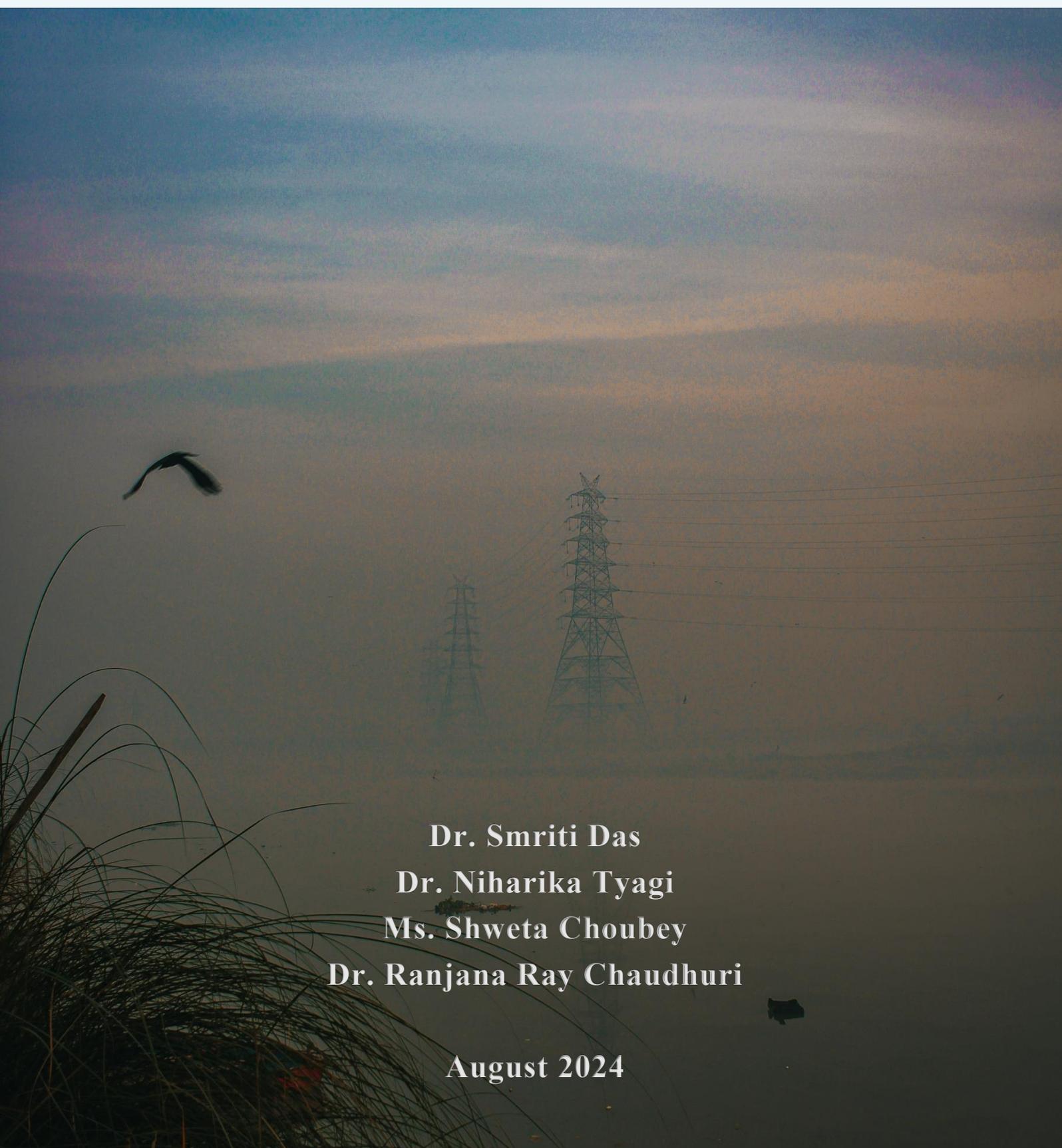


# **Nitrogen and the Energy sector in India: Policy and Stakeholder perspectives**

## **Final Report**



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## List of Acronyms

|                 |   |
|-----------------|---|
| ACMA            | Automotive Component Manufacturers Association of India |
| ADB             | Asian Development Bank                                  |
| ARAI            | Automotive Research Association of India                |
| BEE             | Bureau of Energy Efficiency                             |
| BS              | Bharat Stage  |
| CCEA            | Cabinet Committee on Economic Affairs                   |
| CEA             | Central Electricity Authority                           |
| CERC            | Central Electricity Regulatory Commission               |
| CNG             | Compressed Natural Gas                                  |
| CPCB            | Central Pollution Control Board                         |
| CRRI            | Central Road Research Institute                         |
| CSIR            | Council of Scientific & Industrial Research             |
| EMC             | Energy Management Centre                                |
| EV              | Electric Vehicle  |
| FADA            | Federation of Automobile Dealers Associations           |
| FICCI           | Federation of Indian Chambers of Commerce & Industry    |
| HEV             | Hybrid Electric Vehicle                                 |
| ICAR            | Indian Council of Agricultural Research                 |
| IIP             | Indian Institute of Petroleum                           |
| IIT             | Indian Institute of Technology                          |
| INI             | International Nitrogen Initiative                       |
| INMS            | International Nitrogen Management System                |
| IREDA           | Indian Renewable Energy Development Agency              |
| KVIC            | Khadi and Village Industries Commission                 |
| LRTAP           | Long-Range Transboundary Air Pollution                  |
| MNRE            | Ministry of New and Renewable Energy                    |
| MOCA            | Ministry of Consumer Affairs                            |
| MOEFCC          | Ministry of Environment, Forests and Climate Change     |
| MOF             | Ministry of Finance                                     |
| MOHI            | Ministry of Heavy Industries                            |
| MOP             | Ministry of Power                                       |
| MOPNG           | Ministry of Petroleum and Natural Gas                   |
| MORTH           | Ministry of Road Transport and Highways                 |
| MOST            | Ministry of Science and Technology                      |
| MOUD            | Ministry of Urban Development                           |
| N               | Nitrogen  |
| NIPFP           | National Institute of Public Finance and Policy         |
| NO <sub>x</sub> | Nitrogen oxides   |
| NTPC-NVVN       | NTPC Vidyut Vyapar Nigam Ltd                            |
| OMC             | Oil Marketing Companies                                 |
| ONGC            | Oil and Natural Gas Corporation                         |
| PC              | Planning Commission                                     |
| PCRA            | Petroleum Conservation Research Association             |
| SEB             | State Electricity Board                                 |
| SECI            | Solar Energy Corporation of India Limited               |

|      |   |
|------|---|
| SERC | State Electricity Regulatory Commission       |
| SIAM | Society of Indian Automobile Manufacturers    |
| SMEV | Society of Manufacturers of Electric Vehicles |
| SNA  | State Nodal Agencies                          |
| SPCB | State Pollution Control Board                 |
| TERI | The Energy and Resources Institute            |
| UNEA | United Nations Environment Assembly           |

## Executive Summary

The combustion of fossil fuels for energy generation is a principal contributor to the global increase in reactive nitrogen ( $N_r$ ) emissions (Garg et al., 2006; Ohara et al., 2007; EDGAR 2011; Lü and Streets, 2012; Sharma et al., 2017). Nitrogen oxides ( $NO_x$ ) and ammonia ( $NH_3$ ) are major air pollutants from industrial activities, power generation, and road transportation. Nitrous Oxide ( $N_2O$ ), a more potent greenhouse gas (GHG) than carbon dioxide (IPCC 2021; Bansal et al., 2022), is predominantly emitted from fertilizer applications and other sources, including residue burning, biomass burning for energy, and nitric acid production.

The Indian energy sector is a formidable contributor to  $N_r$ , primarily due to the combustion of fossil fuels for power generation, transportation, and various industrial processes. Despite cleaner technologies, rising energy demand necessitates continued coal use, leading to significant  $N_r$  emissions. Other industries, including refineries, cement, iron and steel, and non-ferrous metal, also contribute to  $N_r$  emissions. Between 2000-2015,  $NO_x$  emissions from industrial combustion and road transportation increased by 1211% and 457%, respectively. Additionally,  $NH_3$  emissions from power generation and other industrial combustion processes rose by 507% and 361%, respectively (Adhya et al., 2023). The transport sector, particularly road vehicles, is a significant contributor to  $N_r$  emissions. The burgeoning number of vehicles (about 326.3 million registered vehicles in fiscal year 2020; MORTH 2023), coupled with outdated technologies and insufficient emission controls, intensifies the problem.

India has implemented measures<sup>1</sup> to regulate  $N_r$  in the transport and energy sectors, including stringent emission standards for vehicles and ambitious 2030 targets to meet 50% of energy requirements with renewables and reducing emission intensity by 45%. However, given the enormity of challenge, more holistic and well-coordinated policies are imperative to effectively address the issue while ensuring a sustainable and secure energy future. Despite the significant environmental impact,  $N_r$  has not received the same level of priority as other compounds like carbon or, to some extent, sulphur. Limited attempts have been made to forecast the long-term direct  $N_r$  emissions resulting from fuel combustion in South Asia (Bansal et al., 2022).

The objectives of this research are to: identify existing  $N_r$  management policies related to India's road transport, power generation, and industrial sectors; identify key stakeholders relevant to  $N_r$  management in these sectors; analyze the roles, interests, and influences of these stakeholders; and identify emerging policy barriers and future opportunities. The research encompasses a comprehensive analytical framework development to guide the data collection process, including a thorough review of key policies and literature, expert interviews, focused group discussions, and stakeholder interviews. All research stages adhere to ethical guidelines, including obtaining necessary approvals and masking identities when requested.

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<sup>1</sup> India National Nitrogen Policy Report: Scientific Evidence, Current Initiatives and Policy Landscape (Adhya et al., 2023) could be referred for further details.

The findings reveal that while the explicit mention of  $N_r$  is relatively recent, national-level policies increasingly aim at mitigating GHG emissions from the energy sector. India's energy policy has evolved to align with international standards and agreements. However, despite its vast economy, the country faces unique challenges in balancing its growing energy needs with environmental concerns. The transition to cleaner energy sources while ensuring affordable and reliable energy to meet the rising rates of production and consumption remains a significant challenge.

The assessment of existing and future stakeholder dynamics in India's road transport, power generation, and industrial sub-sectors reveal dynamic positions among stakeholders, with the possibility of several new actors emerging in the future. The interests and influence of these stakeholders are analyzed using a 3x3 interest-influence matrix. Stakeholders acknowledged the urgency of addressing  $N_r$ , but there was a notable difference in their prioritization. Some emphasized immediate action, particularly in the power and coal industries, while others did not prioritize  $N_r$  as highly compared to other pollutants. They also highlighted limited awareness, and the need for more data and evidence-based research on  $N_r$ . In the power generation sector, there was emphasis on prioritizing renewable energy sources and adopting EVs to reduce emissions. Stakeholders recognized the importance of a multifaceted approach to meet the energy sector's needs, including a mix of renewable energy, thermal power, and sustainable practices.

Several policy barriers and opportunities were identified to mitigate  $N_r$ . Challenges include transitioning from traditional power sources, technological limitations, research gaps, and understanding customer priorities. Opportunities include higher taxes on diesel cars, strict city entry restrictions for high-emission vehicles, adoption of green technologies, and evidence-based decision-making. Stakeholders stressed international engagement to align national policies with global standards for mitigating  $N_r$  and addressing climate change. Identifying  $NO_x$  as a key pollutant in the energy sector is crucial for developing policies, regulatory standards, and technological solutions to mitigate its emissions.

Based on the study, some key policy recommendations include:

1. Establishing multi-stakeholder advisory panels comprising representatives from government bodies, industry sectors, environmental NGOs, academic researchers, and community groups. These panels should focus on discussing  $N_r$  management issues, sharing insights, and collaboratively developing solutions.
2. Encouraging and facilitating public-private partnership (PPP) projects focusing on reducing  $N_r$  emissions. These could include initiatives for developing cleaner technologies, conducting joint research, or implementing pilot projects in mitigating nitrogen emissions.
3. Implementing a robust communication strategy to ensure that all stakeholders are informed about policy changes, research findings, and opportunities for collaboration. This could include newsletters, stakeholder meetings, and dedicated web portals for information-sharing and discussion.

4. Implementing stricter emission norms for NO<sub>x</sub> in the power generation and road transport sectors. This could include setting ambitious targets, monitoring compliance, and imposing penalties for non-compliance.
5. Providing financial incentives, such as tax breaks, subsidies, or grants to industries and consumers adopting clean technologies that reduce nitrogen emissions. These could apply to electric vehicles (EVs), CNG vehicles, and industries implementing advanced emission control technologies.
6. Allocating government funding and support for research and development in nitrogen emission control technologies. This could involve encouraging collaborations between universities, research institutes, and industries to innovate in areas like Selective Catalytic Reduction (SCR) technology, EV batteries, and renewable energy sources.
7. Developing an integrated policy framework aligning nitrogen emission control with the broader environmental objectives of climate change mitigation and air quality improvement. This should encompass coordinated efforts across ministries and departments, ensuring a unified approach to managing nitrogen emissions.

## Report Overview

The report, **“Nitrogen and the Energy Sector in India: Policy and Stakeholder Perspectives,”** focuses on stakeholder research conducted by the UKRI South Asian Nitrogen Hub (SANH) team at TERI School of Advanced Studies (TERI SAS). This work builds upon earlier stakeholder and policy analysis from the previous report<sup>2</sup>, "Nitrogen Management in Indian Agriculture: Policy Perspectives and Stakeholder Research."

In the current report, our research objectives focus on identifying existing nitrogen management policies within India's road transport, power generation, and industrial sectors. We also aim to identify and analyze the key stakeholders involved in nitrogen management, examining their roles, interests, and influence. Through direct engagement with these stakeholders, we seek to uncover emerging policy barriers and explore future opportunities.

Other partner countries may use the developed analytical framework and methodology for similar analysis in the energy and other N-relevant sectors.

## SANH Overview

In a cooperative research program on 'sustainable nitrogen management,' the UKRI Global Challenges Research Fund (GCRF) SANH studies the impacts of N<sub>r</sub> pollution in eight countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. SANH brings together over 32 South Asian and UK institutions, including universities, institutes, NGOs, and the South Asia Co-operative Environment Programme (SACEP), to support progress toward meeting the Sustainable Development Goals (SDGs) by addressing the nitrogen challenge and building a scientific evidence base. This research program aims to support efficient nitrogen use, reduce nitrogen waste, and limit its adverse effects on people and the environment. Reducing nitrogen waste would enhance air, water, land, seas, improve human health, ensure food security, and offer huge economic savings (<https://sanh.inms.international/>).

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<sup>2</sup> Das, S., Tyagi, N., Choubey S. 2023, Nitrogen Management in Indian Agriculture: Policy Perspectives and Stakeholder Research; Final Report, TERI School of Advanced Studies, New Delhi.

## 1. Introduction: From Power to Pollution

Burning fossil fuels for energy production is a key factor in the global rise of reactive nitrogen ( $N_r$ )<sup>3</sup>, with nitrogen oxides ( $NO_x$ ) and ammonia ( $NH_3$ ) being prominent by-products from vehicular emissions, power generation, and industrial processes. Nitrous oxide ( $N_2O$ ), derived primarily from vehicular exhaust, biomass burning for energy, and nitric acid production, poses a serious threat to ozone depletion and climate change. It is 273 times more potent as a greenhouse gas (GHG) than carbon dioxide (Masson et al., 2021 and Bansal et al., 2022). When compared to other  $N_r$  compounds,  $N_2O$  emissions in the year 2018 were the lowest i.e. 894 Gg/year, while  $NH_3$  and  $NO_x$  were about 7,074 and 10,025 Gg/year in 2018, respectively (Adhya et al., 2023). These compounds, once emitted into the atmosphere, trigger a series of reactions in the nitrogen cycle, a phenomenon known as the Nitrogen Cascade (N-cascade) (Galloway and Cowling, 2021; Galloway et al., 2003). Essentially, when the robust triple bond in diatomic nitrogen ( $N_2$ ) is broken, the resultant  $N_r$  circulates through various ecosystems, causing environmental damage. This contributes to issues, such as groundwater nitrate pollution, the expansion of hypoxic coastal zones, and increased levels of  $NO_x$ , impacting both global warming and ozone depletion (Galloway and Cowling, 2021). While the nature of these nitrogen-related issues has remained consistent over the past decades, their severity has intensified.

In South Asia, which comprises less than 5% of the world's total land area and 14% of the arable land, the situation is particularly acute. The region supports around two billion people, which is more than a quarter of the global population (UN 2020). It is marked by numerous  $N_r$  hotspots, where both the quantity and growth rates of  $N_r$  emissions exceed the global averages (Yang et al., 2022). Since the 1980s,  $N_r$  emissions in forms, such as  $NH_3$  and  $N_2O$  have roughly doubled in the region (Yang et al., 2022). Contributing factors include proliferation of coal-based power plants, industrial activities, and dense transportation networks, all of which emit substantial nitrogen compounds into the atmosphere. Furthermore, South Asia faces significant challenges with particulate matter ( $PM_{2.5}$ ) pollution, to which  $N_r$  components, such as ammonium ( $NH_4$ ) and nitrate ( $NO_3$ ) make substantial contributions (Kumar et al., 2018; Aslam et al., 2020).  $PM_{2.5}$  pollution poses a severe health risk, with air pollution identified as a major cause of death in the region (WHO, 2016; Krishna et al., 2017).

In India, the energy sector is the biggest driver of rising  $NO_x$  emissions, contributing to  $N_2O$  and  $NH_3$  emissions due to the combustion of fossil fuels for road transportation, power generation, and industrial processes. For instance, 44% of India's total  $NO_x$  emissions in 2015 were produced by the energy sector (Adhya et al., 2023).

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<sup>3</sup> Reactive nitrogen ( $N_r$ ) includes all biologically, photochemically, and radiatively active nitrogen compounds in Earth's atmosphere and biosphere. Thus,  $N_r$  includes inorganic reduced forms of N (e.g., ammonia [ $NH_3$ ] and ammonium [ $NH_4^+$ ]), inorganic oxidized forms (e.g., nitrogen oxide [ $NO_x$ ], nitric acid [ $HNO_3$ ], nitrous oxide [ $N_2O$ ], and nitrate [ $NO_3^-$ ]), and organic compounds (e.g., urea, amines, proteins, and nucleic acids) Galloway, 2003.

Note: Henceforth, in this study, the term 'nitrogen' refers to 'reactive nitrogen.'

## Nitrogen Emissions and the Power Generation and Industrial Sectors

Owing to rapid economic progress, the escalating need for electricity, and the absence (or weak enforcement) of regulations,  $\text{NO}_x$  emissions in the Indian power industry have been reported to have risen remarkably since the mid-1990s (Garg et al., 2006; Ohara et al., 2007; EDGAR 2011; Lü and Streets, 2012). The country's dependence on coal for generation is a substantial point source<sup>4</sup> of  $\text{N}_r$ , with coal-fired power plants being significant emitters of  $\text{NO}_x$  i.e., contributing ~96% to the total power sector emissions, followed by gas-fired (~4%) and oil-fired plants (<1% plants) (Lü and Streets, 2012) during the combustion process. India's third biennial update report to the UNFCCC in 2021 disclosed total emissions of 67.96 Gg of  $\text{N}_2\text{O}$  from the energy sector, with a majority of 16.92 Gg in 2016 emanating from electricity production (MOEFCC 2021). Furthermore, Mittal et al. (2012) estimated that annual  $\text{NO}_x$  emissions from 86 coal-based thermal power plants escalated from 1 Mt in 2001-02 to 1.6 Mt in 2009-10, with the western region of India recording the highest  $\text{NO}_x$  emissions. More recently, a comprehensive sectoral  $\text{N}_2\text{O}$  emission inventory study (Bansal et al., 2022) for South Asian countries from 1990 to 2017 reveals that emissions from power generation reached about  $50.515 \text{ Gg yr}^{-1}$  in the year 2017. Despite stringent regulations, the demand for electricity in India continues to grow unabated, thus, necessitating increased coal utilization and resulting in significant  $\text{N}_r$  emissions. Hilboll et al. (2017) finds a correlation between the rise in  $\text{NO}_x$  emissions and the rapid expansion of the Indian economy, necessitating an increased energy demand. Large-scale industries (such as cement, iron and steel, glass, aluminum, and paper) and micro-, small- and medium-scale industries variably contribute to  $\text{NO}_x$  emissions (Adhya et al., 2023). Inefficient combustion technologies and the limited adoption of emission control measures have amplified  $\text{N}_r$  emanating from these industrial processes (Hilboll et al., 2017).

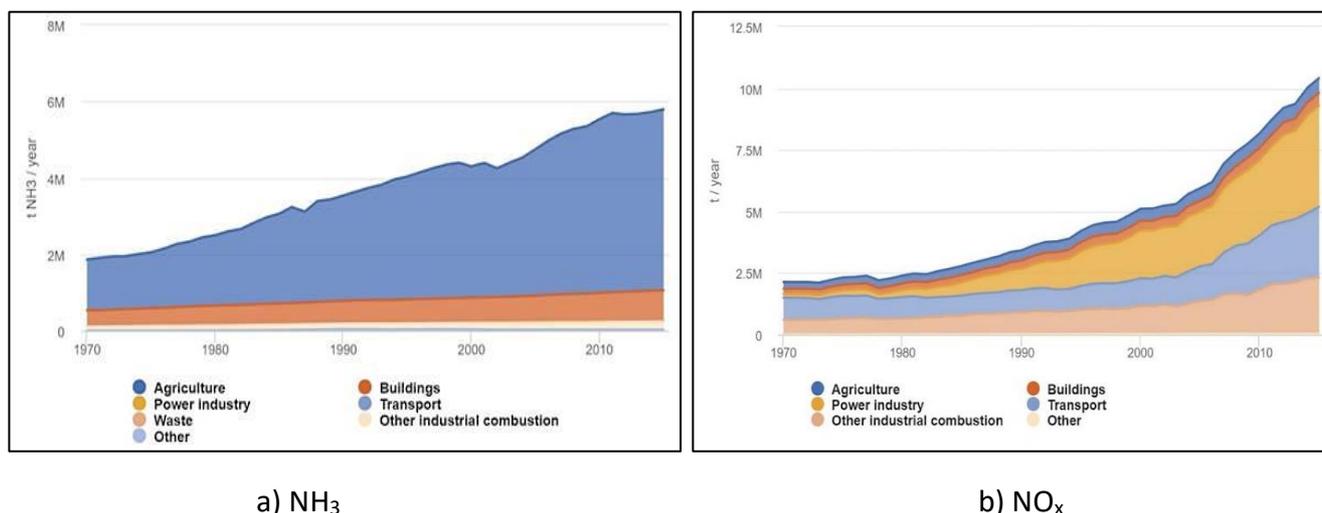


Figure 1: Nitrogen emissions by major sectors in India from 1970 to 2015. (Source: EDGAR v6.1 air pollutants, [https://edgar.jrc.ec.europa.eu/dataset\\_ap61](https://edgar.jrc.ec.europa.eu/dataset_ap61))

<sup>4</sup> The United States Environmental Protection Agency (EPA) defines point source pollution as any contaminant that enters the environment from an easily identified and confined place. Examples include smokestacks, factories and power plants.

## **Nitrogen Emissions and the Road Transportation Sector**

The road transport sector significantly contributes to the emissions of primary NO<sub>x</sub> and particulate matter (PM) from vehicular exhaust and non-exhaust<sup>5</sup> sources such as suspension of road dust (Srivastava and Jain, 2007; Srivastava et al., 2009; Pant et al., 2015; Alshetty et al., 2020). In urban areas, emissions account for about 75% of the overall atmospheric concentration of NO<sub>x</sub>, resulting in the formation of nitrate aerosols (Gurjar et al., 2016; Alshetty et al., 2020). According to a study by the International Energy Agency (IEA) and National Institution for Transforming India (Niti Aayog<sup>6</sup>) (2022), India's road transportation sector released 2.6 million metric tons of NO<sub>x</sub> in the year 2021, accounting for approximately one-third of the country's overall NO<sub>x</sub> emissions. The main sources of NO<sub>x</sub> and fine PM emissions were diesel-powered vehicles, particularly trucks and buses, accounting for about 70% of the total emissions in 2021. Two-wheelers also contributed significantly to NO<sub>x</sub> pollution, accounting for over 15% of transport-related emissions in 2021 (IEA 2022). Thus, these vehicles, coupled with outdated technologies and insufficient emission controls, could intensify the N<sub>r</sub> emissions problem in India. Moreover, the absence of an efficient public transportation system, along with escalating travel demands, has catalyzed the growth of private vehicles. Although the vehicle per capita ratio is considerably lower (i.e. 246 registered vehicles for every thousand people across India in fiscal year 2020) than that of high-income countries, the automobile sector is projected to witness substantial growth, thereby, further contributing to N<sub>r</sub> emissions.

## **India's Energy Sector Policy Developments**

India's approach to managing N<sub>r</sub> in the transport and power sectors, while comprehensive in scope, highlights the need for more robust and integrated strategies to address the significant challenge of nitrogen pollution. The government has implemented several policies to mitigate these emissions. In the early 2010s, subsidies for petrol and diesel were eliminated, and in 2019, incentives for EVs were introduced (Gupta, and Dhar, 2022). This was accompanied by increasingly stringent vehicular emission standards, culminating in the nationwide adoption of Bharat Stage VI (BS-VI) norms in 2020, which significantly limit NO<sub>x</sub> emissions from engines (Gupta, and Dhar, 2022; Gupta and Garg, 2020). In the energy sector, the government has set ambitious goals for augmenting renewable energy capacity and is promoting cleaner fuels like natural gas and biofuels. Furthermore, specific regulations aim to reduce N<sub>r</sub> from industrial sources, especially coal-fired power plants. However, India's experience with NO<sub>x</sub> control technologies, primarily restricted to primary control measures, reflects the early stage in adopting more advanced systems (Wiatros-Motyka, 2019). The high ash content and erosive nature of Indian coal further complicate the selection and effectiveness of NO<sub>x</sub> control systems. Current practices largely involve primary control measures, such as low NO<sub>x</sub> burners and overfire air systems. While effective, these measures are often not accompanied by secondary measures such as selective catalytic reduction, presenting an opportunity for advancement (Wiatros-Motyka, 2019).

Policy efforts in India to manage nitrogen pollution are influenced by both international trends and domestic needs. The impact of recent policy experiments is still emerging,

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<sup>5</sup> Non-exhaust particle emissions from road traffic consist of airborne particulate matter generated by the wearing down of brakes, clutches, tyres and road surfaces, as well as by the suspension of road dust (OECD 2022).

<sup>6</sup> Niti Ayog- the National Institution for Transforming India, serves as the apex public policy think tank of the Government of India.

encumbered by challenges like technological limitations and the need to tailor solutions to India's environmental and infrastructural context. Moreover, the complexity of the energy sector, involving a range of stakeholders, such as government bodies, industries, research institutions, and civil society, emphasizes the need for collaborative approaches. Thus, effective  $N_r$  management in this sector requires integrating diverse viewpoints and expertise to create policies that are both thorough and flexible, catering specifically to the context of India.

Considering the current scenario, this study examines the challenges and prospects within India's dynamic energy sector, aiming to align with global and national commitments to mitigate  $N_r$ . The main objectives of this research are to:

- Analyze the national energy policy landscape concerning road transport, power generation, and industrial sectors, and their approaches to  $N_r$  management.
- Identify key stakeholders and analyze their roles, interests, and influences in  $N_r$  management in these sectors.
- Identify policy barriers and future opportunities related to  $N_r$  management in these key energy sectors.

For systematic and robust analysis of the complex and myriad interactions that  $N_r$  has with various entities, we developed a framework. This framework, rooted in understanding the N-cascade effect, simultaneously evaluates sectoral patterns and policy developments. It guides our examination of emission trends across sectors and their policy implications, as detailed in the following section.

## 2. The Framework: Nitrogen Cascade Effect within the Energy Sector

### Understanding the Nitrogen Cascade Effect

The N-cascade effect, as explained by Galloway (2005) and Galloway et al. (2003), represents the complex journey of  $N_r$  through the environment, triggering a multitude of ecological and human health effects. This phenomenon underscores the dynamic nature of the nitrogen biogeochemical cycle, where a single  $N_r$  molecule, once produced through activities like energy or food production, sequentially impacts various environmental systems. These impacts vary in nature and magnitude, largely depending on the sensitivity of each system to  $N_r$  and the molecule's residence time within it. This cascade effect importantly ties into economic analyses, highlighting the broader implications of human alterations to the N cycle.

The cascade begins with  $N_r$  emissions from sources such as fossil fuel combustion, translating into atmospheric  $NO_x$ . This  $NO_x$ , through a series of transformations, impacts atmospheric chemistry by increasing ozone concentrations, reducing visibility due to fine particulate matter, and contributing to precipitation acidity. Once deposited in terrestrial ecosystems, the same  $N_r$  molecules can affect soil acidity, biodiversity, and productivity. In aquatic systems,  $N_r$  can lead to eutrophication and decreased water quality. Furthermore, when transformed back to  $N_2O$ ,  $N_r$  alleviates GHG effects and stratospheric ozone depletion.

Understanding the N-cascade is imperative for several reasons. Environmentally and ecologically,  $N_r$  emissions are a key contributor to air, water, and soil pollution, affecting biodiversity and ecosystem productivity. From a climate perspective,  $N_2O$ , a potent GHG, significantly contributes to global warming. Human health is directly impacted by exposure to  $NO_x$  and its secondary pollutants, necessitating strategies to mitigate these effects. Policy and regulation development greatly benefit from a thorough understanding of the N-cascade, guiding the implementation of best practices and technologies to minimize  $N_r$  release. Efficiency and cost-effectiveness in addressing  $N_r$  emissions can only be achieved through a comprehensive grasp of the N-cascade effect, aligning economic goals with environmental protection.

### The Framework: Informing Policy and Sectoral Emission Strategies

The N-cascade provides a framework to assess the environmental footprint of sectoral emissions, guiding the development of targeted policy interventions. This comprehensive approach enables the identification of key emission sources and their cascading effects, facilitating a more strategic allocation of resources toward mitigation efforts.

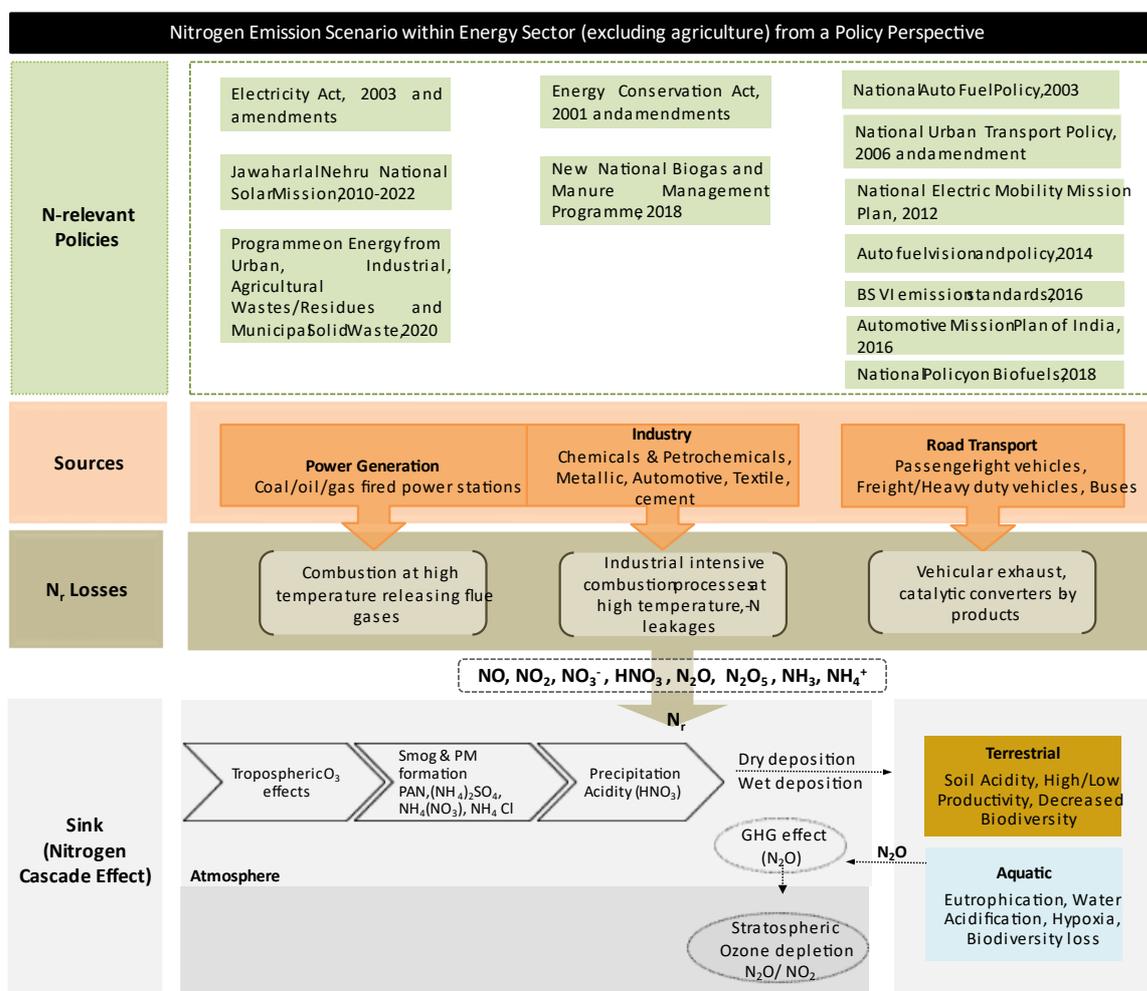


Figure 2: Nitrogen Cascade Effect within the Energy Sector (Source: Author-own compilation from policy and literature review)

The framework helps in 1) mapping sectoral emissions, 2) policy development and evaluation, and 3) technological and management solutions. Employing the N-cascade framework, we identify the sectors with the highest  $N_r$  emissions. Mapping these emissions is crucial for understanding their cumulative impact and targeting effective policy interventions. The framework aids in the development of policies that are both broad in scope and specific in targets (Moomaw, 2002).

The four-tiered framework in Figure 2 establishes a connection between sectoral emissions, pathways of nitrogen losses, cascading effect, and sector-specific policy efforts influencing emissions and related processes. The second tier (sources), shown in orange in the figure, represents the dominant sources of  $N_r$ , where power generation is the primary contributor, followed by industrial emissions, and road transport due to various combustion processes. Upon mobilization when these  $N_r$  compounds arrive at the sink, internal cycling triggers a sequence of interconnected events, disturbing the atmospheric balance and impacting both terrestrial and aquatic systems. The interactions between the stages also depict the close relationship between the ecological and the socio-economic processes.

The interconnectedness between sources and sinks highlights the importance of examining decision processes and stakeholder dynamics in managing  $N_r$  emissions. Key stakeholder actions include implementing regulatory measures, introducing economic incentives, raising public awareness, fostering collaborative initiatives, supporting research and development to improve nitrogen use efficiency, and engaging in international cooperation through platforms like the United Nations Environment Programme's Global Partnership on Nutrient Management. These efforts collectively aim to mitigate the adverse effects of nitrogen pollution on the environment and public health.

Diving deeper into policy analysis, we explore the dynamics among stakeholders—ranging from policymakers and industry players to communities and environmental organizations—to identify leverage points for intervention and collaboration.

### 3. Methodology

This research examines policy contexts and stakeholder dynamics using qualitative, multi-stage, and multi-dimensional approaches. Data collection involved the identification of key policies and literature, with primary data collected through expert interviews, focus group discussions, and stakeholder interviews.

The iterative literature review process (Annexure 4) helped in mapping the global and national policy landscape, understanding sectoral emission trends, and interpreting stakeholder dynamics in  $N_r$  management decisions within the energy sectors. We triangulated multiple data sources to identify recurring themes and patterns in the textual data to enhance data validity and reliability. The overall methodology consisted of four steps (See Figure 3): sub-sector identification, policy identification, policy analysis, and stakeholder analysis (including stakeholder identification, mapping of roles-interests, stakeholder dynamics and stakeholder engagement), as discussed below:

**Step 1. Sub-sector Identification:** The identification of the primary sub-sector was determined based on the levels of  $N_r$  contribution from the corresponding energy sector/s and the subsequent sectoral needs toward  $N_r$  management. We analyzed the sector's contribution to nitrogen pollution, evolutionary trends, the significance of  $N_r$  management in the relevant sub-sector, and the availability of sector-specific policies.

Outcome: Three major sources of  $N_r$  emissions in the energy sectors were identified: road transport, power generation, and industrial sectors. The power generation sector exhibited the highest levels of emissions, followed by the industry and road transport sectors (Bansal et al., 2022).



Figure 3: Methodology Followed for Policy and Stakeholder Analysis

## Step 2 Policy Identification and Selection:

- Using the SANH-Policy database and applying filters for 'National-level policies' and 'energy sector,' we identified 12 relevant policies. Next, we undertook an additional review of the International Energy Agency (IEA)<sup>7</sup> database using the same filters, which yielded 43 additional policies. In total, 55 policies were identified in the first attempt.
- Out of these 55 policies, we applied the criteria from Kanter et al., (2020) and Yang et al., (2020) to narrow down to 21 N-relevant policies: N-relevance, N-impact, and the impact direction (See Annexure 5).

Subsequently, we sought the opinions of energy sector experts through Google Forms, specifically on the nitrogen relevance of these 21 policies. Based on their feedback, we narrowed our focus to 12 key policies for a more in-depth analysis of stakeholder

<sup>7</sup> The IEA website consists of a huge database of the policies on global, regional and national levels that provides access to information on past, existing or planned government policies.

dynamics and positions. These policies, along with their amendments, spanned three sub-sectors of the energy industry: road transportation, power generation, and industry, as detailed in Table 1.

Table 1: Energy Sector Policies and their Nitrogen Implications (total 12)

| Policies and its amendments  | Policy Focus   | N-relevance/Implications (Direct/Indirect)  |
|--|--|---|
| <b>Energy Conservation Act, 2001 and its 2010 and 2020 amendments</b>                                    | Energy consumption standards and labelling; energy conservation building codes, energy trading, institutional mechanisms, mandatory energy audits, penalties and enforcement, and recent carbon credit trading schemes   | <b>Indirect relevance</b> does not refer to N <sub>r</sub> explicitly. This policy promotes energy efficiency measures. By improving efficiency, the power sector and industries can generate the same amount of power or output using less fuel, resulting in lower overall emissions at source, including NO <sub>x</sub> . |
| <b>National Auto Fuel Policy, 2003 and its 2014 amendment The Auto Fuel Vision and Policy 2025, 2014</b> | Phased implementation of emission standards, encouraging R&D for alternative fuels, vehicular pollution control, introduction of cleaner technologies, fuel efficiency, real-world emissions testing   | <b>Direct relevance:</b> Explicit mention of limits on NO <sub>x</sub> emissions for stricter emission standards encourages the use of cleaner fuels and technologies to reduce its emissions.  |
| <b>Electricity Act, 2003 and its 2007 amendment and the recent 2022 Bill</b>                             | Promotion of competition, establishment of regulatory framework, open access and cross-subsidy elimination, promotion of renewable energy, strengthening of regulatory framework - enforcement and penalties, simplifying open access, promote consumer choice, and bring efficiency through competition | <b>Indirect relevance:</b> It encourages private investment and competition, leading to more efficient power generation and reduced emissions. Reduction in N <sub>r</sub> emissions by displacing fossil fuel-based power generation since it promotes renewable energy.   |
| <b>National Urban Transport Policy, 2006 and its 2014 amendment</b>                                      | Encouraging integrated land use and transport planning, greater use of public transport and non-motorized modes, promoting use of cleaner technologies for public transport, developing public transport systems, and reducing growth of private motor vehicles  | <b>Indirect relevance:</b> The policy indirectly reduces N <sub>r</sub> emissions through sustainable urban transportation systems. It focuses on decreasing public vehicle usage and influencing consumer preferences toward making better choices.  |
| <b>National Solar Mission (2010-2022)</b>  | Scale-up solar energy deployment, reduce the cost of solar power, promote research and development, facilitate sustainable solar industry growth, enhance energy access and security   | <b>Indirect relevance:</b> Replacing conventional coal or gas power plants with solar power can help reduce N <sub>r</sub> emissions at the power-generation level.   |
| <b>National Mission for Electric Mobility, 2012</b>  | Manufacturing of electric (& hybrid) vehicles (EVs), R&D support to industry and academia to develop affordable and reliable EVs, and progressive indigenization of critical EV components to develop domestic competence  | <b>Direct relevance:</b> Promoting EVs could cut-off nitrogen at both manufacturing and emission stages. EV produces zero tailpipe emissions, while hybrid electric vehicles (HEVs) typically emit less NO <sub>x</sub> than conventional vehicles.   |
| <b>Automotive Mission Plan of India, 2016</b>  | Support growth of automotive industry, improve export potential, boost employment, and promote 'Make in India'   | <b>Indirect relevance:</b> Development of more fuel-efficient and lower-emission  |

|   |   |  |
|---|---|--|
|   |   | vehicles at manufacturing stages can impact nitrogen emission levels.  |
| <b>Bharat Stage (BS) VI emission standards, 2016</b>  | Regulate output of air pollutants from internal combustion engines, implement BS VI standards with more stringent emission limits, particularly for diesel engines (NO <sub>x</sub> , PM, Sulphur, hydrocarbons in fuels) | <b>Direct relevance:</b> Strict limits on NO <sub>x</sub> emissions via BS VI can reduce permissible emissions from both petrol and diesel vehicles compared to previous standards.  |
| <b>New National Biogas and Manure Management Programme, 2018</b>  | Clean bio-gaseous fuel, promoting sustainable and renewable energy practices, waste management, and rural development and reducing dependence on fossil fuels   | <b>Indirect relevance:</b> The policy targets biogas uses for cooking, lighting, and power generation. It can displace more polluting fuels like firewood or coal in homes or small industries, leading to a net reduction in emissions. |
| <b>National Policy on Biofuels, 2018</b>  | Energy security, waste management, and air quality management; also expands scope of raw material for ethanol production  | <b>Indirect relevance:</b> Biofuel use can lower NO <sub>x</sub> at the emission stages, thus, achieving less pollution levels than traditional fossil fuels.  |
| <b>Programme on Energy from Urban, Industrial, Agricultural Wastes/Residues and Municipal Solid Waste, 2020</b> | Converting Municipal Solid Waste (MSW) to energy, biomass waste to energy, waste to biofuels, waste to biogas, incentives and subsidies   | <b>Indirect relevance:</b> Promotion of waste to energy projects at the end life-cycle can lower NO <sub>x</sub> emissions compared to the use of conventional coal or gas power plants for energy production.                           |

### Step 3. Policy Analysis

*National-Level Energy Policy Review:* Using the content analysis method, we examined national-level policy documents (n=12) and collected literature (n=62; journal papers, reports, book chapters, conference proceedings, working papers and policy briefs) to analyze integration of N<sub>r</sub> management in policies, regulatory shifts, adaptation scenarios, and stakeholder dynamics.

*Global Energy Policy Review:* A qualitative analysis of the prevailing global policy regimes was conducted to critically analyze and evaluate the patterns and transformations in the way N<sub>r</sub> management is recognized and acknowledged at an international level, as well as the various entities and individuals involved in this process. The review of the literature (n=22) comprised of policy documents (n=11) (of which the multi-government treaties and international energy commitments also formed a part), and peer-reviewed articles on global energy policy to ensure a comprehensive understanding of N<sub>r</sub> prioritization in international discourse. The analysis provided insights into the extent to which global policies exert a discernible influence or have a tangible impact on the efforts and initiatives undertaken at the national level through policies or other regulatory means.

**Step 4: Stakeholder Analysis:** The energy sector is highly complex with multiple stakeholders, including government ministries and organizations, public and private industrial units, research institutions, and civil society. Understanding the positions and dynamics of stakeholders regarding N-related energy sector decisions and managing stakeholder interests was crucial to the study. The analysis also included aspects of future (likely) shifts in stakeholder positions that would impact N<sub>r</sub> management. Overall, stakeholder analysis involved the following steps: 1) Stakeholder identification, 2) Mapping stakeholder roles and

interests, 3) Categorizing stakeholders (understanding stakeholder dynamics using interest-influence matrix), and 4) stakeholder interviews (engagement).

*1. Stakeholder Identification:* To identify the stakeholders (whether directly or indirectly impacted or affected by policy) from government, research organizations, industry, civil society, and international organizations, a thorough examination of policies (n=12) and literature (n= 62) was conducted. Stakeholder groups/individuals from each sub-sector were listed, representing the manner and extent to which they influenced or were affected by N-related policy decisions. The list was then triangulated through expert consultation during the focus group discussions (n=3).

*2. Mapping Stakeholder Roles and Interests:* This step involved examining the evolution of stakeholder roles during the energy sector policy formulation and implementation process. The interest mapping, on the other hand, helped in identifying stakeholders' likely concerns and entailed benefits in policy decisions. Quite often, these stakeholders have conflicting or shared interests in pushing forward or obstructing a specific policy reform. Thus, they may exercise the power to influence change based on external pressures. As an outcome, we differentiated the diverse roles and interests of the key stakeholders in the policy process based on their overlapping or contrasting interests. Using findings from policy and literature reviews, we mapped these roles and interests, which were confirmed in the focus group discussion.

*3. Stakeholder Dynamics:* To understand the dynamics among stakeholders and the power they held in influencing N<sub>r</sub> management decisions, a 3x3 interest and influence matrix was used during the focus group discussions (FGDs). The matrix depicted interest on the vertical axis (where 1=low level, 2=medium level and 3=high level) and influence on the horizontal axis (low on the left to high on the right). 'Interest' indicated stakeholders' concerns and benefits from policy decisions, while 'influence' showed their ability to resist or encourage change. The FGDs with sector experts focused on understanding current stakeholder positions in N<sub>r</sub> management decisions (for example, the Energy Conservation Act). We carefully considered sectoral developments and extended the discussion to understand potential future shifts in positions and their implications for N<sub>r</sub> management.

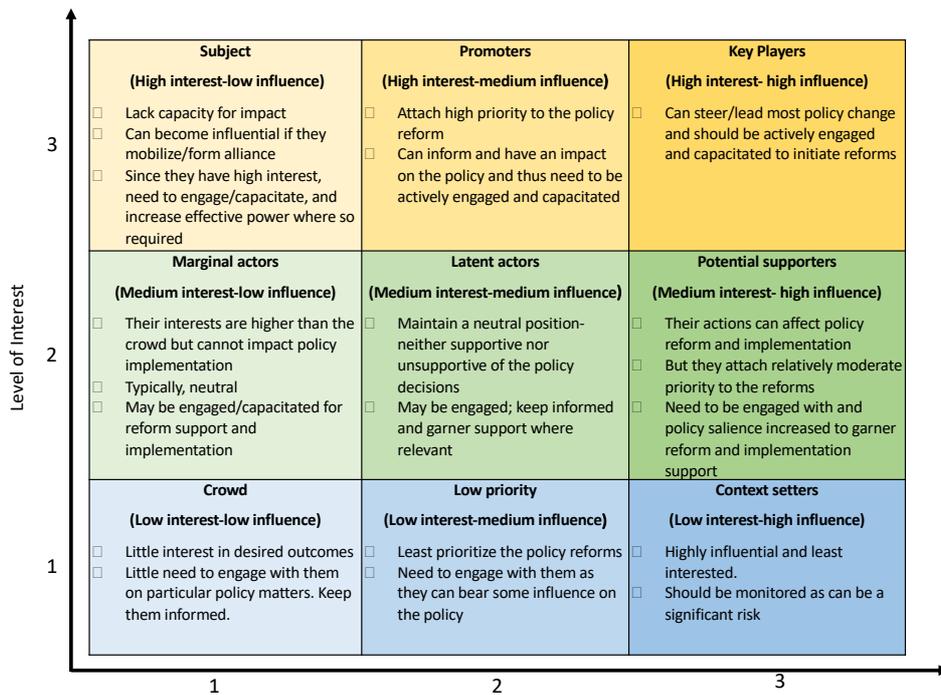


Figure 4: Analytical Categories vis-a-vis Interest and Influence Matrix

This exercise was crucial for developing the interest-influence matrix, which provided insights into stakeholder categories, while also identifying allies and opponents in policy decisions (See Figure 4). This categorization helps manage stakeholders in driving any N<sub>r</sub> management agenda.

4. Stakeholder Interviews: Semi-structured interviews (n=12) with key stakeholders, including industry, government agencies, civil society organizations, and research organizations (Annexure 3), were conducted to understand their perceptions of the N<sub>r</sub> problem in the energy sector and emergent policy challenges. These interviews provided invaluable insights into N<sub>r</sub> management challenges and opportunities, informing future policy initiatives.

## 4. Findings

### 4.1 Assessing the Evolution of India's Energy Policy Landscape

In this section, we present the international and the national policy developments, exploring the international influence, alongside mapping of the emergence of stakeholders and their roles in the N-related policies/policy provisions. Figure 6 provides a comprehensive map of the various stakeholder and international policy influences on India's energy policy vis-a-vis N<sub>r</sub> management in the energy sector.

#### Global Nitrogen Management Initiatives and Their Impact on India's Energy Policy Evolution

The global approach to N<sub>r</sub> management has been shaped by key developments, particularly the Long-range Transboundary Air Pollution (LRTAP) Treaty of 1979. This treaty, involving nations from the Northern Hemisphere, including the United States, Canada, and Europe,

focused on transboundary pollution, leading to two crucial protocols on nitrogen regulation, the Sophia (1988) and Gothenburg (1999) Protocols (Moomaw et al., 2002; Galloway et al., 2014; Reis et al, 2016). Initially, LRTAP's protocols emphasized technology-driven solutions, but the 1990s marked a shift to an effects-oriented approach, recognizing the complex interactions of air pollutants (Moomaw et al, 2002; Sutton et al, 2011). This resulted in the 1999 Gothenburg Protocol's multi-pollutant, multi-effect strategy, which significantly reduced emissions in Europe. However, nitrogen reduction has lagged behind that of Sulphur, continuing to pose challenges such as forest soil acidification (Boyer et al, 2013).

In addition to these multi-lateral environmental agreements, the early 2000s saw the emergence of multi-stakeholder inter-governmental organizations, such as the International Nitrogen Initiative (INI), the Global Partnership on Nutrient Management (GPNM), and the International Nitrogen Management System (INMS). These organizations have played a crucial role in raising awareness about the global  $N_r$  problem and recognizing energy production and combustion as major sources of  $N_r$  (Reis et al, 2016; Sutton et al, 2021).

The Task Force on Reactive Nitrogen, established under LRTAP in 2007, was a significant development in coordinating efforts at the EU level, and understanding the integrated and multi-pollutant nature of  $N_r$  in relation to air pollution (Sutton et al, 2021). This was further strengthened by the 2019 UN Environment Assembly's adoption of the resolution on Sustainable Nitrogen Management (UNEA 4 Resolution), which urged nations to develop national action plans for nitrogen waste reduction by 2030.

India's energy policy landscape has evolved in tandem with these global policy trends, reflecting a commitment to align with international standards and agreements aimed at mitigating  $N_r$  and addressing climate change. This evolution has been characterized by a gradual shift from general air pollution control measures to more specific and stringent regulations aimed at curbing  $N_r$  from the power generation and road transportation sectors (Bardhan et al, 2019). India's ratification of the Kyoto Protocol in 2002 was a pivotal moment in aligning its domestic energy policy with global efforts to combat climate change, prompting new investments in clean energy and afforestation projects (Patel, 2016; Chime and Bajaj, 2022). This commitment has been further strengthened through active participation in international environmental and climate treaties such as the Paris Agreement in 2015 where India pledged to increase the share of non-fossil fuel-based energy capacity to 40% by 2030 as part of its Nationally Determined Contributions (NDCs). The Kigali Amendment to the Montreal Protocol, ratified in 2016, supports transition to energy-efficient appliances, while the SAARC Framework Agreement on Energy Cooperation, signed in 2014, aims to improve energy security and enhance regional cooperation by facilitating the development of a regional energy market and promoting the integration of cross-border electricity grids.

Besides, India's active participation in multi-governmental organizations like the INI demonstrates its commitment to addressing the global challenge of  $N_r$  management. Simultaneously, being a party to the United Nations Environment Assembly (UNEA) 4 Resolution reflects its alignment with the international community in recognizing the importance of  $N_r$  management for environmental sustainability. The UNEA 4 Resolution provides a comprehensive framework that can guide India in formulating its national action plan, which is crucial for addressing the specific challenges related to  $N_r$ . Moreover, India's

recent commitment to COP28, focusing on transitioning from fossil fuels to renewable energy and enhancing energy efficiency, presents an intriguing prospect for policy and regulatory changes in the energy sector. These changes may have significant implications for N<sub>r</sub> management.

However, India's challenges in balancing its burgeoning energy demands with environmental concerns cannot be overlooked. The country's energy mix remains heavily reliant on coal, and the rapid pace of industrialization and urbanization has led to significant air pollution and GHG emissions (Bardhan et al, 2019). The challenge lies in transitioning to cleaner energy sources while ensuring access to affordable and reliable energy for its growing population.

### **The National Policy Landscape**

The evolution of India's energy policies (n=12) with respect to N<sub>r</sub> management in the road transport, power generation and industrial sector can be understood as a five-phase journey, each building upon the previous, toward addressing the challenge of emissions, particularly N<sub>r</sub><sup>8</sup>.

During the **first phase**, dating back to pre-2000, the country was in the process of establishing its environmental regulatory frameworks. The Air (Prevention and Control of Pollution) Act of 1981, while not explicitly mentioning N<sub>r</sub>, was a pivotal piece of legislation aimed at controlling air pollution. This Act laid the essential groundwork for future policies and regulations addressing air pollution in its myriad forms.

The early 2000s marked the **second phase**, which saw the introduction of vehicle emission norms. Known as BS norms, and modelled after European emission standards, the first of these, BS II, was implemented nationwide in 2001. These norms regulated emissions of various pollutants including carbon monoxide, hydrocarbons, and NO<sub>x</sub>. Simultaneously, the Electricity Act of 2003 replaced the previous Electricity Supply Act of 1948, bringing about comprehensive reforms in the power sector. These reforms promoted competition, introduced regulatory changes, encouraged renewable energy, and facilitated consumer choice.

The **third phase**, spanning from the mid to late 2000s, was characterized by a tightening of standards and a renewed focus on energy efficiency. The transition to BS III and the subsequent work toward BS-IV emission standards further restricted NO<sub>x</sub> emissions. The Energy Conservation Act of 2001 and its 2010 amendment were seminal in promoting energy efficiency, thereby, indirectly mitigating N<sub>r</sub>. The Act was formulated to address the growing energy demand and the need to conserve resources while reducing GHG emissions. The Act played a crucial role in motivating energy-efficient practices, raising consumer awareness, and facilitating energy savings. The Amendment expanded the coverage of the Energy Conservation Act to include additional sectors and energy-consuming entities, aiming to cover additional industries, commercial establishments, and buildings.

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<sup>8</sup> While our policy analysis is focused on understanding the evolution of energy sector policies' in addressing the Nitrogen challenge, for a more detailed understanding of the overall energy sector policies and their evolution post-independence, refer to Bardhan, R., Debnath, R., & Jana, A. (2019). Evolution of sustainable energy policies in India since 1947: A review. *Wiley Interdisciplinary Reviews: Energy and Environment*, 8(5), e340.

In the **fourth phase**, during the 2010s, the country witnessed a pivotal shift toward renewables and EVs. The launch of the National Solar Mission in 2010, with its ambitious target of achieving 100 GW of solar power capacity by 2022, was a game-changer. This mission was fundamental in diversifying India's energy mix, reducing reliance on fossil fuels, and, consequently, mitigating NO<sub>x</sub> emissions. In road transportation, the National Electric Mobility Mission Plan of 2012 and the FAME India Scheme incentivized the adoption of electric and hybrid vehicles, thereby, reducing tailpipe emissions. Furthermore, the National Auto Fuel Policy of 2003 was revised in 2014, setting a clear roadmap for the auto industry to meet stricter fuel efficiency norms and reduce GHG emissions. This was largely in response to the increasing environmental and public health concerns associated with rising vehicular pollution in the country.

The **fifth and current phase**, from the 2010s to the 2020s, is marked by explicit regulations aimed at N<sub>r</sub> management. The Central Pollution Control Board (CPCB) 2015 norms for thermal power plants and the nationwide implementation of BS VI emission standards in 2020 were significant strides in limiting nitrogen oxide emissions from vehicles and industrial sources. The Energy Conservation (Amendment) Bill, 2022, currently under review, is another critical step toward achieving COP-26 goals and expediting the decarbonization of the Indian economy. The government's commitment to generating 500 GW of energy from non-fossil sources by 2030 and meeting 50% of its energy needs with renewables is a testament to its dedication to a cleaner, greener future. The Programme on Energy from Urban, Industrial, Agricultural Wastes/Residues and Municipal Solid Waste, 2020 encourages the conversion of waste into energy, addressing India's growing waste problem while simultaneously contributing to the country's energy mix. The government has introduced various incentives and subsidies to promote these initiatives, often through public-private partnerships.

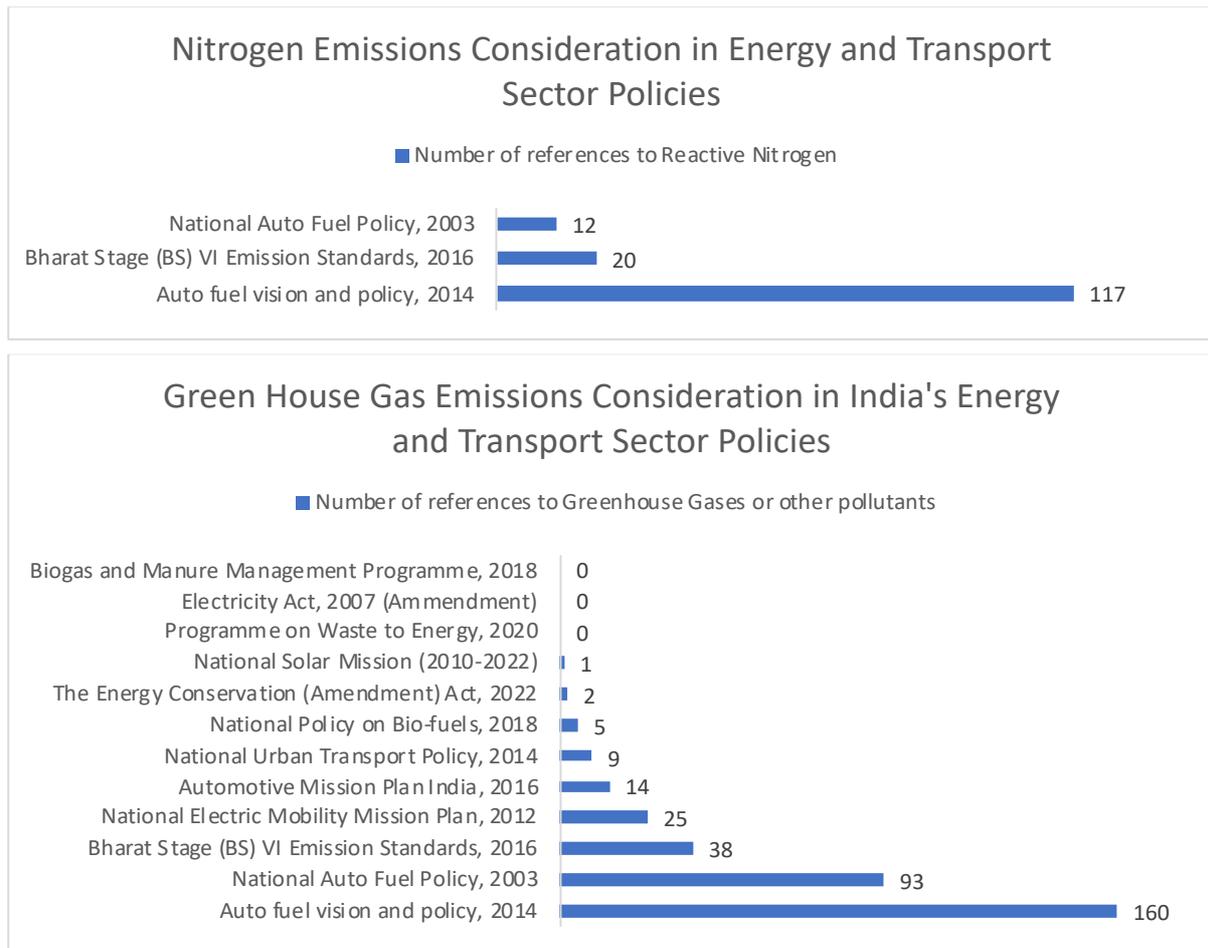


Figure 5: Frequency of References to 'Greenhouse Gases' and 'Nitrogen Emissions' in India's Energy Policy Texts

Though the energy policy evolution marks considerable efforts at mitigating emissions (e.g. GHGs and other air pollutants), the policy analysis exercise showed an explicit mention of  $N_r$  in only three selected policies or regulations, National Auto Fuel Policy, 2003; Auto Fuel Vision and Policy, 2014; and, BS VI Emission Standards, 2016 (Figure 5). Yet, India's approach toward managing  $N_r$  in the energy sector has evolved from general air pollution control to more specific and stringent regulations aimed at curbing  $N_r$  from the power generation and road transportation sectors.

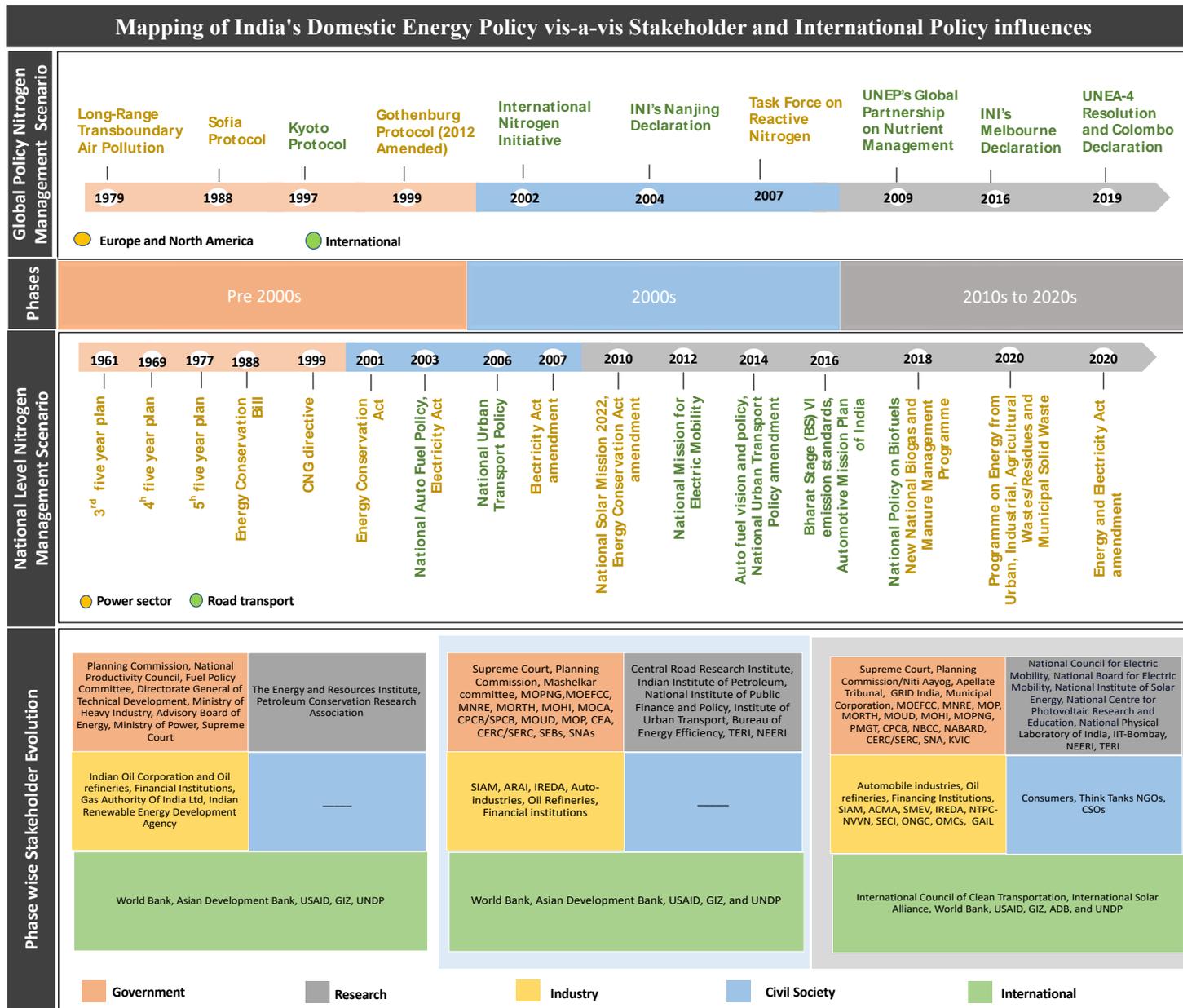


Figure 6: Mapping of India's Domestic Energy Policy vis-a-vis Stakeholder and International Policy Influences (Source: Author-own compilation from policy and literature review)

(For Acronyms: **MOPNG**: Ministry of Petroleum and Natural Gas, **MOEFCC**: Ministry of Environment, Forests and Climate Change, **MNRE**: Ministry of New and Renewable Energy, **MORTH**: Ministry of Road Transport and Highways, **MOHI**: Ministry of Heavy Industries, **MOCA**: Ministry of Consumer Affairs, **CPCB/SPCB**: Central/State Pollution Control Board, **MOUD**: Ministry of Urban Development, **MOP**: Ministry of Power, **CEA**: Central Electricity Authority, **CERC/SERC**: Central/State Electricity Regulatory Commission; **SEB**: State Electricity Board, **SNAs**: State Nodal Agencies, **SIAM**: Society of Indian Automobile Manufacturers, **ACMA**: Automotive Component Manufacturers Association of India, **ARAI**: Automotive Research Association of India, **SMEV**: Society of Manufacturers of Electric Vehicles, **NEERI**: National Environmental Engineering Research Institute, **TERI**: The Energy and Resources Institute, **PMGT**: Prime Minister's Group on Technology, **MOHI**: Ministry of Heavy Industries, **NBCC**: National Biofuel Coordination Committee, **NABARD**: National Bank For Agriculture And Rural Development, **KVIC**: Khadi and Village Industries Commission, **NTPC-NVVN**: NTPC Vidyut Vyapar Nigam Ltd., **SECI**: Solar Energy Corporation of India Limited, **ONGC**: Oil and Natural Gas Corporation, **GAIL**: Gas Authority Of India Ltd., **OMCs**: Oil Marketing Companies)

### **Stakeholder Evolution with Shifting Policy Landscape**

Drawing parallels to the trajectory of domestic energy policy development, the involvement and influence of stakeholders in energy sector policies can be segmented into three distinct phases: **Pre-2000** (from 1980s-90s), which marked the **convergence of traditional energy sector stakeholders** (government bodies, financial institutions, and international organizations); the **2000 to 2010** phase, which **expanded the stakeholder spectrum** (emergence of industrial players and associations, research institutes, and some level of state government participation); and the phase from **2010 to the 2020s**, marked by the **integration of a more diverse range of stakeholders**, including various ministries, research organizations, automotive organizations, and local-level players (See Figure 6). There has been a clear shift toward more collaborative and multi-stakeholder approaches in policy discussions and implementations.

### **Energy stakeholders' pre-2000 phase**

During the 1980s-90s, various stakeholders played pivotal roles in promoting energy efficiency and conservation in India's energy sector. The Planning Commission (PC) and the National Productivity Council (NPC) were instrumental in advocating for energy efficiency in industrial processes, particularly in thermal stations. The government established several committees and organizations, such as the Energy Survey of India committee, State Electricity Boards (SEBs), and the Fuel Policy Committee to study energy demand, promote energy conservation, and formulate a coherent energy policy.

The establishment of the Petroleum Conservation Research Association (PCRA) under the Ministry of Petroleum and Natural Gas (MOPNG) and The Energy and Resources Institute (TERI) in the mid-1970s marked a significant shift toward making fuel conservation a nationwide movement. The PCRA developed national petroleum conservation programs and advocated for policies to accelerate the conservation of petroleum products.

In the 1980s, the Inter-Ministerial Working Group on Energy Conservation and the Advisory Board of Energy were established to develop policy measures and guide technical, financial, and institutional aspects of energy demand. Financial institutions and banks offered schemes to support energy conservation measures, and the MOP played a crucial role in facilitating the implementation of energy conservation programs. In 1989, the Energy Management Centre (EMC) was established with the assistance of the World Bank and the United Nations Development Programme (UNDP) to promote energy conservation measures.

The 1990s saw collaboration between bilateral bodies, such as USAID, Asian Development Bank (ADB), World Bank, UNDP and others with the MOP to enhance energy conservation efforts. The first Oil Conservation Week (OCW) was held in 1991, and the Energy Conservation Bill was approved in 1997. The implementation of BS emissions standards and CNG expansion began in 1999 following a Supreme Court order, though the decision generated resistance from the diesel lobby, the government, and, ultimately, the users including car drivers, owners of three-wheelers etc.

In conclusion, the pre-2000 phase was foundational in establishing the regulatory frameworks and key stakeholders for promoting energy efficiency and conservation. The collaborative

efforts of government bodies, financial institutions, and international organizations were instrumental in shaping the energy conservation movement in the country during this period.

### **Phase 2: Energy stakeholders in the 2000s**

In the **2000s**, the Indian road transportation sector underwent significant policy reforms, driven by the Supreme Court's directives for clean air and health, with the MOPNG being the decision-making authority. The Mashelkar committee, established by the MOPNG in 2001, recommended the phased implementation of vehicular emission norms and the corresponding Auto Fuel Policy. The National Policy on Biofuels, formulated in 2009 (followed by the revised Biofuel policy in 2018) by the government, aimed to achieve 20% biodiesel blending in diesel by 2011–12. Initially, biofuel initiatives were primarily driven by policy actors at the central level, leading to criticism from various actor groups due to the perceived negative effects of biofuels<sup>9</sup> (Chaliganti & Müller, 2015).

Stakeholders from the automobile industry such as the Society of Indian Automobile Manufacturers (SIAM) played a significant role in policy decisions. Additionally, representatives from various ministries, the CPCB, and state governments not only drove policy ideas but also assisted in implementation. The Ministry of New and Renewable Energy (MNRE) and the Ministry of Heavy Industry (MOHI) initiated the development of alternative fuel vehicles, including battery-powered, hydrogen, and fuel-cell vehicles. However, progress in this area remained limited (MOPNG 2015). Moreover, oil companies also made noteworthy investments in technological upgrades and other modifications in the production of gasoline and diesel, in line with auto fuel specifications.

In the power generation and industrial sectors, the MOP, regulatory commissions, and the Central Electricity Authority (CEA) guided the enactment of the Energy Conservation Act 2001 and the Electricity Act 2003, aimed at promoting efficient and environmentally friendly policies. The EMC, reinstated as the Bureau of Energy Efficiency (BEE) (under MOP), was responsible for achieving India's energy efficiency objectives, with the Central Electricity Regulatory Commission (CERC) regulating tariffs and promoting renewable energy. State-level actors, such as SEBs, State Electricity Regulatory Commissions (SERCs), and State Nodal Agencies (SNAs), also played a crucial role in promoting renewable energy and conservation measures.

Throughout this phase, central and state governments were key players in enabling reforms, with states also acting as implementing agencies. Research institutes impacted policy decisions with data-driven approaches, while industrial players and associations influenced policy decisions and were actively engaged by the government. However, policy texts and literature did not explicitly mention the participation/role of civil society and/or consumer (groups) in much of the policy discussions, thus, indicating their absence or insignificant participation in decision-making.

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<sup>9</sup> Land conflicts, loss of biodiversity, and uncertainty about the contribution of biofuel production to rural development, wasteland rehabilitation, and poverty reduction

### Phase 3: Energy Stakeholders 2010s onwards

Since 2010, the Indian government has made significant strides in the EVs, emission standards, biofuels, and thermal norms sectors. Specific ministries, including the Ministry of Environment, Forest and Climate Change (MOEFCC), MNRE, MOP, Ministry of Road Transport and Highways (MORTH), Ministry of Urban Development (MOUD), and the Department of Heavy Industry, were actively involved in shaping the EV initiative, with considerable contributions from the PC and the Ministry of Finance (MOF).

The National Committee on Electric Mobility (NCEM) and the National Board for Electric Mobility (NBEM) played a pivotal role in fostering collaboration among diverse stakeholders in promoting electric mobility. Research organizations, such as the Council of Scientific and Industrial Research (CSIR) and the Department of Science and Technology (DST), contributed to the advancements in EV technology. However, automotive organizations, such as the SIAM<sup>10</sup>, the Automotive Component Manufacturers Association of India (ACMA), and the Society of Manufacturers of Electric Vehicles (SMEV), expressed skepticism and exerted a significant influence on the provisions governing EV promotion (Dutt, 2023). In 2013, a committee led by Shri Saumitra Chaudhury, under the PC, recommended an amendment to Auto Fuel Policy 2003 and strongly emphasized the lack of coordination among stakeholders, including the Ministries of Petroleum and Natural Gas, Road Transport, Heavy Industries, Environment and Forests, and Urban Development, as well as the automobile industry and state governments.

The introduction of BS VI emission norms by the central government in collaboration with the MORTH marked a significant leap toward reducing air pollution. The decision to leapfrog was met with chaos and hesitance among the automobile companies, SIAM, and oil refineries due to the increased economic risks associated with the transition. However, the Supreme Court firmly emphasized the importance of a cleaner environment and unequivocally rejected any extensions. Thereafter, the MOPNG and public sector oil marketing companies played a crucial role in ensuring a nationwide supply of BS-VI-compliant fuel.

The Automotive Mission Plan of India, 2016, resulted from extensive dialogue with stakeholders, including the government, the auto industry (Tata Motors, Mahindra & Mahindra, and Maruti Udyog), and academia, with the MOHI playing a key role in facilitating coordination among the entities. With the adoption of the Biofuel policy in 2018, MOPNG and MNRE, along with the National Biofuel Coordination Committee, emerged as significant players in steering biofuel production and R&D.

In the power generation and industrial sectors, amendments to the Energy Conservation Act and the Electricity Act were proposed to address the growing energy demands and changing climate landscape. The MOP facilitated these amendments, with multi-stakeholder discussions at different levels (via a national consultation workshop and three regional consultations). The stakeholders from concerned Line ministries/departments and state governments provided inputs on the amended Act. MNRE, collaborating with the PC, the Central Electricity Regulatory Commission (CERC), and the state regulators accountable for policy implementation – the SERC, SNAs; and NTPC Vidyut Vyapar Nigam Ltd (NVVN), led

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<sup>10</sup> Beyond BS-VI: Emission norms will drive technology in India. F&L Asia. (2021)

efforts to promote renewable energy, with significant contributions from financial institutions such as the Indian Renewable Energy Development Agency (IREDA) and the Small Industries Development Bank of India (SIDBI), research organizations like the Indian Institute of Technology (IIT), the International Solar Alliance, and the private sector. Local-level players, such as municipal corporations (Urban Local Bodies), played a role in waste management strategies. Multi-stakeholder engagement<sup>11</sup> and the role of civil society (NGOs and think tanks, along with government and private industries) were pronounced in policy efforts including the second and third phases of the National Solar Mission.

Overall, this phase was the most dynamic and entailed comprehensive multi-stakeholder and multi-scalar engagement marking new policy initiatives on electric vehicles, emission standards, biofuels, and thermal norms. The absence of systematic stakeholder engagement in previous phases gave way to a gradually evolving and interactive policy space, albeit with a stronger influence from industrial players and associations.

While consumer involvement in the power sector remains minimal (Mittal et al., 2018; PTI 2021), their inputs on technology awareness, perception and preferences have been considered, particularly in transport policies (for instance, in the National Mission for Electric Mobility).

This shift was influenced by various factors such as the international policy landscape, technological advancements, market dynamics, stakeholder pressures, and political considerations. The environmental outcomes will depend on these variables. Our analysis of stakeholder dynamics in the sector provides deeper insights into decisions and the implications of N<sub>r</sub>.

## **4.2 Stakeholder Dynamics in Energy Sector Policies for Nitrogen Management**

Following stakeholder analysis across international and national policy landscapes for N<sub>r</sub> management, their influence on policy decisions in road transport, power generation, and industrial sub-sectors was evaluated using the 3x3 interest-influence matrix. Expert input and three rounds of FGDs were conducted to analyze stakeholders' relative interest and influence across these energy sectors. We asked experts to predict and justify the likely changes in stakeholder positions in the future and their significance. Analysis of discussion responses provided insights into the future of policy and stakeholder landscapes in N<sub>r</sub> management, which were further validated against literature and policy documents. The nine stakeholder categories (Figure 6) facilitated mapping, trend analysis, and strategizing for future N<sub>r</sub> management decisions.

The following subsections explain policy-wise stakeholder interests and dynamics vis-à-vis the analytical categories. As will be evident in the following sub-sections and matrices, the stakeholder positions across the energy sector are dynamic, marked by the entry of new actors with the evolving policy landscape.

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<sup>11</sup> <https://www.cseindia.org/cse-roundtable-discussion-with-stakeholders-on-the-draft-policy-document-of-the-jawaharlal-nehru-national-solar-mission-phase-ii-4790>

### **Road Transportation Sector**

Figure 7 depicts the seven primary N<sub>r</sub> management policies in the road transportation sector, in response to concerns over air pollution, public health, and the necessity for stricter regulations.

(Data source: Policy analysis, Literature Review and expert FGDs)

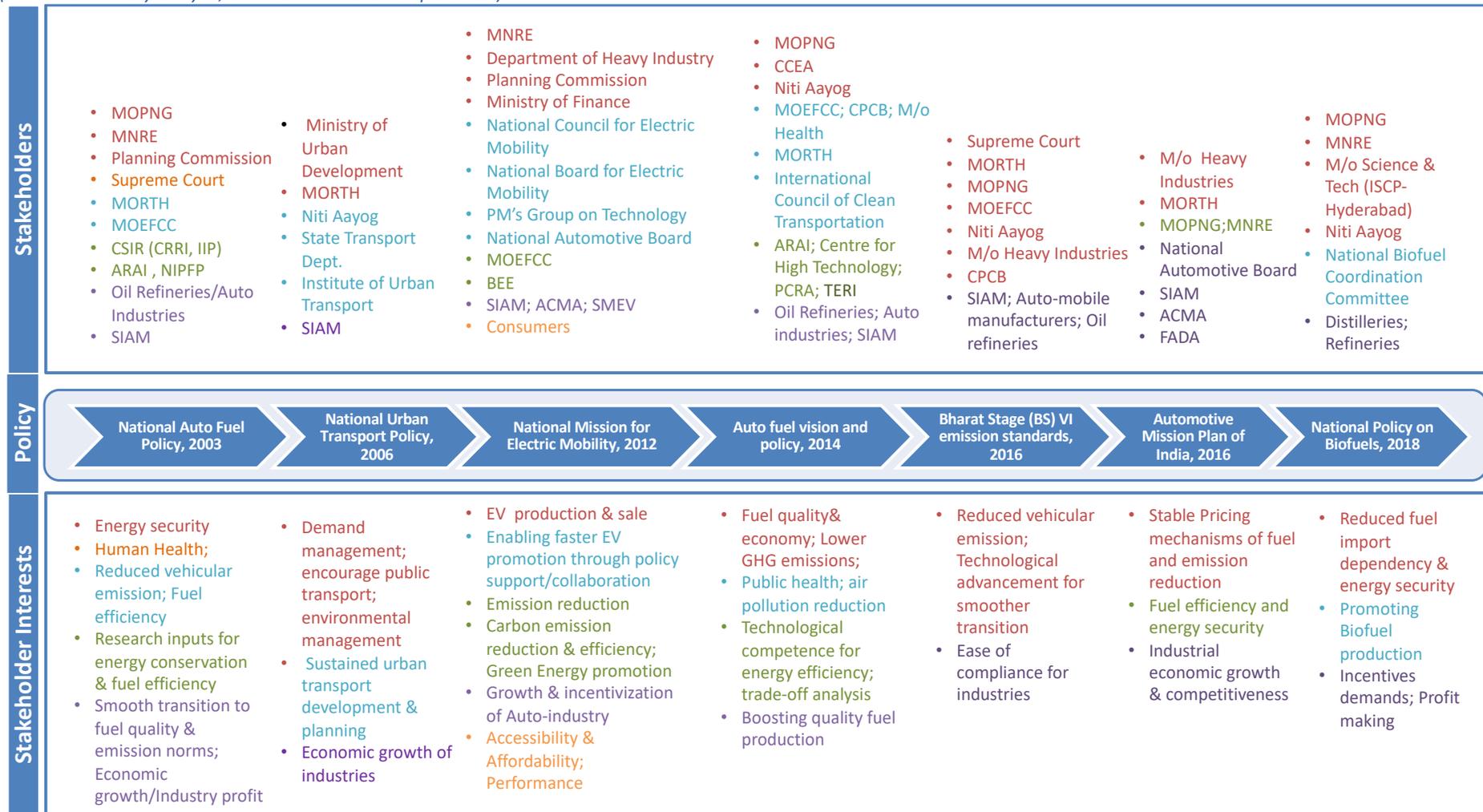


Figure 7: Policy-wise Stakeholders and their Interest in the Road Transport Sector (Note: the various colors denote the shared interest of the diverse stakeholder groups)

These measures include phased emissions standards like the National Auto Fuel Policy, Auto Fuel Vision and Policy, and BS VI Emission Standards. They also emphasize infrastructure development for sustainable transport under the National Urban Transport Policy, advocate for EVs/hybrid electric vehicles (EVs/HEVs) to reduce tailpipe emissions and promote biofuels for alternative/clean energy.

Each transport policy has been analyzed to identify stakeholders and their interests, and color-coded to show overlaps or conflicts. For instance, in the National Auto Fuel Policy 2003, stakeholders like MOPNG, MNRE, and the PC (red) share an interest in promoting energy security. Stakeholders, such as CSIR, ARAI, and NIPFP (green) focus on research inputs for fuel efficiency and technological competence. Meanwhile, stakeholders like oil refineries, auto industries, and SIAM (purple) prioritize smooth transition and economic growth. This stakeholder-interest mapping was validated during FGDs with sector experts.

The broader analysis suggests that interests of the government actors have evolved from focusing solely on fuel security and import dependency to prioritizing environmental sustainability and emissions reduction, including nitrogen. Research organizations are dedicated to generating data for evidence-based policy formulation aimed at reducing vehicular emissions. The primary focus of the automotive industries and associations has consistently been on maximizing economic benefits, exploring incentives, and striving for compliance ease. End-consumers are often drawn toward prioritizing aspects, such as fuel efficiency, and affordability. International organizations have been catering to pivotal and pressing environmental interests, particularly in emission reduction, thereby, showing significant interest in addressing this global challenge. The section below presents a detailed analysis of these stakeholder dynamics.

#### ***A) Current Stakeholder Dynamics***

**Key Players:** The central ministries like MOEFCC, along with regulatory bodies like CPCB/SPCB and the Department of Fertilizer (DOF) steer most policy discussions and interventions for  $N_r$  management as members of various national steering committees (Fig. 8). Ministry of Science and Technology (MOST) has shown proactive engagement in promoting research and development mandated by the government, particularly in areas such as biofuels, EVs, and hydrogen energy. Research institutions like CSIR play a crucial role in data-driven policy formulation and exert significant influence on innovative approaches to  $N_r$  management, including biofuels. The Centre for High Technology is increasingly focusing on technological advancements in the transport sector. Think tanks like TERI and certain CSOs wield considerable influence, notably in decisions such as the transition to BS VI in the Auto Fuel Vision and Policy, aimed at reducing vehicular emissions. Automotive associations, such as SIAM, primarily advocate for the interests of auto industries and hold significant sway over road transport policy decisions. International stakeholders, like the International Council on Clean Transportation (ICCT), exert strong influence on environmental sustainability within the transport sector. These stakeholders are pivotal in driving policy development and shaping  $N_r$  reforms across the sector.

**Latent Actors:** In  $N_r$  management, ministries like MOPNG and MNRE often maintain a neutral stance, with their primary focus typically not centered on nitrogen but rather as a by-product, such as measures aimed at reducing PM. Also, the rise of biofuel prominence in the transport sector has garnered the attention and influence of the MOAFW in promoting the production of biofuels. MOHI and PCRA have been directing their efforts to encourage emission reduction via energy efficiency in manufacturing equipment, which may have indirect implications on  $N_r$  management.

Automotive associations, such as the SMEV, the Automotive Component Manufacturers Association of India (ACMA) and the Federation of Automobile Dealers Associations (FADA) have been influential in advancing the industry's economic interests. Both auto industries and oil refineries have been generally neutral on policy decisions, avoiding significant changes that could pose economic or technological challenges in the transport sector. These actors, while currently passive, possess the potential to respond to and shape efforts related to  $N_r$  management in the transport sector.

**Crowd:** Stakeholders like MORTH and STDs play crucial roles in policy decisions related to infrastructure, public transportation systems, and emission standards. However, experts note that they do not prioritize  $N_r$  management efforts. There have been instances where key ministries and the PC did not align on nitrogen initiatives. Despite the Commission's interest in sustainable management, its influence on N-related policy decisions was limited. Currently, Niti Aayog's influence on promoting EVs/HEVs to reduce  $NO_x$  emissions is also limited. The National Biofuel Coordination Committee indirectly impacts nitrogen mitigation by promoting biofuel production. The National Institute of Public Finance (MIPFP) and Policy and the general public/consumers have minimal interest and influence in  $N_r$  management decisions, though informed engagement could align them better with more involved groups.

**Context setters:** Stakeholders like MOUD and MOF, despite appearing disinterested in nitrogen strategies, wield significant influence over transport sector decisions. They play a pivotal role in promoting urban transport systems and offering financial support, making effective monitoring crucial to prevent potential risks to  $N_r$  mitigation policy reforms.

**Potential supporters:** Although the Supreme Court's focus is not specifically on nitrogen, experts believe its directives significantly influence air quality improvement (e.g., CNG expansion, establishment of the Environment Pollution (Prevention and Control) Authority and the Commission for Air Quality Management), thereby impacting  $N_r$  management.

|                   |   |  |                 |   |
|-------------------|---|--|-----------------|---|
| Level of Interest | 3 | (SUBJECT)  | (PROMOTERS)     | MOEFCC, MOST, DOF, CPCB/SPCB ICAR, CHT, TERI SIAM, CSOs ICCT<br>(KEY PLAYERS)                             |
|                   | 2 | (MARGINAL ACTORS)  | (LATENT ACTORS) | MOPNG, MNRE, MOAFW, MOHI PCRA Auto Industries, Oil Refineries, SMEV, ACMA, FADA<br>(POTENTIAL SUPPORTERS) |
|                   | 1 | MoRTH, PC State Transport Dept NBCC NIPFP Consumers/users<br>(CROWD) | (LOW PRIORITY)  | MOF, MOUD<br>(CONTEXT SETTERS)  |
|                   |   | 1  | 2               | 3   |
|                   |   | Level of Influence   |                 |   |

Figure 8: Current Stakeholder Dynamics in Road Transport Sector

Research stakeholders, including organizations like the Institute of Urban Transport (IUT), possess the potential to shape transport infrastructure from a sustainability standpoint. While they may not specifically address sustainable  $N_r$  management, their key interests lie in reducing GHG emissions and ensuring the adoption of green energy, which is likely to have an impact. Another influential entity is the Bureau of Energy Efficiency (BEE), which wields significant influence in decision-making, especially concerning energy efficiency and environmental sustainability. Despite their seemingly low interest in policy outcomes, these actors exert considerable influence, directly impacting nitrogen-related policy measures. Therefore, engaging and empowering them is crucial to support reforms and effective policy implementation.

### b) Future Stakeholder Dynamics

In future stakeholder discussions (Fig. 9) on  $N_r$  management in the transport sector, experts from the FGDs agreed that key decision-makers from the past, such as MOEFCC, MOST, DOF, and CPCB/SPCB, will continue to wield influence in policy decisions, regulations, and actions related to  $N_r$  management, air pollution, and public health. MOEFCC, along with regulatory bodies, such as CPCB and SPCB, are expected to play an increasingly important role in enforcing standards, guiding policy development, and improving  $N_r$  management.

Based on experts' opinions, the DOF will play a crucial role in the future, particularly in increasing urea utilization for integrating SCR technology in heavy-duty vehicles. They also noted that the automotive industries, as potential stakeholders, may increasingly support initiatives focused on improving air quality and reducing  $NO_x$  emission. Furthermore, stakeholders foresee agencies such as TATA Power, Fortum India, and others playing a significant role in promoting EV infrastructure and electric mobility as the EV/HEV industry niche expands. Experts also expressed concerns about potential growth challenges facing the oil industry and refineries as alternative fuels like hydrogen gain traction. While they can contribute significantly to emission reduction through increased production of biofuels and biodiesel, it's worth noting their potential role in cutting down emission levels. Experts anticipate the MNRE will play an increasingly influential role as a promoter, aligning its efforts with net zero goals and synergizing with  $N_r$  reduction efforts. Currently showing minimal interest, MORTH may transition to a latent actor position by prioritizing sustainable infrastructure and promoting measures for engine efficiency. Experts also emphasized that the Supreme Court's judicial intervention, compelling the government and central ministries to implement adequate

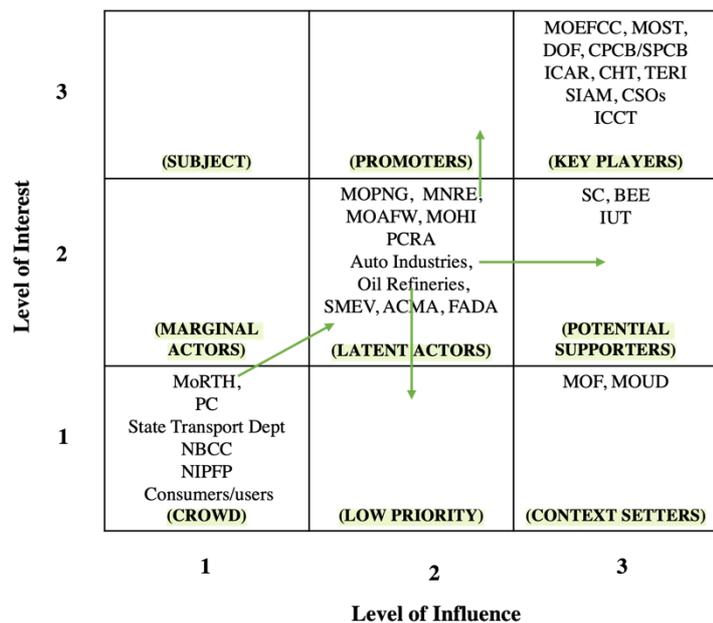


Figure 9: Future Stakeholder Dynamics in Road Transport Sector

Experts also emphasized that the Supreme Court's judicial intervention, compelling the government and central ministries to implement adequate

measures to mitigate rising vehicular pollution levels, will significantly improve air quality and public health.

Automotive associations like SIAM, SMEV, ACMA, and FADA were seen continuing to prioritize economic benefits, incentives exploration, and compliance ease. These priorities could inadvertently hinder environmental decision-making for EVs and emission standards. Despite growing environmental awareness, consumers are expected to prioritize accessibility, affordability, pricing, and fuel efficiency in the transport sector, potentially missing environmental protection goals.

### **Power Generation Sector**

Figure 10 illustrates the policy evolution in the power generation and industrial sectors, aiming to meet growing energy demand while promoting energy conservation. The Energy Conservation Act was pivotal in encouraging energy efficiency across industries, buildings, and appliances. The subsequent Electricity Act transformed the power sector by promoting competition, endorsing renewable energy sources, and enhancing consumer choice. The objectives of diversifying the energy mix and reducing dependence on fossil fuels to ensure the provision of clean and affordable energy were achieved through the formulation of numerous programs, including the solar mission, biogas manure management, and waste-to-energy programs. The solar mission, as a major component of India's National Action Plan on Climate Change, is aimed at scaling up solar energy deployment and reducing the cost of solar power through various mechanisms, such as long-term policy support, incentives, and economies of scale.

(Data source: Policy analysis, Literature Review and expert FGDs)

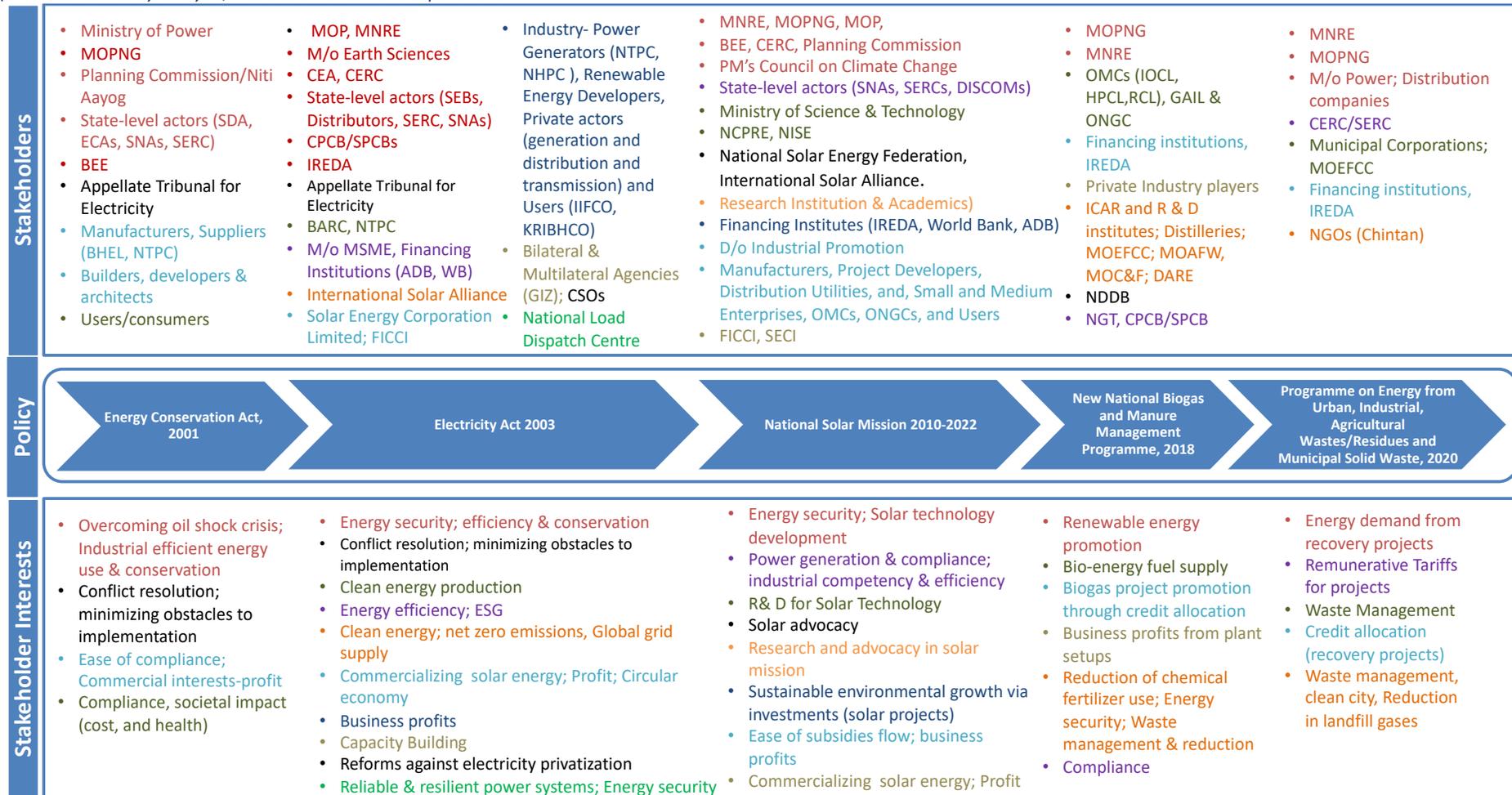


Figure 10: Power Generation and Industrial Sector Policy Stakeholders Interest (Note: the various colours denote the shared interest among the diverse stakeholder groups)

Parallel to the policy evolution, Figure 10 also maps the emergence of stakeholders and their interests, clustering them to better understand the conflicts and congruence with the larger goal of sustainable energy transition. Our analysis shows that the interests of the government, including key ministries and departments, are directed toward meeting growing electricity demand (energy security) and planning for a gradual transition from traditional to renewable energy sources. The power generation and manufacturing industries are strongly motivated by commercial interests, such as maximizing profits, accessing incentives, and achieving regulatory compliance. Civil society (CSOs, NGOs, and consumers) remains focused on advocating for strict adherence to environmental norms, promoting clean energy use, and effective waste management practices. The sections below provide a detailed analysis of the stakeholder dynamics.

### A) Current Stakeholder Dynamics:

**Key players:** While all central ministries hold influence in the policy process, their specific roles in nitrogen strategies vary (Fig 11). In the FGDs, the MOP and the MOPNG were perceived as exerting the highest influence in formulating laws and regulations. These ministries have championed the substitution of energy demands with renewable energy. The MOM was noted for its role in mining rare earth metals to support solar capacities, while the MORD was seen as significant in executing renewable energy projects and solar installations. BEE’s role was crucial in energy conservation and promoting energy efficiency through timely regulations and monitoring across the industrial sector. Since funding support to promote renewable projects is necessary, the roles of financial institutions (Rural Electrification Corporation Limited i.e. REC, and Small Industries Development Bank of India i.e. SIDBI) including IREDA, were considered significant by the experts. International organizations including financial institutions, like the ADB, and World Bank, and others like UNEP, GIZ, and USAID were considered key actors in extending support and aid to various sustainable global projects, thus, influencing technical advancement in developing countries. While the experts identified the International Solar Alliance (ISA) as a highly influential organization, they also acknowledged its limited influence on national-level policies.

**Promoters:** Think tanks, NGOs, and industry bodies, such as Federation of Indian Chambers of Commerce & Industry (FICCI) and the National Solar Energy Federation (NSEFI) were believed to hold the greatest interest in renewable reforms, according to FGD experts. These bodies actively participate in policy advocacy, research, and public awareness campaigns, thereby, making valuable contributions to N<sub>r</sub> management efforts. However, their influence is limited, in contrast to the ministries. Unlike the PC, which could influence policies to a great extent, Niti Aayog’s

|                   |   |   |   |  |
|-------------------|---|---|---|--|
| Level of Interest | 3 | R&D institutes, academics, NISE, NPL, NCPRE<br>Consumer groups/associations<br><br><b>(SUBJECT)</b> | Niti Aayog, GRID India, Think Tanks, NGOs, FICCI, NSEFI<br><br><b>(PROMOTERS)</b>                                   | MOP<br>MOPNG, MOM, MORD, BEE<br>Finance Institutes, IREDA<br>ISA, ADB, World Bank, UNEP, GIZ, USAID<br><br><b>(KEY PLAYERS)</b>  |
|                   | 2 | <b>(MARGINAL ACTORS)</b>  | MNRE, MOEFCC, CEA, SEBs, CPCB/SPCB, Municipal Corporations, DSICOMS<br>IIFCO, KRIBHCO<br><br><b>(LATENT ACTORS)</b> | MOAFW, MOCF, MOST, DARE<br>ICAR<br>ONGC, OMCs, GAIL, SECI, Industry (Manufacturer, Supplier, Generators, Developers, Distributors, Distilleries)<br>Users/Consumers<br><b>(POTENTIAL SUPPORTERS)</b> |
|                   | 1 | MOH<br>SNAs<br><br><b>(CROWD)</b>   | MSME<br>MOES<br>CERC/SERC<br>Apellate Tribunal<br><br><b>(LOW PRIORITY)</b>   | <b>(CONTEXT SETTERS)</b>   |

Figure 11: Current Stakeholder Dynamics in Power Generation and Industrial Sector

influence was deemed to be medium, with major decision-making in control of the respective line ministries. The Grid Controller of India holds significant interest and operational influence in balancing the renewable energy mix. This influence could impact the overall proportion of renewables under use. However, from a policy perspective, the influence tends to be limited. Experts argued that all these stakeholders prioritize energy sector reforms and can have a significant impact. Therefore, they should be actively engaged and empowered for sustained involvement in advancing nitrogen mitigation agendas in the power and industrial sectors.

**Subject:** Academics and research organizations, such as the National Institute of Solar Energy (NISE), the National Physical Laboratory (NPL), the National Centre for Photovoltaic Research and Education (NCPRE), and the Indian Council of Medical Research (ICMR), play a pivotal role in conducting research and extending expertise to drive advancements in clean energy solutions. Nevertheless, their potential to implement substantial reforms and exert significant influence on policy decisions was perceived to be limited. Similarly, the powers of civil groups/associations with high interest in energy consumption and pricing factors were also limited. Yet, given their high interest, experts suggested that these groups can become influential once when they mobilize to form alliances.

**Potential Supporters:** During the FGDs, ministries such as MOST, MOAFW, and MOCF, along with DARE, and research institutions like ICAR were perceived to be highly influential in driving crucial decisions concerning bio-energy sources. However, their interests rarely align with nitrogen mitigation strategies unless there is a government mandate, resulting in a lack of interest in policy outcomes. Industrial actors, such as ONGC, Indian Oil Corporation, distilleries, and others including manufacturers, suppliers, energy users, and distributors were identified as potential supporters. It is crucial to acknowledge their significant role in ensuring fuel production and availability. However, these players often face challenges when transitioning to new norms. As a result, they advocate for reforms that facilitate compliance, which may impact policy outcomes and implementation in line with their business and profit interests.

**Latent Actors:** Though focused on energy conservation and promoting the use of renewable and clean energy, key ministries like MNRE and MOEFCC were perceived to have a neutral position. These ministries tend to have a lesser authority than other ministries, like the MOP, to impact key energy sector decisions concerning Nr. As opposed to central ministries, stakeholders, such as CEA, SEBs, DISCOMs, and Municipal Corporations channel their efforts toward the execution of existing rules/regulations rather than proactively influencing decisions. Regulatory agencies, such as the CPCB, and SPCB are key stakeholders responsible for benchmarking and enforcement. These stakeholders, along with others like the Indian Farmers Fertilizer Cooperative (IIFCO), and Krishak Bharati Cooperative Limited (KRIBHCO), with moderate levels of interest and influence currently are neither supportive nor unsupportive of the nitrogen reforms in the energy sector. Yet, given their roles in setting standards, enforcing compliance, and mobilizing resources, they stand a fair chance to become key actors in future policy processes.

**Low priority:** The Ministry of Micro, Small and Medium Enterprises (MSME), Ministry of Earth Sciences (MOES), Appellate Tribunal for Electricity, and CERC/SERC are placed in the low priority category with the least interest and medium level of influence. While these

stakeholders can moderately influence energy conservation and efficiency measures, they tend to attach a shallow interest and do not prioritize nitrogen policy reforms.

**Crowd:** The MOH and SNAs were categorized as low-interest and low-influence, given their limited interest and impact in N<sub>r</sub> management.

### b) Future Stakeholder Dynamics

Experts believe shifting to renewable energy by 2030 will create a more dynamic stakeholder landscape, impacting nitrogen management efforts (Fig. 12). They expect the MOEFCC to become a key player, enforcing NO<sub>x</sub> emission laws for thermal plants and ensuring compliance through organizations like CPCB and SPCB. Further, as a consequence of the reduction in the use of petroleum-based products and increasing share of green energy, the MOPNG may become less influential after 2030 and be closer to the 'promoter' group. The possibility of the emergence of new players like nuclear corporations in the context of increasing renewable energy production is also high. These actors could significantly influence clean energy production and net zero transition goals. Experts also foresee consumer groups and associations becoming more impactful, asserting that mobilizing these groups from 'subjects' to 'promoters' is essential for sustainable environmental reform.

The MOP, with support from Niti Aayog and CEA, would continue to promote energy efficiency and conservation to reduce nitrogen issues in thermal sectors. Since energy targets depend on rare earth metals for solar panels, the MOES will be crucial in the future. Financial institutions will also remain crucial in funding renewable energy projects like waste-to-energy and solar. Global initiatives will be supported through financial aid, capacity building, and technology from organizations such as the World Bank, ADB, and other international agencies.

State-level actors will play a crucial role in implementing reforms and restructuring the power sector. Major companies in power generation (e.g., NTPC) and manufacturing (e.g., Jindal, TATA Steel) will continue to have a significant impact. Driven by financial interests, including profit maximization, incentives, and regulatory compliance, industries are increasingly recognizing the importance of circular economy strategies and ESG principles. Energy experts highlight their commitment to sustainable technologies and R&D, which could reduce N<sub>r</sub> emissions.

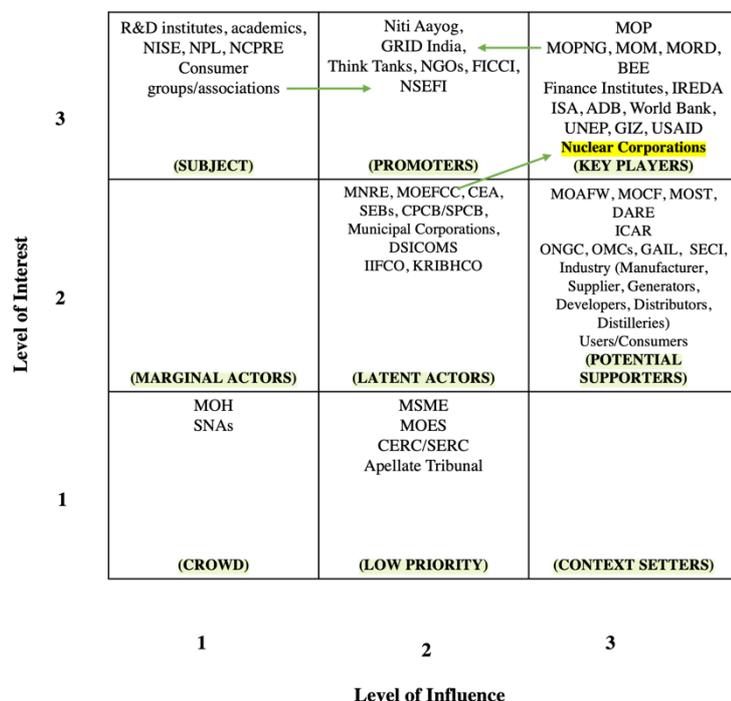


Figure 12: Future Stakeholder Dynamic in Power Generation and Industrial Sector (Note: highlighted in yellow are emerging actors)

The next section discusses the key barriers and opportunities at the policy and practice levels, based on expert interviews from transport, power generation, and industrial sectors. The findings, consolidated for a comprehensive view of the energy sector, and the challenges and opportunities concerning  $N_r$  management, combine inputs from a review of policies and literature.

### 4. 3. Stakeholder Perspectives on Nitrogen Management in the Energy Sector: Debates, Challenges, Opportunities, and Future Outlook<sup>12</sup>

#### Understanding the Magnitude of the Nitrogen Problem

The interviewed stakeholders in the energy sector recognize the importance of addressing  $N_r$ , particularly regarding power generation and vehicular emissions. However, there is a difference in how they prioritize  $N_r$  compared to other pollutants. Stakeholders from key environmental ministries and the air quality research sectors emphasize the urgency of taking immediate action to reduce  $N_r$ , particularly in power generation, coal, and diesel engines. They emphasize shifting focus from gasoline to diesel emission control due to the historical impact of diesel on nitrogen issues. Additionally, transport sector research experts suggest revisiting Compressed Natural Gas (CNG) policies to reduce  $NO_x$  emissions from personal transport vehicles. They argue that while CNG is seen as an environmentally friendly alternative to gasoline or diesel, existing CNG policies must be thoroughly evaluated and potentially revised to ensure they effectively reduce  $NO_x$  emissions as intended. In addition to CNG policies, stakeholders emphasized addressing challenges in sourcing rare earth metals for EV batteries. As the automotive industry increasingly shifts to EVs for emission reduction, it increases the demand for these metals, critical to EV batteries. However, their extraction and processing pose environmental risks, alongside concerns about availability and geopolitical implications. Addressing these challenges will be crucial to ensure that the transition to EVs is sustainable and does not create new environmental problems.

*“India’s air quality index primarily relies on particulate concentration, with carbon monoxide (CO) and nitrogen oxides ( $NO_x$ ) considered relatively less critical at present.” – Transport Industry Stakeholder*

*“Nitrogen may not have a direct impact on you; it affects a much larger cycle.”- Key Environment Ministry Stakeholder*

*“The Ministry’s primary focus does not involve specific policies for  $N_r$ . Nevertheless, efforts to reduce emissions from the energy sector can indirectly contribute to the overall reduction of emissions, including those related to nitrogen.”- Key Power Ministry Stakeholder*

Figure 13: In Their Own Words: Stakeholder Narratives on Nitrogen Management

Conversely, some energy sector stakeholders do not accord the same significance to  $N_r$  as they do to other pollutants like PM. They tend to prioritize the control of PM emissions over that of  $NO_x$ , recognizing the necessity for regulations in specific sectors like urban brick production and low-efficiency industries. In drawing a parallel, a stakeholder from the automobile industry pointed to Europe’s shift to the EURO 7 norms as a testament to the importance placed on  $NO_x$  control. This transition was a response to Europe’s significant

<sup>12</sup> In conducting this policy research, we engaged with various stakeholders who provided valuable insights and feedback. To prioritize privacy and safety, we have anonymized the identities of our stakeholders. We are committed to ethical research practices and are dedicated to safeguarding their confidentiality.

challenges with air pollution, particularly from SO<sub>x</sub> and NO<sub>x</sub>, and an attempt to increase the EV fleet. However, they also emphasized the uniqueness of India's situation in comparison to Europe. While the European experience and standards offer valuable insights, transplanting the EURO 7 norms to India's road transportation sector beyond its current BS 6 norms might not necessarily be the most effective or practical approach. India faces its distinctive challenges including the economic implications of upgrading vehicles or adopting cleaner technologies, the need for improved infrastructure to support cleaner technologies such as EVs, limited access to such cleaner technologies, and the necessity for increased public awareness and education on the importance of reducing vehicular emissions. Therefore, any attempts to implement emission standards akin to EURO 7 must be carefully calibrated, taking into consideration these distinct factors, which may subsequently give rise to a different set of challenges and debates. This perspective highlights the importance of tailoring international best practices to the local conditions and requirements of a particular region or country. This was also exemplified in the context of thermal emission norms, in 2015, which were not enforced due to several techno-economic constraints.

In tandem with these perspectives, stakeholders, particularly from research organizations, academia and policy think tanks, highlighted significant gaps in awareness and information regarding N<sub>r</sub>, its significance as a key pollutant and its environmental and health impacts, along with data gaps. Moreover, the calibration of NO<sub>x</sub> levels within the Air Quality Index (AQI) often does not receive the same level of attention as other compounds like PM<sub>2.5</sub> and PM<sub>10</sub>. Therefore, it is imperative to adopt an approach that emphasizes the development of more precise and effective quantification techniques for NO<sub>x</sub> while giving it the same level of importance as PM. This lack of emphasis has led scientific stakeholders to argue that elevating the status of nitrogen data within the AQI framework would improve the accuracy and comprehensiveness of air quality representation.

### **Implications for Energy Security and Clean Transition**

Energy sector stakeholders face a dilemma between ensuring stable energy supply for national demands and addressing environmental sustainability, including reducing harmful emissions such as NO<sub>x</sub>.

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 ■ Maximum demand rose to high of 223.3 gigawatts on June 9  
 ■ Record coal production helped contain electricity blackouts

Figure 14: Striking a Balance: The Dual Challenge of Meeting India's Rising Energy Demands While Navigating a Transition to Cleaner Energy Options (Source: Newspaper clippings from National and International media in the last 5 years)

Stakeholders in the power generation sector, including government, industry, and policy research think tanks, are cautious about rapid transitions away from traditional energy sources like coal. They recognize the importance of these sources for maintaining a stable and secure energy supply and express concerns that too rapid a shift could jeopardize energy security. A public sector power utility stakeholder emphasized the significant growth in electricity demand in 2020 and 2021, stressing the necessity to critically re-evaluate the nation's energy planning. They underscored that energy security, encompassing generation and consumption, is strategically tied to the nation's development priorities and needs, while acknowledging international commitments and emerging pressures.

Government stakeholders from environment and power ministries are navigating the balance between energy security and sustainability goals by gradually increasing renewable energy capacities. Power generation sector stakeholders stress the importance of enhancing affordability and consumer-friendliness of renewable energy. They advocate for greater consumer involvement, ensuring financial viability in renewable energy generation, and attracting private sector investments to improve accessibility.

Furthermore, one of the stakeholders from a government's policy think tank highlights the significance of electrification as an essential approach to reducing emissions. This entails shifting various sectors, such as transportation and industry, toward utilizing electricity as the primary energy source, with an emphasis on adopting EVs, electric heating systems, and other cleaner energy alternatives. By doing so, emissions can be significantly reduced, particularly when the electricity consumed is generated from cleaner and renewable sources. A diverse and multifaceted energy strategy is also advocated by energy sector experts working in energy transition. They acknowledge the necessity of adopting a mix of renewable energy, thermal power, and sustainable practices to effectively meet the growing energy demands, while simultaneously transitioning to cleaner energy sources.

*“When discussing alternative energy, a key challenge is the availability of essential raw materials. Technologies like solar, wind, hybrids, and hydrogen energy depend on heavy metals and rare earth elements. India's limited access, compared to China's dominance in production, hinders progress. Recent discoveries such as lithium in Kashmir offer hope, but raw material constraints persist.”*  
Energy Sector Research Expert

Figure 15: In Their Own Words: Stakeholder Narratives on India's Transition to Clean Energy Sources

However, stakeholders acknowledged potential challenges and implications in renewable energy production. A research expert in energy emissions highlighted concerns that India's reliance on other nations for renewable energy resources could threaten energy security. The transition to renewable energy is influenced by factors like carbon emissions, resource availability, and security. Dependence on materials such as rare earth metals for solar panels and wind turbines introduces challenges related to resource security, including concerns about scarcity, geopolitical factors, and limited availability of critical materials needed for renewable technologies.

### **Policy Barriers to Nitrogen Emission Mitigation**

We also examined the various challenges associated with managing and reducing  $N_r$  across different energy sub-sectors, as highlighted by stakeholders. These challenges can be broadly categorized into regulatory, technological, economic, behavioral, and informational challenges, as follows:

**Regulatory Challenges:** Stakeholders were largely concerned about the inconsistency and complexity of nitrogen emission norms, particularly in the power sector. The challenges stem from the issues faced with SCR technology, a method used to reduce  $NO_x$  emissions. However, this technology faces criticism for inconsistent results, with power sector stakeholders questioning its effectiveness in meeting emission norms. They also criticize the regulatory process for lacking collective responsibility, leaving individual companies burdened with compliance without adequate support from regulators or other stakeholders. Moreover, stringent regulatory processes in power generation are seen as potentially stifling innovation and hindering companies from finding effective  $N_r$  reduction solutions. Furthermore, in the road transportation sector, a policy expert pointed to the absence of comprehensive policies or regulations for scrapping older vehicles, which adds another layer of complexity to the regulatory landscape. The absence of clear guidelines or incentives for retiring older vehicles contributes to ongoing  $N_r$  emissions issues, as they are typically less fuel-efficient and emit more than newer models.

**Technological Challenges:** The transition toward cleaner practices in the energy sector is faced with significant technological limitations, especially in energy-intensive industries such as steel and aluminum. Power sector experts highlighted that old-design power plants and inadequate technological intervention for nitrogen control are major barriers to reducing  $N_r$  emissions. Older plants are less efficient and often lack the necessary technology for effective  $N_r$  control. This challenge is aggravated by limited technological upgrades across plants. Financial constraints, use of lower-quality coal, and ineffective monitoring further complicate efforts, leading to uneven outcomes in  $N_r$  reduction among plants. This, in turn, leads to an

overall lack of progress in emission reduction in the energy sector. A stakeholder from the automobile industry stated that while alternative fuels such as biofuels and hydrogen offer promising potential to curtail  $N_r$  from vehicles, there remain considerable technological and infrastructural hurdles to overcome in terms of their production, distribution, and utilization. These challenges must be addressed to fully harness the benefits of alternative fuels in mitigating  $N_r$ .

**Economic Challenges:** Government and automotive industry stakeholders underscored the need for financial viability and debt management during the shift from thermal power generation to greener alternatives. They also highlighted the economic ramifications of transitioning to clean vehicle technologies, emphasizing the subsequent effects on manufacturing costs, especially for diesel vehicles. A stakeholder from the automotive industry remarked, "In the Indian automotive sector, we grapple with challenges surrounding fuel specifications, notably the Sulphur content and octane number. These specifications are swayed by aspects such as refinery output and the prioritization of LPG production. Harmonizing these factors with our ambition to curtail  $N_r$  remains a persistent hurdle."

**Behavioral Challenges:** In the context of the Indian automobile market, a stakeholder observed, "Indian customers prioritize price and fuel consumption when buying vehicles, with environmental concerns ranking lower. While this trend is not unique to India, similar preferences can be observed in various markets around the world. The prioritization of cost and fuel efficiency over environmental impact can hinder the adoption of cleaner but potentially more expensive vehicle technologies that are designed to reduce  $N_r$ ."

**Informational Challenges:** Stakeholders unanimously identified lack of baseline data and the absence of comprehensive information on  $N_r$  as significant challenges to be addressed. They believe these gaps in knowledge and data not only hinder informed decision-making but are also prevent the development and implementation of effective strategies to mitigate  $N_r$ . An air pollution expert emphasized the crucial importance of having baseline data, which serves as a starting point for understanding the extent of the problem and for measuring progress over time. The expert stated "Without baseline data, it is difficult to accurately assess the impact of  $N_r$  on air quality and human health. It also makes it challenging to set realistic and achievable targets for reducing emissions."

### **Policy Opportunities for Nitrogen Emission Reduction**

Stakeholders reflected on various strategies and interventions to address  $N_r$  across various sectors. These strategies can be broadly categorized into six primary areas: regulatory measures, green energy and technology adoption, research and evidence-based decision-making, balanced energy policy, behavioral change and awareness, and alignment with global and international standards.

**Accelerate Emission Reduction through Regulation:** A stringent regulatory environment is needed to significantly curb  $N_r$  in the two energy sub-sectors. For instance, Vestreng et al., (2009) reported a downward trend in  $N_r$  from road transport and power plants due to stringent policies in Europe and the US that led to the adoption of both primary and secondary control measures. In the interviews, air pollution experts and stakeholders from policy think tanks proposed higher taxes on diesel cars as a direct and effective way to combat air quality

problems, while also promoting the use of cleaner alternatives. One specific recommendation was to incorporate NO<sub>x</sub> parameters in vehicular pollution certificates. Additionally, the imposition of strict city entry restrictions for high-emission vehicles in high-population and vehicle-dense cities was seen as a necessary step to reduce emissions from transportation. A stakeholder from an environmental research organization also stressed the need for employers to provide workplace accommodations and leverage campus housing facilities to minimize employee commutes, thereby, reducing emissions associated with daily transportation. This suggested integrative urban planning, which also emphasized decentralization and necessitated re-zoning.

**Promote Green Energy and Technology Adoption:** Stakeholders from government policy think tanks emphasized the critical role of green hydrogen and green ammonia in the decarbonization process, with green ammonia potentially replacing imported NH<sub>3</sub> for urea production. This shift is seen as cost-effective, particularly in volatile gas price scenarios (Gezerman, 2022). They also advocated for the use of biofuels and the widespread adoption of EVs as crucial steps toward reducing N<sub>r</sub>.

Further, the government's efforts to reduce crude oil imports and promote sustainable energy solutions, including recycling materials from used batteries and exploring local sources of minerals like lithium (Figure 16), were recognized as key measures to support battery production and address N<sub>r</sub> in India's transportation sector.

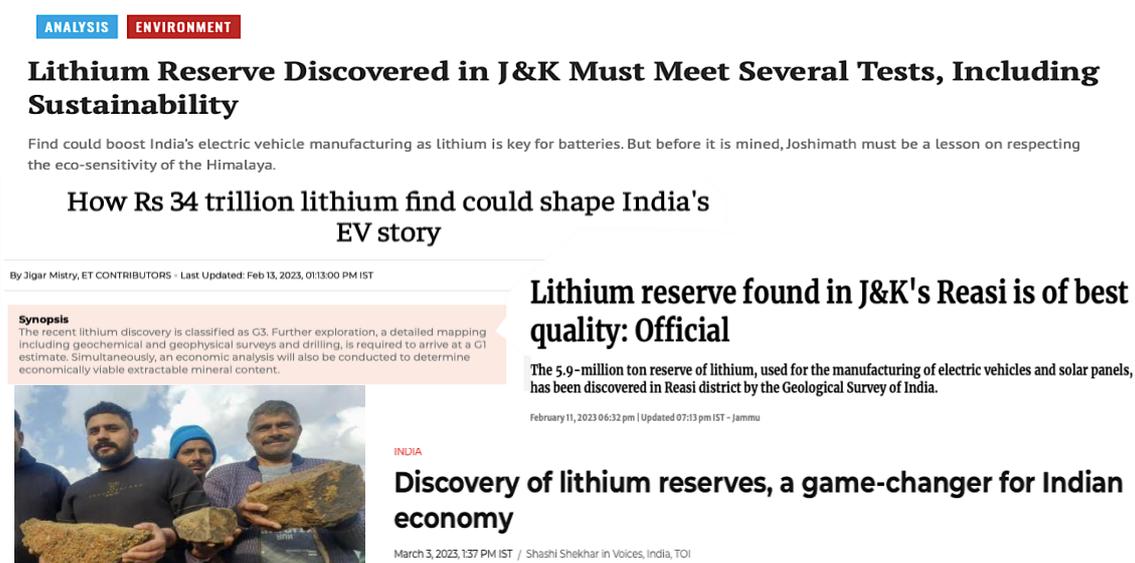


Figure 16: Recent discovery of lithium reserve in India (Source: Newspaper clippings from National media)

**Strengthen Research and Evidence-Based Decision-Making:** Informants from policy research institutes underscored the importance of robust research, evidence generation, and accurate data compilation to inform policy decisions and quantify nitrogen emission levels effectively. Research institutes in India have been consistently pointing out a dearth of data as a major obstacle to meaningfully contributing to the national energy debate (CPR 2017). Informants urged funding support for research projects and a collaborative approach involving government, industries, and the scientific community to enhance policy-making

effectiveness. They emphasized the importance of analyzing past progress on global issues like carbon emissions to inform nitrogen research comprehensively.

**Ensure a Balanced Energy Policy:** India faces significant energy challenges as it strives for economic growth to address poverty and other social issues. According to Bhattacharyya (2010), “Following the Western-style energy-intensive path to development is not an option for India in the long run. Achieving a secure, affordable and environmentally benign energy supply requires immediate attention.” An informant from a public sector power entity stressed the importance of a balanced energy policy that ensures energy security, affordability, and clean energy for sustainable  $N_r$  management and decarbonization efforts. Energy sector experts highlighted the necessity of increasing renewable capacity to meet rising power demand, aligning peak demand with solar generation, and balancing renewables, power generation, and emissions control in India's power sector. They also emphasized the need for access, affordability, and stringent emissions control measures with penalties for non-compliance.

**Foster Behavioral Change and Awareness:** Stakeholders unanimously called for a concerted effort to sensitize the public, promote behavioral changes, and create an enabling environment to encourage energy efficiency and emissions reduction. A stakeholder from the public sector power entity stressed the importance of formulating decentralized integrated energy policies catering to consumption needs based on resource availability, promoting clean energy and environment approaches, and spreading awareness about  $N_r$ . Mohan and Topp (2018) analyzed India's future energy transition debate, focusing on the political and social dimensions. They highlighted debates over technology application in renewable energy, addressing energy accessibility through preferences for decentralized and centralized systems. Strict penalties, incentives, industry sensitization, and collaborative efforts were emphasized as crucial components of this strategy.

**Alignment with Global and International Standards:** Stakeholders from different research organizations recognized the importance of international pressure to align policies with global standards. They stressed the need for international collaboration, adherence to global resolutions on  $N_r$  management, and the establishment of transparent business processes for environmental standards. Voluntary participation and the involvement of multiple stakeholders, including government, industries, and the scientific community, were also deemed crucial for addressing  $N_r$  effectively.

### **Stakeholder Perspectives on Future Nitrogen Policy Scenarios**

Stakeholders in the energy sector held varied perspectives on integrating nitrogen management policies. While all agreed on the importance of addressing  $N_r$ , their preferred approaches to policy formulation differed greatly. Some advocated for dedicated, stand-alone policies and standards targeting  $N_r$  management, emphasizing its distinct environmental significance. This view was particularly prevalent among stakeholders from research institutions and academia, specialized in  $N_r$  research and mitigation. For example, one stakeholder emphasized the importance of formulating nitrogen-related standards and policies, stating that “... *international recognition of the nitrogen issue is crucial, and we need to develop specific standards and policies that address the unique challenges posed by  $N_r$ .*”

On the other hand, environmental policy experts advocated for an integrated approach, embedding  $N_r$  management within existing environmental and energy policies. According to them, *"We need to incorporate nitrogen reduction goals into our broader policy frameworks, ensuring that we address  $N_r$  as part of our overall strategy for carbon management, clean energy, and environmental protection."*

International engagement and cooperation were also identified as key elements in addressing  $N_r$ . Research stakeholders stressed the importance of domestically implementing international resolutions and gaining international recognition for the nitrogen issue. Additionally, a stakeholder from the key environment ministry stated, *"We need to push for swift domestic implementation of UN resolutions on nitrogen management and encourage inter-ministerial committees to expedite evidence-based policies."* Stakeholders in the road transportation sector emphasized the importance of recognizing  $NO_x$  as a key pollutant in the energy sector, arguing that this recognition is critical for developing policies, regulatory standards, and implementing technological solutions to address and mitigate  $NO_x$  emissions. A stakeholder from the energy sector highlighted the importance of  $NO_x$  identification, stating *"We need to emphasize the identification of  $NO_x$  as a key pollutant in the energy sector, as this will pave the way for the development of effective policies, regulatory standards, and technological solutions to address and mitigate  $NO_x$  emissions."*

While the debate continues whether standalone policies and standards or an integrated approach is the most effective way to address  $N_r$ , it is clear that  $N_r$  management is a critical issue that requires careful consideration and action to mitigate its impact on the environment and human health. The discussion may benefit from acknowledging the merits of both strategies, potentially leading to a more comprehensive and effective solution for nitrogen emission management.

## **Conclusion and the Way Forward**

India's energy sector is a complex and intricate ecosystem, comprising a multitude of interconnected components that together define its sustainability and overall impact. These elements encompass diverse energy sources, intricate production processes, extensive distribution infrastructure, varying consumption patterns, deep environmental consequences, economic considerations, multifaceted regulatory frameworks, nuanced social and cultural influences, ongoing technological advancements, and a multitude of stakeholders. Within this intricate web of factors, one pressing challenge stands out: the management of  $N_r$ . Addressing this challenge effectively demands a comprehensive, well-coordinated, and holistic policy approach. Our analysis of the current state of  $N_r$  management in India, along with the insights gathered from key stakeholders, highlights the urgent need for targeted interventions and innovative solutions to mitigate its environmental impacts.

In summary, the evolution of energy policies can be segmented into five phases, each building upon the previous one, with the latest phase explicitly addressing  $N_r$  management through a few regulations. The first phase, dating back to pre-2000, laid the foundational groundwork for environmental regulatory frameworks but did not directly address air pollution or  $N_r$ . The subsequent phases saw significant policy development through the vehicle emission norms, promotion of renewables and EVs, and policy leapfrogging as evidenced through BS VI emission standards. Concurrently, the diversity and participation of stakeholders in energy

policies increased with traditionally influential actors like the central ministries offering deliberative space to think tanks, industry associations, and other stakeholders. This difference was distinctly noticeable in the policies of pre-2000, 2000-2010 and 2010-2020s, the last phase being distinctly marked by the integration of a diverse range of stakeholders, leading to a more collaborative and multi-stakeholder governance framework. While these stakeholders collectively push for an energy transition and an optimized energy mix, they confront substantial challenges. Notably, the thermal sector's unique requirements and limitations necessitate a contextualized policy approach to ensure effectiveness. Execution challenges further compound the situation, demanding meticulous planning and coordination. In this context, the role of Distribution Companies (DISCOMS) and other agencies becomes pivotal. They must seamlessly integrate renewable energy sources into the grid, expand infrastructure, and maintain energy reliability, all the while enforcing emissions standards.

Existing legislation, such as the CPCB's 2015 norms for thermal power plants and the nationwide implementation of BS VI emission standards in 2020, have provided a regulatory framework to limit NO<sub>x</sub> emissions. These regulations have set specific emission limits, effectively encouraging the adoption of cleaner technologies in both power generation and transportation. However, the regulatory landscape still harbors notable gaps including inconsistencies in enforcing and implementing regulations, leading to compliance variations across regions. Furthermore, there is a conspicuous absence of comprehensive policies or regulations for retiring older vehicles, which contributes to ongoing N<sub>r</sub>. To address such gaps effectively, there is a pressing need for further tightening of emission standards and the proactive inclusion of emerging sources of N<sub>r</sub> as technology continues to evolve.

Technological advancements have played a crucial role in reducing N<sub>r</sub>. SCR technology, for instance, has been effective in some cases. Additionally, the promotion of EVs and the development of alternative fuels like biofuels hold promise for further emission reduction. Technological challenges persist, including limited technological intervention in energy-intensive industries like steel and aluminum, where old-design power plants lack the necessary technology for nitrogen control; infrastructure and technological hurdles in the production, distribution, and utilization of alternative fuels like hydrogen and biofuels; and the need for continuous research and development to enhance the efficiency of emission control technologies.

Raising awareness and promoting behavioral change among consumers and industries can lead to more sustainable practices. Encouraging the use of public transportation, advocating carpooling, and promoting the adoption of cleaner vehicles can significantly contribute to emission reduction. Nonetheless, challenges linked to behavioral change are inherently complex. They encompass the imperative need for effective public awareness campaigns to educate consumers about the paramount importance of N<sub>r</sub> reduction and the multitude of benefits associated with adopting cleaner transportation choices. Equally challenging is overcoming resistance to change, particularly in industries where economic interests may clash with environmental imperatives. Moreover, ensuring that consumers have ready access to cleaner transportation options and are incentivized to make environmentally friendly choices is a multifaceted endeavor requiring thoughtful planning and execution.

Policy integration, in this context, signifies adopting a holistic perspective on the  $N_r$  problem and crafting solutions that account for the complex interplay of regulatory, technological, and behavioral aspects. This approach involves recognizing the inherent interconnectedness of these elements and their mutual influence. The process of integration can encompass several facets, including identifying and remedying gaps in existing legislation to make it more comprehensive and effective, integrating emerging sources of  $N_r$  into regulatory frameworks as technology progresses, aligning technological innovations with regulatory standards to ensure that new technologies contribute to emission reduction goals, and actively engaging stakeholders from various sectors, including government, industry, research organizations, and civil society. This collaborative effort aims to collectively formulate policies that adeptly tackle the multifaceted challenges posed by  $N_r$ , ultimately leading to a more sustainable and environmentally responsible energy sector in India.

Specific recommendations for policy and stakeholder engagement for sustainable  $N_r$  management in India's energy sector emerging from our research are as follows:

1. Establish multi-stakeholder advisory panels that include representatives from government bodies, industry sectors, environmental NGOs, academic researchers, and community groups. These panels should focus on discussing  $N_r$  management issues, sharing insights, and collaboratively developing solutions. The formation and mandate of these panels could be overseen by government regulatory bodies, particularly the MOEFCC.
2. Encourage and facilitate public-private partnership (PPP) projects that focus on nitrogen emission reduction. These could include initiatives for developing cleaner technologies, conducting joint research, or implementing pilot projects in  $N_r$  management.
3. Implement a robust communication strategy to ensure that all stakeholders are informed about policy changes, research findings, and opportunities for collaboration. This could include newsletters, stakeholder meetings, and dedicated web portals for information sharing and discussion. A joint task force, combining efforts from the CPCB, SPCB, and industry representatives should be established to develop and execute the communication strategy.
4. Implement stricter emission norms for  $NO_x$  in the power generation and road transport sectors. This includes setting ambitious targets, monitoring compliance, and imposing penalties for non-compliance. The enforcement of these norms should be a collaborative effort between the MOEFCC, and industry regulatory bodies. The focus should be on implementing and monitoring  $NO_x$  emission standards with a support system in place to help industries achieve compliance.
5. Provide financial incentives such as tax breaks, subsidies, or grants to industries and consumers adopting clean technologies that reduce  $N_r$ . These could apply to EVs, CNG vehicles, and industries implementing advanced emission control technologies. These incentives must be strategically created to encourage industries and consumers to adopt technologies that reduce  $N_r$ , focusing on sectors facing economic challenges during the transition to cleaner technologies.
6. Allocate government funding and support for research and development in nitrogen emission control technologies. Encourage collaborations between universities, research institutes, and industries to innovate in areas like SCR technology, EV batteries, and renewable energy sources. This initiative could be led by the

Department of Science and Technology, working closely with academic institutions and industry partners.

7. Develop an integrated policy framework that aligns nitrogen emission control with broader environmental objectives, including climate change mitigation and air quality improvement. This should encompass coordinated efforts across various ministries and departments, ensuring a unified approach to managing N<sub>r</sub>.
8. Establish a comprehensive data management system for N<sub>r</sub> that tracks emissions across all sectors. Create a task force with members from government bodies, industry experts, and environmental economists to regularly update and analyze this data. This system should be transparent and accessible, enabling better monitoring, enforcement, and strategy formulation. The task force would be responsible for interpreting the data to inform policy adjustments and industry practices, ensuring that N<sub>r</sub> management strategies are data-driven and effective in meeting emission targets.

### **Limitations of the Study**

- The study involved diverse stakeholders in understanding their perspectives on barriers and opportunities in sustainable N<sub>r</sub> management in the energy sector. However, it might have limitations in capturing the full range of perspectives, particularly from less represented groups like grassroots organizations or local communities directly impacted by N<sub>r</sub>. Moreover, the intended further engagement of stakeholders through methods like workshops and focus groups, which are instrumental in deepening understanding and refining policy actions, could not be realized due to logistical constraints. Such engagements are crucial for interactive and detailed discussions, helping to uncover nuanced viewpoints and create a more collaborative and inclusive policy-making process.
- The emphasis on technologies like SCR and EVs might have overshadowed other emerging or traditional practices that could contribute to nitrogen management. Future research could explore a wider array of technological solutions.
- Given the rapidly evolving nature of environmental policies and technological advancements, the study might not reflect the very latest developments or future policy directions.
- The study might have limitations in terms of quantitative data, predictive modelling, and long-term impact assessment of nitrogen management strategies.

For future research, a focused, multidisciplinary approach is essential to ensure that solutions are not only environmentally sound but also socio-economically viable. This should include broader stakeholder engagement, especially with underrepresented groups, to capture diverse perspectives on nitrogen management. Emphasizing regional studies could address specific local challenges, while longitudinal studies can track the long-term effectiveness of policies and technologies. Additionally, exploring behavioral aspects and emerging technologies will provide comprehensive insights for refining nitrogen emission regulation strategies.

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## Annexure 1: Nitrogen Management in the Energy Sector: Global Policy Mapping

| Year                      | Policy (Multilateral Environmental Agreements) | Nitrogen Related Policy Measures  | Stakeholders   | Geographical Extent   |
|---------------------------|--|---|--|---|
| 1979                      | Long-Range Transport of Air Pollutants (LRTAP) | <ul style="list-style-type: none"> <li>• The first multilateral agreement addressing transboundary air pollution, created a regional framework applicable to Europe, North America and Russia.</li> <li>• Convention has been extended by eight protocols containing legally binding targets for emission reductions.</li> <li>• Most Protocols address specific pollutants</li> <li>• Two protocols, Sofia Protocol (1988) and Gothenburg Protocol (1999) address Nitrous Oxides emissions.</li> </ul> | <ul style="list-style-type: none"> <li>• Regional economic integration organizations</li> <li>• Economic Commission for Europe</li> <li>• Member Parties</li> </ul>  | Europe, North America and Russia and former East Bloc countries |
| 1988                      | Sofia Protocol under the LRTAP                 | <ul style="list-style-type: none"> <li>• Protocol concerning the Control of Emissions of NO<sub>x</sub></li> <li>• Mandated parties to make unleaded fuel sufficiently available and to facilitate the circulation of vehicles equipped with catalytic converters.</li> <li>• The sources were classified as stationery (power generation, heating plants, residential and public heating, industrial emissions etc.) and mobile (vehicles)</li> </ul>  | <ul style="list-style-type: none"> <li>• Member Parties</li> <li>• Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe</li> <li>• Executive Body for the LRTAP Convention</li> <li>• United Nations Economic Commission for Europe</li> </ul> | Europe and North America  |
| 1997                      | Kyoto Protocol by UNFCC                        | <ul style="list-style-type: none"> <li>• While the preceding Montreal Protocol (1987) on substances that deplete the ozone layer completely missed N<sub>2</sub>O, the Kyoto Protocol included it in the GHG that needed to be regulated.</li> <li>• Sources of GHG included fuel combustion in the energy sector.</li> </ul>   | <ul style="list-style-type: none"> <li>• Parties to the UNFCC</li> </ul>   | International-covers all regions                                |
| 1999<br>2012<br>(Amended) | Gothenburg Protocol under LRTAP                | <ul style="list-style-type: none"> <li>• Protocol concerning the control of NO<sub>x</sub> and NH<sub>3</sub> emissions</li> <li>• Asked parties to increase measures for increasing energy efficiency and renewable energy, decrease use of</li> </ul>   | <ul style="list-style-type: none"> <li>• Member Parties</li> <li>• Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe</li> <li>• Executive Body for the LRTAP Convention</li> </ul>  | Europe and North America  |

|      |  |   |   |   |
|------|--|---|---|---|
|      |  | polluting fuels, and reduce overall transport emissions.  | <ul style="list-style-type: none"> <li>• United Nations Economic Commission for Europe</li> </ul>   |   |
| 2002 | International Nitrogen Initiative (INI) founded by the Scientific Committee on Problems of the Environment (SCOPE) | <ul style="list-style-type: none"> <li>• International program to minimize the negative environmental and health effects of energy production</li> <li>• To assess the state of knowledge on nitrogen sources, fluxes, and dynamics in ecosystems at regional and global scales</li> </ul>  | <ul style="list-style-type: none"> <li>• The International Geosphere Biosphere Programme (IGBP) (a body established by ICSU, the International Council for Science) and of the Scientific Committee on Problems of the Environment (SCOPE)</li> <li>• Steering Committee consisting of Chair, Past Chair and Regional Centre Directors for East Asia, South Asia, North America, Latin America, Africa and Europe</li> <li>• Scientific Advisory Committee (SAC)</li> </ul> | International-covers all regions                                |
| 2004 | INI's Nanjing Declaration  | <ul style="list-style-type: none"> <li>• Affirmed the need for an international protocol to decrease N<sub>r</sub> to acceptable levels by enhancing nitrogen usage in food production, reducing energy consumption, or changing energy carrier fuels</li> </ul>  | <ul style="list-style-type: none"> <li>• 30 govts.</li> <li>• China Academy of Science</li> <li>• China Association for Science and Technology</li> <li>• Soil Science Society of China (SSS C)</li> <li>• CAS Institute of Soil Science (ISSA S)</li> <li>• CAS Key Laboratory of Material Cycling in Pedosphere</li> <li>• INI</li> <li>• Energy research Centre for the Netherlands</li> </ul>   | International-covers all regions                                |
| 2007 | Task Force on Reactive Nitrogen under LRTAP  | <ul style="list-style-type: none"> <li>• To develop technical and scientific info in order to encourage coordination of international air pollution policies on nitrogen</li> <li>• To understand the integrated and multi-pollutant nature of N<sub>r</sub>, particularly in relation to air pollution</li> <li>• Cooperate with bodies outside the Convention, such as INMS and IPCC</li> </ul> | <ul style="list-style-type: none"> <li>• Working Group on Strategies and Review of the UNECE Convention on Long-range Transboundary Air Pollution</li> <li>• UNECE</li> </ul>   | Europe, North America and Russia and former East Bloc countries |
| 2009 | UNEP's Global Partnership on Nutrient Management   | <ul style="list-style-type: none"> <li>• The Global Partnership on Nutrient Management (GPNM) is a partnership of governments, scientist, policymakers, private sector, NGOs and international organizations.</li> </ul>  | <ul style="list-style-type: none"> <li>• Govts</li> <li>• NGOs- Bay of Bengal Large Marine Ecosystem,</li> <li>• Dutch Nutrient Platform,</li> <li>• Global TRAPS, Task Force on Reactive Nitrogen, Partnership in</li> </ul>   | International-covers all regions                                |

|      |   |   |   |                                  |
|------|---|---|---|----------------------------------|
|      |   |   | <p>Environmental Management for the seas of East Asia</p> <ul style="list-style-type: none"> <li>• Pvt- Global Environment and Technology Foundation, International Fertilizer Association, Nagarjuna Group</li> <li>• UN- UNDP, FAO, UNHSP</li> <li>• Science Organizations- WRI, VU University, SCOPE, International Plant Nutrition Institute</li> </ul>   |                                  |
| 2016 | INI's Melbourne Declaration   | <ul style="list-style-type: none"> <li>• Declaration on Responsible Nitrogen Management for a Sustainable Future</li> <li>• Recognizes energy combustion as one of the major sources of reactive nitrogen emission</li> <li>• Research is needed for enhanced energy use efficiency in industry and transport.</li> </ul> | <ul style="list-style-type: none"> <li>• 44 Governments</li> <li>• Environmental and agricultural scientists, policy advisors, farmers, fertilizer and other industry participants</li> <li>• Department of Economic Development, Jobs, Transport and Resources, Australia</li> <li>• Australia and New Zealand International Plant Nutrition Institute</li> <li>• Fertilizer Australia</li> <li>• Australian Centre for International Agricultural Research</li> <li>• International Fertilizer Industry Association</li> <li>• INI</li> <li>• INMS</li> </ul> | International-covers all regions |
| 2019 | UN Environment Assembly adopted resolution on Sustainable Nitrogen Management (UNEA 4 Resolution) | <ul style="list-style-type: none"> <li>• Encourages member states to accelerate actions to reduce nitrogen waste globally by 2030</li> <li>• Also encourages Member States to share information on national action plans</li> </ul>   | <ul style="list-style-type: none"> <li>• GEF</li> <li>• UNEP</li> <li>• The United Nations Environment Programme Working Group on Nitrogen</li> <li>• Member Parties</li> </ul>   | International-covers all regions |
| 2019 | INMS' Colombo Declaration   | <ul style="list-style-type: none"> <li>• Declaration on Sustainable Nitrogen Management</li> <li>• Countries urged to develop and implement comprehensive policies on sustainable nitrogen management with an ambition to halve nitrogen waste by 2030</li> </ul>   | <ul style="list-style-type: none"> <li>• INMS</li> <li>• UNEP</li> <li>• GEF</li> </ul>   | International-covers all regions |
| 2021 | First Global Assessment of Air Pollution Legislation  | <ul style="list-style-type: none"> <li>• GPNM Published first Global Assessment of Air Pollution Legislation with focus on Nitrogen Dioxide from burning of fossil fuels and energy production</li> </ul>   | <ul style="list-style-type: none"> <li>• IISD</li> <li>• UNEP</li> <li>• FAO</li> <li>• GPNM</li> <li>• INMS</li> <li>• SACEP</li> </ul>  | International-covers all regions |

## Annexure 2: Energy Sector Policy Objectives and Nitrogen Management Implications

### Road Transportation

#### 1. National Auto Fuel Policy, 2003 and its 2014 amendment- The Auto Fuel Vision and Policy 2025

##### Why was the Policy formulated?

- Growing concerns about air pollution: Rapid urbanization, increasing vehicular population, and the dominance of old and poorly maintained vehicles have led to rising air pollution in many Indian cities.
- Health concerns: There were increasing concerns about the adverse health effects of air pollution.
- Need for uniform emission standards: The Indian automotive industry needed a clear, long-term roadmap for the implementation of emission norms.

##### What were the key features of the policy?

- Phased implementation of emission standards: The policy set forth a roadmap for the progressive introduction of Euro-based emission standards for vehicles and corresponding fuel quality across the country. It proposed to implement Bharat Stage III (equivalent to Euro III) norms by 2005 in the National Capital Region, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad including Secunderabad, Ahmedabad, Pune, Surat, Kanpur, and Agra, and BS II (equivalent to Euro II) norms in the rest of the country. By 2010, the policy aimed for nationwide implementation of BS III norms and BS IV (equivalent to Euro IV) norms in the above-mentioned 13 cities.
- Encouraging R&D for alternative fuels: The policy also recommended steps to encourage research and development in the area of alternative fuels like Hydrogen, Bio-Diesel, Ethanol, etc.
- Vehicular Pollution Control: The policy called for the introduction of measures to control pollution caused by in-use vehicles through stringent Inspection & Maintenance (I/M) norms.
- Introduction of cleaner technologies: The policy sought the introduction of cleaner technologies in vehicles like the common rail direct injection (CRDI) system and suggested measures for traffic management, driver training, and fleet modernization.

##### Why was the Policy Amended in 2014?

- The National Auto Fuel Policy of 2003 was revised with an Amendment in 2014 by the Ministry of Road Transport and Highways (MORTH). The **Auto Fuel Vision and Policy 2025** was drafted by an expert committee and was built upon the previous policy. The main aim of the Amendment was to set a clear roadmap for the auto industry to prepare for tighter fuel efficiency norms and reduced GHG emissions. This was largely in response to the increasing environmental and public health concerns associated with rising vehicular pollution in the country.

##### What were the key features of the policy amendment?

- New Emission Standards: The Amendment advanced the timelines for the nationwide implementation of BS IV, BS V, and BS-VI (equivalent to Euro IV, V, and VI respectively) emission standards for vehicles. For example, BS IV standards were set for nationwide implementation by 2017, BS V by 2019, and BS VI by 2021.
- Fuels: The policy aimed at improving the quality of available automotive fuels, specifically reducing the sulphur content.
- Fuel Efficiency: The policy also proposed setting up a framework for the introduction of fuel efficiency norms for vehicles to reduce the country's carbon footprint and dependency on fossil fuels.
- Alternative Fuels: The policy continued to emphasize the importance of research and development in alternative fuels, including biofuels and electric mobility solutions.
- Real-World Emissions Testing: The Amendment also recommended the introduction of real-world emissions testing to supplement lab-based tests. This is to ensure that vehicles remain within emission limits as they are used in everyday conditions, not just under lab testing conditions.

##### How do these policies factor in $N_r$ and its management in the energy sector?

This policy includes a roadmap for the implementation of progressively stricter emission standards, which include explicit mention of limits on NO<sub>x</sub> emissions. It also encourages the use of cleaner fuels and technologies to reduce NO<sub>x</sub> emissions.

## **2. National Urban Transport Policy, 2006 and its 2014 Amendment**

### **Why was the Policy formulated?**

- The NUTP was formulated in response to the increasing problems of congestion, air pollution, and road accidents in Indian cities, largely due to rapid urbanization and motorization. There was a need for a comprehensive policy that could guide the development of urban transport infrastructure sustainably and equitably.
- The main objective of the policy was to ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents to jobs, education, recreation and other needs within cities.

### **What were the key features of the policy?**

- Encouraging integrated land use and transport planning in all cities so that travel distances are minimized and access to livelihoods, education, and other social needs, especially for the marginalized, are improved.
- Encouraging greater use of public transport and non-motorized modes over private vehicles to achieve a more sustainable urban transport system.
- Incorporating a focus on the transport needs of women, children, and disadvantaged sections of society.
- Ensuring the development of technology and promoting the use of cleaner technologies for public transport.

### **Why was the Policy Amended in 2014?**

- The Amendment emphasized the need for developing public transport systems and aimed to reduce the growth of private motor vehicles through investments in public transport and non-motorized transport. It also emphasized urban transport reforms and capacity building at the city level for urban transport management.
- The Amendment was necessary because, despite the guidelines of NUTP 2006, the situation of urban transport in India had continued to deteriorate with increasing congestion, pollution and road accidents. It was felt that a renewed emphasis on public transport and non-motorized transport, backed by reforms and capacity building, was necessary to reverse this trend.

### **How do these policies factor in $N_r$ and its management in the energy sector?**

It doesn't directly address  $N_r$ , however, it indirectly influences such emissions through its focus on sustainable urban transportation. The NUTP's objectives, which include promoting public transport and non-motorized transport, reducing congestion, and improving fuel efficiency, contribute to an overall reduction in vehicle emissions, including Nitrogen oxides. While the policy does not directly regulate vehicle emissions, it creates a framework for urban transport planning and development that can lead to lower emissions. For instance, promoting the use of public transport can lead to fewer private vehicles on the road, reducing total vehicular emissions. Similarly, promoting non-motorized transport (such as cycling and walking) for short trips can also reduce the reliance on motor vehicles and their associated emissions.

## **3. National Mission for Electric Mobility, 2012**

### **Why was the Policy formulated?**

- Environmental Concerns: Increasing pollution from the transport sector and the need to reduce carbon emissions.
- Energy Security: With India's dependence on oil imports, electric vehicles offer an avenue to significantly reduce the country's import bill and improve energy security.
- Economic Opportunities: The global shift toward electric mobility offers significant economic opportunities for the Indian automotive sector.

### **What were the key features of the policy?**

- The NMEM is a comprehensive initiative aimed at promoting electric mobility and manufacturing of electric (& hybrid) vehicles (EVs) in the country. The goal is to bring about a transformational paradigm shift in the automotive and transportation industry in the country.
- The mission outlines targets for sales of EVs and seeks to provide the necessary early-stage R&D support to industry and academia to develop affordable and reliable EVs. It also plans to incentivize the progressive indigenization of critical EV components to develop domestic competence.
- Following the NMEM 2012, the FAME India (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India) scheme was launched in 2015 under the aegis of the NMEM. This scheme was aimed

at providing fiscal and monetary incentives for the adoption and market creation of both hybrid and electric technologies vehicles in the country.

#### **How do these policies factor in $N_r$ and its management in the energy sector?**

By promoting the use of electric and hybrid vehicles, these policies aim to reduce emissions from the transport sector, including  $N_r$ . Electric vehicles produce zero tailpipe emissions, while hybrid vehicles typically emit less  $NO_x$  than conventional vehicles.

#### **4. BS VI emission standards, 2016**

##### **Why was the Policy formulated?**

- The decision to move directly to BS VI standards was taken given the severe air pollution problems in many Indian cities. By implementing these standards, the Indian government aims to significantly reduce the contribution of vehicular pollution to overall air pollution.

##### **What were the key features of the policy?**

- These standards regulate the output of air pollutants from internal combustion engines, including those in motor vehicles. The BS VI standards are two stages up from the earlier BS IV standards, as the Indian government decided to skip BS V and move directly to BS VI in a bid to combat high levels of air pollution in many Indian cities.  
Compared to the preceding BS IV standards, the BS VI standards introduce more stringent emission limits, particularly for diesel engines. For example:
  1. Nitrogen Oxides ( $NO_x$ ): The permissible levels for  $NO_x$  emissions from diesel passenger cars under BS VI standards are nearly 70% lower than those under BS-IV standards.
  2. Particulate Matter (PM): The BS VI standards introduce PM emission limits for petrol engines, and the permissible levels for PM emissions from diesel passenger cars are 80% lower than those under BS-IV standards.
  3. Hydrocarbons (HC): The BS VI standards introduce separate HC emission limits for both petrol and diesel engines, whereas previous standards had combined limits for HC and  $NO_x$ .
  4. Sulphur content in fuels: The BS VI standards also mandate a maximum sulphur content of 10 parts per million (ppm) in petrol and diesel fuels, compared to 50 ppm under BS IV. Lowering the sulphur content in fuels is critical for the performance of emission control technologies in vehicles.

#### **How do these policies factor in $N_r$ and its management in the energy sector?**

The BS emission standards, especially the latest BS-VI, which came into effect in April 2020, have strict limits on  $NO_x$  emissions. The BS VI standards significantly reduced the permissible  $NO_x$  emissions from both petrol and diesel vehicles compared to previous standards.

#### **5. Automotive Mission Plan of India, 2016**

##### **Why was the Policy formulated?**

- Support Growth: To support and accelerate the growth of the automotive sector in India and make it a global hub for manufacturing.
- Improve Export Potential: To improve the export potential of Indian-made vehicles and components.
- Boost Employment: To create additional employment opportunities in the sector and contribute toward skill development.
- Promote 'Make in India': To advance the "Make in India" initiative, which aims to transform India into a global design and manufacturing hub.

##### **What were the key features of the policy?**

- The Automotive Mission Plan (AMP) 2016-2026 is a collective vision of the Government of India and the Indian Automotive industry. This plan aims to define the trajectory of the evolution of the automotive ecosystem in India including the enabling policy measures, for the ten years from 2016 to 2026.
- The AMP 2016-2026 aims to propel the Indian Automotive industry to be the engine of the "Make in India" initiative, contributing toward 12% of the country's GDP, providing additional employment to 65 million people, and significantly contributing to the skill development initiatives in the country.

#### **How do these policies factor in $N_r$ and its management in the energy sector?**

Although this plan is not strictly regulatory in nature, it supports the development of more fuel-efficient and lower-emission vehicles, which indirectly helps to reduce  $N_r$ .

## **6. National Policy on Biofuels, 2018**

### **Why was the Policy formulated?**

- Energy Security: India is heavily dependent on oil imports, exposing it to the volatility of global oil prices and supply disruptions. Biofuels can be produced domestically from a variety of biomass sources, improving the country's energy security.
- Climate Change: Biofuels can help mitigate climate change by reducing GHG emissions. When biofuels are burned, they only release as much carbon dioxide as was absorbed by the plants they are derived from, making them carbon-neutral (ignoring emissions from biofuel production and transport).
- Rural Development: The production of biofuels can boost rural economies by providing new markets for agricultural and waste products.
- Waste Management: Certain types of biofuels can be produced from organic wastes, providing a sustainable waste management solution.
- Air Quality: Biofuels burn cleaner than fossil fuels, reducing the emissions of pollutants that cause air pollution.

### **What were the key features of the policy?**

- The policy categorizes biofuels as "Basic Biofuels" viz. First Generation (1G) bioethanol & biodiesel and "Advanced Biofuels" - Second Generation (2G) ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third Generation (3G) biofuels, bio-CNG etc., to enable the extension of appropriate financial and fiscal incentives under each category.
- It expands the scope of raw material for ethanol production by allowing the use of sugarcane juice, sugar-containing materials like beet, and sweet sorghum, starch-containing materials like corn, cassava, damaged food grains like wheat, broken rice, and rotten potatoes that are unfit for human consumption.
- The policy also encourages the setting up of supply chain mechanisms for biodiesel production from non-edible oilseeds, used cooking oil, and short gestation crops.

### **How do these policies factor in $N_r$ and its management in the energy sector?**

This policy encourages the use of biofuels, which can have lower NO<sub>x</sub> emissions compared to traditional fossil fuels, depending on the type of biofuel and the conditions under which it's used.

## **Power Generation and Industries**

### **1. Energy Conservation Act, 2001 and its 2010 and 2020 Amendments**

#### **Why was the Policy formulated?**

- The Energy Conservation Act was formulated to address the growing energy demand and the need to conserve resources while reducing GHG emissions.
- It aimed to create a comprehensive regulatory framework to promote energy efficiency and conservation practices across industries, buildings, and appliances in India.
- The Act played a crucial role in developing energy-efficient practices, raising consumer awareness, and facilitating energy savings in the country.

#### **What were the key features of the policy?**

- Institutional mechanisms: It established the Bureau of Energy Efficiency (BEE) as the central authority responsible for implementing and enforcing energy efficiency measures.
- Energy Conservation Building Codes (ECBC): The Act mandated the development and implementation of ECBC to improve energy efficiency in buildings.
- Energy Consumption Standards and Labelling: The Act authorized the BEE to introduce energy performance standards and labelling requirements for equipment and appliances.
- Energy Audits: The Act made it mandatory for designated energy-consuming industries to conduct regular energy audits.
- Energy Conservation Fund: The Act provided for the establishment of an Energy Conservation Fund to support and finance energy efficiency initiatives and projects.
- Energy Conservation Rules: The Act empowered the government to make rules and regulations for the effective implementation of energy conservation measures.

#### **Why was the Policy Amended in 2010?**

- The Amendment expanded the coverage of the Energy Conservation Act to include additional sectors and energy-consuming entities. It aimed to bring more industries, commercial establishments, and buildings under the purview of energy conservation regulations.

- **Mandatory Energy Audits:** The Amendment made it mandatory for specific designated energy-intensive industries and establishments to conduct regular energy audits. This provision aimed to identify energy-saving opportunities, improve energy management practices, and enhance energy efficiency in these sectors.
- **Energy Consumption Standards:** The Amendment empowered the government to prescribe energy consumption standards for various energy-consuming appliances, equipment, and processes. These standards would be implemented through the labelling and certification process.
- **Appointment of Energy Managers and Energy Auditors:** The Amendment introduced the provision for appointing energy managers and energy auditors by designated consumers. Energy managers are responsible for ensuring compliance with energy conservation measures, while energy auditors conduct energy audits and recommend energy-saving measures.
- **Penalties and Enforcement:** The Amendment strengthened the penalty provisions for non-compliance with the Energy Conservation Act. It also specified the enforcement mechanisms and powers of designated officials in monitoring and enforcing energy conservation regulations.

#### **What was the need for the 2020 Bill?**

- At the 2021 COP-26 summit, India committed to reducing projected carbon emissions by one billion tons and decreasing carbon intensity by 45% by 2030, from 2005 levels. The country also aims to generate 500 GW of energy from non-fossil sources and meet 50% of its energy needs with renewables by 2030.
- In alignment with these goals, the Energy Conservation (Amendment) Bill, 2022 was introduced in Lok Sabha and is currently under review in Rajya Sabha. The bill aims to facilitate the achievement of COP-26 goals and hasten the decarbonization of the Indian economy by mandating the use of non-fossil sources and introducing carbon credit trading.
- **Key Features:**
  - o The Bill empowers the central government to specify a **carbon credit trading scheme**. Carbon credit implies a tradeable permit to produce a specified amount of carbon dioxide or other greenhouse emissions.
  - o Different consumption thresholds may be specified for different non-fossil sources and consumer categories. Designated consumers include (i) industries such as mining, steel, cement, textile, chemicals, and petrochemicals, (ii) the transport sector including Railways, and (iii) commercial buildings, as specified in the schedule.
  - o The Act empowers the central government to specify the Energy Conservation Code for buildings. The code prescribes energy consumption standards in terms of area. The Bill amends this to provide for an 'Energy Conservation and Sustainable Building Code.'

#### **How do these policies factor in $N_r$ and its management in the energy sector?**

This Act promotes energy efficiency measures, which indirectly contribute to the reduction of  $N_r$ . By improving energy efficiency, the power sector and industries can generate the same amount of power or output using less fuel. This results in lower overall emissions, including NOx. The Act provides for the establishment of the BEE, which is tasked with implementing energy conservation and efficiency measures across various sectors of the economy.

## **2. Electricity Act, 2003 and its 2007 Amendment and the recent 2022 Bill**

### **Why was the policy formulated?**

- The Electricity Act 2003 replaced the previous Electricity Supply Act of 1948 bringing comprehensive reforms to India's power sector. It promoted competition, introduced regulatory reforms, encouraged renewable energy, and facilitated consumer choice.

### **What were the key features of the policy?**

- **Promotion of Competition:** The Act aimed to introduce competition in the electricity sector by encouraging multiple players, including private sector participation. It sought to create a level playing field for various entities involved in electricity generation, transmission, and distribution.
- **Establishment of Regulatory Framework:** The Act provided for the establishment of regulatory commissions at the central and state levels (CERC and SERC) to regulate the power sector's functioning. These commissions were responsible for tariff setting, quality of supply, promotion of competition, and other regulatory functions.

- **Unbundling of the Electricity Sector:** The Act facilitated the unbundling of vertically integrated state electricity boards into separate entities responsible for generation, transmission, and distribution. This separation aimed to improve operational efficiency and introduce competition at various levels.
- **Open Access and Cross-Subsidy Elimination:** The Act promoted open access, allowing consumers to choose their power suppliers and encouraging competition in the market. It also aimed to gradually reduce cross-subsidies, earlier prevalent in the power sector, to ensure a more transparent and cost-reflective tariff structure.
- **Promotion of Renewable Energy:** The Act included provisions for the purchase and generation of electricity from renewable energy sources. It mandated the creation of renewable purchase obligations for distribution licensees, encouraging the integration of renewable energy into the power grid.

#### **Why was the Policy Amended in 2007?**

- **Strengthening of Regulatory Framework:** The Amendment enhanced the powers of regulatory commissions and introduced measures to improve their independence, accountability, and effectiveness in regulating the power sector.
- **Simplifying Open Access:** The Amendment aimed to further promote open access in the power sector by simplifying the procedures and reducing barriers for consumers to choose their electricity suppliers.
- **Strengthening of Enforcement and Penalties:** The Amendment introduced stricter enforcement provisions and penalties to ensure compliance with the Act's provisions and deter any non-compliance.

#### **What was the need for the 2022 Bill?**

- The financial performance of Indian power distribution utilities (discoms) has been consistently poor, with cumulative losses amounting to about three lakh crore rupees between 2017-18 and 2020-21. Discoms, often state government-owned monopolies, have required periodic government bailouts. Key reasons for these losses include high technical and commercial losses (22% as of 2020-21), which encompass energy transfer losses and theft, and underpricing of tariffs.
- The Bill enables more than one discom to supply electricity in a given area, without each owning a separate network. Where multiple discoms operate in the same area, the Bill provides for (i) non-discriminatory open access to the distribution network, (ii) sharing of existing power purchase agreements (PPAs) between discoms, (iii) determination of only ceiling and floor tariffs for retail supply, and (iv) setting up of cross-subsidy balancing fund.
- Overall, the Bill seeks to promote consumer choice and bring efficiency through competition.

#### **How do these policies factor in $N_r$ and its management in the energy sector?**

The Act reformed the electricity sector in India to attract more private investment and promote competition, which can encourage more efficient power generation and reduce emissions. It also includes provisions for promoting renewable energy, which can help reduce  $N_r$  by displacing fossil fuel-based power generation.

### **3. National Solar Mission (2010-2022)**

#### **Why was the Policy formulated?**

- The National Solar Mission, also known as the Jawaharlal Nehru National Solar Mission (JNNSM), is a flagship initiative of the Government of India launched in 2010. It is a major component of India's National Action Plan on Climate Change and aims to promote the development and deployment of solar energy in the country.

#### **What were the key features of the policy?**

- **Scale-up Solar Energy Deployment:** The mission seeks to increase the capacity of solar energy generation in India. It has set a target of deploying 100 gigawatts (GW) of solar power capacity by 2022, making it one of the largest solar energy expansion programs in the world.
- **Reduce the Cost of Solar Power:** The mission aims to significantly reduce the cost of solar power through various mechanisms, such as long-term policy support, incentives, and economies of scale. The objective is to make solar power competitive with conventional sources of energy.
- **Promote Research and Development:** The National Solar Mission encourages research, development, and innovation in solar energy technologies. It focuses on promoting indigenous manufacturing and improving the efficiency of solar cells, modules, and other related components.
- **Facilitate Sustainable Solar Industry Growth:** The mission aims to create an enabling environment for the growth of a sustainable solar industry in India. It includes providing financial and policy support for solar projects, establishing standards and regulations, and fostering the development of a skilled workforce in the solar sector.

- Enhance Energy Access and Security: The National Solar Mission seeks to enhance energy access and energy security in the country by diversifying the energy mix and reducing reliance on fossil fuels. It aims to provide clean and affordable energy to remote and rural areas through decentralized solar power solutions.

**How do these policies factor in  $N_r$  and its management in the energy sector?**

This mission aimed to promote solar power in India, with a target of achieving 100 GW of solar power capacity by 2022. Replacing conventional coal or gas power plants with solar power can reduce  $N_r$ .

**4. National Biogas and Manure Management Programme (NBMMP), 2018**

**Why was the policy formulated?**

- The primary objective of the National Biogas and Manure Management Programme is to promote the installation of biogas plants for efficient utilization of organic waste, including agricultural residues, animal dung, and other biomass sources, while also addressing the management of animal manure.

**What were the key features of the policy?**

- The National Biogas and Manure Management Programme has been instrumental in promoting sustainable energy practices, waste management, and rural development in India.
- The program aligns with the government's renewable energy and sustainable development goals by utilizing organic waste resources, reducing dependence on fossil fuels, and promoting environmentally friendly agriculture practices.

**How do these policies factor in  $N_r$  and its management in the energy sector?**

This program promotes the use of biogas that can be used for cooking, lighting, and power generation. While the combustion of biogas does produce NOx emissions, they are typically lower than those from fossil fuels. Additionally, the use of biogas can displace the use of more polluting fuels like firewood or coal in homes or small industries, leading to a net reduction in emissions.

**5. Programme on Energy from Urban, Industrial, Agricultural Wastes/Residues and Municipal Solid Waste, 2020**

**Why was the policy formulated?**

- India's waste-to-energy program is an initiative that encourages the conversion of waste materials into usable energy. The idea behind these initiatives is to help manage India's growing waste problem while simultaneously contributing to the country's energy mix. The government has introduced various incentives and subsidies to promote these initiatives, often through PPPs.

**What were the key features of the policy?**

- MSW to Energy: This is the most common type of waste-to-energy conversion in India. The government encourages municipalities to convert their solid waste into energy, reducing the amount of waste that goes into landfills while also producing useful energy. This can be achieved through methods like incineration, gasification, and pyrolysis.
- Biomass Waste to Energy: Biomass waste, such as agricultural residues and waste from forestry, can also be converted into energy. The energy can be used for heating, electricity generation, and transportation fuels.
- Waste to Biogas: This program focuses on converting organic waste, such as kitchen waste and animal manure, into biogas. The biogas can be used for cooking, electricity generation, and transportation fuel.
- Waste to Biofuels: The government is also encouraging the conversion of waste materials into biofuels. For example, the National Policy on Biofuels 2018 envisages the production of biofuels from used cooking oil.

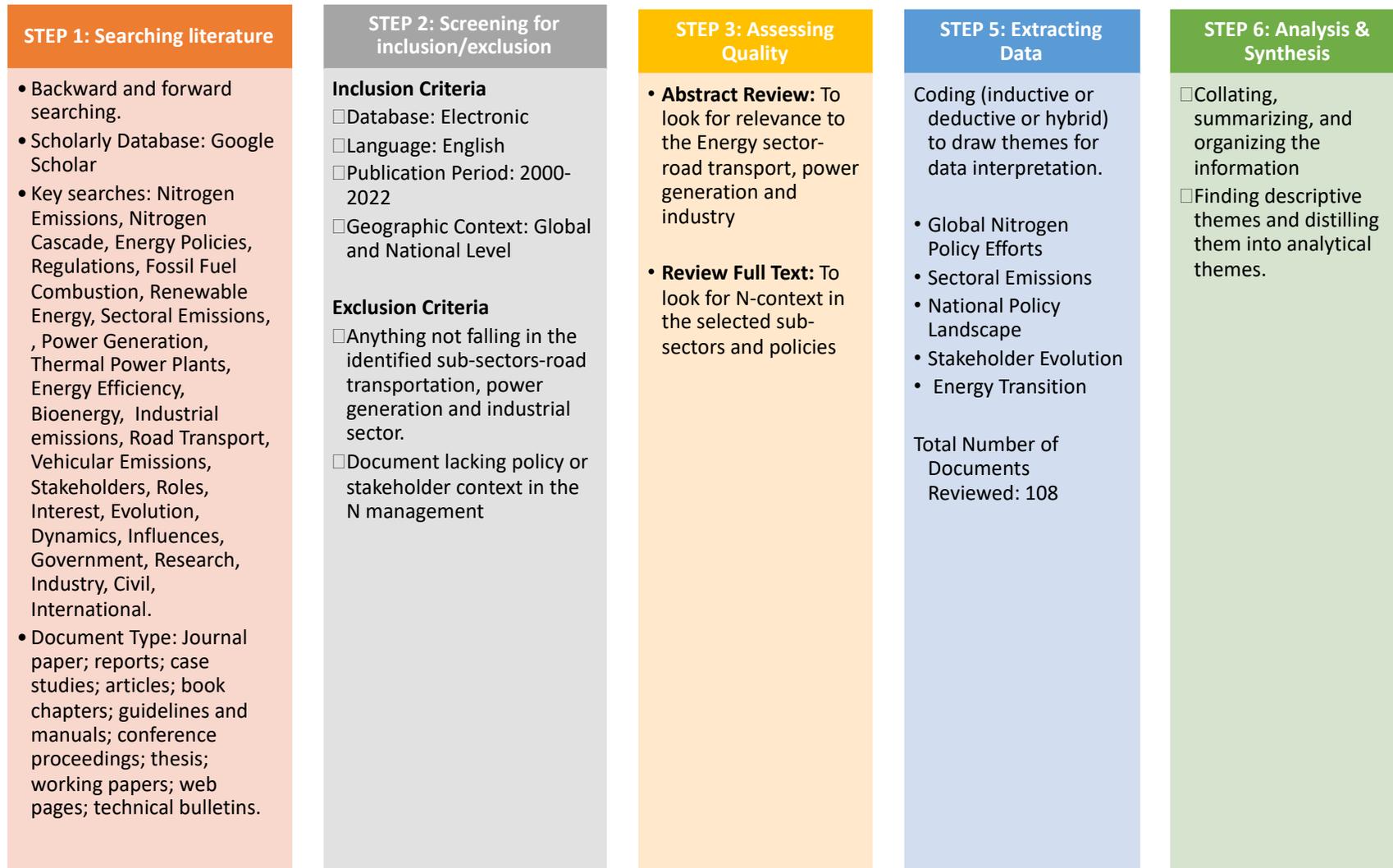
**How do these policies factor in  $N_r$  and its management in the energy sector?**

The waste-to-energy program in India promotes the conversion of MSW into energy. Depending on the technology used, waste-to-energy plants can have lower NOx emissions compared to conventional coal or gas power plants.

## Annexure 3: Stakeholder Interviews (n=12) details for understanding nitrogen management issues in Energy sector reforms

| Stakeholder Groups                | Affiliation   | Interview Completed | Status- |
|-----------------------------------|---|---------------------|---------|
| Government Bodies                 | Ministry of Power   | (n=1)               |         |
|                                   | Ministry of Environment, Forest and Climate Change                      | (n=1)               |         |
|                                   | Central Electricity Authority   | (n=1)               |         |
|                                   | Niti Aayog  | (n=1)               |         |
| Research Organization/Think Tanks | TERI  | (n=1)               |         |
|                                   | Delhi Skill and Entrepreneurship University                             | (n=1)               |         |
|                                   | World Resources Institute   | (n=1)               |         |
|                                   | Guru Gobind Singh Indraprastha University                               | (n=1)               |         |
|                                   | Jawaharlal Nehru University   | (n=1)               |         |
| Industry                          | Power generation industries (GAIL, NTPC) and Automobile industry (SIAM) | (n= 3)              |         |

## Annexure 4: Flow Chart for Steps Followed in a Systematic Literature Review



## Annexure 5: Policy Selection Criteria

| N-relevance  | Impact Direction   | Impact Scope   |
|--|--|--|
| <ul style="list-style-type: none"> <li>• <b>Direct (High):</b> Policy text must have one or more of the 29 key words i.e. Kanter’s search criteria.</li> <li>• <b>Indirect (Medium):</b> Policies that still have clear relevance to N, but do not contain any of the 29 key words but synonyms of these-</li> </ul> <p><b>(Developed key searches:</b><br/> “Reactive nitrogen”, “Energy Efficiency”, “Electrification”, “Energy Access”, “Transport technologies”, “vehicular emission”, “climate control technologies”, “auxiliary power units”, “biodiversity”, “bioenergy”, “biomass”, “biogas”, “clean air”, “coal”, “crop residues”, “crop burning”, “diesel, gasoline”, “petrol”, “electric vehicles”, “green transport”, “hybrid vehicles”, “particulates”, “point source”, “non-point source”, “renewable energy”, “biofuel”, “non-conventional energy”, “clean fuel”, “power generation”)</p> | <ul style="list-style-type: none"> <li>• <b>Positive Direction :</b> If a policy promoted a reduction in Nitrogen pollution and/or improved Nitrogen management (whether directly/indirectly)</li> <li>• <b>Mixed:</b> A policy that could have both positive and negative implications on the nitrogen management.</li> </ul> | <ul style="list-style-type: none"> <li>• <b>Large:</b> Include nation-wide policies with potentially wide implications for Nitrogen management</li> <li>• <b>Medium:</b> Include Policies that may encompass large area (national) but have potentially indirect implications for Nitrogen management or a sub national level policy which may have direct effects, but these are more localized.</li> </ul> |