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Leveraging Potential of Dung for Energy Security and Sustainable Agriculture

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In developing countries, rural communities have long recognized the importance of dung as a source of renewable energy for domestic purposes and organic fertilizers for crop production. However, the utility of dung, both as a source of energy and fertilizers, has diminished owing to the increasing use of chemical fertilizers and fossil fuels, rendering it a less essential resource and a potential environmental contaminant. Nevertheless, owing to their increasing negative externalities on natural resources and the environment, a new perspective has emerged on the utility of dung as biogas and bio-compressed natural gas (CNG), while maintaining its traditional use as an organic fertilizer.

This perspective is particularly relevant for India, which relies on the import of fertilizers and fossil fuels to meet its growing domestic demand. In 2022-24, the country imported an average 7.9 million tons of nutrient equivalent fertilizers (i.e. nitrogen, phosphorus and potash)[2] and 22.2 million tons of liquefied natural gas[3] (LNG), approximately equivalent to 31% and 46% of their domestic consumption, respectively. Such a large dependence on imports not only strains the country's foreign exchange reserves but also makes it vulnerable to potential supply chain disruptions due to geopolitical tensions and fluctuations in global markets, affecting the cost of food production, farm profits, and consumer food prices.

The development of a value chain for dung can address energy and fertilizer requirements, enhance soil properties and agricultural sustainability, and reduce greenhouse gas emissions. India has a population of over 300 million bovines (i.e., cattle and buffaloes) that produce huge quantities of dung, which can be processed into biogas or bio-CNG without compromising the nutritional value of the resultant slurry.

In light of these considerations, this study has assessed the potential of dung as a substitute for chemical fertilizers and fossil fuels.

Estimates of dung production

The estimates of dung production in India, contingent upon assumptions regarding dung evacuation rates vary considerably from 659 to 2600 million tons per annum[4],[5]. The National Dairy Development Board (NDDB) reports a figure of 1655 million tons.[6]Such imprecise estimates pose a challenge to policy decisions regarding infrastructure planning and resource allocation for developing the dung value chain.

India has a bovine population of 303 million, comprising 193 million cattle and 110 million buffaloes. Based on the feed consumption rates for these species[7], a total of 635 million tons of dry matter, from crop residues, cultivated and gathered green fodders, and grains/

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2 Annual Review of Fertilizer Production and Consumption 2023-24. Fertilizer Association of India.

3 Annual Report 2023-24. Ministry of Petroleum and Natural Gas, Government of India.

4 Ravindranath, N.H., Somashekar, H.I., Nagaraja, M.S., Sudha, P., Sangeetha, G., Bhattacharya, S.C. and Salamb, P.A. (2005). Assessment of sustainable non-plantation biomass resources potential for energy in India. *Biomass and Bioenergy* 29: 178–190.

5 Vinayak, F. and Dashora. K. (2021). A sustainable potential source of ruminant animal waste material (dung fiber) for various industrial applications: A review. *Bioresource Technology Reports* 15(100693): 1-15.

6 PIB. (2021). *Waste Generation from Animal Husbandry Sector*. Press Information Bureau, Ministry of Fisheries, Animal Husbandry & Dairying, Government of India.

7 Dikshit, A.K. and Birthal. P.S. (2010). India's livestock feed demand: Estimates and projections. *Agricultural Economics Research Review* (23)1: 15-28.

concentrates enters the bovine production system as feed. This estimate closely corresponds to the dry matter available as feed. Dry matter intake serves as the basis for estimating dung production. Based on 60% dry matter digestibility and 20% total solids in dung, approximately 1271 million tons of wet dung is produced in the country which has been used in this study.

Potential of dung to substitute fossil fuels and chemical fertilizers

The abundant availability of dung suggests significant potential for its conversion into biogas or bio-CNG. Biogas contains approximately 60% methane, 40% carbon dioxide and traces of hydrogen sulfide. It can be used directly as a fuel or processed into bio-CNG by removing carbon dioxide and traces of hydrogen sulfide. Bio-CNG contains more than 90% methane and is similar to natural gas in terms of composition and energy potential.

Approximately 35% of the dung produced in the country is converted into dung cakes for use as domestic fuel[8]. The remaining 65% is used as manure in crop production. It is important to note that both domestic fuel and manure contribute to environmental pollution and pose potential health risks to humans.

To assess the potential of dung as a substitute for fossil fuels and chemical fertilizers, three scenarios are analyzed: the current usage pattern (business-as-usual), a situation in which 65% of the dung used as manure is processed into biomethane/bio-CNG, and a scenario in which all dung produced is converted into bio-CNG.

In the business-as-usual scenario, dung manure provides 6.28 million tons of nitrogen, phosphorus, and potassium (NPK) valued at Rs. 530 billion (Table 1). With the inclusion of monetary value of dung as a traditional domestic fuel, the total value increases to Rs. 752 billion. This scenario is the benchmark for evaluating value addition to dung.

In a hypothetical scenario in which 65% of the dung (826 million tons) currently utilized as manure is processed into biomethane for utilization as bio-CNG or piped cooking gas in the City Gas Distribution (CGD) network, it produces 31 billion cubic meters (or 39 million tons) of biogas or 18.3 billion cubic meters (or 14.2 million tons) of bio-CNG, with an estimated value of Rs. 773 billion. Upon inclusion of monetary value of slurry (Rs. 530 billion) and traditional domestic fuel (Rs. 222 billion), the total value increases to Rs. 1525 billion.

Table 1. Estimated potential of dung as a source of bio-CNG and organic fertilizers

	Dung used as		
Particulars	**65%: manure 35%: cake**	**65%: bio-CNG 35%: cake**	**100%: bio-CNG**
Biogas produced (billion m^3)	-	30.98	47.70
Biomethane/ Bio-CNG produced (million t)	-	14.20	21.80
Fertilizer nutrients (million t)	6.28	6.28	9.66
N	2.64	2.64	4.07
P	1.16	1.16	1.78
K	2.48	2.48	3.81
Dung cake (million t)	89	89	-
Gross economic value (Rs. billion)			
Biomethane/Bio-CNG	-	773	1189
Fertilizers	530	530	815
Dung cake	222	222	-
Total	**752**	**1525**	**2004**
Value addition (Rs. billion)	-	773	1,474

In the third scenario, when the entire dung (1271 million tons) were to be processed, approximately 47.7 billion cubic meters (or 60.1 million tons) of biogas or 28.1 billion cubic meters (or 21.8 million tons) of bio-CNG are produced, while contributing an additional 3.4 million tons to its NPK yield. Its total value as an organic fertilizer increases to Rs. 815 billion and value addition as bio-CNG to Rs. 1189 billion.

If the full potential of dung is harnessed, to a large extent, it can meet the country's demand for CNG in the transportation sector or biogas for domestic fuel and the demand for essential plant nutrients. This potential is apparent when India's substantial imports of NPK and LNG are considered. During the conversion of dung into biogas or bio-CNG, an additional 3.4 million tons of NPK is produced, valued at Rs. 285 billion. During 2022-24 the country imported on an

[8] GOI. (2024). *National Accounts Statistics 2024*. Ministry of Statistics and Programme Implementation, Government of India.

average 22.20 million tons of LNG and 7.90 million tons of NPK, valued at Rs. 1158 and Rs. 650 billion, respectively (Table 2). By tapping this potential, India can dramatically reduce its dependence on imports, leading to substantial savings in foreign exchange and potential self-sufficiency in both fertilizers and energy.

Table 2: Import substitution potential of dung-based fertilizers and bio-CNG, 2021-22 to 2023-24

Particulars	Fertilizers			
	N	P	K	Total
Consumption of chemical fertilizer nutrients (million t/annum)	20.03	3.50	1.70	25.24
Import of fertilizers (million t/annum)	5.08	1.41	1.41	7.90
Available from dung				
Current usage pattern (million t/annum)	2.64	1.16	2.48	6.28
Additional availability at 100% conversion into bio-CNG (million t/annum)	1.43	0.62	1.33	3.38
Value of imported fertilizers (Rs. billion/annum)				650
Value of additional NPK from dung (Rs. billion/annum)				285
	LNG			
Consumption of LNG (million t/annum)	47.30			
Import of LNG (million t/annum)	22.20			
Bio-CNG production from dung				
65% conversion into bio-CNG (million t/annum)	14.20			
100% conversion into bio-CNG (million t/annum)	21.80			
Value of imported CNG (Rs. billion/annum)	1158			
Value of bio-CNG from dung (Rs. billion/annum)				
65% conversion into bio-CNG	773			
100% conversion into bio-CNG	1189			

Furthermore, converting dung into bio-CNG can contribute significantly to reducing greenhouse gas emissions and enhancing the sustainability of natural resources. Livestock emits 11.75 million tons of methane[9], of which manure accounts for approximately 9%. India has set a target of net-zero emissions by 2070, and the conversion of dung into biogas or bio-CNG could contribute significantly to this. By harnessing its full potential, dung can produce 21.8 million tons of bio-CNG, which is equivalent to 31.9 billion liters of petrol. Utilizing bio-CNG in the transportation sector could lead to a 60% reduction in GHG emissions. In addition, the green CO_2, thus produced, can be used commercially in various industries.

Our estimates of value addition to dung as biogas or bio-CNG represent an extremely optimistic scenario that may not be fully achievable in practice because of the prevalence of mixed crop-livestock systems, where collection of the entire dung output is not feasible. Furthermore, traditional applications of dung, such as domestic fuel or construction materials, may compete with its utilization as an energy and fertilizer.

Even if two-thirds of the dung produced is collected and converted into biogas or bio-CNG, this can significantly reduce the country's import dependence on LNG or LPG. Our estimates suggest that biogas alone can supply 12 LPG cylinders to 128 million households, annually.

Policy Implications

The Government of India has been promoting biogas for several decades to provide clean cooking fuel, reduce dependence on fossil fuels, and manage organic waste. The success has been limited because of the inadequate supply of feedstock, lack of technical expertise for the maintenance of biogas plants at the household level, and increasing use of LPG and electricity. However, technological advancements in waste management have made it possible to process dung into biogas or bio-CNG on a commercial scale. The estimates presented in this brief indicate significant potential for the generation of biogas or bio-CNG and organic fertilizer from dung, which, if fully harnessed, can significantly reduce the country's dependence on

9 Chhabra, A., Manjunath, K. R., Panigrahy, S. and Parihar, J. S. (2009). Spatial pattern of methane emissions from Indian livestock. *Current Science* 96(5):683–689. https://www.currentscience.ac.in/Volumes/96/05/0683.pdf

imports of LNG and fertilizers, while simultaneously reducing greenhouse gas emissions. In light of these findings, the following suggestions merit attention when developing the dung value chain:

Promote community biogas plants: Despite India having a huge bovine population, the average herd size is too small to produce sufficient dung for efficient operation of biogas plants at the household level. Thus, emphasis should be placed on promoting community or cooperative biogas plants to ensure an adequate supply of feedstock for optimal capacity utilization and reduce the cost of operations. This also requires models for cost and revenue sharing with dung supplies to ensure effective community participation.

Mandatory establishment of biogas facilities for commercial peri-urban dairy farms and Gaushalas: Mandating the installation of biogas plants, either on an individual or collective basis, for peri-urban commercial dairy farms and Gaushalas will facilitate meeting their energy requirements or supply to households while contributing to urban cleanliness and environmental sustainability. Governments can finance and provide incentives in terms of tax breaks, subsidies, and low-interest loans to biogas plants.

Evolve aggregation models: Large-scale dung-based biogas or bio-CNG plants require a consistent and sufficient supply of feedstock. A key strategy toward this is the development of aggregation models, incorporating the integration of dung collection by dairy cooperatives alongside milk procurement. Further, it is crucial to design a comprehensive incentive system for farmers in terms of fair prices for dung, access to bio-slurry, and profit-sharing from the sale of bio-CNG. This is exemplified by the three-way collaboration among Banas Dairy (a Gujarat-based cooperative society), Suzuki Motor Corporation, and the National Dairy Development Board (NDDB) for producing bio-CNG from dung.

Finance bio-CNG plants: The financing of new bio-energy plants at concessional rates is particularly important in their early stages is crucial for enhancing their viability and product competitiveness. The scale of financing may vary depending on the size of the plant, with larger plants potentially requiring more investment. Smaller enterprises or start-ups may benefit from targeted financial assistance programs tailored to their needs and growth stages.

Carbon credits from dung-to-biogas/bio-CNG: The carbon credit trading scheme offers incentives for companies to invest in carbon offset projects. This market-based mechanism allows businesses to earn tradable credits by reducing their greenhouse gas emissions or supporting projects that sequester carbon. Dung-based biogas or bio-CNG projects are particularly attractive as they address several environmental concerns: a renewable source of energy, reduced methane emissions, and improved soil health.

Integrate bio-CNG or biogas distribution into existing delivery systems of LPG or CNG: Integrating bio-CNG or biogas distribution into existing delivery systems of LPG or CNG is a promising opportunity to leverage established infrastructure. This can be achieved by modifying the existing pipelines, storage facilities, and distribution networks to accommodate the properties of bio-CNG or biogas. By utilizing established infrastructure, companies can capitalize on economies of scale, reducing overall distribution costs while maintaining their current supply chains.

Improve synergy among programs and policies: While the production-related aspects of dung, including monitoring livestock populations and promoting sustainable animal husbandry practices, are under the purview of the Ministry of Fisheries, Dairying, and Animal Husbandry, the programs related to renewable energy are managed by the Ministry of Non-Renewable Energy, and those pertaining to organic fertilizers are under the jurisdiction of the Ministry of Chemicals and Fertilizers. A lack of coordination among schemes can result in inefficiencies. Therefore, synergy among the programs of different government parastatals is crucial for ensuring coherence in policies and programs, which could lead to more effective resource allocation and the improved implementation of dung-based energy initiatives.

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