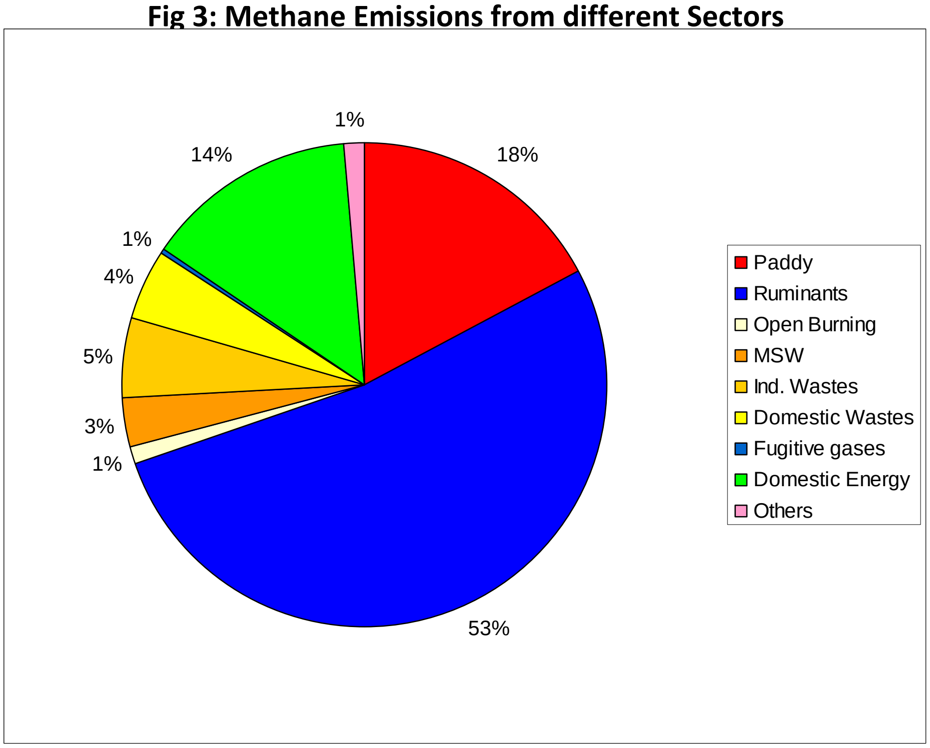
Table-1 and the accompanying pie-charts (see Figs.1 and 2) also give us a good indication of priority sectors or sub-sectors within each Non-CO_2 emission category. These are now examined.

4. Issues & Strategies for Mitigation

4.1 Methane Methane emissions being clearly the largest of the Non-CO2 GHGs in India, we shall begin with examination of the different sectors which produce these emissions, and discuss the various potential strategies to tackle them and possible priorities for mitigation keeping in mind the different co-benefits and other factors that may influence adoption and implementation of such policies.

Break-up of Methane emissions from different sectors is depicted in Fig.3 below.

Fig 3: Methane Emissions from different Sectors



[19] NATCOM2, p.80
[20] NATCOM2, p.80
[21] NATCOM2, p.80

From the figures in Table-1 and their depiction in the pie chart in Fig.3, we may quite readily conclude that Methane emissions from enteric fermentation in ruminants (53%), paddy cultivation (18%), wastes (12%) i.e., solid wastes and sewage both domestic and industrial taken together, as well as domestic sources chiefly biomass burning in cookstoves (13%) are clearly the four largest sources. Wastes are currently the smallest but the most rapidly growing Methane source given India's urban growth. Emissions from biomass burning in cookstoves are, as we shall see, declining quite sharply due to changes in domestic cooking fuels and practices.

Mitigation efforts related to each of these emission sources have several co-benefits and, in a few cases, some negative effects too.

On the other end of the scale, methane emissions from road transport, power generation, biomass burning in fields, fugitive gases released during oil coal mining and natural gas extraction, and manure management, i.e. emissions from handling, transport and storage of manure, dung cakes and so on, are all tiny as fractions of Methane emissions and obviously, even tinier as fractions of all Non-CO2 emissions and negligible in relation to Total GHG Emissions. Some of these are quantitatively significant seen by themselves, such as fugitive gases from fossil fuel extraction etc, and call for measures to reduce them. But in comparison with other much larger Methane sources, it would appear that priority attention to these Methane sources and policy measures directed at reducing these emissions would not be cost-effective and would yield little benefit in overall terms for the considerable effort required, especially in the case of scattered rather than concentrated sources such as with fugitive gases. Any economy-wide policy-based effort requires mobilization and deployment of resources as well as an expensive and arduous implementation effort and endeavours to overcome institutional inertia, which one could justify only if returns were commensurate.

Among the sectors mentioned above, methane emissions from fugitive gases and power generation may be expected to gradually decrease with improvements in technology, and management of procedures in oil, natural gas and coal extraction, processing, handling and storage. Sector-specific abatement measures could yield dividends in this sector given the relatively small number of players involved, even though the mitigation achieved may appear small compared to the larger sources.

Open burning of biomass in fields after harvest, which is a traditional farming practice especially in north and north-western India, and helps the farmer prepare the field for the next crop and also adds fertilizer to the soil, is believed to contribute substantially not only to emissions of Methane and a limited quantity of some other GHGs but also to heavy local and regional pollution and generation of aerosols known to contribute to the infamous "Asian brown cloud"[22] or Atmospheric Brown Cloud (ABC) to use the more generic instead of geographically-specific term. All types of aerosols

[22] See Niveta Jain, Arti Bhatia and Himanshu Pathak, "Emission of Air Pollutants from Crop Residue Burning in India" in Aerosol and Air Quality Research, 14: 422–430, 2014, available at http://aaqr.org/VOL14_No1_February2014/40_AAQR-13-01-OA-0031_422-430.pdf. See also also "Atmospheric brown Clouds: emissions inventory manual" pp.1-2, UNEP, 2013 at http://www.unep.org/delc/Portals/119/atmospheric/ABC_EIM.pdf

combined are likely to have an overall cooling rather than warming effect,[23] but it would be incorrect to assume that all aerosols have negative or neutral effects on global warming.[24] Further, their impact on climate is not limited to effects on temperature rise but may affect air circulation and precipitation patterns. The ABC phenomenon is also known to have serious negative effect on agricultural productivity.[25] Some estimates are that mitigation of crop residue burning and other activities leading to the ABC phenomenon could help reduce global temperature rise by around 0.6°C by 2050 and also yield substantial co-benefits as regards agricultural productivity and improvements in public health.

However, it should be noted that clearing forests for various commercial plantation and other forest fires are much larger contributors to emissions from biomass burning.[26] The numbers in India are therefore relatively small and there are also several constraints to being able to achieve significant behavioral changes especially among dispersed small farmers in India. Longer-term solutions would have to include generating options that farmers could resort to for alternative uses of crop wastes and agro-residues, particularly in the "green revolution" rice-wheat areas of Punjab, Haryana and Western UP where extensive deployment of combined harvesters is known to generate large quantities of crop wastes in a form unsuitable for traditional uses due to which farmers resort to burning more than they used to.[27]

4.1.1 Enteric fermentation Although Table-1 shows that ruminant animals are the largest single source of methane emissions, one cannot immediately suggest that tackling these CH_4 emissions should be the priority task. The enteric fermentation story in India is more complex.

India has the largest bovine population in the world with about 176 million cattle and about 100 million buffaloes.[28] Animal husbandry provides most farmers and many landless rural families a secondary income and a kind of insurance against crop failure or fall in rural employment or wages. Yet cattle population is declining, albeit at a slow rate of around 1.5% annually,[29] mainly due to rising input costs, lower use of animals for draught and poor returns from milch cattle. Buffaloes are, on the other hand, showing a small rise in population of the same order,[30] because they are reared primarily for milk often in reasonable numbers and their milk yield is higher.

Most cattle are indigenous breeds with low milk yields and are mostly grass-fed, being reared on free pastures and forage,[31] which makes control over feeds, one of the known methods of reducing the formation and emission of CH_4, a very difficult

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[23] IPCC/AR4/WG1/p.31; also see Chapter 7 for detailed discussion on role and effect of aerosols
[24] See UNEP Manual on ABC inventory cited above and various other studies
[25] Ibid
[26] See Niveta Jain, Arti Bhatia and Himanshu Pathak op. cit.
[27] ibid
[28] INCCA 4x4 p.23-24
[29] INCCA 4x4 p.23-24
[30] INCCA 4x4 p.23-24
[31] INCCA 4x4 p.23-24

proposition. Quality of feed even for dairy buffaloes is relatively poor, mainly due to high input costs. Clearly, making the transition to stall feeding of over 150 million head of cattle and the additional cost of special feed will not only be extremely difficult, it would substantially increase the cost of cattle rearing and milk production. Not only will this be virtually impossible for most small and marginal farmers, and the landless, it would put an additional strain on most farmers' budgets and push up prices of milk and milk products in a scenario of already high food prices inflation in India. However, there is potential for introducing new feeds for buffaloes which contribute 60% of methane emissions from the livestock sector due to their higher emission factors than other cattle[32] and which are dominantly stall fed, but again this might entail higher costs than tolerable except by larger dairies.

All the above problems would also present themselves in the case of small ruminants such as goats and sheep which are reared by even poorer groups especially the landless.

The Multi-Criteria Analysis (MCA) Table below captures the pros and cons.

<table>
<tr><th colspan="4">Table 2: MCA for CH4 Emissions from Ruminant Animals[33]</th></tr>
<tr><td colspan="4">Broad Goal:
• Objective: reduce CH4 emissions from Enteric Fermentation in Ruminant Animals (mainly cattle and goats/sheep in India) through improved Feeds etc
• Stakeholders: dairy farmers, other small farmers, Agri Research & Extension Organizations, Agri Universities, Central and State governments
• Time-scale: short to medium term</td></tr>
<tr><td colspan="2">Co-benefit</td><td>Description of benefit or cost</td><td>Grade (1 to 5)</td></tr>
<tr><td rowspan="3">Growth</td><td>Aggregate demand</td><td>• may dampen already stressed AH sector due higher costs</td><td rowspan="3">3</td></tr>
<tr><td>Job Creation</td><td>• a few new jobs in making/ supply of new Feed</td></tr>
<tr><td>Energy security</td><td>• adds to energy demand in Feed manufacture/supply</td></tr>
<tr><td rowspan="2">Inclusion</td><td>Improving access/outcomes for the poor</td><td>• adds costs to small farmers
• reduces fall-back potential of animal husbandry</td><td rowspan="2">2</td></tr>
<tr><td>Reducing disparities in distribution</td><td>• no impact</td></tr>
<tr><td rowspan="3">Local Environment</td><td>Air</td><td>• nil</td><td rowspan="3">3</td></tr>
<tr><td>Water</td><td>• nil</td></tr>
<tr><td>Land</td><td>• nil</td></tr>
<tr><td colspan="2">Carbon mitigation</td><td>• not much due most (≈85%)</td><td>3</td></tr>
</table>

[32] INCCA 4x4 p.24

[33] See sources cited in the description. Also see National Mission on Sustainable Agriculture (NMSA)

		cattle being grass-fed free pasture animals (not stall-fed cross-breeds) • declining cattle pop. Due rising input costs	
Implementation	Costs	• higher feed costs • may require incentives or state subsidies	1
	Stakeholder resistance	• likely poor acceptance by small farmers	
	Tech. difficulties	• small proportion (<15%) animals stall-fed, so limited impact of new Feeds	
	Conflict w/ other goals	• higher AH energy intensity	

To briefly explain the scores, on Growth an average score of 3 has been assigned. Reasoning is that costs associated with introducing improved feeds to reduce Methane emissions are not large in a macro sense. However, it will push up input costs for small cattle owners who are already finding maintenance costs of cattle high, especially for cows, with low yields. Transition from grazing to stall feeding practices for over 85% of cattle would also add to costs of small cattle owners, thus working against equity, so a score of 2, i.e. below par, has been assigned for Inclusion. Implementation would face considerable difficulty due to the scattered cattle population and due to resistance from small cattle owners owing to costs involved, and might require substantial input or other subsidies adding to total costs. These implementation problems lead to a low score of 1 on this count. To top it all, even if all this trouble were taken to introduce new feeds, their efficacy in an environment where most cattle are not kept in stalls for want of space and are allowed to forage for food, questions about the actual reductions achievable in methane emissions would seem to render any policies towards this end ineffective. A par score of 3 on Mitigation, and on Local Environmental Co-benefits, appear reasonable.

As may be seen, this policy option has, on average, an under middling score[34] (i.e. if one adds all the scores, they total to 12, under the mean 15). In other words, the option is likely to have more difficulties or penalties than benefits. Comparison with other policy options is made through the spider diagram further below.

[34] In earlier work on the MCA methodology, and as acknowledged in the Paper co-authored by Dubash, Raghunandan and Sreenivas cited above, some reviewers had opined that "adding" scores or arithmetically deriving an "average" score was not appropriate since the categories are not alike and that mathematical operations on qualitative scores is methodologically incorrect. Although in my opinion, such "averaging" is not impermissible, as for instance is done in academic CGPA scores, respecting this opinion by experts we decided to only depict and compare different options using "spider diagrams."

4.1.2 Methane from Paddy Cultivation It is ironic that one of the oldest policy arguments in the climate change debate has once again gained credence, at least partially overcoming the considerable notoriety it had acquired in the 1990s when methane production from agriculture especially paddy cultivation obviously in developing countries in Asia had been projected, especially by the US, as being among the largest contributors of GHGs.[35] The major arguments against targeting agricultural emissions still retain substantial validity, namely that food production is essential for survival of a still growing global population, and therefore any measures that might adversely affect productivity and costs in agriculture should be eschewed, and also that small and marginal farmers, who already suffer from enormous deprivations such as poverty, low incomes, poor access to energy and social infrastructure, should not be called upon to also shoulder emission reduction responsibilities particularly when they have historically contributed so little to the problem.[36] The Indian Planning Commission's Expert Group on Low-Carbon Inclusive Development and Growth, tasked with working out pathways to achieve the 20-25% reduction in emissions intensity promised by the Indian Government prior to the Copenhagen Summit, in its Interim Report had therefore completely stayed away from agricultural emissions.[37]

In any case, there is only a marginal rise in emissions from agriculture, with a CAGR of 0.7% in the period 2000-2007 and CAGR of 0.6% between 1994 and 2007.[38] This is hardly surprising given that agricultural production appears to have plateaued off, with little or no increase in acreage under cultivation, and scarcely any significant improvement in productivity.[39]

On the other hand, there is growing evidence that emissions from agriculture such as in paddy cultivation are at levels higher than they need be due to some entrenched practices which could well be modified to reduce emissions while maintaining productivity and even reducing costs.[40] Indeed, even though official policy has so far stayed away from specifically advocating a mitigation strategy in agriculture, there is widespread acknowledgement including in official circles that substantial emission reductions can be obtained from the agricultural sector, even if as a co-benefit of more sustainable and climate-resilient practices.[41]

In India, while enteric fermentation contributes 63% of GHGs from agriculture, paddy cultivation is responsible for 21% of these emissions. In terms of Methane alone, paddy cultivation contributes 16% while enteric fermentation is responsible for around 49% of CH_4 emissions.

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[35] See footnote 2 above for references

[36] See discussion on p2 and Footnote 2 above

[37] Low-Carbon Strategies for Inclusive Growth, Interim Report, Planning Commission, May 2011, at http://www.cstep.in/uploads/default/files/publications/stuff/8833d184f48579e6a0707b7b2ca8e283.pdf
In the spirit of full disclosure, it should be mentioned that D.Raghunandan, Lead Investigator for this Study, was a Member of this Committee from March 2011 to June 2013 when he, along with some other Members, resigned.

[38] NATCOM2, p.81

[39] NMSA, p.9, NATCOM2 p.9 and numerous studies

[40] Ref: IPCC/AR4/WG3, NATCOM2, NMSA

[41] NMSA (2010), p.14 and ff.; Rajeswari S. Raina in Navroz Dubash, "Handbook"

There are of course, many different types of paddy cultivation in India. Over half the area under paddy is irrigated, with around 15% irrigated paddy under continued flooding and about 20% each respectively under single aeration and multiple aerations. About 30% of paddy cultivation is rainfed, in either drought prone or flood prone areas. Upland paddy cultivation amounting to around 12% is a net sink as there are no anaerobic conditions here for generation of methane.[42]

As would be readily understood, the methane emissions in these different types of cultivation are very different with widely varying methane emission coefficients.[43] Thus, continuously flooded paddy cultivation accounts for over 32% of methane production despite being practiced in only 15% of the area under paddy, and paddy under rainfed flood-prone conditions in 8% of paddy land results in 21% of emissions. Similarly, whereas irrigated paddy under single aeration results in 17% of methane emissions from 20% paddy land, paddy under multiple aeration results in only 5% of methane emissions from an equal 20% paddy land.[44]

The data relating to area under different types of paddy cultivation and corresponding emissions are summarised below. These are updated estimates based on extensive field-level monitoring data covering 471 stations combined with satellite-based remote sensing data.[45]

Table 3: Types of Paddy Cultivation and respective Emissions

Type of Cultivation	Area (%)	Emissions Co-eff.	Methane Emissions (%)
Irrigated continuously flooded	15	162	32
Irrigated single aeration	20	66	17
Irrigated multiple aeration	20	18	5
Rainfed flood prone	8	190	21
Rainfed drought prone	22	70	19
Deepwater	3	190	6
Upland	12	0	0

Source: INCCA p.26

The data, published studies and research suggest substantial potential for reduction of emissions from paddy by changing cultivation practices, especially continuous flooding and paddy cultivation under permanent standing water. Apart from shifts away from continuous flooding which would result in lower CH_4 emissions as seen above, many other changes in practices have been suggested for paddy cultivation that would reduce methane emissions while also reducing consumption of scarce water resources which are predicted to be under severe stress because of climate change.[46]

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[42] INCCA 4x4 pp.25-26

[43] op. cit. p.26

[44] op.cit.

[45] NATCOM2, p 63

[46] NMSA p.44 and ff.

The now well-known System of Rice Intensification or SRI is also known to reduce methane emissions by well over 50%, apart from yielding other co-benefits.[47]

Mitigation efforts in agriculture in India would, as discussed further below, also target Nitrous Oxide (N_2O) emissions. In terms of implementation, therefore, policy interventions, capacity-building and institutional engagement would necessarily target methane and nitrous oxide both, yielding multiple benefits.

Other mitigation measures aiming to reduce methane emissions and increase carbon sequestration in soil relate to inter-cropping, not leaving land fallow, and growing some temporary vegetative cover between crops.[48] However, evidence suggests that emissions reduction in methane may be offset to some extent by increase in nitrous oxide emissions, albeit with net mitigation benefits.[49]

None of these measures are inimical to the interests of small and marginal farmers, nor will they prove harmful in any other way.

Perhaps the biggest constraint in bringing about changes in agricultural practices is likely to be the prevalent institutional weakness in agricultural extension. During the heady days of the "green revolution" in the 1960s and '70s, a vast agricultural extension machinery robustly backed by agricultural universities and research institutions ensured that the new technology package of high-yielding varieties of seeds with large doses of irrigation and fertilizer inputs was made available to and put to use by medium- and large farmers in a large swathe of the country. In comparison, it is widely accepted that today, the agricultural extension system in India today is virtually moribund even though the research institutions under the Indian Council of Agricultural Research (ICAR) and a chain of national and state-level Agricultural Universities and district level Krishi Vigyan Kendras (Agricultural Science Centres) continue to function.[50] Thus, whereas SRI paddy cultivation has already demonstrated considerable success in many parts of India, this is yet to be adopted and given full support by the State system.

It is therefore imperative that, whatever measures are proposed for climate-resilient and sustainable agriculture with co-benefits in mitigation, adaptation and safeguarding production, food security and farm incomes, effective extension services and capacity-building are ensured so that these policies are actually translated into changed practices and benefits on the ground.[51]

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[47] Niveta Jain, Rachana Dubey, D. S. Dubey, Jagpal Singh, M. Khanna, H. Pathak & Arti Bhatia, "Mitigation of greenhouse gas emission with system of Rice Intensification in the Indo-Gangetic plains," in Paddy and Water Environment, DOI 10.1007/s10333-013-0390-2; see also National Mission on Sustainable Agriculture (NMSA), p.44

[48] NMSA p.44

[49] Niveta Jain et al., op. cit.

[50] Raina, Rajeswari S. in Navroz Dubash (ed) Handbook on Climate Change

[51] NMSA emphasizes this, notably in the detailed operational guidelines in the Appendices.

Table 4: MCA for Methane from Paddy Cultivation			
Broad Goal: • Objective: reduce CH4 emissions from Paddy cultivation through SRI and other improved agri practices • Stakeholders: Farmers, Agri Research & Extension Organizations, Agri Universities, Central and State governments • Time-scale: short to medium term			
Co-benefit		**Description of benefit or cost**	**Qualitative grading 1 to 5**
Growth	Impacts on aggregate demand	• neutral (but lower fertilizer use may reduce subsidy outlay) • worries about output, but many reports suggest higher yields[52]	3
	Creation of jobs	• no impact	
	Energy security	• no impact; lower water use may reduce power demand	
Inclusion	Improving outcomes for the poor	• SRI helps small farmers without irrigation facilities • incentivizing SRI systems along with other climate-resilient Ag practices would help vulnerable small farmers	4
	Reducing disparities in distribution	• no impact	
Local Environment	Air	• nil	4
	Land	• will improve soil health[53]	
	Water	• substantial water conservation and improved water efficiency[54] • reduced chemical run-offs and seepage into aquifers[55]	

[52] INCCA p.25-26; Niveta Jain et al., op. cit. says an initial small drop in yield is possible with SRI

[53] NMSA advocates a series of measures aimed at developing climate resilient and sustainable agriculture in India such that these systems and practices, such as improved varieties for meeting changing conditions as also to increase carbon sequestration, changes in farm and cropping practices to increase year-round vegetative cover, improvement in soil health, prevention of soil erosion, water conservation etc would yield benefits in both adaptation and mitigation. See especially pp.33-34 and the Appendices. Also note that mitigation benefits would include reduction of Nitrous Oxide besides Methane.

[54] NMSA pp.33-34 and Appendices

[55] NMSA as above

	Other	• pest management improved • other improved agri practices contribute to climate resilience	
Carbon mitigation		• sizeable reduction in CH_4 emissions[56] • increased soil C sequestration[57]	5
Implementation	Cost-Benefit	• no large investments needed • good returns for low costs • however some institutional costs for extension, training	3
	Stakeholder Resistance	• acceptance by farmers and other stakeholders may be slow • but experience so far shows good response	
	Tech. difficulties	• SRI etc require locale-specific adaptation • institutional capacity for outreach currently low	
	Conflict w/ other goals	• none • may support other goals • reduce N_2O emissions too • aids other NMSA goals and climate resilient Ag	

Let us now briefly discuss the scores assigned, with brief justification based on salient facts in each of the co-benefit categories already given in the Table.

On the criteria of Mitigation, a score of 4 may therefore be assigned to Methane from Paddy Cultivation. In other words, the quantum of Mitigation obtainable from known measures is substantial. However, given institutional limitations in agricultural extension, and laxity in being able to reach out to small and medium farmers and bring about significant changes in practices, on the criteria of Implementability, a middling score of 3 may be as, in other words the odds are not insurmountable but it will be a somewhat uphill struggle.

A score of 3 may be assigned for the criterion of Growth, in that the changes suggested in agricultural practices to mitigate CH4 emissions are projected to not negatively impact crop yields and, although studies have suggested some possible boost to yields, there is insufficient evidence to back these claims, so one should assume that any such augmentation in yields would not be quantitatively significant.

On Inclusiveness, a better than average score of 4 may be assigned because, as explained above, measures such as shifts to SRI and lower irrigation requirements are likely to benefit small farmers, especially if this is in addition to lowering the use of

[56] NMSA pp.33-34 and ff; especially see Appendices
[57] INCCA p.22 and ff.; NMSA p.34 and ff, and especially the Appendices

inorganic nitrogenous fertilizers as recommended for mitigation of N_2O. Further, measures that promote sustainable agriculture along with climate-friendly practices are also favourable to small farmers.

A score of 4 is assigned to the Criterion of Local Environmental co-benefits given the conservation of water especially groundwater due to lower water use, the lower contamination of sub-surface aquifers due to less run-off of inorganic fertilizers, and improvements in soil health due to better practices.

However, all these benefits will accrue only if and when farmers are motivated and incentivized to adopt the improved practices, and provided the necessary capabilities to do so. As we saw, this is the weakest link in the chain, given the degradation of the agricultural extension system in India. Along with the usual inertia in changing agricultural practices, implementation remains the biggest worry, thus leading us to assign an average score of 3 for this criterion.

The scores above would seem to indicate that the option of tackling agricultural methane emissions is a good one, given the co-benefits in different categories, and this will be borne out by comparing it with other options in the spider diagrams below.

4.1.3 Wastes As already stated, we shall consider the three waste streams, namely solid wastes, domestic waste waters and industrial waste waters, together. Collectively, they amount to about 12.2% of Methane emissions, and a very small amount of N_2O emissions in the domestic waste waters stream generated by proteins in this waste.[58] Of the total emissions of 57.7 million tonnes $CO_{2\text{-eq}}$, domestic waste waters contribute around 40%, while industrial effluents contribute 38% and solid wastes around 22%.[59]

Methane generation from solid wastes is mostly from municipal solid wastes (MSW) since organized collection of domestic garbage and other solid wastes in India takes place mainly in a few major urban areas, where the common practice is keeping the wastes in landfills creating the anaerobic conditions for methane generation.[60] By contrast, in rural areas and smaller towns including so-called Tier-2 and Tier-3 cities, domestic solid wastes are simply dumped in scattered locations where anaerobic conditions for methane production do not exist,[61] although other problems of public health and hygiene could indeed arise.

Rates of urbanization in India are fairly high, at least in absolute numbers, although 68.84% still live in rural areas as per the latest 2011 Census. For the first time, though, absolute population in urban areas grew more than the rural population in the previous decennial.[62] Urban population in 2011 stands at 31.16% compared to 27.81% in 2001, that is, an increase of around 3.35% in the past 10 years. In most cities, certainly outside one or two metropolitan areas, collection of domestic garbage and solid waste is poorly organized and its disposal in landfills even worse, with landfills

[58] INCCA p.38; NATCOM2 pp.75-79
[59] INCCA p.38
[60] INCCA p.38; NATCOM2 pp. 75-79
[61] INCCA p.38; NATCOM2 p.75-79
[62] Census of India 2011

themselves being poorly designed, constructed and managed.[63] Per capita solid waste generation in India is relatively low, at around 0.55kg/capita/day,[64] yet collection, disposal and management of this waste has become a major problem in India. As already noted, therefore, the result of poor landfills and other waste handling systems has meant a steep rise in methane generation from this sub-sector, growing at a galloping 7% or more annually, among the highest growth rates of GHG emissions in India.[65]

Methane emissions from urban landfills may actually be growing at an even faster rate due to dumping of domestic garbage in informally designated sites on the outskirts of small towns under both aerobic and anaerobic conditions, although there is no hard data to support this estimation. There is virtually no bio-methanation or other methane recovery in India from landfills[66] and the alternative incineration route being chosen by some cities may cause serious urban air pollution even if it does reduce methane emissions.[67]

Domestic and industrial waste waters are another major problem. Only the largest cities in India have any sewage treatment facilities. "About 49.2% of the waste water generated from the urban centres is not collected, and further, treatment is done for only 72% of what is collected… Anaerobic route as a treatment is used in about a quarter of the waste water treated… [and] the use of advanced technologies in waste water treatment in India is still at infancy stage."[68]

Undoubtedly this scenario will undergo changes in the coming years. Although no projections or trend figures are available, certainly more towns and cities will organize garbage collection and landfills which will generate more methane. Similarly, sewage treatment in cities will gather momentum and again contribute to rising methane emissions.

The GHG emissions from waste increased by 7.3% between 1994 and 2007, this fairly high rate of growth attributed to accelerated urbanization and higher generation of municipal solid waste due to increasing consumption and changing lifestyle in urban areas.[69]

Correspondingly, there is potential for reduction of CH_4 emissions through improved landfill design and management, methane recovery systems, decentralized garbage collection and composting systems, modern sewage treatment plants with higher capacity, and so on. (methane recovery is not unknown in India: in industrial waste waters, a considerable amount of methane recovery already takes place, around 70%, 75%, and 75% in sugar, beer and dairy industries respectively.[70]) Needless to say,

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[63] NATCOM2 p.81
[64] NATCOM2 p.76
[65] NATCOM2 p.81
[66] INCCA p.40; NATCOM2, p.74 and ff
[67] See "Down to Earth," Centre for Science & Environment, New Delhi, July 8, 2013 and many other "grey" reports
[68] NATCOM 2, p.76
[69] NATCOM2, p.81
[70] NATCOM2, p.77

all measures to control waste disposal and increase managerial efficiency will yield substantial co-benefits in public health, reduction of disease vectors, lower water pollution, and so on.[71] The potential for reducing GHG emissions from waste streams using better technologies may be gauged from the fact that between 1990 and 2003, GHG emissions from wastes declined in developed countries, i.e. UNFCCC's Annex-1 and EIT countries, by 14-19%, and constituted only 2-3% of emissions from A1 and EIT countries compared to 4.3% from non-A1 developing countries.[72]

Of course, measures to reduce and control methane emissions from MSW and waste waters will require substantial public investments in garbage collection and management as well as sewage and industrial effluent treatment infrastructure. This would certainly require considerable initial outlay, but with manifold benefits in public health especially reduction in water-borne diseases, reduced contamination of surface and sub-surface water bodies and other environmental pollution.

This once again brings out the merits of the co-benefits approach and demonstrates how an approach that does not prioritize or privilege one criterion, say mitigation, may not yield a good policy option whereas an approach that considers multiple criteria and benefits or disadvantages across them will enable a better, more optimized, policy choice.

The MCA table below encapsulates the various benefits and difficulties associated with mitigation efforts relating to Methane from the waste sector. References for the description of benefits and penalties or difficulties regarding different aspects have already been given in the foregoing discussion, and so are not given separately in the Table below.

Table 5: MCA for Methane from Waste handling			
Broad Goal: • Objective: reduce CH^4 emissions from Improved Handling & Treatment of MSW, domestic and industrial Waste waters • Stakeholders: Municipalities, Central and State governments, Industries, Local Govt bodies, urban citizens, local CSOs • Time-scale: medium term			
Co-benefit		**Description of benefit or cost**	**Qualitative grading 1 to 5**
Growth	Impacts on aggregate demand	• public expenditure on municipal infrastructure will be required	3
	Job creation	• some new municipal jobs	
	Energy security	• marginal positive impact from waste-to-energy systems	
Inclusion	Improving outcomes	• some positive impact possible if waste collection, sorting,	3

[71] IPCC/AR4/WG-III/Chap.10.1 in http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch10s10-1.html
[72] IPCC/AR4/WG3/Chap 10.3.1 in http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch10s10-3.html#10-3-1

	for the poor	segregation etc are organized around the urban poor	
	Reducing disparities in distribution	• no impact	
Local Environment	Air	• no impact for waste waters; but incineration of solid wastes has negative impact on air quality	4
	Land	• improvement in urban/peri-urban environment; some evidence of local opposition to landfills and waste utilization plants; need for better landfill design and management	
	Water	• significant improvement in surface and below-ground water quality	
	Other	• reduced water-borne diseases and improved public health	
Carbon mitigation		• sizeable reduction in CH_4 emissions (NMSA) • impact on fastest-growing CH_4 category • but must contend with rising urban population • likely continued lack of waste treatment in rural areas	4
Implementation	Costs	• initial investment required	4
	Stakeholder Resistance	• municipalities traditionally slow to take on add'l costs • with adequate finances, can be effectively implemented due to institutionalized jurisdiction of civic authorities • industry cooperation likely to be weak as regards industrial waste waters; requires strong monitoring even of mandates	
	Tech. difficulties	• institutional weaknesses of municipal bodies • distributed industries tougher to tackle than sewage	
	Conflict w/ other goals	• none • will improve quality of life	

Again, some brief explanation of the scores assigned, even though the discussion and Table above with referenced reasoning provides sound enough basis.

The score of 4 assigned for Mitigation reflects the sizeable potential for reducing Methane from the wastes sector, especially MSW, but tempered by the fact of rapid growth of urban population, gradual increase of landfills in urban municipalities with attendant anaerobic conditions generating CH4. Absence of landfills in smaller towns although inhibiting methane production, is not generally desirable from public health and hygiene points of view, and there is a trend of more towns and municipalities starting landfills thereby increasing methane production. Similarly, sewage treatment is slow to be taken up and however pro-active the government is in incentivising municipalities to do this task effectively, mitigation achieved is bound to lag behind effort. A score of 4 is preferred to a high score of 5 despite the potential for mitigation, and even though technology is readily available, due to the likelihood of waste generation outpacing setting up good waste handling facilities and methane recovery systems.

A score of 3 is assigned on the Growth category indicating that considerable public investment and expenditure would be required no doubt involving additional taxes or rates especially by municipalities. Some revenue generation from methane recovery is likely but not any significant amount. Co-benefits and savings from improvements in public health may offset sanitation expenditures.

This issue is more or less neutral to equity considerations, although if the urban poor are involved meaningfully and creatively with waste collection, segregation and handling, significant income could be generated for the urban poor. A score of 3 seems appropriate.

Sound waste management including sewage treatment would yield substantial co-benefits in public health, improvements in quality of surface waters due to better sewage treatment and of underground aquifers due to prevention of seepage of pollutants into water bodies from wastes on the surface. Avoidance of incineration options and preference afforded to bio-methanation will also help maintain air quality. An above-average score of 4 is assigned.

MCA Table shows a broadly above-average overall score, reflecting very good mitigation potential, substantial co-benefits, some difficulties in implementation due to inertia and capability handicaps of municipal bodies compensated by their established jurisdiction and institutional structures.

4.1.4 Methane (and N_20 and BC) from Domestic Biomass burning Methane emissions from domestic biomass burning is being covered together with N_2O and Black Carbon from this source because almost all measures contemplated to deal with domestic biomass burning would deal with all these emissions together.

Methane from domestic energy, mainly from biomass-based cookstoves, constitutes 13% of all CH_4 emissions, while domestic energy as a whole contributes around 12.3% of $CO_{2\text{-eq}}$ emissions in the energy sector. N_2O from the biomass combustion in its place comprises 15.2% of all N_2O emissions. Together they constitute about 12% of total Non-CO2 emissions. As such they are quite substantial emissions both in their respective categories and with regard to the whole. If black carbon were also to be taken into account, although there are only vague guesstimates and no authoritative figures for the same, it would appear that domestic wood-burning cookstoves are major GHG emitters and should be a major target of mitigation endeavours.

It is little wonder then that the issue of domestic wood-burning cookstoves has, in recent times, rather rapidly built up into a major campaign issue. In India, a new National Biomass Cookstoves Programme (NBCP) was also initiated in 2009.[73] While driven by several goals and motivations, the NBCP obviously sought to play up different co-benefits so as to sell the Programme better and appeal to a variety of stakeholders. Thus, the objectives of the pilot projects launched under the Programme include innovating new or improved cooking energy solutions, fuel savings, reducing emissions including improvement in indoor air quality, mitigating drudgery and addressing health related concerns of women and children, and also specifically, "to demonstrate the impact of using biomass improved cookstoves on mitigating climate change by reducing the carbon and other emissions resulting from burning biomass for cooking… [and] to gather field performance data for preparing a strategy plan for expansion of deployment of biomass cookstoves, including exploring CDM benefits to improve the affordability of biomass cookstoves."[74]

This underlines the point made in the methodology section about how co-benefits tends to be used rather subjectively as a post-facto rationalization, invoking certain benefits, of an a priori policy decision or one arrived at for other reasons. In this case, whereas checking indoor air pollution and the consequent health benefits may perhaps have been the main and initially conceived goals, carbon mitigation has been invoked as a major benefit, even to the extent of using this justification to make a case for CDM funds!

The issue of black carbon and aerosols from domestic wood-burning cookstoves is addressed in a subsequent section below, where it is argued essentially that the issue is quite intractable and that, because it is virtually impossible to isolate black carbon from the much larger fraction of organic carbon and other aerosols, it is also highly problematic to assess the impact of reducing cookstove aerosol emissions on warming. This needs to be kept in mind even when addressing methane and N_2O emissions from wood-burning stoves since, again, almost all new-design cookstoves will reduce aerosols along with all other GHGs.

It would be useful therefore to look at the various pros and cons of policies designed to reduce GHG emissions from domestic wood-burning cookstoves in a more comprehensive manner rather than singling out this or that GHG or emission.

A salient fact that needs to be noted is that urbanization is taking place at a fairly high rate in India, with around 55% of population expected to be living in urban areas by

[73] See Ministry of Renewable Energy Sources, Government of India, website at http://www.mnre.gov.in/schemes/decentralized-systems/national-biomass-cookstoves-initiative/

[74] Ibid.

2050[75] compared to around 31.2% in the 2011 Census. All data, including from the National Sample Survey, show that use of biomass for cooking declines sharply with urbanization and is chiefly a rural phenomenon.[76] This would indicate a steady decline in domestic biomass burning in the coming decades. Secondly, penetration of LPG (liquefied petroleum gas) for cooking is also increasing quite sharply in rural areas. Total consumers are today believed to be over 150 million households[77] and officially known to be 125.388 million in 2011,[78] clearly well above the total number of around 78.8 million urban households in the 2011 Census.[79] The Government has ambitious plans to increase LPG penetration in rural areas from the current about 50% to around 75% of households by the end of the XIIth five-year plan in 2017, specifically aiming to cut down on use of biomass-based cooking.[80] Clearly, we are looking at a sharp decline in wood-burning cookstoves, certainly well over the above planned 25%, and much earlier than our target year of 2035.

It may also be noted though, that no authentic numbers are available to indicate how much net increase in GHGs would ensue from this shift to LPG. Methane, N_2O and aerosols from would burning stoves would of course be eliminated, but CO2 and some other fugitive emissions from the increased fossil-fuel LPG would shoot up. One could estimate the net difference in emissions based on the likelihood that users of wood-burning stoves would all be migrating to LPG but there re large uncertainties involved. Part of the uncertainty also results from the fact that there are no definitive data on the proportion of commercial wood burned in domestic cookstoves. It is often assumed that most domestic cooking using fuel-wood uses naturally fallen twigs and loppings, but this is clearly not the whole picture, and commercial wood-burning stoves may well continue to function. Emissions from wood-burning cookstoves are not all counted towards national emissions as per UNFCCC guidelines, but in any case use of twigs and fallen branches or trimmings are certainly fully renewable and should not be counted.

Table 6 below looks at the scenario of reducing emissions from wood-burning domestic stoves.

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[75] UN World Urbanization Prospects, 2011 Revision

[76] Energy Sources of Indian households for cooking and lighting," National Sample Survey 68th Round, National Sample Survey Organisation, Ministry of Statistics and Programme Implementation, Sept 2012, available at: http://www.indiawaterportal.org/sites/indiawaterportal.org/files/energy_sources_of_indian_households.pdf ; see also International Energy Agency, "World Energy Outlook: focus on key topics" 2006, available at: https://www.iea.org/publications/freepublications/publication/cooking.pdf p.421-424 and ff.; "Cooking fuels in India: trends and patterns," The Energy & Resources Institute, New Delhi, 2011, available at: http://www.teriin.org/div/CES/Policy_brief_cooking_fuels.pdf

[77] Financial Express, August 21, 2013, in http://www.financialexpress.com/news/lpg-burning-bright/1162558

[78] Ministry of Petroleum & Natural Gas, Annual Report, 2012-13

[79] http://www.devinfolive.info/censusinfodashboard/website/index.php/pages/household_size/total/Households

[80] XIIth Plan, Planning Commission, Govt of India, 2012; see Summary in http://www.slideshare.net/PlanComIndia/energy-sector-in-the-12th-plan

Table 6: Methane (and N_2O and BC) from Domestic Biomass burning

Broad Goal:

- Objective: reduce CH_4 (and N_2O and BC emissions) from Domestic Biomass Burning eg. through Improved Cookstoves
- Stakeholders: householders especially Women, Ministry of New & Renewable Energy, Min of Health, Central and State governments
- Time-scale: medium term

Co-benefit		**Description of benefit or cost**	**Qualitative grading 1 to 5**
Growth	Impacts on aggregate demand	• none if thru Cookstoves • subsidy burden if sought thru LPG	3
	Creation of jobs	• new jobs in manufacture/ installation/distribution of new Cookstoves or better Fuels	
	Energy security	• temporarily reduce pressure on LPG demand if cookstoves • but neutralized by urbanization rates and increased penetration of LPG in rural areas	
Inclusion	Improving outcomes for the poor	• positive impact on QoL esp for Women in rural areas • some new jobs in rural areas • but high cash cost of 2nd Gen Cookstoves and/or improved Fuels may work against equity but may be offset by subsidy	3
	Reducing disparities in distribution	• will slow down access to modern cooking energy • may skew positives in favour of rural rich	
Local Environment	Air	• some improvement but mainly due to reduced particulates	4
	Land	• nil	
	Water	• nil	
	Other	• marked improvement in indoor air pollution	
Carbon mitigation		• some GHG release reduced but actual net mitigation doubtful • small in overall terms due to cost and institutional factors • benefits likely to be low compared to reductions due to urbanization and LPG shift	2

Implementation	Costs	• could be high in short term especially if subsidies are involved	1
	Stakeholder Resistance	• likely poor acceptance by householders due high cost	
	Tech. difficulties	• institutional factors biggest impediment cf. old cookstoves programme • delivery systems v. weak	
	Conflict w/ other goals	• conflict with agenda for step-improvement in access to modern energy • with urban:rural pop ratio slated to go from 30:70 to 50:50 by 2050, Biomass Burning slated to decline • similarly, LPG penetration in rural areas slated to increase	
Total (5 to 25)			**13**

The scores assigned above are now briefly summed up.

On Mitigation, a below-par score of 2 has been assigned. As explained in detail above, since BC is bound up with OC, any decrease in the former would also mean a much larger drop in the latter which has a cooling effect, thus leading to a net cooling effect, prompting a "negative" or less than average score.

However, since the mail rationale advanced for improved cookstoves is the sharp drop that could be brought about in indoor air pollution (IAP), and hence a marked improvement in women's health in particular, a thorough consideration of the other criteria is also required.

There would be only marginal impact on Growth, mainly through generation of a few jobs in stove manufacturing but offset by an increased subsidy burden without which the expensive second-generation cookstoves would likely not gain acceptance. A par score of 3 is being assigned.

On Inclusion too a score of 3 is being assigned. It might appear that this is a measure aimed at the rural poor who constitute the majority of biomass-burning cookstoves and who would undoubtedly gain from a substantial improvement in indoor air pollution. But a closer look would reveal some contrary outcomes. If there is no subsidy, the poor would be paying a considerable amount for the new stoves, and additional amounts if improved fuels are also added to the mix. And if new biomass-burning stoves are pushed, this will delay access of the poor to LPG. On several counts, therefore, the cookstove programme may actually work against the interests of the poor. Taking all this into account, a neutral score of 3 is assigned.

On Local Environment/Health co-benefits, on Methane and NO_2, an above average score of 4 can be assigned since particulates are being reduced significantly, even though the main factor in IAP or even outdoor pollution causing smog and the atmospheric brown cloud (ABC) is neither of these gases.

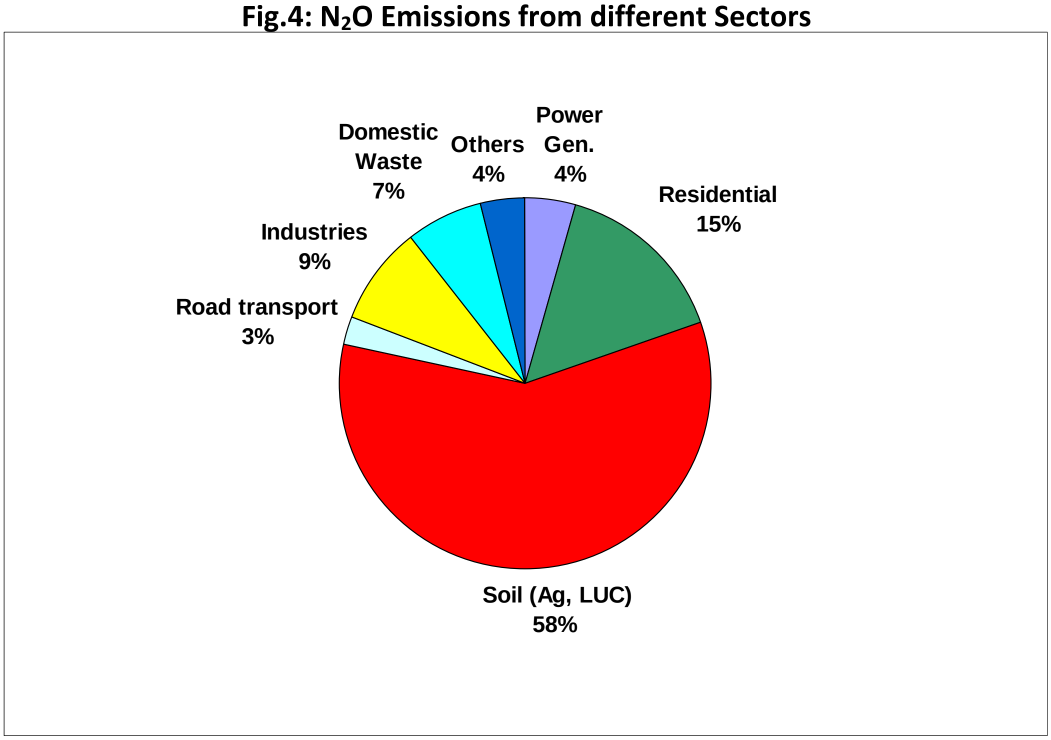
Implementation will be the biggest problem in a Biomass-burning Cookstove programme as discussed extensively above. Added to the known problems experienced in the first-generation improved cookstove programmes, especially institutional weaknesses in the delivery system, would be the much higher cost of new-generation cookstoves. For these reasons, a low score of 1 is given on Implementability.

4.2 N_2O It would be recalled from Table-1 that N_2O emissions are only 4% of all emissions and 11% of Non-CO_2 emissions in India.

Of this, N_2O emissions from Agriculture and Land-Use Change constitute as much as 58% as would be seen from the pie-chart below, making this the largest sector of concern for N_2O emissions. The next largest contribution comes from the residential sector, again chiefly from wood-burning cookstoves which have already been dealt with in Section 4.1.4.

In this section therefore, we will deal primarily with N_2O emissions from Soil (Agriculture and LUC) but will also briefly discuss N_2O emissions from the industrial sector even though these contribute a small proportion, around 9%, of N_2O emissions and therefore an extremely small proportion of Non-CO_2 emissions and a tiny proportion of total Indian emissions.

Fig.4: N_2O Emissions from different Sectors



4.2.1 N_2O from Soil (Agriculture) *(Note: includes converted NO_x)* This is clearly the dominant source of N_2O emissions and is therefore dealt with first.

It has long been almost an article of faith in policy-making circles in India, and in civil society too, that agricultural emissions are a "no-go area" as far as mitigation actions go. This is mainly based on an understanding that agricultural emissions in India are "survival emissions," that is, essential for human survival in the context of a large proportion of marginal farming and hence subsistence levels of food production that should not be interfered with. Yet, especially of late, agricultural experts have argued that patterns of agricultural production promoted over several years have resulted in widespread adoption of practices that have upset the ecological stability especially as regards the nitrogen balance, damaged soil health and resulted in decreasing productivity to the detriment of sustainable food production and farmers' incomes, calling for changes in agricultural policies simultaneously addressing sustainability, climate resilience and mitigation.[81] Officially too, such as in the national Mission on Sustainable Agriculture (NMSA), the idea of adopting agronomic practices such as SRI techniques in paddy, greater use of organic inputs and other practices to increase soil carbon sequestration have been put forward,[82] although much will depend on implementation capabilities as argued while discussing Methane.

N_2O emissions from soils originate mostly from two sources, namely, excess inorganic nitrogen in inputs, and land-use change resulting in reduction of the ability of the soil to absorb carbon and to fix the nitrogen in the soil itself instead of allowing it to escape into the atmosphere as N_2O. The nitrogen-handling problem of soils in India may be briefly summed up as follows based on broad scientific consensus among Indian scientific institutions and experts.

Excessive use of inorganic nitrogenous fertilizers in Indian agriculture is a well-known problem in Indian agriculture especially since the green revolution era. Use of urea in particular, both domestically manufactured and imported, rose sharply in the 1970s through the 1990s based dominantly on naphtha in the 1970s and natural gas later, all of which received generous subsidies and policy support in the effort to augment domestic food production especially cereals and pulses. These policies, including differential taxation so as to lower urea prices and decontrol of phosphor- and potash-based fertilizers, skewed the fertilizer policy in favour of nitrogenous fertilizers and resulted in substantial rise of urea application in farms, not just in the green revolution areas but elsewhere too due to farmers in these latter areas adopting what they perceived as successful practices elsewhere. Evidence suggests progressive loss of yield per unit of fertilizer application in many areas of the country.[83]

[81] Rajeswari Raina, "Agriculture in the environment: are sustainable climate friendly systems possible in India?" in Navroz Dubash (ed), "Handbook of climate change and India," Oxford University Press, New Delhi, 2011.

[82] NMSA, pp.33-34; see also Appendix III-D for some further plans in this direction

[83] Numerous studies in India have shown the deleterious effect on soil health of excessive use of inorganic fertilizers, For instance see Jaga P.K., and Upadhyay V.B., "Effect of integrated nutrient management on wheat," Inovare journal of Agricultual Science, Vol.1 Iss.1, 2013, p.1

With more warming, excessive nitrogen in the soil adversely affects the absorption of methane and increases release of methane to the atmosphere to a substantial degree. Some soil microbes feed off the inorganic nitrogen and facilitate the release of N_2O into the atmosphere. Excess nitrogen also leaches into groundwater and finally finds its way to surface water bodies or the oceans where it is consumed by algae, depleting the availability of Oxygen for other aquatic life and reducing the capacity of these water bodies to act as sinks.

There is growing recognition in India, even if grudgingly and slowly, that the overuse of nitrogenous fertilizers is becoming harmful with respect to soil health and counterproductive even as regards productivity, besides adding to agricultural emissions.[84] Farmers, especially small and marginal farmers, are also feeling the pinch of rising input costs especially those of fertilizers and would welcome measures that reduce their dependence and use of these costly inputs, while the government would also gain from reduced subsidy burden (currently very high) on these fertilizers. There are thus clear co-benefits from policies designed to reduce use of nitrogenous fertilizers and emissions of N_2O which would also reduce other emissions especially Methane and promote Carbon sequestration in the soil. Indeed, IPCC Assessment Reports have consistently been underlining the multi-dimensional character of agricultural emissions and hence the need to look for co-benefits and synergies between different policy spheres while addressing mitigation of agricultural emissions.[85] Policies being thought of in India at present also look at appropriate taxation policies, capacity-building to rationalize application of chemical fertilizers especially urea and modify agricultural practices such as introducing or increasing inter-crop vegetative cover.[86]

The main constraint would be the institutional weaknesses discussed earlier too with respect to capabilities and institutional mechanisms for agricultural extension which have become seriously degraded over the past few decades. In the absence of institutional reforms and strengthening, the only policy instruments available are top-down advice to farmers and taxation measures such as the present nutrition-based taxes to replace the earlier specific fertilizer-based taxes which, in theory, should modulate use of urea and other fertilizers as per need. Competitive uses for naphtha and demands from industry would also contribute to tightening the availability of naphtha for fertilizer production.

The Table below summarizes the different benefits and counter-factors working in favour or against policies designed to reduce NOx from soil. Again, references are not being given within the Table itself since they have been provided in the preceding discussion.

[84] Ibid and Rajeswari Raina, op. cit.
[85] IPCC/AR4/WG3 pp.500-507 and ff.
[86] NMSA

<table>
<tr><th colspan="4">Table 7: Multi-Criteria Analysis for N_2O from Agriculture (Soil)</th></tr>
<tr><td colspan="4">Broad Goal:
Objective: reduce N_2O emissions from Soil (Agriculture, Land Use Change etc) through reducing application of inorganic nitrogenous fertilizers, increasing bio-fertilizer application, appropriate vegetative cover between crops etc
Stakeholders: Farmers, Fertilizer companies, Ag Co-ops, Central and State governments, Ag Research and Extension Institutions, Ag Universities, CSOs
Time-scale: medium term</td></tr>
<tr><td colspan="2">Co-benefit</td><td>Description of benefit or cost</td><td>Qualitative grading (1 to 5)</td></tr>
<tr><td rowspan="3">Growth</td><td>Impacts on aggregate demand</td><td>• neutral</td><td rowspan="3">3</td></tr>
<tr><td>Job creation</td><td>• no specific impact</td></tr>
<tr><td>Energy security</td><td>• no specific impact</td></tr>
<tr><td rowspan="2">Inclusion</td><td>Improving outcomes for poor</td><td>• climate-resilient Ag to reduce risks and benefit small/ marginal farmers esp in dryland areas</td><td rowspan="2">3</td></tr>
<tr><td>Reducing disparities in distribution</td><td>• no specific impact</td></tr>
<tr><td rowspan="3">Local Environment</td><td>Air</td><td>• no</td><td rowspan="4">4</td></tr>
<tr><td>Land</td><td>• improved soil health expected</td></tr>
<tr><td>Water</td><td>• improvement in surface and sub-soil water quality due reduced chemical run-off and seepage</td></tr>
<tr><td></td><td>Other</td><td>• no</td></tr>
<tr><td colspan="2">Carbon mitigation</td><td>• good reduction in N_2O emissions</td><td>4</td></tr>
<tr><td rowspan="4">Implementability</td><td>Costs</td><td>• no major cost implication</td><td rowspan="4">3</td></tr>
<tr><td>Stakeholder Resistance</td><td>• institutional weaknesses in Ag extension/support
• experience shows good farmer response to better Ag practices incl less chemical fertilizer load
• governmental inertia (incl of Ag Insttns) likely main hurdle</td></tr>
<tr><td>Tech. difficulties</td><td>• institutional weaknesses
• some concerns about yields</td></tr>
<tr><td>Conflict w/ other goals</td><td>• none
• will improve climate resilience and sustainability of Ag esp in dryland areas</td></tr>
<tr><td colspan="2">Total (5 to 25)</td><td></td><td>17</td></tr>
</table>

As usual, a brief summing up of the rationale for the scores assigned against the five categories now follows, although the analysis and Table above explain this in much greater detail.

On Mitigation, a score of 4 has been assigned because the measures suggested would lead to significant reduction in N_2O from Soil (including indirect nitrous oxide converted from NOx) although even with best efforts not all emissions can be prevented and, compared with other Non-CO2 emissions such as methane the quantum of emissions avoided is not so large as to merit a 5.

A score of 3 has been assigned on Growth indicating that the recommended action neither gives a particular boost to economic activity nor does it exact a penalty.

Similarly, a neutral score of 3 is also assigned on Inclusion or equity, even though restoring soil health and a balanced nitrogen cycle, as well as reducing application of nitrogenous fertilizers and hence costs, will undoubtedly help small farmers. Since this measure would also benefit larger farmers, a score more than 3 may not be merited.

Again in dealing with Agriculture, Implementation is the Achilles heel of any policy recommendation due to the institutional weaknesses in extension and farmer motivation and support systems. We may be somewhat skeptical of governmental intentions and will to actually carry out the measures recommended, and we would like to be proved wrong and revise our score upwards at a later date. But for now, if only to be cautious, a neutral score of 3 seems appropriate.

Co-benefits in local environment, as well as for adaptation and sustainability as posited in the National Mission on Sustainable Agriculture, are a strong point in favour of this option. A score of 4 has been assigned on this count.

4.2.2 N_2O from Domestic Sources (biomass cookstoves)**:** *already covered in 4.1.4*

No change of scores from the Methane case is felt to be necessary.

4.2.3 N_2O from Domestic Waste Wate*r: already covered in 4.1.3*

Again, no change from the Methane case is seen as being required.

4.2.4 N_2O from Industry Although not significant in quantitative terms in comparison with N_2O emissions from other sources, a few comments on this sector may be of interest.

About 80% of NO_x emissions come from a single industry, that is, manufacture of Nitric Acid, and the quantum of indirect N_2O from this source is tiny. Efforts to tackle industrial emissions are usually focused sector-wise. For purposes of this Study, it is assumed that as part of India's mitigation efforts with regard to industrial emissions, NO_x and indirect N_2O emissions are best controlled by a sharp focus on the Nitric Acid industry and are best handled in this manner, rather than calling for any specific new set of policies which would be difficult to justify given the quantity of emissions involved.

The remaining sources of industrial N_2O emissions are far too scattered both geographically and sectorally to be effectively tackled in any focused manner.

4.3 F-Gases As we have seen from the overall figures, F-gases, mostly from Air-conditioning and Refrigeration along with a minor contribution from industrial processes and products, are a very small fraction currently amounting to only 6% of Non-CO_2 emissions and a mere 2% of total GHGs from India in $CO_{2\text{-eq}}$ terms, that is, allowing for their much higher Global Warming Potential (GWP), several thousand times that of CO_2. However, F-gas emissions in India are rising at a rapid rate, having climbed from 1% of overall emissions in 2001 to 2% in 2007[87] at a 14.7% compounded annual growth rate[88] mainly due to the rapid increase of air-conditioning in buildings and vehicles in the growing Indian economy.

In discussions on India's international stance on climate change issues, the issue of F-gases has recently become controversial due to trends in on-going multilateral processes underway to regulate hydro-fluorocarbons (HFCs), which were introduced to replace the ozone-depleting chloro-fluorocarbons (CFCs) and hydro-chlorofluorocarbons (HCFCs) phased out under the Montreal Protocol. While HFCs have no ozone depleting potential, they are very potent greenhouse gases. The debate is whether HFCs should be regulated under the Montreal Protocol even though it is not ozone depleting, but because it is a substitute for CFCs and HCFCs which were being effectively regulated under the Montreal Protocol with tried and tested mechanisms and institutional structures, or under the UNFCCC which deals with all other GHGs.

Discussions so far have been held under the Montreal Protocol, and India has disagreed with decisions taken, and agreed upon by most countries, that HFCs too will soon be phased out along with some financial packages for countries that need it. India contends along with some other countries, till recently including China, that HFCs should be handled under UNFCCC arrangements instead.[89] Consequently, without forward movement on India's part on this issue, there are currently no policies in place to regulate HFCs and their emissions in the country.

Now, there is little doubt that reducing F-gas emissions, especially the production and use of HFCs in refrigeration and air-conditioning which is increasing sharply in large and growing economies like India, is an important issue. It needs to be addressed globally as well as domestically in a mostly hot sub-tropical and tropical country like India, where demand for air-conditioners and refrigerators is bound to grow, and grow fast if current trends of high economic growth and expansion of the middle-classes continue.

Without for the moment going into the merits of which regulatory framework is to be preferred, it is important that emissions of F-gases especially HFCs in India be viewed in perspective, particularly as regards their relative magnitude compared to other non-CO2 GHGs and to total emissions.

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[87] NATCOM2; INCCA p.80-82

[88] INCCA, p.80

[89] A large literature has built up around this issue and is beyond the scope of this Study to address. For an overview of the issue, although clearly supporting the proposition favouring the regulation of HFCs under the Montreal Protocol, see http://www.eia-international.org/wp-content/uploads/EIA-policy-briefing_Bangkok-intersessional_August_2012_FINAL.pdf

Much has been made of the burgeoning uptake in India of room air-conditioners and automobiles with built-in air-conditioners. Studies have frequently cited the 20% annual growth in demand for air-conditioners during the period 2001-2010.[90] This has been rightly attributed to the booming Indian economy with liberalization taking hold, pent-up demand, rise of the Indian middle-class and its growing purchasing power. However, in our opinion, these trends should not be over-estimated nor should they be treated as permanent or long-term trends. Many a multi-national company and international investor has come a cropper in India over-estimating its growth story and the size and purchasing power of its middle-class!

Demand for air-conditioners has of late been slowing, with the cooling down of the Indian economy in recent times and GDP growth rates coming down from the dizzying 10% per year to a more sedate 5-6%, consumer sentiments too have dampened, what with incomes and disposable incomes tapering off, and prices rising. Air conditioner sales are said to have registered -20% in 2012 compared to the previous year and refrigerator sales had gone flat.[91] In 2012-13, air conditioner sales were flat and refrigerator sales had gone up by a mere 5% year-on-year.[92]

All this is not to claim that there would be low growth in domestic air-conditioner and refrigerator use in India: in the long term demand for these products will undoubtedly rise as the Indian economy grows. But it would be unrealistic to expect the scorching growth rates of the first decade of the new millennium to sustain over a very long period, especially with a slowing global economy. It is also important to fully comprehend the socio-economic reality in India where nearly half the population lives at or below the poverty line, where around 45% of the population does not have electricity in their homes, and where prospects of this large section of the populace entering the middle-class with high disposable incomes any time soon are remote.

Having said all that, given the size of the Indian economy and middle-class, there is should also be no under-estimation of the growth in use of air-conditioners in commercial buildings and offices, homes and automobiles, and therefore the pressing need to regulate them and the emissions arising from use of GHG-producing refrigerants in them.

It should also be noted that, as quantitative estimates will show later, the potential to reduce HFC emissions in India is comparatively higher than for most other Non-CO_2 GHGs, and if the global agreement to phase out HFCs in a time-bound manner proves to be as effective as the successful phase-out of CFCs and HCFCs, a major GHG with high GWP could be almost completely eliminated.

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[90] See for instance the authoritative study on refrigerants and GHG emissions in India by a consortium of Organizations led by the Natural Resources Defence Council, "Cooling India with Less Warming: The Business Case for Phasing Down HFCs in Room and Vehicle Air Conditioners," Natural Resources Defense Council, June 2013, available at: http://www.nrdc.org/international/india/files/air-conditioner-efficiency-IP.pdf

[91] See news report in a prominent Indian fortnightly citing an interview with a leading air conditioner manufacturer in http://indiatoday.intoday.in/story/sales-of-fridge-and-ac-set-to-go-down/1/182710.html

[92] See http://articles.economictimes.indiatimes.com/2013-02-13/news/37079333_1_price-hike-input-costs-refrigerator-prices

In our opinion, given the international pressure building up towards phasing out of HFCs, and the moves to replace currently-used HFC based refrigerants with other gases with far lower warming potential, whether the phasing-out takes place under the Montreal Protocol or the UNFCCC, the momentum is decisively in favour of gradually replacing HFCs. India and its corporate sector engaged in manufacturing air-conditioners and refrigerators will soon realize the disadvantages of remaining isolated on this issue and the merits of going along with the growing international consensus on it.[93] If the transition from HFCs to other refrigerants is also supported by suitable financial assistance from developed countries, especially those with companies IPRs for the substitute refrigerants, this will accelerate the phase-out as was earlier evidenced in the Montreal Protocol.

One way or another, therefore, mitigation programmes in India would sooner or later aim at complete and possibly time-bound *elimination* of HFCs from the production cycle altogether as had earlier happened with CFCs and HCFCs, and not just some reduction as with other GHGs. In this sense, resolving the jurisdictional issue, and taking timely mitigation action on HFCs, would yield perceptible dividends in terms of reducing India's emissions in $CO_{2\text{-}eq}$ terms, even if these reductions are not very large in absolute terms.

Some Indian companies, such as Godrej, even though with low shares in the air-conditioning and refrigeration markets in India and very low stakes in the export markets have, on their own and without incentives or regulatory prodding, already introduced non-HFC air-conditioners, that too with a non patent protected R-290 hydrocarbon refrigerant, in the hopes of making an early entry into the "green" if higher-priced air conditioners segment.[94] Most other major AC and refrigerator manufacturers in India are international companies who are more like than not to follow international trends as they have already started doing, especially as the Indian entities develop greater stakes in the export markets as companies have done elsewhere, notably in China.

It is clear that there are no apparent down sides to the regulation and phasing out of HFCs in India, except the issue of technology transfer and IPRs of substitute refrigerants if required which can be dealt with by the Indian corporate sector in what is obviously an up-market consumer segment, with some support from government if needed in the form of appropriate international agreements and domestic regulatory mechanisms.[95] Civil society organizations in India are also mounting pressure on the government to quickly resolve the current imbroglio regarding whether action should be taken under UNFCCC or the Montreal Protocol, and tackle this important issue in a timely and effective manner. In light of the above, in our opinion, F-gases need no additional prioritization over and above what is already taking place in terms of campaigns to phase out HFCs. These campaigns would also of course have to factor-in

[93] For a persuasive account of Indian industrial interests, see NRDC (2013) op. cit.
[94] ibid
[95] Several studies including the one referenced above have brought out efforts made by Indian companies to develop substitute refrigerants in both fixed and mobile A/C segments, so the Patent issue is not as big an obstacle as initially thought.

and work with the on-going policy tussle in India regarding the appropriate jurisdiction of dealing with HFCs, whether under the UNFCCC or the Montreal Protocol.

4.4 Black Carbon Some discussion on Black Carbon (BC) is also called for even though it is not included among the GHG sources to be controlled under the UNFCCC, nor even to be separately reported on to the UNFCCC in National Communications and inventories. This is felt to be necessary because several studies and experts have opined that BC is an important and quantitatively significant contributor to global warming and therefore needs tpo be specifically targeted since it will likely yield near-term dividends for limiting temperature rise and co-benefits in a number of areas.[96] In the Indian and broader Asian context in which India is a major contributor, BC and related carbonaceous aerosols are expected to continue to rise over the next two decades, in contrast to the declining trend in North America and Europe due to regulatory policies and their implementation in these areas.[97]

At the outset it should be noted that there is considerable controversy over the global warming role of Black Carbon as well as over the effectiveness of mitigation efforts targeting BC.

IPCC's understanding is that all aerosols considered together actually have a negative warming (i.e. cooling) potential because they tend to dissipate radiation rather than contribute to warming by absorbing radiation.[98]

Many leading experts who have specifically studied BC and played a major role in advancing the scientific understanding of their warming effects, warn that BC has huge and hitherto underestimated impact on global warming and that mitigation of BC emissions could have possibly dramatic impact on short-term (two to three decades) temperature rise due to BC's short life of a few weeks compared with the 100 years life of Carbon Dioxide in the atmosphere.[99] An important assessment study under the auspices of UNEP and WMO concludes that reduction of BC will yield significant climate benefits in the short term in the two-to-three decades frame, assisting in the task of keeping temperature rise below 2 degrees C.[100]

On the other hand, IPCC's Fourth Assessment Report however does not arrive at any definitive or unambiguous pronouncement regarding the benefits of BC mitigation.[101] India's own official assessments, as conveyed in National Communications

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[96] References are given in the discussion to follow

[97] "Integrated Assessment of Black Carbon and Tropospheric Ozone," pp.33-35, UNEP/WMO, available at: http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf, pp.33-35

[98] IPCC/AR4/WG1 p.4, p.29 & ff; see also INCCA 24x7, p.13

[99] See especially V. Ramanathan and G.Carmichael in http://acmg.seas.harvard.edu/students/Ramanathan&Carmichael2008_Nature_BlackCarbon.pdf. See also UNEP/WMO op.cit., and Mark Z. Jacobson, Testimony for the Hearing on Black Carbon and Climate Change, U.S. House Committee on Oversight and Government Reform 12 (18 October 2007), available at http://oversight.house.gov/documents/20071018110606.pdf;

[100] "Integrated Assessment of Black Carbon and Tropospheric Ozone," UNEP/WMO, p.ix, available at: http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf

[101] IPCC/AR4/WG3 p.92, p.163 and ff point to high degree of uncertainties with regard to BC due to knowledge gaps and hence the Report refrains from making any definitive assessments of the warming

(NATCOM) to the UNFCCC, and those of scientists in the Indian Network of Climate Change Assessment (INCCA),[102] have each in their own way arrived at rather equivocal conclusions.

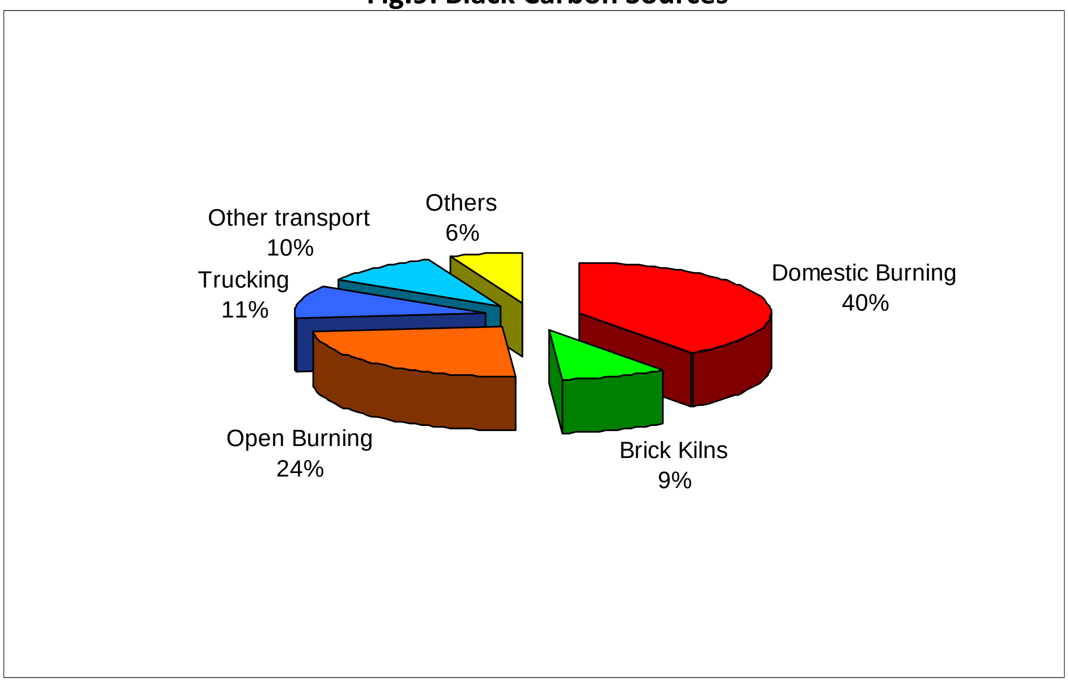
There are valid reasons for this equivocation, particularly in the Indian context, and also as concluded so far by the IPCC.

A consideration of what is known thus far on BC emissions in India would illuminate this issue.

As explained in the methodology Section on Inventory data and sources, there is unfortunately no official data in India on BC inventory. Therefore, after going through various publications, reports, papers and other works by authorities on Black Carbon, it was decided to take inventory data from the USEPA Report on Black Carbon in South Asia which is not original data collection but a compilation of data from various sources, and has itself relied for data on India on the most cited authorities on the subject.

Based on the above, the pie-chart below presents possible the best available estimate of BC sources in India.[103]

Fig.9: Black Carbon Sources



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potential of BC as distinct from aerosols taken together which have negative warming effect. There is also no attempt in the WG3 Report to deal with mitigation of BC.

[102] "Black Carbon Research Initiative (BCRI): national carbonaceous aerosols programme," INCCA, Ministry of Environment & Forests, Govt of India, available at http://www.moef.nic.in/downloads/pu See also "Integrated Assessment of Black Carbon and Tropospheric Ozone," UNEP/WMO, available at: http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdfblic-information/Black%20Carbon%20Research%20Initiative.pdf

[103] Date sourced from "Reducing Black Carbon Emissions in South Asia: Low Cost Opportunities," US EPA, June 2012 available at: http://nepis.epa.gov/Exe/ZyPDF.cgi/P100EF3D.PDF?Dockey=P100EF3D.PDF

It is now well established that Black Carbon by itself is a dangerous particulate emission, even though it is not listed among the GHGs to be controlled by, and reported on, to the UNFCCC. Apart from its global warming potential, BC also causes other problems, particularly accelerating the melting of glaciers and snow cover which, in turn, have further impact on heat exchange across different layers in the atmosphere and on the feedback system affecting global temperature rise. Along with other aerosols, BC is also believed to have an impact on the monsoons and on agriculture by cutting sunlight.[104]

However, much of the BC released into the atmosphere is not amenable to be tackled by itself, since it often come bundled with other aerosols.

Most BC in India, for instance, emanates from domestic wood-burning cookstoves and from open burning of biomass in agricultural fields or other operations. Whereas BC emitted from transport vehicles, especially the dangerously rising numbers of diesel vehicles in India, and from brick kilns or other industrial operations mostly from burning of coal and diesel, are mostly straightforward BC, in the case of emissions from wood-burning, the carbon soot is bound together with organic carbon and other aerosols.[105]

And this is where the big problem lies for mitigation, as indeed acknowledged also by international experts and studies on BC.[106]

There are other uncertainties also associated with the impact of BC on warming. Vertical distribution of BC is an important factor in determining its effects, with the altitude of the aerosol presence and their position above or below clouds being significant parameters, and not enough is known about these at present. BC increase atmospheric temperature in higher altitudes due to greater absorption, but may cool the surface by reducing solar irradiation. The net effect is not yet fully understood, although cumulatively they might add up to a marginally positive radiative forcing.[107]

In India, the ratio of organic carbon (OC) to black carbon, in a scenario with open biomass burning or indoor burning in wood-burning stoves, is believed to be higher than in many other regions. (see Fig below)

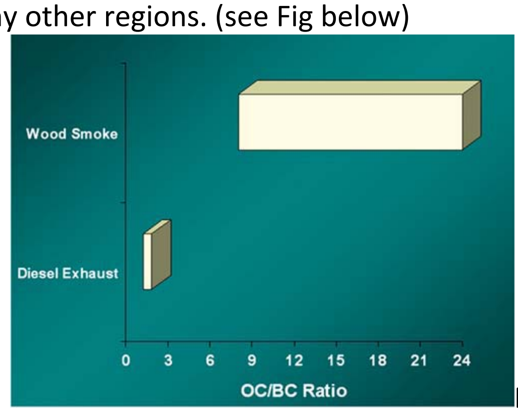

Fig.10: Ratio of BC to OC in India

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104 INCCA, BCRI p.13

105 See IPCC/AR4/WG1 pp.153-180 for detailed discussion on the complexities and uncertainties relating to behaviour and effect of aerosols; see also UNEP/WMO; INCCA/BCRI p.9

106 See UNEP/WMO, op. cit., pp.?? &ff

107 INCCA, Black Carbon Research Initiative, p.22; IPCC/AR4/WG1 p.153 and ff

Source: INCCA/BCRI

The UNEP/WMO study therefore cautions that "efforts to mitigate BC will reduce concentrations of BC as well as OC. The warming effect of BC and the compensating cooling effect of OC introduce large uncertainty in the net effect of any BC mitigation of global warming. This uncertainty is particularly large for mitigation options that focus on biomass cookstoves and open biomass burning and smaller for those that focus on fossil fuels (i.e. diesel) because biomass combustion emits significantly more OC compared with fossil fuel burning."[108]

In such a situation, the Indian research warns: "it is possible that a drastic decrease in BC aerosols may result in an increase in surface temperature by several degrees. Consequences associated with such a reduction in BC should be assessed accurately and adequately before it is implemented to mitigate climate change."[109]

In light of these uncertainties, it is recommended that a broad brush mitigation effort towards BC, particularly embracing carbonaceous and other aerosol emissions from wood-burning, not be undertaken in India till a better understanding emerges.

4.4.1 BC from Domestic Biomass Burning To explain this better, Table-8 below presents the Multi-Criteria Analysis for Mitigation of Black Carbon from Domestic Biomass Burning, representing around 40% of BC in India. The Table itself reproduces Table-6 from p.?? summarising Co-benefits (or penalties) for reduction of Methane (and BC and N_2O) for each of the 5 defined categories and assignation of qualitative scores or rankings against each.

<table>
<tr><th colspan="4">Table 8: Multi-Criteria Analysis for BC (and Methane and N_2O) from Domestic Biomass burning</th></tr>
<tr><td colspan="4">Broad Goal:
• Objective: reduce BC (and CH_4 and N_2O emissions) from Domestic Biomass Burning eg. through Improved Cookstoves
• Stakeholders: householders especially Women, Ministry of New & Renewable Energy, Min of Health, Central and State governments
• Time-scale: medium term</td></tr>
<tr><td colspan="2">Co-benefit</td><td>Description of benefit or cost</td><td>Qualitative grading 1 to 5</td></tr>
<tr><td rowspan="3">Growth</td><td>Impacts on aggregate demand</td><td>• none if thru Cookstoves
• subsidy burden if sought thru LPG</td><td rowspan="3">3</td></tr>
<tr><td>Creation of jobs</td><td>• new jobs in manufacture/ installation/distribution of new Cookstoves or better Fuels</td></tr>
<tr><td>Energy security</td><td>• temporarily reduce pressure on LPG demand if cookstoves</td></tr>
</table>

[108] UNEP/WMO BC Assessment, p. 116
[109] Ibid, p.22

		• but neutralized by urbanization rates and increased penetration of LPG in rural areas	
Inclusion	Improving outcomes for the poor	• positive impact on QoL esp for Women in rural areas • some new jobs in rural areas • but high cash cost of 2nd Gen Cookstoves and/or improved Fuels may work against equity but may be offset by subsidy	3
	Reducing disparities in distribution	• will slow down access to modern cooking energy • may skew positives in favour of rural rich	
Local Environment	Air	• some improvement but mainly due to reduced particulates	4
	Land	• nil	
	Water	• nil	
	Other	• marked improvement in indoor air pollution	
Carbon mitigation		• some BC release reduced but net cooling likely due cut in OC • small in overall terms due to cost and institutional factors • benefits likely to be low compared to reductions from urbanization and LPG shift	2
Implementation	Costs	• could be high in short term especially if subsidies are involved	1
	Stakeholder Resistance	• likely poor acceptance by householders due high cost	
	Tech. difficulties	• institutional factors biggest impediment cf. old cookstoves programme • delivery systems v. weak	
	Conflict w/ other goals	• conflict with agenda for step-improvement in access to modern energy • with urban:rural pop ratio slated to go from 30:70 to 50:50 by 2050, Biomass Burning slated to decline • similarly, LPG penetration in rural areas slated to increase	

However, it appears that BC from Brick Kilns and from Transport, particularly from diesel vehicles whose numbers in the passenger vehicle segment have risen dramatically in recent years, are more amenable to regulation and control.

4.4.2 BC from Brick Kilns The burnt brick industry in India is characterized by energy inefficient and polluting technologies, mostly based on coal. More than 140,000 brick kilns operate in India which is the world's second highest producer of bricks after China. The industry is mostly in the unorganized sector and, as such, has long been outside the purview of any form of regulation which has been a major concern as regards pollution, unfettered use of top soil including in fertile agricultural land, exploitation of labour including child labour, and so on. The first major move towards regulation came with a judgment by the Supreme Court in 1996 banning Moveable Chimney Brick Kilns on environmental grounds, followed by initiatives by some organizations such as the Delhi-based NGO Development Alternatives to offer energy- and resource-efficient technologies such as vertical Shaft Brick Kilns (VSBK).[110] Further measures to regulate the brick industry were also introduced,[111] although experience suggests that most of these regulations are implemented more in the breach and are also associated with pervasive rent-seeking.

While the recent debate on Black Carbon has gathered traction, and has once again focused attention of technical institutions and regulatory agencies on the environmental performance of brick kilns, this has not yet led India to take up any systematic programme to regulate the industry or introduce better technologies in a phased manner. There are perceived to be many constraints in bringing about the desired policy shifts and accompanying implementation measures including supporting legislation, incensives and dis-incentives, enforcement and so on. Constraints include the fact that vast numbers of brick kilns are not registered with local authorities; they operate on leased rather than own land with little incentive to invest over the long term; alternative energy-efficient and low pollution technologies such as Zig-Zag Kilns cost far more than the existing Fixed Chimney Bulls Trench Kilns (FCBTK) or like Vertical Shaft Brick Kilns (VSBK) offer lower productivity; there is little if any mechanization in brick-moulding and other processes making adoption of measures such as internal fuels extremely difficult.[112]

Despite these constraints, it is universally agreed that a transition from conventional brick-making to more energy-efficient systems especially in kiln technology

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[110] See http://www.devalt.org/

[111] For a summary of these different regulatory measures, see http://www.ecobrick.in/environmentPolicies.aspx

[112] Many studies in India have brought out the structural problems of the brick industry, most from the points of view of energy, pollution, conditions of labour and regulation. The description in this paragraph is based on readings of several such studies as well as the experience of one of the Principal Investigators, D.Raghunandan, with the brick industry. Among the studies are "Energy efficiency improvement in Indian Brick industry," Punjab State Council for Science & Technology, Government of Punjab, available at http://pscst.gov.in/pscstHTML/brick.html; "Brick Kilns Performance Assessment," Greentech Knowledge Solutions Pvt Ltd, New Delhi, India, April 2012, available at: http://www.unep.org/ccac/Portals/50162/docs/Brick_Kilns_Performance_Assessment.pdf

as well as composition and moulding of bricks would significantly reduce local air pollution, greenhouse gas emissions and emissions of black and organic carbon, and make the entire burnt brick-making process less damaging to the environment. Such measures have been known to be effective in China and Vietnam, for instance.

Unfortunately, the National Mission on Sustainable Habitat, one of the 9 Technology Missions under the National Action Plan on Climate Change, does not pay specific attention to the Brick industry except in addressing building materials in a very general manner.[113]

Multi-Criteria Analysis and assigning of qualitative scores for the option to reduce Black Carbon from Brick Kilns, about 9% of BC emissions in India, is depicted below.

Table 9: Multi-Criteria Analysis for Mitigation of BC from Brick Kilns

Broad Goal:

- Objective: reduce BC emissions from Brick Kilns through change in Kiln technology, better Brick material, appropriate mechanization
- Stakeholders: brick kiln owners/operators; builders and architects; regulators, workers, rural inhabitants near brick kilns
- Time-scale: medium to long term

Co-benefit		**Description of benefit or cost**	**Qualitative grading (1 to 5)**
Growth	Impacts on aggregate demand	• neutral though initially some state investments/incentives needed	3
	Job creation	• no specific impact	
	Energy security	• no specific impact	
Inclusion	Improving outcomes for poor	• will promote bringing brick industry into organized sector with better labour conditions	3
	Reducing disparities in distribution	• no specific impact	
Local Environment	Air	• substantial improvement due energy/combustion efficiency and lower local pollution	4
	Land	• improved soil health due to reduced soot deposits; regulation may lead to less use of top-soil	
	Water	• slight improvement due less polluting seepage	
	Other	• better health in neighbourhood due less air pollution	
Carbon mitigation		• good reduction in CO2 and lower	4

[113] See "National Mission on Sustainable Habitat,"available at http://moud.gov.in/NMSH

		BC emissions with little OC	
Implementability	Costs	• additional investment needed by brick-makers who may demand incentives or subsidies	2
	Stakeholder Resistance	• low investment capacity among brick-makers, poor bank credit due unorganized sector industry, low incentive to shift to new tech; • poor regulatory capacity and weak enforcement • weak regulation of and incentives for building industry	
	Tech. difficulties	• few providers of new techs • low skills in brick industry • low level of mechanization in brick industry	
	Conflict w/ other goals	• none • should synergize with National Mission on Sustainable Habitat	
Total (5 to 25)			**16**

4.4.3 BC from Transportation One may, similarly, take a closer look at possible mitigation of BC from Transportation (21% of BC). Arguments advanced here may also be applied to BC from Industrial Sources which, incidentally, include burning of diesel in captive power plants (an additional 6% approximately).

First a quick overview of the transportation sector itself would be useful.

India has seen huge changes in the transportation scenario since Independence from colonial rule in 1947 and notably since the 1990s and the onset of liberalization of the Indian economy and growing integration with rapidly globalizing economic activities worldwide.

Transportation of goods by road has gone up from around 14% of rail-cum-road carriage in 1950-51 to around 61% in 2004-5, and 87% of passenger traffic was carried by road compared to 15% of inter-modal traffic in the early 1950s. The number of vehicles has grown by a compound annual growth rate of over 11% over the previous 5 decades, with heavy vehicles (buses, trucks etc), almost all operating on diesel, growing at around 7% and cars at about 8%, the latter growing at close to 10% over the past two decades.[114]

The story of the huge growth in personal cars in India is well known spurred by pent-up demand, opening up of the automobile manufacturing sector and rising incomes in the middle-class. But while personal cars grew at an overall rate exceeding

114 Road Transport for the XIth Five Year Plan, Planning Commission, Government of India, available at planningcommission.nic.in/aboutus/committee/.../wg11_roadtpt.doc

10% between 2000 and 2010, diesel powered cars shot up from just 4% of all cars in 2000 to 40% in 2011.[115]

Much of this spurt has been attributed to the large disparity between diesel and gasoline prices due to administrative pricing mechanisms under which diesel is heavily subsidized in the belief that this helps keep prices of food, other essential commodities and small consumer goods low because of lower transportation costs. Many measures were suggested to level the playing field, ranging from allowing diesel prices to be market driven to levying an additional tax at source on personal diesel vehicles equivalent to the difference between diesel and petrol prices over average vehicle life so as to level the playing field.[116] While there has been a slight slowing down of the growth of SUVs and other diesel vehicles since then, cities like Delhi continue to suffer high air pollution especially from particulates, which most experts attribute to the large number of diesel vehicles plying on the roads,[117] prompting the Environment and Pollution Control Authority to file a report in the Supreme Court calling for a ban on diesel cars in Delhi![118] To cap it, the tailpipe emission norms for diesel vehicles are much more lenient than those for petrol vehicles, and allow far higher levels of PM pollution that, for example, Euro standards.[119]

Trucks too have seen huge growth during 2001-2011, with a CAGR of around 20% during the pervious decade, while demand for passenger buses has stayed mostly flat, growing at a mere 1% each year, itself revealing of the state of public transportation in India.[120] It is well known that trucks in India are mostly fuel inefficient vehicles, much more so than their counterparts in the US, Europe or Japan,[121] are mostly single-axle vehicles which, combined with poor road conditions in most parts of India, make for very poor fuel economy. Road transport accounts for about 66% of diesel consumption, and trucks and buses account for about 77% of the diesel consumption within the sector.[122]

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115 Centre for Science & Environment press statement based on industry data, available at http://www.cseindia.org/userfiles/diesel_press_conf.pdf

[116] "Report of The Expert Group on A Viable and Sustainable System of Pricing of Petroleum Products," Government of India, Feb 2010, http://petroleum.nic.in/docs/reports/reportprice.pdf

[117] Numerous reports and studies both in India and abroad attest to this. See for instance, "A detailed study to ascertain the effect of diesel operated trucks, tempos, three-wheelers and other commercial vehicles on the ambient air quality of Delhi," (a study conducted by researchers at the Indian Institute of Technology, Delhi), Department of Environment, Government of Delhi, Feb 2007 available at http://www.environment.delhigovt.nic.in/doc/dieselpro.pdf. Note that this study even predates the explosive growth of personal diesel-powered cars in Delhi!

[118] See Report in The Hindu Business Line, Dec 17, 2012, at http://www.thehindubusinessline.com/news/states/pollution-control-body-for-ban-on-diesel-vehicles-in-delhi/article4209480.ece

[119] See CSE Press Release cited in Note ??? above

[120] "Market Survey leading to Fuel Consumption norms for Diesel (Engine Driven) Trucks & Buses in India," p.8, Petroleum Conservation Research Association, New Delhi, 2013, available at http://pcra.org/English/latest/Diesel%20Trucks%20&%20Buses%20in%20India.pdf

[121] Ibid, p.29

[122] Ibid, p.???

In the Indian scenario, curbing automobile pollution in general, and emissions including BC from diesel vehicles in particular, especially from trucks, is going to be difficult for some familiar reasons

It is known that vehicular pollution can be mitigated by various measures chiefly mandated fuel-efficiency and tailpipe emission norms, improved technologies in drives and transmission, better driving practices, improved road conditions, better traffic engineering and management, and so on.[123]

The automobile industry in India has a long history of resisting mandatory regulations governing tailpipe pollution, vehicular emission standards and lastly vehicular fuel economy standards, each time citing reasons of cost, changes driving up prices for the consumer leading on to depressed demand, time required by the industry to develop the requisite technologies etc. The industry has also been aided in these efforts by a sympathetic government that has viewed the industry as an important driver of economic growth.[124]

It has therefore come as no surprise that efforts to curb emissions from diesel vehicles in the major metropolitan cities has been met with stiff resistance from the automobile industry.

This being the case in the major metros, where the news media, civil society organizations, even regulatory agencies are active and mobilize public opinion as well as governmental action to curb pollution, the condition in smaller towns and cities, and along the numerous national and state highways running through the countryside on which trucks ply may well be imagined.

Notwithstanding all the above difficulties, the measure that would work best in India, given weaknesses in regulation and lack of capacity in agencies responsible for monitoring and control, is to regulate technologies through mandatory standards at the vehicle manufacturer's end and at the refinery to improve the fuel itself. Ultimately this is what prevailed with adoption and fairly effective implementation of tailpipe emission norms for most categories of light vehicles, even if these norms have lagged behind norms prevailing in the US, EU or Japan.

In the case of BC, tailpipe emission standards are once again perhaps the best way to go, leaving the exact technology to be used for reducing or trapping particulates to the vehicle manufacturers

The other measures that have shown some success is periodic pollution checks, although gaming the system and rent-seeking cannot be ruled out, and putting restrictions on vehicle age especially in commercial vehicles. Benefits that may accrue from changing driving practices may take a very long time if driving habits even in the metropolitan cities are any indication. In some developed countries, such measures have been implemented through fleet owners and/or operators, but with dispersed ownership especially of commercial vehicles such as taxis, trucks, other goods carriers etc, this too would prove difficult in India.[125] Improving road and traffic conditions in

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[123] See PCRA, op.cit., for a brief overview; see also US??? Do we need?

[124] Some refs?? Say CSE??

[125] PCRA, op. cit., p.???

Tier-II and Tier-III cities, small towns and roads in the interior would also take considerable time, especially given the quantum of investment required.

This more or less applies also to other vehicles such as tractors, three-wheeler goods vehicles and diesel-powered electricity generating equipment.

We may now construct the MCA Table for Mitigation of BC from Transportation.

Table 10: MCA for Mitigation of BC from Transport Sector

Broad Goal:

- Objective: reduce BC emissions from Vehicles especially diesel-fuelled Trucks and cars, taxis, other vehicles, and electricity generation equipment mainly through mandatory fuel economy standards, tailpipe emission norms and related regulation, monitoring and enforcement
- Stakeholders: vehicle manufacturers, owners/operators, fleet owners/managers, regulators
- Time-scale: near-term to medium-term

Co-benefit		**Description of benefit or cost**	**Qualitative grading (1 to 5)**
Growth	Impacts on aggregate demand	• large gains from lower oil import • export market for vehicles to go up with better fuel-effy and emission standards • economy gains with more efficient transportation	4
	Job creation	• no significant impact	
	Energy security	• huge impact due lower imports	
Inclusion	Improving outcomes for poor	• should improve public transport due fuel savings	3
	Reducing disparities in distribution	• no specific impact	
Local Environment	Air	• substantial improvement in air quality due tighter emission norms PM2.5, PM10, NOx, CO • less smog	4
	Land	• improved soil health due to reduced BC deposits	
	Water	• no significant impact	
	Other	• better health due lower PM2.5 and other pollutants	
Carbon mitigation		• good reduction in BC • CO_2 emissions also down due to fuel economy measures	4
Implementability	Costs	• initial but phased investments by	3

		manufacturers in better engines, pollutant traps, transmission	
	Stakeholder Resistance	• resistance by powerful and well-funded manufacturers but will ultimately agree if persisted with • poor regulatory capacity and weak enforcement • driving practices difficult to change but enables fuel saving	
	Tech. difficulties	• time and inertia in introducing new techs • skill upgradation required in manufacturing and driving (truck drivers training currently poor)	
	Conflict w/ other goals	• none	
Total (5 to 25)			**19**

A score of 4 has been assigned on Growth although, if the entire possible range of fuel economy measures are achieved on which there is doubt, impact on fuel import bill and downstream impact of better technology on export potential of the Indian automobile industry could be substantially greater. Nevertheless considerable benefit is expected to accrue even with only sound fuel economy norms and tighter tailpipe emission norms along with better quality fuel from refineries.

On mitigation a high score of 4 has been assigned because, whereas BC was the main target and vehicular BC is the largest segment that can be targeted with clear mitigation results (unlike BC from biomass burning), control of BC would be accompanied by mitigation of substantial CO2 emissions (India's second highest and the fastest rising source of GHGs after power generation) through fuel economy measures. The extent of mitigation is also expected to be high because the current fuel economy and engine efficiency of most trucks, buses and old diesel cars is so poor. Measures such as higher taxation on personal diesel vehicles which would have the effect of checking the high demand for diesel-engine passenger cars in already crowded metropolitan cities like Delhi would have contributed even more to mitigating BC, but does not seem likely to be adopted as a policy as If the whole suite of fuel economy measures including better driving practices could be implemented, a score of 5 could have been considered but has not been done because the measures that could realistically be taken in the near term are likely to be limited to factory-end fuel economy and tail-pipe emission norms.

Similarly, a high score of 4 has been assigned to Local Environment impacts since particulate emissions, especially PM2.5 which is mostly BC, could be substantially reduced with focused attention to diesel vehicles especially trucks and buses. Smog especially during winter would come down. With both these measures, significant improvements in pubic health especially respiratory problems would also result. Although consensus is not complete on the effect of BC deposits on snow and glacier melt, [126] it is not unreasonable to expect lessening of these climate impacts as well, and possibly also of precipitation patterns.

As usual, Implementation scores the lowest at 3 due to poor regulation, ineffective implementation, weak monitoring and enforcement, low capacity of regulatory agencies and the time likely to be taken to gain support of the industry to actually implement all the proposed plans.

We can see from the above that even though there is some evidence of a net declining trend in BC emissions in India despite a steep rise in emissions from transportation and diesel vehicles in particular,[127] it would be worth while to target BC from Brick Kilns and Vehicular Emissions. This is because, as we have discussed above, BC from brick kilns and fossil-fuel vehicles is far less bound up with other aerosols, unlike wood-burning carbonaceous aerosols. It should also be noted that BC from these two major sources will go down with better technology, more efficient combustion and with regulatory policies targeting stack or tailpipe emissions respectively. Such efforts could indeed bring about some mitigation benefits as regards BC with short-term benefits, and simultaneously reduce CO2 emissions, besides generating substantial co-benefits in reducing local pollution, slowing glacial and snow-pack melt, and reducing changes in precipitation patterns.

5. Policies & Priorities for Mitigation of Non-CO2 Emissions

We now put together all the above analysis and discussion to arrive at a set of preferred or prioritized policies aimed at mitigation of the major Non-CO2 GHGs. As discussed at the outset, in order to delineate these policies and priorities, it is necessary to weigh different options and select the best i.e. those that would yield substantial mitigation benefits while simultaneously delivering significant co-benefits as regards economic growth, equity or inclusion, local environment and health impacts, and leveraging institutional capabilities and mechanisms for implementation.

The various pros and cons, and the different factors involved in mitigation policy options for each major Non-CO2 GHGs have already been outlined in the Multi-Criteria Analysis Tables above. Scores have also been assigned for each of the 5 different co-benefits. Based on these, the different mitigation options are compared so as to arrive at the better options giving benefits across the identified criteria.

Each of the mitigation options have also been graded and, as discussed in the Methodology section, the scores for the five co-benefit criteria for each Option can be depicted on "spider diagrams" super-imposed on each other such that they can be compared, the option with a larger area enclosed by its "spider diagram" being judged to be the better option and thus accorded a higher priority for policy formulation, adoption and implementation.

As touched upon in the Introduction (see Section 1.3), for administrative reasons conveyed in the Narrative Report, this Study was curtailed roughly mid-way and so was

[126] INCCA/BCRI, p.??
[127] INCCA/BCRI p.13

unable to go into the desired detailed examination of the relevant policy environment in India (which would invariably go far beyond the environmental arena into many other sectors), trends in respect of shifts in policy or their implementation and capacity to do so, institutional structures impinging on policy formulation and implementation, implications of recent pronouncements in climate policy both domestically and in the international arena. Such a detailed assessment of the policy scenario would then have enabled a more specific discussion of policy options, instruments, mechanisms and institutional structures required for the set of mitigation recommendations arising out of this Report. Regrettably this has not been possible, at least with respect to the desired scope, depth and rigour of analysis of the policy firmament.

An attempt is nevertheless made to sketch out the major policy issues relevant to the mitigation actions and priorities recommended here. Major policy dimensions involved have been highlighted and discussed in the description and analysis of different mitigation options. These discussions, however brief, on extant policies and official thinking on likely policy directions emerging from the different mitigation pathways already laid down or being considered, can be useful starting points for outlining relevant considerations for policy options to address the mitigation recommendations for Non-CO2 emissions emerging from this Study.

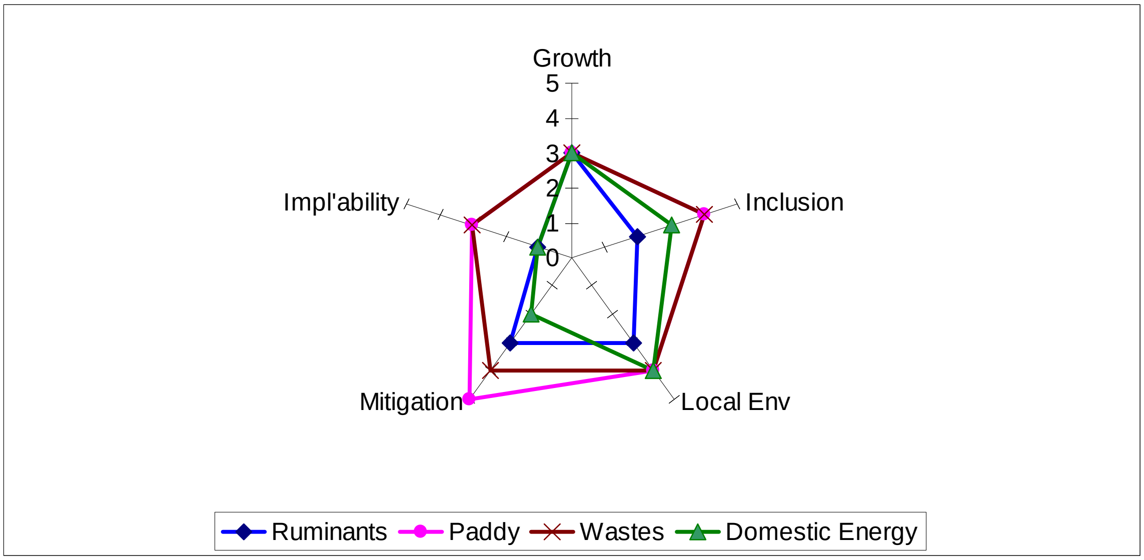
5.1 Methane mitigation options and priorities Scores for each of the criteria or co-benefit categories for the different GHG mitigation options for Methane, as tabulated in Section 4, are summarized in Table 8 here.

Table 11: Scores for Methane Mitigation Options

Co-benefit Criteria	**Options**			
	Paddy Cultivation	***Wastes***	***Domestic Energy (cookstoves)***	***Ruminants***
Growth	3	3	3	3
Inclusion	4	4	3	2
Local Env. & Health	4	4	4	2
Mitigation	5	4	2	3
Implementation	4	4	1	1

These can be depicted in spider diagrams as shown below.

Fig.11: Spider Diagram for Methane Mitigation Options



From the above, the different options for Methane Mitigation may be ranked as:

1) Paddy cultivation
2) Wastes
3) Domestic Energy
4) Ruminants

The discussion above brings out that trying to tackle Methane emissions from the domestic energy sector, chiefly from biomass-burning cookstoves, may call for too much effort with low returns in the near term. This is despite the substantial co-benefits of lower indoor air pollution, and simultaneous reduction of N_2O and carbonaceous aerosol emissions. A sharp drop in emissions from this source is in any case anticipated in the medium to long term due to the expected steady and, over the years, substantial drop in domestic biomass-burning and shift to LPG or other modern energy. As such, special efforts directed at these emissions do not seem worth it, especially endeavours such as improved cookstoves which are unlikely to yield sizeable dividend in the near term, which is the very rationale for targeting Non-CO2 forcers.

Methane emissions in India from Ruminants too do not appear amenable to policy-driven reductions, for similar reasons of difficulty in implementation (see the low scores for both these options). The large and scattered numbers of the ruminant population, their largely forage-based rather than stall-based feeding practices, and the unlikelihood of major shifts in these patterns which would be required to introduce feeds to lower methane emissions, would likely overwhelm possible policy measures aimed at this emissions source.

As such it is recommended that targeting changes in Rice Cultivation practices and in handling and treatment of Wastes, especially municipal solid wastes (MSW) and domestic waste waters, would yield the best results for reducing Methane emissions and may therefore be prioritized for the same. As the earlier discussions have shown, both these sources are quite amenable to policy-driven changes which are likely to deliver substantial reductions in Methane emissions and considerable co-benefits. In both, state agencies are the main actors for implementation so there are few other actors to worry about, although institutional weaknesses would need to be overcome in the Agricultural sector and historical weaknesses in implementation would require to be rectified in Waste management.

5.1.1 Policy issues related to CH_4 mitigation The major policy options have already been touched on in the discussions above, but it may be useful to highlight them here. Also, some discussion on how these policy options could be actualized may be of interest especially for civil society actors and others engaged in advocacy.

In the first place, the present "hands-off agriculture" stance as regards mitigation needs to be abandoned. Not only are Non-CO2 emissions high in agriculture especially Methane from Rice Cultivation, and N_2O from this and other agricultural activities, there are substantial benefits to be obtained from a policy frame that will yield benefits in mitigation *as well as* in sustainable agriculture and related practices such as water conservation and restoration of soil health which also have important contributions to adaptation. Experience has shown that shifts in agricultural practices are responsive to policy drivers provided the policies are accompanied by vigorous implementation especially through strengthened extension systems. However, the shrinking capability and reach of the state agricultural extension system is a major concern here.

The National Mission on Sustainable Agriculture (NMSA), at least on paper, seems to recognize not only the desirability but also the feasibility of pursuing this trajectory. Shifts to SRI, low-flooding or low-irrigation rice cultivation techniques, lower use of inorganic nitrogenous fertilizers, have all been extensively demonstrated and are today widely acknowledged as technically feasible and as not involving any significant penalties in yield besides having long-term benefits for soil health. Yet there will be contradictory pulls and pressures faced by any major policy push, especially pressure by larger farmers for supposedly higher yields to the virtual exclusion of all other especially longer-term considerations, and resistance from the agri-business sector and the corporate chemical agri-inputs industry. Decades of agricultural policy orientation favouring inputs intensity and quantitative yield rather than a more holistic view of agriculture have also built up a great deal of inertia across the board in government, agricultural research institutions and the extension system, with farmers not being immune either.

Requisite policy shifts will have to be pushed and communicated, not as mitigation-focused policies with an implication of asking those targeted, in this case farmers, for taking on apparent "sacrifices" and "hardships" for the greater public good, especially of others. The co-benefits approach advocated here, therefore precisely positions such policies as aimed at multiple benefits rather than as mitigation-focused with a few other benefits "on the side."

5.2 N_2O mitigation options and priorities Several of the mitigation options for Methane such as emissions from Domestic Energy and Domestic Waste Waters would also form part of Mitigation options for N2O, so the same scores as assigned for Methane in Section 4 are given here as well. We have also seen that N_2O emissions are by themselves very small in comparison to the Methane emissions, and that indirect N_2O converted from NO_x from industrial production is a very small fraction of total N_2O emissions.

Since an overwhelming proportion of these industrial-orgin N_2O emissions are from a single industry, namely the nitric Acid industry, these emissions do not require any special policy or complex considerations, but can be taken care of at source by regulating this specific industry. As such, the Industry source of N_2O emissions are not considered while comparing the other options for mitigation of N_2O emissions.

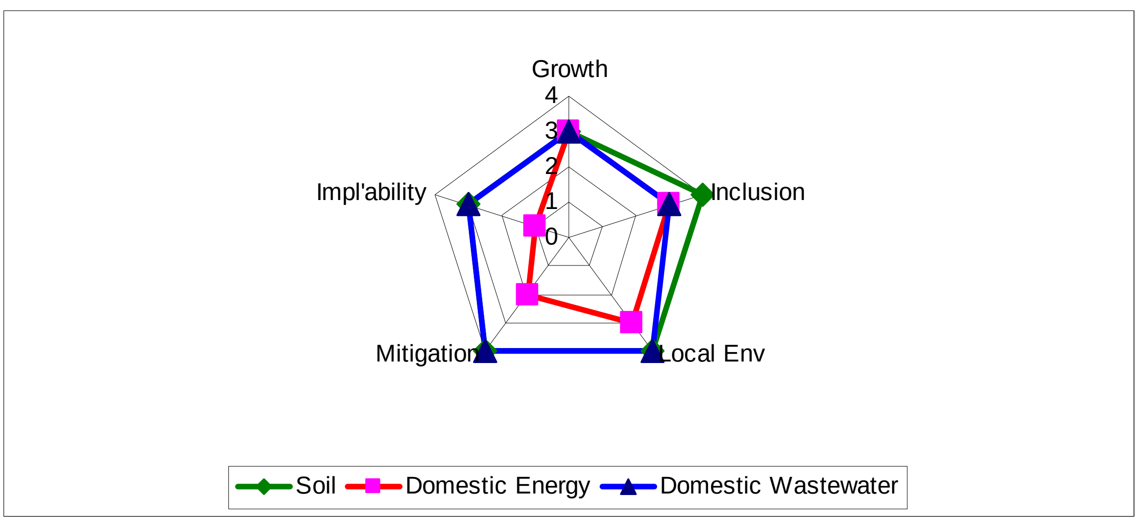
Taking all this into account, the different GHG mitigation options for N_2O may be summarized in **Table 9** below.

Table 12: Scores for N_2O Mitigation Options

Co-benefit Criteria	***Options***		
	Soil/Ag.	***Domestic Waste Waters***	***Domestic Energy***
Growth	3	3	3
Inclusion	4	3	3
Local Env. & Health	4	4	3
Mitigation	4	4	2
Implementation	3	3	1

These options can be depicted in and compared through the spider diagrams given below.

Fig.12: Spider Diagram for N_2O Mitigation Options



From the above, the options for N_2O Mitigation may be ranked as follows:

1) Soil/Ag
2) Wastes
3) Domestic Energy (cookstoves)

The ranking and preceding discussion show that the best results would be achieved by prioritizing emissions from Agriculture and from Wastes, mainly domestic waste waters. Much of the rationale for such prioritization has already been covered while discussing Methane, so they do not need repetition here. However, salient points relating to Domestic Energy, emphasizing why it need not figure (or at least not rank high) in a priority set of Non-CO2 Mitigation goals, may be reiterated here.

Targeting N_2O emissions from Domestic Energy essentially means targeting biomass-burning for cooking which, again as discussed in the CH_4 context, is problematic both because of large uncertainties on the mitigation effects of reducing the mixture of BC and OC (organic carbon) and due to the huge challenges posed by the proposed modality and related policies, namely through provision of improved cookstoves.

The current phase of the National Improved Cookstove Programme (NICP) has not tackled any of the main problems that had bedeviled the earlier phase of the programme during the 1980s, especially the delivery system and institutional limitations with respect to outreach. Further, the second generation cookstoves are far more expensive than the first-generation stoves of the '80s, adding another big negative.

The expected decline in domestic biomass-based cooking over the next decade or two, accompanied by increased provision of LPG for this purpose (which unfortunately would increase CO_2 emissions, thus negating the very rationale of targeting Non-CO_2 emissions), would in any case contribute to a substantial reduction of CH_4 and N_2O emissions.

Taken together, there is little merit in targeting Domestic Energy (mainly biomass burning for cooking) for reducing N_2O and CH_4.

5.2.1 Policy Issues related to N_2O mitigation As noted above, most of the issues at the policy level relating to N_2O have been discussed earlier in the context of Methane.

We saw that the main policy instrument aimed at tackling indoor air pollution affecting women's health, namely the new generation improved cookstove programme which would also supposedly reduce black carbon, methane and nitrous oxide emissions, misrepresents or at least misunderstands the mitigation co-benefits and underestimates the implementation challenges. This is especially true for BC of course since, even if there is some mitigation in terms of reduced BC, its effects on global warming may actually be counteracted by simultaneous reduction of Organic Carbon and other aerosols which have negative global warming potential. Even though the same problem of being bound up with other aerosols does not apply to CH_4 and N_2O, the net mitigation effect is still in doubt (hence the low scores for mitigation). So this policy does not commend itself.

Nor does any other policy to deal with biomass burning for cooking meet the requirement except for a speedier transition from biomass in (mostly rural) homes.

5.3 Mitigation Options for F-gases As already discussed at some length, in our considered opinion, there is little option for India but to join the international effort to phase out HFCs, currently under the Montreal Protocol. With most countries already committed to this course, and with financial assistance also provided for if required, there is little reason for India to persist with its obdurate stand of demanding that HFCs be handled under the UNFCCC which is extremely unlikely since most UNFCCC Parties have already agreed to the contrary. Going forward, India will only find itself increasingly isolated on this issue in the international community. India also stands to lose by missing out on opportunities to penetrate the export market for ACs and refrigerators which it can otherwise do as China has done.

There is also no other policy option that India can pursue on its own that would achieve the goal of reducing HFC emissions with anywhere near the effectiveness of an international agreement, whether it is the current understanding under the Montreal Protocol or what would be, if that were at all to happen, a very similar agreement under the UNFCCC. This is clearly evidenced by the successful and timely transition from CFCs and HCFCs to HFCs under the Montreal Protocol earlier.

Having said that, it should also be recognized that, as discussed in Section ?? above, the quantum of emissions likely to be witnessed in India in the next two decades is not likely to be as frighteningly large as is sometimes projected. As stated earlier, there is a danger of over-estimation of the economic growth rate in India going forward, and also an over-estimation of the growth of the middle-class and its purchasing power. So while there is undoubted need to reduce HFC emissions especially from air-conditioners and refrigeration both fixed and mobile, this is best done through an agreed international process to completely eliminate it, such as is already underway under the Montreal Protocol, rather than through some India-specific regulatory mechanism with doubtful efficacy and outcome.

Since multiple options do not exist for this category of mitigation, an MCA analysis is not performed and spider diagrams are not constructed for comparison.

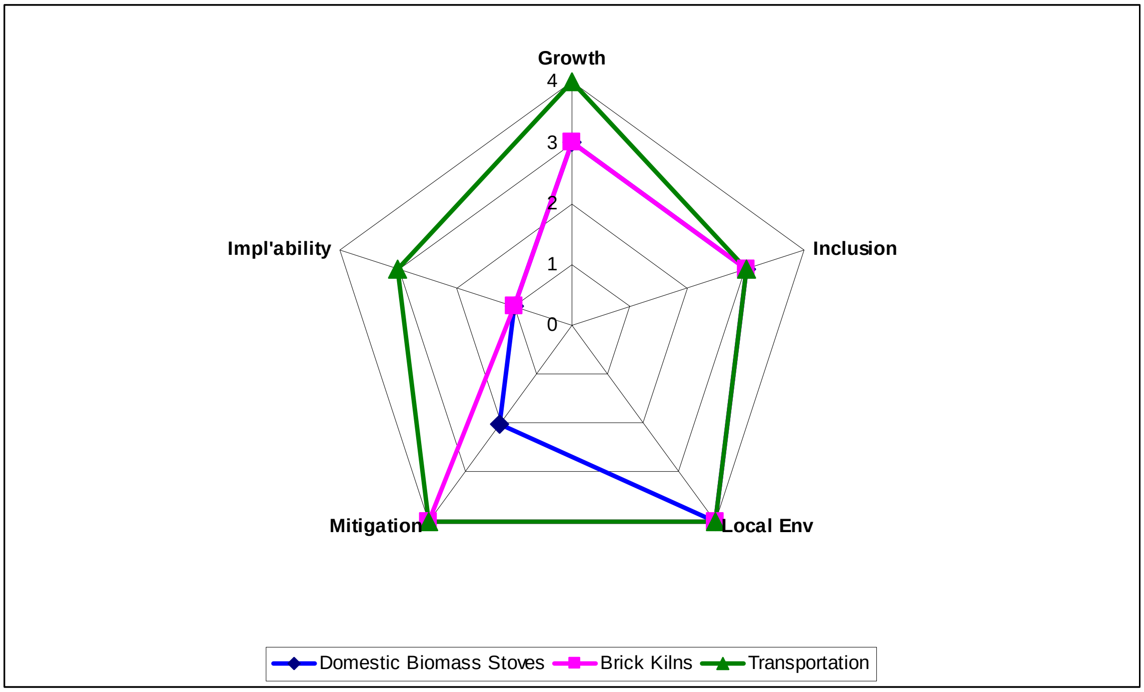
5.4 Mitigation Options for Black Carbon It is worth reiterating the caution sounded at the outset of the Inventory section, that Black Carbon should not be taken as an independently existing GHG since this would raise issues of double counting.

We may now put together a Table depicting scores assigned to each of the BC Mitigation options and then construct spider diagrams to enable comparison.

Table 13: MCA Scores for BC Mitigation Options

Co-benefit Criteria	***Options***		
	Domestic Biomass Stoves	***Brick Kilns***	***Transportation***
Growth	3	3	4
Inclusion	3	3	3
Local Env. & Health	4	4	4
Mitigation	2	4	4
Implementation	1	1	3

Fig.13: Spider Diagram for N_2O Mitigation Options



5.4.1 Policy Issues related to BC mitigation The main policy issue in India, going by the tenor of discussions and the Black Carbon Research Initiative document, is likely to be if and whether at all to target Black Carbon as a distinct category calling for special or focused attention. Perhaps it is to do with on-going tensions regarding the UNFCCC negotiations, but India has been seen to be somewhat of a stickler for the letter of the law. India has taken a firm position hitherto that it would not deal with HFCs or aviation emissions outside the UNFCCC framework, and it is therefore likely that it may not like to deal with BC specifically since it is not listed as one of the GHGs to be regulated under the UNFCCC.

Yet as we have discussed above, BC is very likely to have dangerous global warming potential if it is not bound up together with organic carbon, and that too in as high a proportion as seems to be the case in India. Reducing BC emissions will definitely bring about many benefits including on mitigation, taking care to avoid double counting.

In our opinion, the co-benefits approach advocated here offers a way around this dilemma.

One need not exclusively target Black Carbon but advocate its mitigation as a major co-benefit to CO2 mitigation efforts in the Transportation sector and from Brick Kilns. In both these sectors, BC and other PM 2.5 particulates additionally cause huge local environmental problems, worsening air pollution in major cities and serious health especially respiratory problems being the most noticeable.

Other policy issues have been dealt with in the body of the text above.

6. Quantitative Analysis of Potential Mitigation by 2035

Based on the above Multi-criteria qualitative analysis, and the recommended policy priorities derived from that, quantitative estimates of potential mitigation that could be achieved in these priority sectors/sources were estimated based on the mathematical function and methodology discussed in the beginning.

Estimates of possible mitigation is based on trend figures where available and other information discussed in the analysis in Sections 4 and 5.

Results obtained from the different priority sectors/sources are given and briefly discussed below.

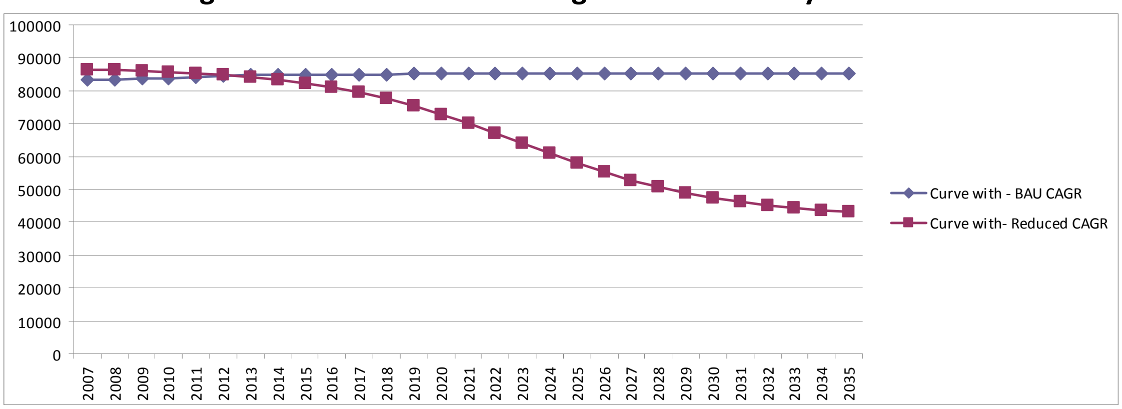
6.1 Methane from Paddy Cultivation It is estimated that CH4 emissions from Paddy cultivation could be reduced by 50% by the target year of 2035 by taking measures to reduce cultivation under standing water or flood irrigation, introduction and popularization of SRI and other agricultural practices and better land and water management as discussed earlier.

Also see more detailed discussion in 6.5 on reducing N_2O from Soil/Ag.

The possible reduction of CH4 emissions by 2035 is depicted in the curve below.

The estimations using the specified sigmoid function show a slight increase in emissions till 2015 at a Cumulative Annual Growth Rate (CAGR) of 0.2717 with a subsequent decline at a CAGR of -3.4064 till 2035 resulting in a reduction of around 511 kt CO2-eq over that time period.

Fig.13: Possible Methane Mitigation from Paddy Cultivation



6.2 Methane from Wastes Similarly, it is estimated that CH4 emissions from Wastes including municipal solid wastes (MWS), sewage and industrial liquid effluents could be reduced significantly. As discussed earlier, even the capital Delhi currently treats only 50% of its sewage and most of its MSW is dumped in poorly set up and managed landfills with significant production and leakage of methane to the atmosphere. Even though there is significant increase of MSW due to rapid and unplanned urbanization with poor garbage management and infrastructure, this also implies enormous scope for mitigation actions.

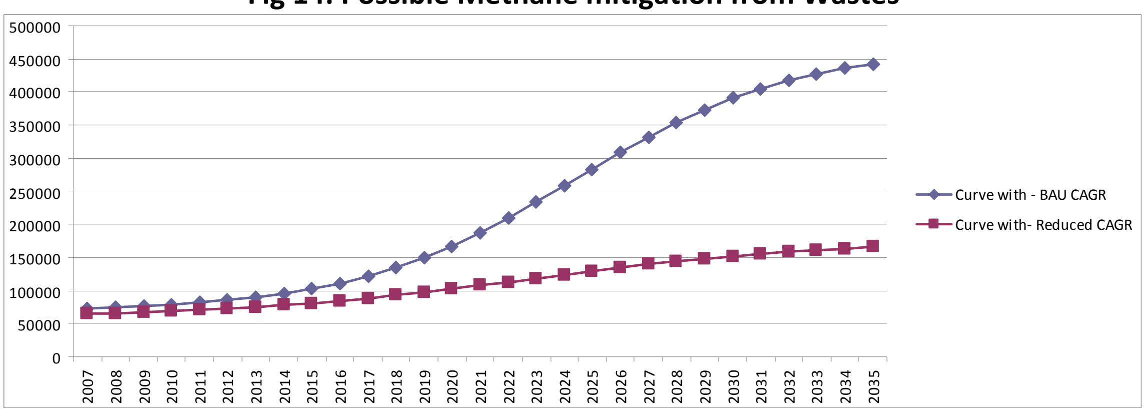
Given the concern shown by all levels of government from Union to State to municipal, despite lack of capability at present, it is estimated that even with modest effort and commitment of resources and capacity building, some of which is already factored into the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) with significant funding from the union government and international donor agencies, growth rates of emissions from this sector can be reduced to half over the period till 2035.

With CAGR being brought down from the current 7% to 3.5%, it is estimated that CH4 emissions can be brought down by -3,270 million tonnes CO2-eq by 2035. The projected mitigation pathway is depicted in Fig.12 below.

It may be noted that, given the present high growth rates, and the expected continuing upward trends in urbanization rates and generation of wastes, the Methane emissions from the Wastes sector are expected to grow even by 2035 despite mitigation efforts, albeit at a much slower rate enabling close to flattening out of the curve within a short period from the target year of 2035.

As discussed earlier, this is due to rapid urbanization which is expected to outstrip generation of waste management infrastructure, capacity-building and resource deployment. Additional financial resources, for instance from external agencies and developed country governments especially as part of an equitable international GHG emissions control agreement, would enable more ambitious mitigation efforts.

Fig 14: Possible Methane mitigation from Wastes



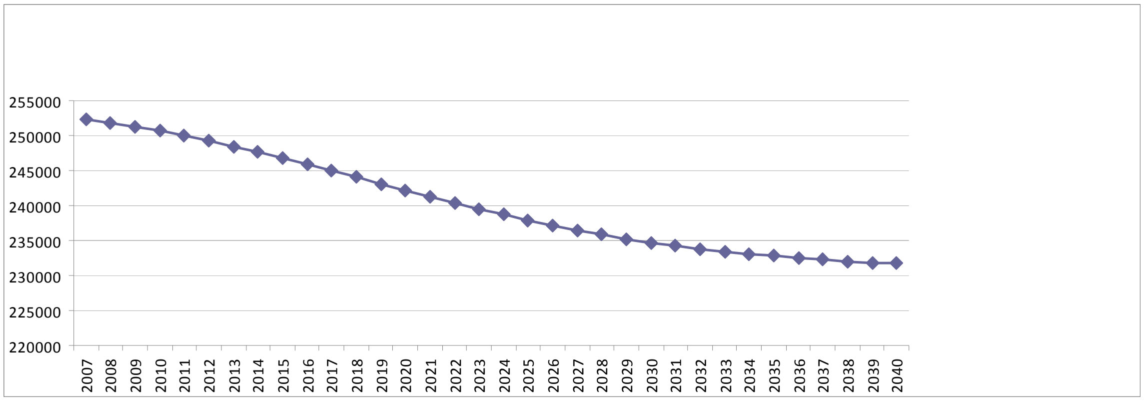
6.3 Projected "BAU" Reduction of Methane from Enteric Fermentation (Ruminants)

As brought out by the MCA analysis, the difficulties in implementation along with the marginal benefits likely to be obtained from mitigation efforts aimed at mostly grass-fed cattle whose population is already in decline, suggested that any major policy-backed endeavour towards mitigation of CH4 from this sector would be a poor investment.

Even at current rates of declining cattle population, expected to accelerate in coming years due to rise of input costs and low returns from poor yields, a marginal decline in CH4 emissions can be expected as projected in Fig.15 below.

The calculations show a decline of emissions at a CAGR of -0.3% till 2035.

Fig.15: Estimated "BAU" mitigation of CH4 from Ruminants



6.4 "BAU" reduction of CH4 from Domestic Energy (cookstoves) Again in the case of domestic energy, mainly CH4 emissions from wood-burning cookstoves, the earlier discussions showed that a secular, steady and substantial decline in use of wood burning stoves is expected in the coming years and decades.

Even discounting the anticipated higher penetration of LPG in rural areas, a reduction of at least 50% in use of such cookstoves is projected by 2035.

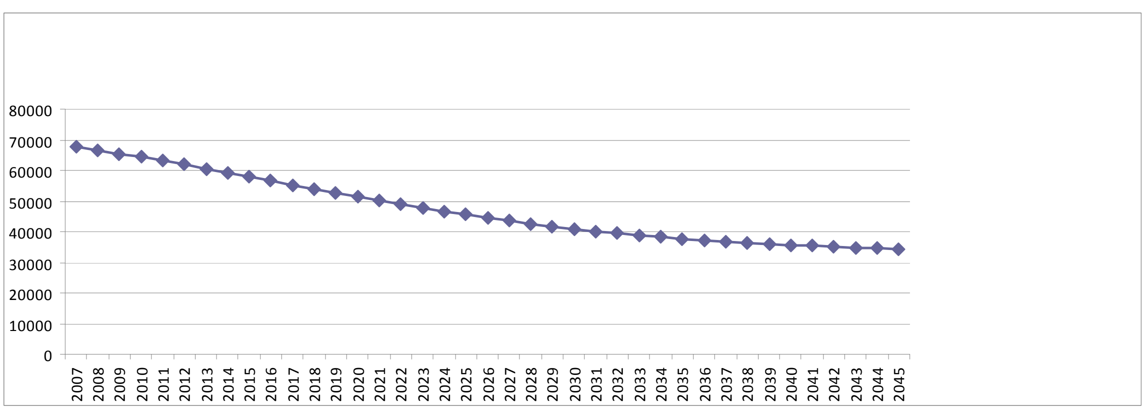
With this rate of reduction already taking place more or less under "BAU" conditions, it is strongly felt that no special effort is required to take on targeted new policy-based measures to reduce Methane from the domestic energy sector.

As stated earlier, this argument also applies to NOx and BC emissions from this sector, since all these would be emitted together and would also decline in proportion.

Projections show that a decline of -2.0% CAGR is attainable till 2035 resulting in a substantial reduction of CH4 emissions from this sector to the tune of around 35,000 kT CO2-eq in that time frame from Methane reduction alone.

These projections are depicted in Fig.16 below.

Fig 16: Projected "BAU" reduction of CH4 emissions from Domestic Energy



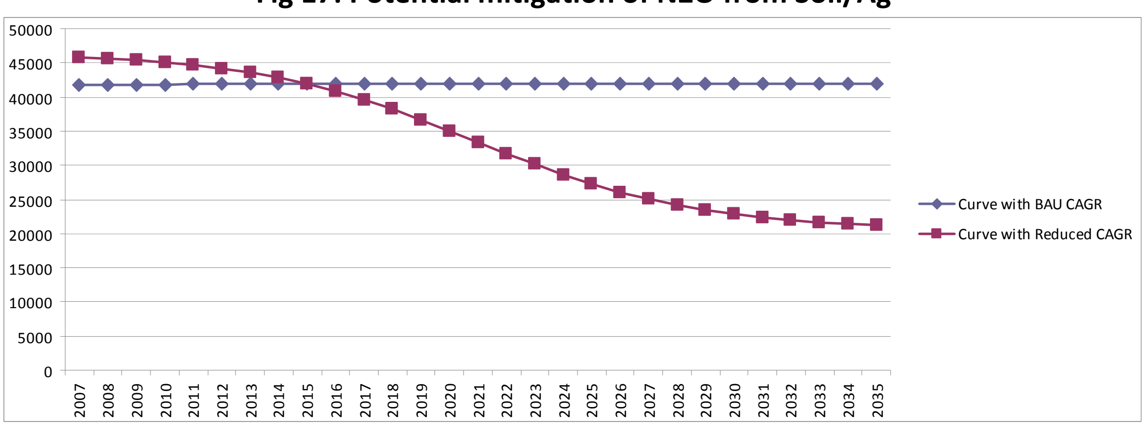
6.5 Potential Mitigation of N_2O from Soil/Ag Although mitigation actions in agriculture have been generally thought of as a "no-go area" in policy circles and even by civil society for several years, there is increasing evidence, also being acknowledged in agricultural research institutions and official quarters, that mitigation actions in the agricultural sector has significant co-benefits in promoting climate-resilient and sustainable agriculture, in reducing costs to the national economy and to individual farmers including small farmers on account of agricultural inputs such as inorganic especially nitrogenous fertilizers, in reducing acidification of water bodies including seas or oceans, and also in ameliorating adaptation costs from climate impacts on water resources. Earlier fears about declining yields due to lower use of chemical fertilizers have now yielded way to appreciation of the gains in soil health and ultimately in sustainable yields to be had from optimum or even minimum or no use of inorganic fertilizers. One of India's 8 major technology missions under its National Action Plan on Climate Change (NAPCC), namely the National Mission on Sustainable Agriculture, lays special emphasis on these co-benefits especially from reduction of inorganic nitrogenous fertilizers and advances several strategies to achieve the same.

As such, a pro-active policy-driven endeavour to promote sustainable, climate-resilient agriculture which would also have significant co-benefits in mitigation of emissions, particularly N2O and Methane, is not only desirable but also very much in order. Main constraints are likely to be the degraded capability of the State apparatus and of academic and research Institutions in agricultural extension.

Nevertheless, with commensurate efforts, capacity-building and resource allocation, it is estimated that 50% reduction in N2O emissions can be achieved in paddy cultivation by 2035, an estimation easily borne out by emissions data in experimental plots and agricultural research institutions.

Fig.17 below shows the projections in this regard.

Fig 17: Potential mitigation of N2O from Soil/Ag



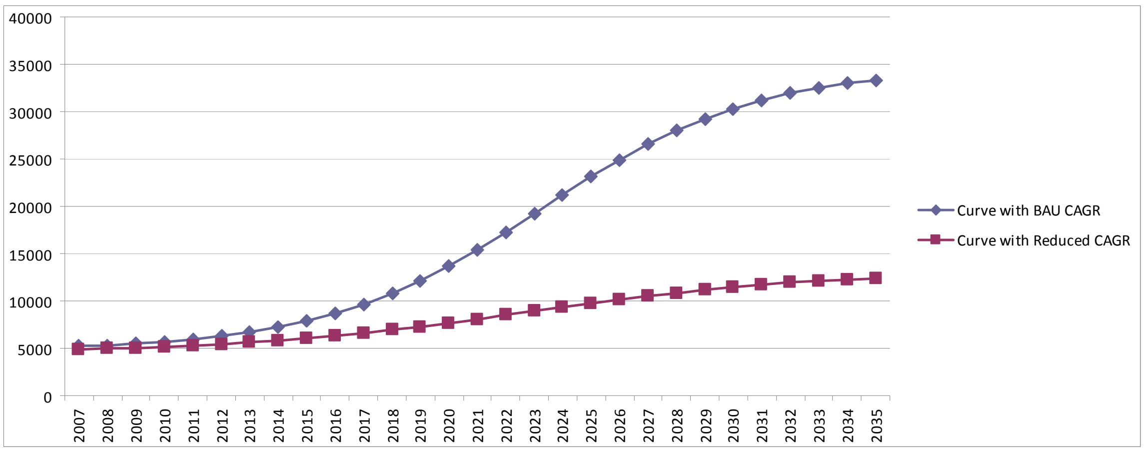
It is estimated that N2O emissions from Soil/Ag to the tune of -246,052 ktCO2-eq can be reduced by 2035 at a CAGR of -3.406.

6.6 N2O from Waste Waters Along the lines of the discussion above in 6.2 on Methane from Wastes, it is estimated that N2O from waste streams both industrial and domestic can be reduced by 50% by 2035.

It is projected that such measures could reduce N2O emissions by -265,664 kt CO2-eq by 2035 at a CAGR of 3.5% compared to the current growth rate of 7%.

The projected reduction pathway is shown below in Fig.18.

Fig.18: Potential reduction in N2O from Waste Waters



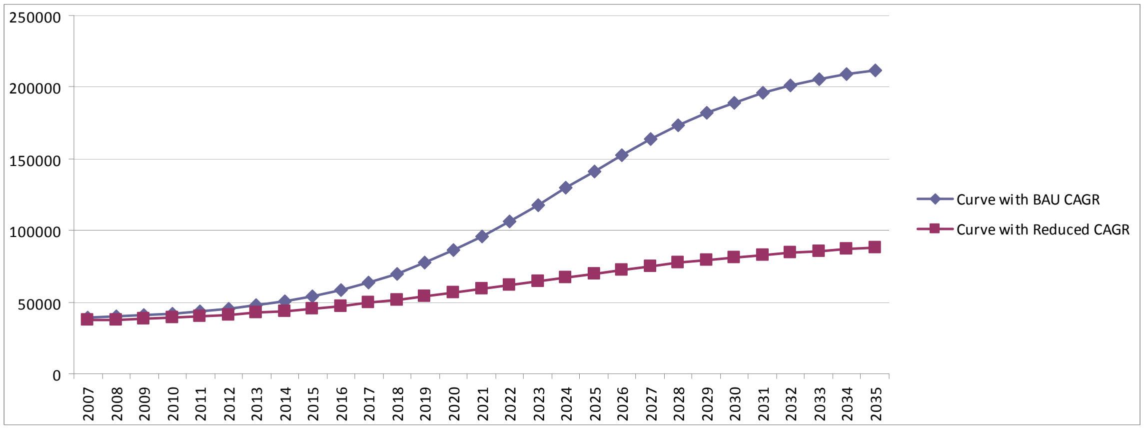
6.7 F-gases As discussed in detail in Section 4, there is ample scope for mitigation of F-gases, mostly HFCs in the air-conditioning and refrigeration sectors, even under current circumstances due to market and external pressures on phasing out of HFCs despite the current contretemps in Indian policy circles about whether this should be taken up under the Montreal Protocol or the UNFCCC. Of course, if India agrees and a full-scope HFC phase-out programme comes into effect, the mitigation target would be achieved in a short time period.

Even if not, it is projected that a substantial reduction in F-gas emissions would take place over the period till 2035 due to on-going measures in appliance efficiency, demand management and the desire of manufacturers to adopt a more environment-friendly posture and product profile.

It is projected that the current 6.6% CAGR can be reduced to 3% over the target period resulting in an estimated reduction of a substantial -1,471,580 kt CO2-eq.

Fig.19 below depicts the mitigation trajectory.

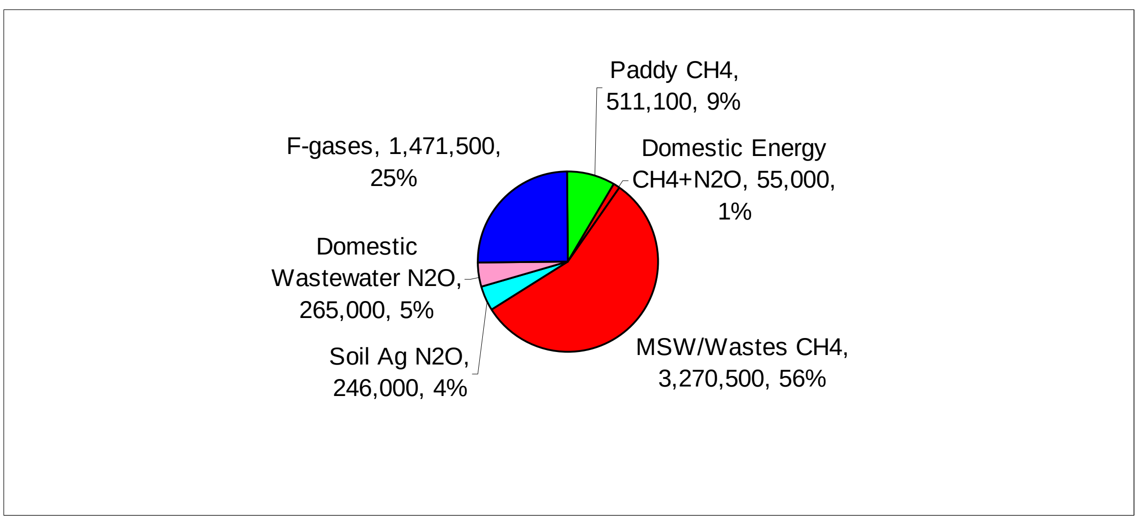
Fig.19: Projected reduction of F-gases



6.8 Total mitigation potential from Priority Non-CO2 Sectors/Sources All the above projected reductions of Non-CO2 emissions total up to a very substantial mitigation of -5.819 Giga tonnes CO2-eq.

Of this, the major share of roughly over half is projected to come from Methane reductions from Wastes, followed by F-gases producing around a quarter of possible reductions, with Methane and N2O from Soil/Ag coming next at around 13%.

Fig.20: break-up of Total Non-CO2 Mitigation achievable by 2035



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