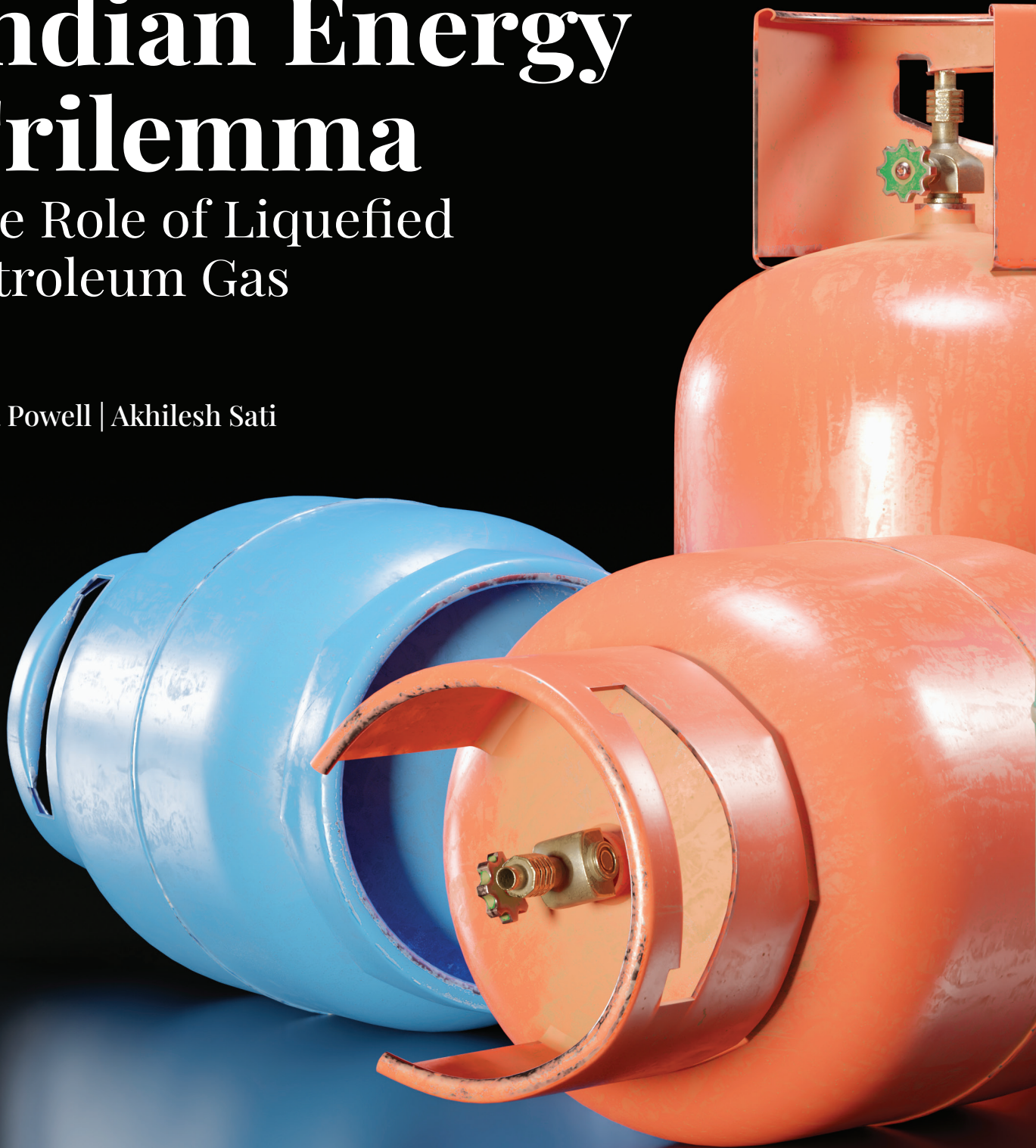


Navigating the Indian Energy Trilemma

The Role of Liquefied
Petroleum Gas

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Executive Summary

The energy trilemma,¹ which calls for optimising the competing needs of energy security, sustainability, and affordability, poses an acute challenge for India. Unprocessed biomass and fossil fuels accounted for over 90 percent of India's primary energy basket in 2022² and need to be reduced and eventually eliminated for long-term sustainability. For most of the Indian population, affordability is an important factor that often limits fuel choices.³ Geopolitical tensions also threaten supply security and increase the price volatility of imported energy.

Fuels such as liquefied petroleum gas (LPG), one of the cleanest conventional fuels currently available, is making a significant contribution to India's progress on all three dimensions of the energy trilemma, especially in meeting household cooking fuel needs.⁴ LPG is a clean cooking fuel with zero global warming potential (i.e., it is not a greenhouse gas as per the classification of the Intergovernmental Panel on Climate Change.)⁵ LPG has the lowest supply and price risks among conventional fuels, and its modular nature makes it rapidly scalable, replaceable, and affordable. Indian households that switched from biomass to LPG saw a substantial reduction in indoor pollution and

a consequent reduction in respiratory illness among women and children.⁶ Reduced biomass gathering and cooking time as a result of LPG increased the scope for the education and employment for women, who are typically assigned by social norms to domestic chores. LPG adoption has also contributed to increasing energy-use efficiency, one of India's commitments to the Paris Agreement; about 60 percent of the decline in India's energy intensity in the last two decades has been attributed to the switch from biomass to LPG.⁷ Continued policy push could enable LPG to play a more important role as a bridge fuel through complementing the use of natural gas to increase energy access, security, and sustainability.

In 2022-23, India's LPG consumption was 28.5 million tons (MT) and production was 12.8 MT.⁸ At over 41.1 percent, LPG imports accounted for the largest share of petroleum product imports in 2022-23.⁹ Domestic LPG consumption accounted for over 89 percent of total consumption.¹⁰ The adoption of LPG by low-income households in rural and urban India was accelerated through the provision of government subsidies. The welfare gains associated with subsidies for energy access for cooking are often higher than the long-term costs involved in providing the subsidy. Smaller LPG canisters may increase affordability for weekly-wage earners and promote LPG use among poor households, eventually paving the way for an LPG-subsidy phase-out. The decentralised nature of LPG enables it to be transported through multiple modes to access difficult terrains. As a relatively cleaner fuel than petrol and diesel, promoting the use of LPG in the transportation sector will contribute to the reduction of pollution. LPG can also serve as a robust and affordable backup energy source for villages with off-grid renewable-energy solutions. It can also enable small-scale industries in rural areas to flourish. As LPG supply does not require specialised infrastructure, it can be scaled up easily and, under the right conditions, eventually replaced with renewable LPG (rLPG). Easing regulatory burdens on the use of LPG without compromising

on safety will create more avenues for the private sector to become involved in the sourcing and distribution of LPG. This may also open up the co-benefit of greater LPG access for domestic and service-sector consumers.

LPG use can be accelerated by international financial assistance along with the use of carbon credits to encourage the shift from biomass to LPG for cooking fuel, which will reduce local pollution, reduce carbon emissions, and ease the subsidy burden on scarce public funds. The upcoming 29th Conference of Parties (COP29) will provide an opportunity for developing countries such as India, which have a record of improving access to clean and modern sources of cooking fuels, to seek international financial assistance and carbon credits for LPG use.

1

Introduction

The preamble of the United Nations Framework Convention on Climate Change (UNFCCC) 1992 acknowledges that energy consumption in developing countries such as India will need to grow in order to meet their social and economic goals, with an emphasis on increasing energy efficiency and limiting greenhouse gas (GHG) emissions.¹¹ The preamble of the Paris Agreement of 2015 also endorses this position.¹² Sustainable Development Goal 7 (SDG 7) of the UN 2030 Agenda for Sustainable Development calls for universal access to affordable, reliable, and modern energy for all.¹³ With 2023 being the mid-point of implementation of the SDGs, current trends suggest that SDG 7 is not likely to be achieved by 2030 without strong policy support in developing countries that are faced with the challenge of simultaneously increasing energy consumption and decreasing GHG emissions.

In 2022, India's per-capita commercial energy consumption (excluding unprocessed biomass consumption) was estimated at 25.7 gigajoules (GJ) per year,¹⁴ which is only a third of the world average, the lowest among G20 countries and lower than the minimum requirement for decent living in tropical countries.¹⁵ India also has the largest share of

population with energy access deficit, estimated at over 505 million.¹⁶

However, energy consumption in the country is growing rapidly, and if the current momentum is sustained, India is likely to close the energy deficit gap earlier than anticipated. In 2022, India's energy consumption grew by 5.6 percent compared to 1.1 percent globally and electricity generation grew by 8.4 percent compared to 2.3 percent globally.¹⁷ Petroleum liquids consumption in India, which accounts for 5.3 percent of global liquids consumption, grew by about 8.2 percent in 2022 compared to 2.3 percent globally.¹⁸ Coal, oil, and natural gas (fossil fuels) accounted for over 73 percent of primary energy consumption in India in 2022. At over 17.3 percent, energy derived from unprocessed biomass (firewood, agricultural waste, and animal dung) had the third largest share in India's primary energy basket after coal (45.5 percent) and oil (22.8 percent).¹⁹ With unprocessed biomass and fossil fuels accounting for over 90 percent of India's primary energy basket, navigating the competing demands of the energy trilemma becomes challenging.²⁰

LPG, as one of the cleanest conventional fuels, has a significant role to play in India's household energy use. While natural gas is often proposed as a bridge fuel for energy transition due to its ability to deliver on all three demands of the energy trilemma, LPG can match and possibly exceed these capabilities, thus complementing its role as a bridge fuel towards a net-zero future.²¹ According to the World Health Organization (WHO), LPG has zero global warming potential (GWP), and therefore, it is not a GHG as per the classification of the Intergovernmental Panel on Climate Change (IPCC), making it sustainable.²² LPG is also abundantly available, thus ensuring energy security. Further, the simplicity of LPG production and the modularity in its storage and transport make it an affordable option.

The growth in LPG consumption in India in the last few decades has been driven by economic growth, urbanisation, and improved literacy, especially among women. Government subsidies also accelerated the adoption of LPG in low-income households in rural and urban India, which resulted in reduced indoor air pollution and limited deforestation. The adoption of LPG as cooking fuel also facilitated women's participation in the workforce by substantially reducing cooking time. LPG is also used by industries as feedstock and for process heat, as well as for transportation fuel, especially for three-wheelers.

However, LPG consumption in India is likely to face some challenges. In the near term, the phase-out of LPG subsidies may limit LPG adoption and consumption in low-income households in India. The expansion of pipeline networks for the supply of Piped Natural Gas (PNG) in cities across the country, along with natural gas price regulations may also negatively impact LPG consumption in households, industries, and the automobile sector. In the long term, the promotion of renewable energy (RE) through the electrification of all activities, including cooking, may also impede LPG consumption.

2

The Basics of LPG

2.1 Energy Properties

LPG is a combination of propane (C_3H_8) and butane (C_4H_{10}) gases in varying proportions;²³ in India, the ratio of propane-to-butane is usually 60:40 but can vary depending on end-use specifications and the relative prices of butane and propane.²⁴ In the United States (US), LPG consists of a minimum of 90 percent propane, whereas in Europe, propane in LPG ranges from 70-80 percent depending on the season, while Korea utilises over 85 percent butane in LPG in the summer months.²⁵ The ratios in which the components are present can have significant impacts on the fuel properties of LPG, such as energy content, vapour pressure, and octane number.²⁶

LPG has distinct properties compared to other conventional fuels.²⁷ Its moderate vapour pressure allows for it to be stored in a liquid state at medium pressures in relatively inexpensive steel vessels, thus allowing for high energy densities. In comparison, natural gas needs to be highly compressed at pressures over 200 bar (i.e., 200 times atmospheric pressure) or cryogenically frozen to liquid form at temperatures less than $-160^{\circ}C$ in order to achieve

suitable energy densities for transportation.²⁸ Compressed natural gas (CNG) and liquefied natural gas (LNG) require expensive storage tanks due to their extreme pressures and temperature requirements.²⁹

LPG can be stored for long periods of time without any degradation in its quality, which makes it suitable for multiple uses in rural, urban, and industrial settings.³⁰ Shelf life is critical for energy use in rural contexts, where replacement and maintenance services are often scarce. LPG can also be transported in small or large quantities, making it a versatile energy source at the household level as well as a key fuel at the industry level. As the transportation of LPG does not require an elaborate infrastructure of pipelines, it is often the only fuel that is able to reach communities on islands or high altitudes and therefore becomes vital during emergencies and national disasters. In India, LPG, along with electricity, has been critical in improving the quality of life of rural communities.

While a sample of LPG may have a degree of natural variation in heating values due to the proportions of butane and propane, LPG has a comparably high heating value, i.e., it contains more energy per kilogram than most competing fuels.³¹ On a mass basis, LPG has one of the highest energy contents (Table 1). However, on a volume basis, LPG has a lower energy content than conventional fuels such as petrol and diesel due to the comparatively lower density of LPG. Therefore, on a volume basis, more LPG is required to achieve the same output as conventional fuels,³² which reduces its appeal as a transportation fuel. However, in this respect, LPG has a marginal advantage over other alternative fuels such as LNG and ethanol.

TABLE 1: ENERGY CONTENT AND DENSITY OF SELECT FUELS

Fuel	Density kg/litre	Lower heating value MJ/litre	Lower heating value MJ/kg
LPG	0.508	23.7	46.6
Low sulphur petrol	0.748	31.7	42.4
Low sulphur diesel	0.847	36.1	42.6
LNG	0.428	20.8	48.6
Ethanol	0.789	21.3	27.0

Notes: MJ (Million Joules), kg (kilograms)

Source: Ryskamp (2017)³³

Compared to petrol, LPG has a relatively high octane number.³⁴ The octane number decreases with an increase in the percentage of higher order hydrocarbons than propane (e.g., butane); with an increase in the percentage of lower order hydrocarbons, e.g., methane and ethane, the octane number increases. The higher octane number of LPG relative to petrol can offer performance and efficiency advantages. Compared to petrol, the more advanced ignition timing and higher compression ratio of LPG can be utilised with less susceptibility to pre-ignition or knock.³⁵

2.2 Environmental Properties

The composition of LPG (i.e., the ratios of propane, butane, and other hydrocarbons) determines its carbon intensity, which is often quantified by the hydrogen-to-carbon (H:C) ratio of the fuel. Propane has eight hydrogen atoms and three carbon atoms, equating to an H:C ratio of approximately 2.67.³⁶ The H:C ratio increases for lower order alkanes such as methane and ethane and decreases for higher order alkanes such as butane.³⁷ On the other hand, conventional transportation fuels, i.e., petrol and diesel, typically exhibit an H:C ratio ranging from 1.7 to

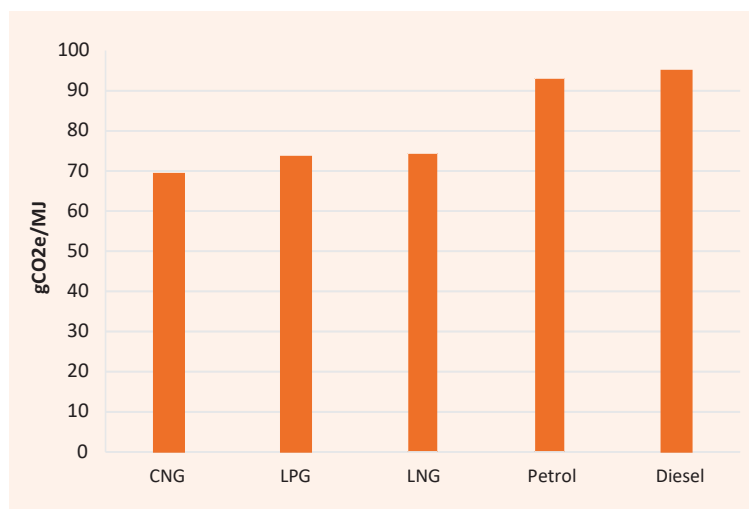
1.9. In theory, the higher H:C ratio of LPG compared to alternative fuels results in lower carbon dioxide (CO₂) and soot production during combustion.³⁸

The carbon intensity, or the quantity of carbon emitted per unit energy, delivered by LPG is comparable to that of natural gas, although it also depends on the chemical composition of LPG and its use case.³⁹ The full lifecycle default carbon intensity of LPG is about 76 CO₂e/MJ (carbon-dioxide equivalent per million joule) compared to about 75-78 CO₂e/MJ for natural gas, 90 CO₂e/MJ for petrol and diesel, and 112 CO₂e/MJ for coal.⁴⁰

IPCC's 100-year GWPs are commonly used for fuel lifecycle and carbon footprint⁴¹ analysis and are recommended for use in footprint guidelines.⁴² A fuel's GWP is its global warming impact relative to an equivalent unit of CO₂ over 100 years. By definition, CO₂ is assigned a GWP of 1.⁴³ LPG has a GWP of zero, indicating that it is not a GHG. Therefore, the leakage or accidental release of LPG will not contribute to global warming. This is in contrast to natural gas (mainly methane), whose accidental release or leakage contributes to global warming with 28 times more potency than CO₂.⁴⁴

WHO defines clean fuels and technologies as those that attain either the annual average air quality guideline level (AQG) of 5 µg/m³ (micrograms per cubic metre) or 35 µg/m³ for PM_{2.5} (particulate matter), and 7 mg/m³ (milligrams per cubic metre) for carbon monoxide (CO).⁴⁵ As per this definition, solar/electric cookers, biogas, natural gas, LPG, and alcohol fuels, including ethanol, are clean cooking fuels. Therefore, the use of abundant and robust fuels such as LPG and natural gas has enabled countries to move closer to achieving SDG 7 of the UN 2030 Agenda for Sustainable Development.⁴⁶

FIG. 1: AVERAGE LIFECYCLE GHG INTENSITY OF SELECT FUELS



Source: Ross (2017)⁴⁷

For India, which is ranked 63rd among 91 countries in the World Energy Trilemma Index for 2022, continued policy push to replace unprocessed biomass with LPG as primary cooking fuel will contribute to improving its ranking.⁴⁸ LPG use in transport and industry will further strengthen India's energy security. In addition, the use of LPG will reduce local pollution and decrease carbon emissions compared to alternatives such as liquid petroleum fuels. Finally, as LPG can be delivered in small quantities as needed, especially to poor households, it can contribute to equitable access to energy.⁴⁹

3

The Supply of LPG

3.1 Domestic Production

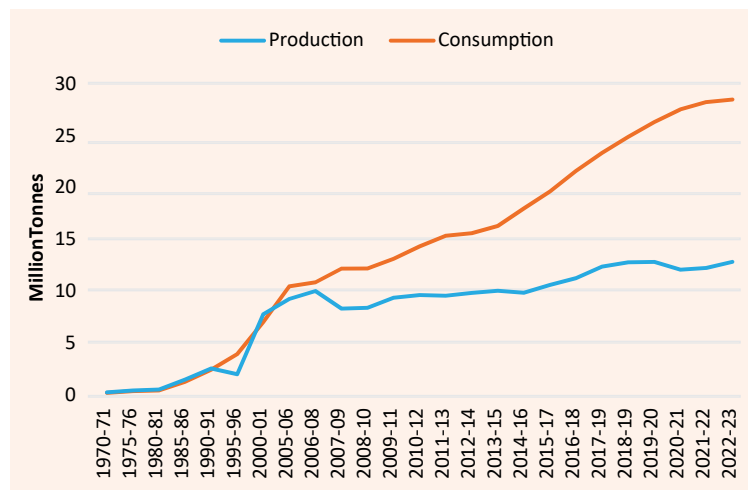
LPG is produced either through the oil-refining process or extracted directly from the ground alongside petroleum and natural gas fractionation.⁵⁰ Approximately 60 percent of LPG produced worldwide is the result of natural gas processing, whereas crude oil processing accounts for the remaining 40 percent.⁵¹ Globally, 1-4 percent of crude oil is processed for LPG. The LPG yield from refining depends on the type of crude oil, the degree of sophistication of the oil refinery, and the market values of propane and butane compared to other oil products.⁵²

Because LPG is a byproduct, supplies rely on the availability of natural gas and crude oil refining. In some countries, LPG is flared off because the cost of moving it to demand centres exceeds the value of the product.⁵³ However, there was a marginal surplus in LPG production in 2023. Recent LPG production in North America and elsewhere, which are driven by shale gas production along with the planned production of LPG from natural gas fields, indicate that this surplus will persist, thus ensuring sufficient LPG supply in the next few decades.

In India, production of LPG was initiated by Burmah-Shell and Stanvac, international oil companies operating in the country, in the 1940s and 1950s. In the 1980s, with domestic production of LPG proving insufficient to cover the demand and extraction of propane and butane from large quantities of ‘associated gas’,⁵⁴ the extraction of much larger quantities of ‘free gas’ from the Bombay and South Bassien fields was initiated.⁵⁵ Specific budgetary provisions were made for setting up LPG extraction and bottling plants and for marketing LPG as fuel for cooking.⁵⁶ Between 1970-71 and 2010-11, LPG production grew at an annual average rate of over 9.91 percent while consumption grew at 11.33 percent—the fastest growth rates among all petroleum derivatives, including petrol and diesel.⁵⁷ In 1970-71, domestic production of LPG amounted to just 0.17 MT.⁵⁸ From 1970-71 to 1980-85, production grew at an annual average of over 13.3 percent.⁵⁹ Production grew at an annual average of about 22.8 percent from 1980-81 to 1985-86 as a result of additional refining capacity coming onstream and new cracking units being commissioned, which led to increased LPG production from natural gas.⁶⁰ Annual average growth in LPG production slowed to about 3.11 percent between 1985-86 and 1995-96 but increased to over 31.34 percent from 1995-96 to 2000-01, when the private sector refinery in Jamnagar came onstream.⁶¹ From 2000-01 to 2010-11, LPG production grew by an annual average of just 2.1 percent, only marginally increasing to 2.2 percent during the 2010-20 period.⁶² From 2020-21 to 2022-23, LPG production grew by an annual average of 3.1 percent.⁶³ LPG accounted for about 5 percent of crude oil processing capacity in India in 2010-11 and fell to about 4.2 percent in 2022-23.⁶⁴ In 2022-23, India’s LPG consumption was 28.5 MT, which marginally exceeded the consumption levels of 28.3 MT in 2021-22. Production in 2022-23, at 12.8 MT, also marginally exceeded production, at 12.2 MT, in 2021-22. However, despite rising consumption, Indian refineries have not been able to meaningfully ramp up LPG production capability. Indian refineries are designed to produce petrol and diesel, which results in lower LPG

yields and limits domestic LPG production.⁶⁵ With abundant LPG availability in international markets due to increased production from the US, Indian oil companies are unlikely to aim for improved LPG production.

FIG. 2: LPG PRODUCTION AND CONSUMPTION IN INDIA (1970-2022)

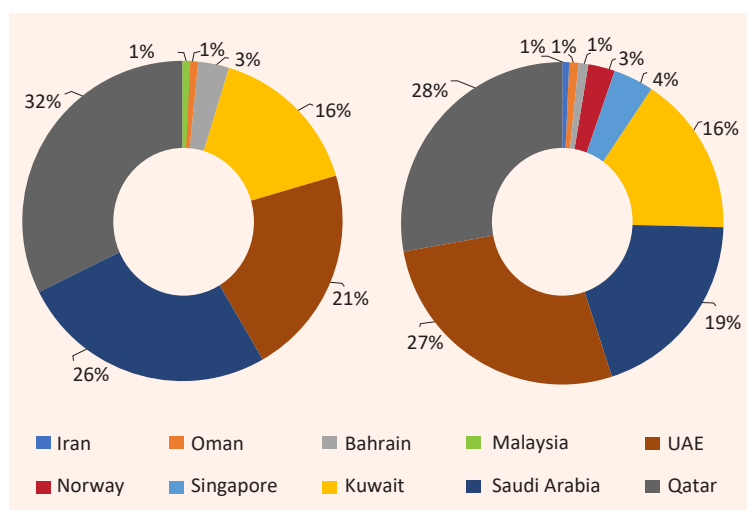


Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India⁶⁶

3.2 Imports

As the domestic production of LPG is stagnant, imports have increased to meet the growth in demand. Imports met roughly 47.3 percent of the demand for LPG in 2010-11, which increased to over 64.2 percent in 2022-23.⁶⁷ LPG imports also accounted for the largest share of petroleum product imports in 2022-23, at over 41.1 percent.⁶⁸ Private-sector imports, which accounted for roughly 7.8 percent of LPG imports in 2010-11, fell to almost zero in 2022-23⁶⁹ due to reduced private-sector involvement in LPG imports and strong regulatory interventions.

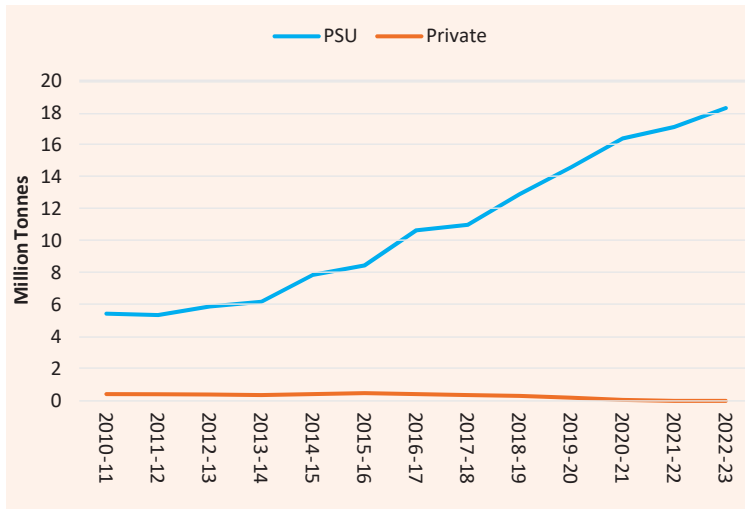
FIG. 3: TOP LPG IMPORT SOURCES (2012-13 AND 2022-23)



Source: Ministry of Commerce & Industry, Department of Commerce, Government of India⁷⁰

In 2012-13, countries in the Middle East were the source of over 99 percent of India's LPG imports,⁷¹ which fell to about 92 percent in 2022-23.⁷² Qatar, Saudi Arabia, and the United Arab Emirates (UAE) were the top LPG import sources for India since 2012-13.⁷³ In 2012-13, Qatar was the largest source of LPG imports to India, and though it continues to be India's top LPG supplier, its share fell from 32 percent in 2012-13 to 27 percent in 2022-23.⁷⁴ Saudi Arabia was the second largest supplier of LPG to India in 2012-13, accounting for 25 percent of total imports, but fell to the third spot in 2022-23, with a share of 19 percent.⁷⁵ The UAE, which was the third largest supplier in 2012-13 with a share of 21 percent, moved up to the second spot in 2022-23, with its increased share of 26 percent.⁷⁶ In 2022-23, India imported 18.3 MT of LPG, valued at US\$13.8 billion.⁷⁷ LPG imports accounted for 41 percent of total petroleum product imports in terms of volume and 51 percent of total product imports in terms of value.⁷⁸

FIG. 4: LPG PSU AND PRIVATE SECTOR IMPORTS



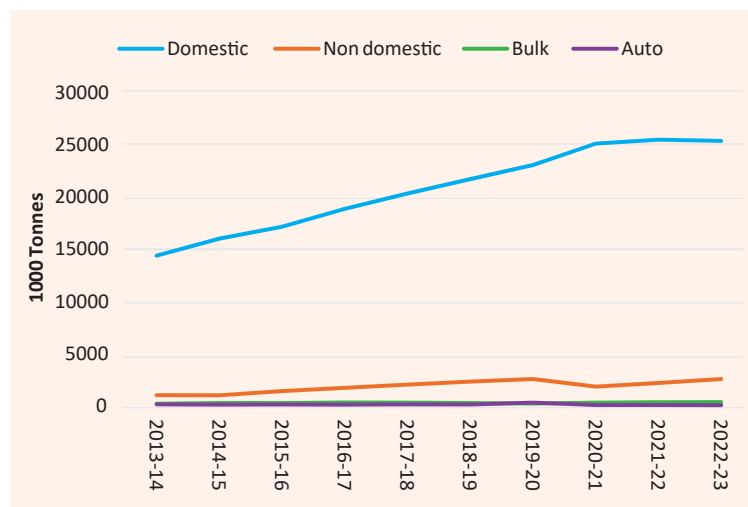
Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India

4

Consumption of LPG

4.1 Background

In 1975, unprocessed biomass accounted for over 46 percent of India's primary energy basket, followed by coal, which had a share of 31 percent.⁷⁹ In the late 1990s, as coal-based power generation accelerated, coal displaced biomass in the top spot; even by 1990, coal and biomass together accounted for over 70 percent of India's primary energy basket, with each accounting for over a third of India's primary energy consumption.⁸⁰ By the turn of the century, the share of biomass had fallen to about a quarter of India's energy basket, with biomass burning in Indian kitchens being replaced initially with kerosene and later by LPG.⁸¹ Since 2002, the share of biomass in India's primary energy basket has fallen at an annual average rate of about 3 percent due to modern cooking fuels such as natural gas and LPG becoming dominant in urban households.⁸²

FIG. 5: LPG CONSUMPTION BY SECTOR

Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India⁸³

In 2022-23, over 89 percent of total LPG consumption was attributed to domestic LPG consumption. Non-domestic consumption of LPG was about 9.1 percent, while bulk consumption of LPG was about 1.4 percent.⁸⁴ Transportation accounted for a meagre 0.3 percent of total LPG consumption.⁸⁵ Bulk and non-domestic LPG consumption are growing, while consumption growth in the domestic and transportation sectors is declining. In 2022-23, domestic consumption fell by 0.4 percent—marginal in comparison to the previous year—while transport consumption fell by over 12 percent.⁸⁶ Non-domestic consumption of LPG grew by over 16 percent in 2022-23 compared to the previous year, while bulk consumption grew by 4 percent.⁸⁷

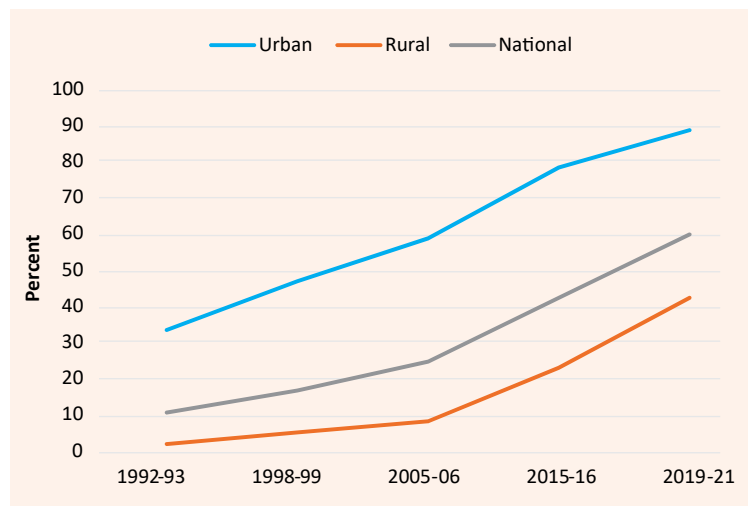
In the decade ending in March 2023, domestic consumption of LPG grew by an annual average of over 6.4 percent, while non-domestic consumption of LPG grew by an annual average of over 8.3 percent.⁸⁸ Bulk consumption grew by about 4.9 percent, while transport consumption fell by an annual average of over 6.6 percent in the same period. Overall LPG consumption grew by about 6.2 percent from 2012-13 to 2022-23. The share of bulk consumption of LPG fell from about 2.3 percent in 2010-11 to about

1.4 percent in 2022-23, while the share of non-domestic consumption increased from about 7 percent in 2010-11 to about 9 percent in 2022-23.⁸⁹

4.2 Domestic Consumption

Domestic consumption has been falling despite the government's push to increase LPG access through subsidies. Burmah Shell began marketing operations for LPG in 1955 in Mumbai.⁹⁰ The first LPG connection, under the brand name 'Indane', was installed ten years later, in Kolkata, by the Indian Oil Corporation (IOC), which had by then taken over nationalised refineries of Burmah Shell.⁹¹ In the early 1970s, concerns over the safety of LPG use inhibited its use in households; in 1970, IOC's Indane LPG had only 235,000 registrations.⁹² It took almost three decades, a well-orchestrated media campaign, and subsidies to increase registrations to 14.8 million.⁹³

FIG. 6: SHARE OF HOUSEHOLDS WITH LPG



Source: National Family Health Survey (various issues), Ministry of Health & Family Welfare, Government of India⁹⁴

In 1977, there were 3.2 million LPG connections across India (constituting 2.5 percent of households).⁹⁵ In 1984, the number of LPG connections tripled to 8.8 million (5

percent of households),⁹⁶ and in 1990, the number of LPG connections increased to 19.6 million (11 percent of households).⁹⁷ LPG connections grew at over 14 percent between 1977 and 1990, which was more than the rate of growth for electricity connections, though the starting base for LPG was very small.⁹⁸ Adoption rates of LPG in rural households was low due to the high initial cost of connection relative to rural incomes.⁹⁹ The difficulty in obtaining replacement cylinders also inhibited adoption in rural areas, as most dealers were located in towns and cities.

Demand for LPG outstripped supply in urban households in the 1980s and 1990s. Shortages reduced following the import of LPG after India partially opened up its economy in the early 1990s. A number of southern state governments launched dedicated programmes for the distribution of subsidised or free LPG connections to households 'below poverty line' (BPL),¹⁰⁰ which substantially increased the number of households in southern India with access to LPG. The success of state-level policies to subsidise LPG access to poor households led to the implementation of the Rajiv Gandhi Gramin LPG Vitak (RGGLV), a 2009 federal government programme aimed at increasing LPG distributors in rural areas and providing subsidised access to LPG.¹⁰¹ RGGLV more than doubled LPG dealers in rural areas and increased the adoption of LPG by rural households.¹⁰² In 2016, the federal government relaunched RGGLV as the Pradhan Mantri Ujjwala Yojana, with some changes.¹⁰³ The scheme was designed to provide INR 1600 per household, to the woman member of a BPL family, to cover the security deposit for a 14.2 kg cylinder and regulator. The cost of the stove and purchase of the first refill was to be borne by the beneficiary.¹⁰⁴ Ujjwala 2.0 was launched in 2021. According to the government, 90 million LPG connections have been registered under the Ujjwala programme.¹⁰⁵

As per the fifth National Family Health Survey 2019-2021 (NFHS-5), carried out by the Ministry of Health & Family Welfare, Government of India, 88.6 percent of urban households use LPG or PNG as the primary cooking fuel, while only 42 percent of rural households use LPG or natural gas.¹⁰⁶ Overall, only about 56.2 percent of the population use LPG or PNG as the primary cooking fuel.¹⁰⁷ About 8.9 percent of urban households use wood, straw, shrubs, grass, crop waste, dung, and other materials (solid fuels) as primary cooking fuel, while 54.6 percent of rural households use solid fuels for cooking. Nationally, about 43.3 percent of households continue to use solid biomass as primary fuel for cooking.¹⁰⁸

4.2.1 Drivers of Domestic Consumption

In the 1980s, domestic concern over dwindling supplies of fuelwood and deforestation drove the government to seek alternatives for cooking fuel.¹⁰⁹ Initially, this led to kerosene—which could be used both as fuel for lighting (in oil lamps) and as fuel for cooking—being heavily subsidised and supplied through the public distribution system.¹¹⁰ The retail price of subsidised kerosene was almost a fourth of market prices, which facilitated a shift from biomass to kerosene as fuel for cooking in urban households.¹¹¹ However, the steep price discount resulted in the large-scale diversion of subsidised kerosene for adulteration with other refined petroleum products and for sale in the black market.¹¹² The introduction of packaged LPG as fuel for cooking was instrumental in displacing kerosene as cooking fuel, initially in urban households and eventually in rural households, and in reducing the extent of kerosene adulteration in petroleum products.

Concern for the health of women and children in households using biomass was another driver of LPG use. A large body of academic literature in the 1980s from within and outside India empirically demonstrated the negative impact of biomass burning in poor households. One study¹¹³

conducted in India found that conventional biomass fuels (i.e., firewood, dung, and crop wastes) emit more total suspended particles (TSP), benzo-a-pyrene, carbon monoxide, and polycyclic organic pollutants than fossil fuels.¹⁴ The study showed that women who spent three hours a day cooking with biomass are exposed to 700 micrograms of particulate matter per cubic metre, while the safety level is less than 75 micrograms. The women inhaled benzo-a-pyrene equivalent to smoking 400 cigarettes a day. The study also subjected 20 albino rats to cow-dung smoke inhalation and found that the rats soon developed chronic bronchitis, bronchiolitis, and emphysema. The conclusions of the study were reported to the Lok Sabha (or the lower house of Parliament). More recently, NFHS-5 concluded that there was a significant variation in the prevalence of medically treated tuberculosis (TB) according to the type of cooking fuel used by a household, ranging from a low of 179 persons per 100,000 residents in households using electricity, LPG, natural gas, and biogas, to a high of 490 persons per 100,000 residents in households using firewood, animal dung, straw, shrubs, and grass.¹⁵

Government subsidies also accelerated LPG adoption. Subsidies for LPG adoption were initiated in the late 1970s and 1980s because concerns over the safety of LPG use had limited LPG adoption even in urban households.¹⁶ However, the demonstrated safety of LPG use in households promoted the increased use of LPG in urban middle-class households. Urban middle- and high-income households appropriated most of the subsidies because of their capacity to invest in gas stoves, maintain them, and use LPG safely. Poor households could not afford the initial investment in gas stoves and they lacked the housing (stone- and cement-based) required to protect the stoves. Most importantly, they could not afford to pay for refills of the LPG canisters.

By the early 1990s, LPG subsidies to middle- and high-income urban households began to burden the government

exchequer.¹¹⁷ Since the 1990s, successive governments have tried to minimise and eliminate these subsidies but rolled back their efforts when faced with backlash from urban middle-class voters.¹¹⁸ More recently, the government shifted to the targeted delivery of subsidies exclusively to BPL households through direct benefit transfer (DBT), whereby a cash equivalent of the subsidy is directly transferred to the beneficiary's bank account.¹¹⁹

In the last decade (2011-12 to 2020-21), the overall adoption of LPG as primary cooking fuel grew by 6.84 percent annually, with an average of about 3.14 percent in urban households and 14.33 percent in rural households.¹²⁰ The low average for urban households signifies the near-saturation of LPG adoption but this figure is likely to grow with an increase in urbanisation. The double-digit growth of LPG adoption in rural households signifies improved access to LPG due to increased incomes, improved female literacy levels, and subsidies for LPG registrations.

Increased LPG use has increased India's overall energy use efficiency, thus reducing India's carbon intensity; it has also substantially reduced indoor pollution arising from biomass combustion, resulting in health benefits. The transition from traditional stoves, which burn biomass (fuelwood), to LPG has resulted in a reduction in indoor $PM_{2.5}$ levels,¹²¹ reducing respiratory illnesses, especially among women and infants.¹²² A household-level study in southern India showed that households that switched from biomass to LPG saw a 93 percent reduction in $PM_{2.5}$ concentration in the kitchen and a 78 percent reduction in mean personal $PM_{2.5}$ exposures over a two-month period.¹²³

The adoption of LPG has also contributed to increasing energy-use efficiency, which is one of India's commitments to the Paris Agreement. Between 1990 and 2019, India's GDP increased more than six-fold, while total final energy consumption increased only by a factor of 2.5 (i.e., GDP grew more than twice as fast as energy consumption).¹²⁴

This means that, during this period, India required less energy to produce an additional unit of economic output. India's CO₂ intensity in 2021 was also 28 percent lower than in 2005.¹²⁵

According to studies, the decline in the share of biomass in India's energy basket was responsible for 60 percent of the decline in energy intensity.¹²⁶ The switch from biomass, which has a very low conversion efficiency (5-10 percent), to high-efficiency LPG has been one of the key drivers of increased energy-use efficiency, enabling a growth in economic activity without a commensurate growth in energy consumption.

4.2.1.1 The Role of Policy

India's LPG journey is distinct from those of its South Asian neighbours. Rather than waiting for households to achieve income and socio-economic levels that make clean cooking fuels such as LPG affordable, access to such fuels was enabled through policy measures. As a result, despite a per capita GDP of just US\$2,410 in 2022, India has increased access to LPG to about 60 percent of households.¹²⁷ In Côte d'Ivoire in West Africa, for example, which has a comparable per capita GDP, only 32 percent households have access to clean cooking fuels.¹²⁸

The divergence in the per capita GDP and the share of households with access to clean cooking fuels in countries in South Asia is illustrative of how policy can compensate for the shortcomings of the market in order to provide equitable access to clean energy. Among South Asian countries, Maldives has the highest per capita GDP of US\$11,780 (as of 2022) and a 100 percent access to clean cooking fuels.¹²⁹ In Bhutan, which has the second highest per capita GDP in South Asia, at US\$3,560, 87 percent of households have access to clean cooking fuels.¹³⁰ However, Sri Lanka, with a comparable per capita GDP of US\$3,354, has only 33 percent households with

access to clean cooking fuels.¹³¹ Afghanistan, which has a per capita GDP ten times less than that of Sri Lanka, has a higher share of households with access to clean cooking fuels, at 35 percent. Despite having a higher per capita GDP than India, at US\$2,688,¹³² Bangladesh has the lowest share of households with access to clean cooking fuels among South Asian countries, at 27 percent.

The LPG subsidy in India, when assessed by its relative efficacy, welfare benefits, and cost effectiveness, does not necessarily amount to a net negative. In terms of efficacy, the subsidy reaches the intended poor demographic, with the DBT model minimising errors of inclusion and exclusion. Additionally, the welfare gains of providing energy access for cooking (increase of female literacy and engagement in productive activity; improvement in health, particularly respiratory health, of women and children in a household) are often much higher than the long-term costs involved in providing the subsidy.¹³³ The subsidy is structured in a way that it encourages the provision of service at the least cost, as LPG does not require elaborate infrastructure such as pipelines or transmission lines. The cost of laying gas pipelines and high-voltage electricity transmission lines is estimated to be about INR 60-70 million per kilometre.¹³⁴ This makes LPG subsidies and service provision more cost effective in remote rural areas compared to gas pipelines and electricity distribution infrastructure. Its cost-effectiveness means that the subsidy achieves social goals at the lowest programme cost while providing incentives to LPG distributors to serve the poor and rural populations.

The line of causality between economic growth and energy consumption runs both ways.¹³⁵ Thus, welfare benefits that accrue to poor households on account of higher energy consumption contribute to economic growth (i.e., the education and employment of women).¹³⁶ Energy subsidies and energy poverty are linked, with energy subsidies improving social well-being by mediating the effects of energy poverty.¹³⁷ There is empirical evidence that

eliminating the subsidy will push millions of households back to burning biomass.¹³⁸ Instead, innovation in energy subsidy to reduce leakage and abuse will combat energy poverty and ensure clean, sustainable, and affordable energy for all in line with the aims of SDG 7.

4.3 Non-Domestic and Bulk Consumption

4.3.1 Status

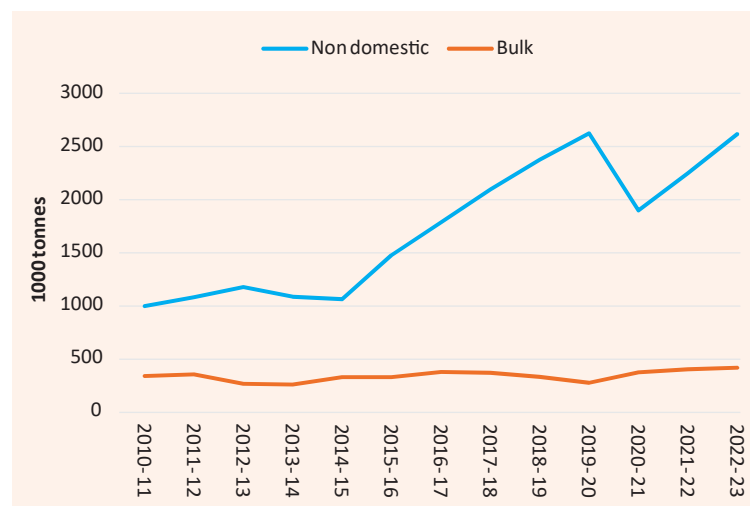
In India, LPG is perceived primarily as a household cooking fuel. However, LPG is widely used in the non-domestic service sectors (food and hospitality segments), and the bulk consumption of LPG supports a wide range of industrial processes and services that require a high degree of precision and flexibility in process temperatures, as well as a strong flame.¹³⁹ LPG is used in various industrial activities, including space, process and water heating, metal processing, drying, food production, petrochemical production, as well as powering industrial ovens, kilns, and furnaces.¹⁴⁰ It is valued by industry for its highly controllable temperatures, homogeneous content, low emission of pollutants (negligible NO_x [nitrogen oxides], SO_x [oxides of sulphur], and PM emissions), and easy availability. LPG has a higher calorific value and therefore burns 'hotter' than natural gas.¹⁴¹ LPG is also particularly useful in the manufacture of glass and ceramic products, which involve a number of chemical reactions.¹⁴² The use of a clean fuel also enhances product quality and reduces technical problems related to manufacturing activity. LPG is used for heating bitumen, repairing and laying roads, illuminating road signs, and floodlighting. Manufacturers of aerosol products also use pure field-grade LPG as a propellant for household products.¹⁴³

Chlorofluorocarbons (CFCs), which are the most common refrigerants, contribute to the depletion of the ozone layer.¹⁴⁴ Therefore, LPG, with a zero ozone depletion potential (ODP), is emerging as a credible replacement for

CFCs in industrial and household refrigeration.¹⁴⁵ Although various LPG classifications have refrigeration applications, isobutane is the most frequent in domestic fridges and freezers, while propane is common in commercial heat pumps, air conditioning, and refrigeration and freezer applications.¹⁴⁶ The cooling capacity of LPG is 10 percent higher than alternatives and its thermodynamic properties result in energy efficiency gains of 10-20 percent.¹⁴⁷ LPG also operates at slightly lower pressures than other main refrigerants while maintaining a similar volumetric refrigerating effect. Further, LPG does not form acids, thereby eliminating blocked capillaries.

Despite these benefits, LPG consumption by the service and industrial sectors accounts for less than 10 percent of total LPG consumption in India.¹⁴⁸ It is possible that strong policy support for LPG use as a cooking fuel in households, driven by political and environmental goals, marginalised LPG consumption in other segments.¹⁴⁹ Promoting the industrial use of LPG can also serve India's economic and environmental goals. In addition, the use of LPG in rural small-scale industries will create additional demand that will incentivise dealers to serve rural areas.

FIG. 7: NON-DOMESTIC AND BULK CONSUMPTION OF LPG



Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India¹⁵⁰

4.3.2 Drivers of Non-Domestic and Bulk Consumption

Non-domestic and bulk consumption of LPG increased from 2.63 MT in 2021-22 to 3.015 MT in 2022-23.¹⁵¹ As noted earlier, non-domestic consumption grew by over 16 percent in 2022-23 compared to the previous year, while bulk consumption grew by about 4.6 percent in the same period.¹⁵² The growth in non-domestic consumption can be attributed to the end of the COVID-19 pandemic and the growth in demand for hospitality and tourism sector services. Double-digit growth may not be sustained in the longer term, but overall non-domestic consumption of LPG is likely to continue growing in comparison to other consumption segments. The bulk consumption of LPG is growing slower in comparison to non-domestic consumption due to slower post-pandemic recovery in the industrial segment as well as the availability of substitutes such as natural gas.

One of the key factors inhibiting the widespread adoption of LPG by industries is the availability of natural gas. In all three sectors (household, transport, and industries), PNG at regulated prices is a less expensive option than LPG. Policy support to increase natural-gas consumption to about 15 percent of India's primary energy basket by 2030 has increased investment in transport infrastructure for natural gas, such as pipelines.¹⁵³ In addition, accommodative pricing incentivises the domestic production of natural gas from complex and difficult offshore fields,¹⁵⁴ which will increase the availability of domestically produced natural gas at regulated prices.

Historically, natural gas has traded at a discount to oil and oil products. However, the current volatility in imported natural gas prices creates the opportunity for substituting LPG for natural gas to contain costs.¹⁵⁵ Refineries can increase the internal consumption of propane as process fuel to reduce the need for expensive natural gas. Industries can also substitute LPG for natural gas, although

this depends on regulatory restrictions. Policy measures can mandate the use of LPG in off-gas grid industrial clusters, where the use of LPG will contribute to energy efficiency and the reduction of emissions.

In China, several industrial plants used LPG as their primary fuel source for local power generation and process fuel.¹⁵⁶ As natural gas supply expanded, many of these facilities were linked to gas distribution networks but retained their LPG storage tanks and the ability to switch back. As in the case of India, most of China's state-owned industrial plants are connected to domestic gas supply, which is subject to price controls, while most private-sector gas users have to buy imported re-gasified LNG at market-determined international prices.¹⁵⁷ Private-sector gas users are thus exposed to the price volatility in LNG-based natural-gas trade. Therefore, every time the price of globally traded natural gas increased, LPG became competitive compared to imported LNG, which this led to "reverse switching" from gas to LPG and contributed to China's LPG import demand. As per current regulations, fuel switching is not permitted in China,¹⁵⁸ once an industrial user is connected to the natural gas grid, LPG has to be eliminated from the system.

In India, LPG may be promoted as a source of power generation and process heat in industries that are not connected to the gas grid. The decentralised nature of LPG as a fuel can facilitate the industrialisation of rural areas, with industries such as glass and industrial painting benefiting from LPG use. For industries that are connected to the natural gas grid, the policy provision to switch between LPG and natural gas will sustain the momentum in consumption growth as well as alleviate the cost pressure on industries by reducing exposure to volatility in imported natural gas prices.

4.4 LPG Consumption in the Transportation Segment

4.4.1 Status

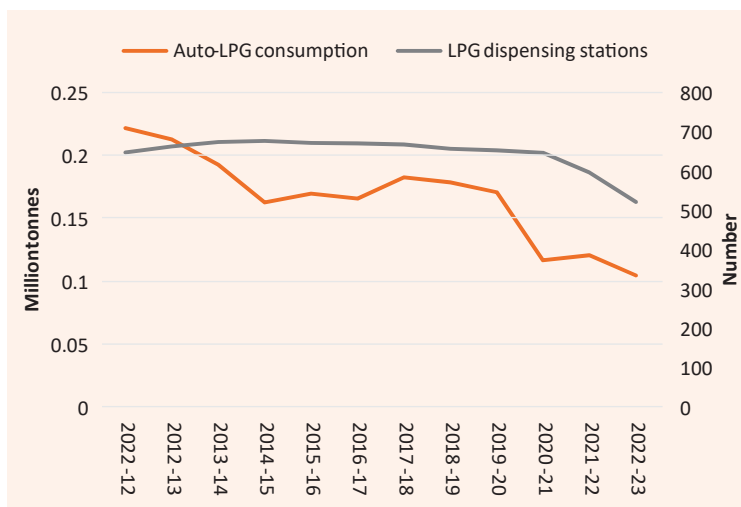
LPG, also known as “autogas”, is the most common unblended alternative vehicle fuel in use.¹⁵⁹ The share of autogas in total automotive fuel consumption ranges from a mere 0.04 percent in the US to almost 28 percent in Ukraine. Five countries—i.e., Russia, Turkey, Korea, Poland, and Ukraine—together accounted for 50 percent of global autogas consumption in 2021, whereas 25 countries accounted for 80 percent of total consumption.¹⁶⁰ In India, out of over 348 million registered vehicles, just over two million petrol-LPG dual-use vehicles were registered, which accounted for about 0.5 percent of total registered vehicles, whereas, at just over 131,125 vehicles, LPG vehicles accounted for less than 0.04 percent of total registered vehicles in 2023.¹⁶¹ The differences among countries in the share of LPG use as transportation fuel correspond to differences in government policies. In many former Soviet Union countries, subsidised LPG is a primary fuel in personal vehicles, which has increased vehicle ownership despite relatively low household incomes.¹⁶²

4.4.2 Drivers of Transport Consumption

In India, the amendment of Section 52 of the Motor Vehicles Act, 1988, followed by the introduction of LPG Regulation of Use in Motor Vehicles order¹⁶³ and the introduction of Central Motor Vehicles (Amendment) Rules in 2001 permitted the use of LPG as an auto fuel.¹⁶⁴ The order, issued by the Ministry of Petroleum & Natural Gas (MOPNG), specified that Auto LPG Dispensing Station (ALDS) dealers, which will be appointed by a government oil company or a parallel marketeer,¹⁶⁵ is required to obtain the necessary licence from the Chief Controller of Explosives for meeting safety norms in respect of the dispensing facilities under the Static and Mobile Pressure Vessels (Unfired) Rules, 1981.¹⁶⁶

The order also stated that auto LPG would be sold only by an authorised ALDS dealer.¹⁶⁷ Every ALDS dealer is required to procure or purchase auto LPG either from a government oil company or a parallel marketeer and no person shall purchase or use auto LPG in a motor vehicle or vehicle unless the motor vehicle is permanently fitted with an auto LPG tank and includes a conversion kit as approved by authorities/testing agencies, as notified in the Central Motor Vehicles Rules, 2001.¹⁶⁸ Among other things, the dealer has to take steps to ensure the adequate availability of auto LPG stocks at the dispensing station at all times.¹⁶⁹ The pricing of auto LPG is market driven, but the government maintains overall control over the pricing of non-domestic LPG. As domestic production of LPG is inadequate to cover demand, auto LPG demand is met through imports. The unauthorised diversion of subsidised domestic LPG cylinders for non-domestic use, such as in motor vehicles, is not permitted.¹⁷⁰ The burden of regulatory controls and interventions in auto LPG dispensation is among the primary reasons for the limited growth in the segment.

In India, LPG vehicles are cheaper than CNG and petrol vehicles.¹⁷¹ Using a petrol vehicle with a mileage of 12 km/l (kilometre/litre) for 50 km a day is likely to cost twice as much as using an LPG vehicle at current prices.¹⁷² The conversion kit for LPG is less expensive than those for CNG and LPG vehicles and can cover three times the distance for the same volume of fuel compared to CNG vehicles. The maintenance of LPG vehicles is relatively easier than CNG vehicles. Further, LPG vehicles and dispensing stations are relatively safer, as LPG is stored at 10-12 times the atmospheric pressure, while CNG is stored at around 200-250 times the atmospheric pressure.¹⁷³

FIG. 8: AUTO LPG CONSUMPTION AND DISPENSING STATIONS

Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India¹⁷⁴

Its high octane number favours the use of LPG as a transport fuel. An octane rating is a standard measure of a fuel's ability to withstand compression in an internal combustion engine without detonating.¹⁷⁵ The higher the octane number, the more compression the fuel can withstand.¹⁷⁶ The use of fuel with a lower-than-prescribed octane number¹⁷⁷ may cause the air-fuel mixture to prematurely self-ignite before the ignition system sparks, with a characteristic “knocking” or “pinging” sound,¹⁷⁸ which may damage engine components due to higher pressures. In a spark ignition engine, the air-fuel mixture is heated during the compression cycle¹⁷⁹ and is triggered by the spark plug¹⁸⁰ to burn rapidly. Higher compression ratios enable the engine to extract more mechanical energy from a given mass of air-fuel mixture,¹⁸¹ leading to higher thermal efficiency. High compression ratios are typically used with LPG as with petrol, though the octane number of LPG is higher than that of petrol. In India, petrol brands are required to have a minimum octane rating of 91.¹⁸² The octane number for propane is 112 and of butane is 94; when blended, these result in LPG having a higher octane number than petrol,¹⁸³ which can offer performance and efficiency advantages.

More advanced ignition timing and the higher compression ratio of LPG engines make them less susceptible to pre-ignition or knock compared to standard petrol engines.¹⁸⁴ In spark ignition engines, port fuel injection and direct injection are the most relevant LPG-fuelling technologies. With LPG as fuel, port fuel injection systems¹⁸⁵ individual injectors can be controlled to deliver more or less fuel to specific cylinders based on air flow differences among the cylinders. This provides tighter air-to-fuel ratio control¹⁸⁶ in the engine and more efficient three-way catalytic conversion, which reduces the emission of harmful pollutants like hydrocarbons (HCs), NO_x, NH₃ (ammonia), and PM.¹⁸⁷

LPG has an inherent advantage over petrol in some engines with respect to PM formation.¹⁸⁸ The higher volatility of LPG promotes mixing within the combustion chamber, providing a less stratified air and fuel mixture and reducing locally fuel-rich regions that are associated with soot (CO) production.¹⁸⁹ The lower carbon intensity of LPG compared to petrol reduces its propensity to produce soot and limits CO₂ production.¹⁹⁰ Furthermore, the direct injection of LPG in liquid state maintains and can exceed the efficiency advantages of advanced petrol engines.

India has dual-use LPG vehicles that can switch between petrol-and-LPG and LPG-only models.¹⁹¹ Dual-fuel vehicles require the installation of additional fuel injectors for LPG, whereas in LPG-only vehicles, petrol injectors are replaced with LPG injectors.¹⁹² This is necessary due to the lower energy per volume of LPG and the lubricity differences between LPG and petrol, which necessitate different injector designs. Regardless of the type of LPG in use in vehicles, a dedicated injector per cylinder can provide more refined control of air-to-fuel ratio on a per-cylinder basis compared to single-point injection systems.¹⁹³

Despite these benefits, LPG consumption in transport is falling in India. Inadequate LPG-dispensing stations reduce the appeal of LPG as a transportation fuel. The easy

availability of petrol and diesel also contribute to the limited adoption of LPG as automobile fuel.

In 2011-12, auto LPG consumption was 233,000 tonnes, or just 1.4 percent of total LPG consumption. In 2022-23, auto LPG consumption was 106,000 tonnes, which was less than 0.3 percent of total LPG consumption.¹⁹⁴ The number of ALDSs grew from 652 in 2011-12 to 681 in 2014-15 but has since been falling continuously; as of 2022-23, there were 526 ALDSs.¹⁹⁵

In India, supply-side incentives for LPG are focused on its use as a cooking fuel rather than as a transportation fuel. As LPG is a relatively cleaner fossil fuel compared to petrol and diesel, promoting its use in the transportation sector will contribute to reduced pollution at the local and national levels. Reducing the transaction costs in accessing auto LPG and lightening the regulatory burden in using auto LPG are among the low-hanging policy initiatives that can boost its use.

5

LPG Consumption: Long-Term Challenges

5.1 Subsidising Energy Access

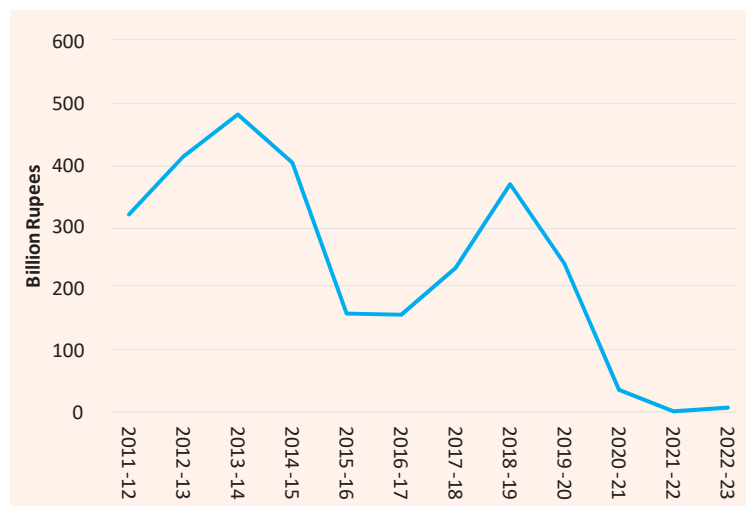
India is pursuing energy access policies at low levels of economic and social development. Most other countries initiated energy access programmes (particularly electricity and cooking fuel needs) with much higher per-capita incomes. For example, when the rural electrification administration was set up in the US in 1935,¹⁹⁶ the GDP per capita was US\$9,644 (2017 US\$),¹⁹⁷ which is four times the GDP per-person of India in 2022.¹⁹⁸ When South Africa launched its electricity access programme, in the late 1990s and early 2000s, its per-capita income was more than twice India's current per-capita income.

India's industrialisation and urbanisation rates are slower than those of other countries that have implemented energy access programmes.¹⁹⁹ Therefore, in the medium term, LPG access and use in India is critically dependent on subsidies rather than on urbanisation or higher incomes from industrialisation. China, which shared some of India's challenges in the early stages of its development, supplemented its energy access programmes with initiatives for the industrialisation, modernisation, and urbanisation

of rural areas. This resulted in increased rural incomes, which made cleaner cooking fuels affordable for rural households.²⁰⁰

The causality between low household incomes and energy access is bidirectional;²⁰¹ therefore, the low demand for energy sources such as LPG is both the cause and consequence of low incomes. In the longer term, access to LPG can facilitate reduction in poverty (i.e., increase in incomes)²⁰² by reducing transaction costs (time and labour) in the collection and use of firewood for cooking.²⁰³ This is especially true for women, who are the primary gatherers and users of firewood in poor households in India. The reduction in transaction costs in accessing and using fuel for cooking can, in theory, increase women’s access to education and participation in remunerative economic activity.²⁰⁴ This, in turn, would increase household income, thus making LPG affordable.²⁰⁵

FIG. 9: LPG SUBSIDY TRENDS



Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India²⁰⁶

However, in the short term, poverty can limit LPG demand, as illustrated by the data on refill numbers from Ujjwala beneficiaries. The average per-capita private final consumption expenditure (PFCE) in India was estimated at

INR 104,811 in 2022-23.²⁰⁷ This puts the expenditure on one 14.2 kg LPG cylinder, which was priced at INR 1,100-1,350 across states in August 2023, at about 10 percent of monthly consumption expenditure per person.²⁰⁸ Households that have to spend more than 10 percent of their income to access modern energy services are considered to be experiencing energy poverty.²⁰⁹ By this definition, LPG purchase, coupled with the purchase of electricity for lighting and petrol for two wheelers, could push single-income households into energy poverty.²¹⁰ Energy poverty is not just a private problem. Households that cannot afford to purchase LPG canister refills will “switch back” to burning biomass. The smoke from biomass burning will increase indoor and outdoor pollution, creating a public problem with huge social costs.

5.2 Improving the Affordability of LPG

5.2.1 Background

According to standard consumer theory, households with a fixed budget maximise utility in purchasing decisions on household fuels. The decision is a function of incomes, prices, and, to some extent, cultural preferences. The energy ladder theory derived from this concept anticipated a shift in households from traditional biomass and solid fuels to kerosene and LPG in response to higher incomes.²¹¹ Till the mid-2010s, the energy ladder theory dominated the understanding of household energy choices. However, studies in the late 2010s from most developing countries such as Mexico, Brazil, Nicaragua, South Africa, Vietnam, Guatemala, Ghana, Nepal, and India have shown that rural households do not “switch” fuels but follow a multiple fuel or “fuel stacking” strategy, by which new cooking technologies and fuels are added but even the most traditional systems are rarely abandoned.²¹² This applies even to households in the highest expenditure brackets in rural areas. There is also evidence of a “switching back” to traditional fuels such as biomass, mainly due to

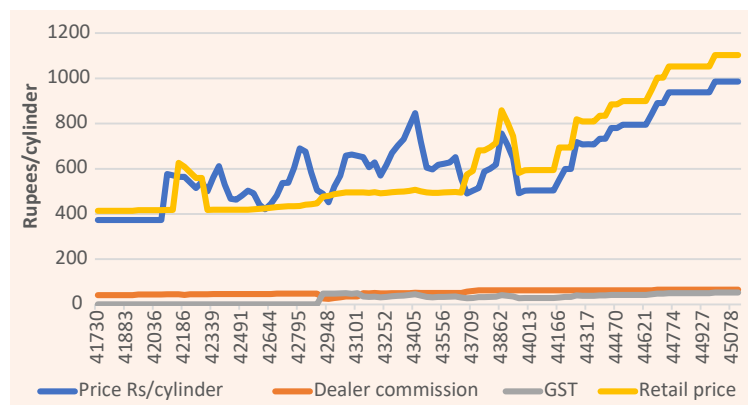
increases in the price of modern fuels such as LPG or falling incomes.²¹³

Recent data from India demonstrates that both fuel stacking and “switching back” are common in poor households.²¹⁴ In 2022 and 2023, responses were recorded for questions raised in Parliament and through the provisions of the Right to Information (RTI) Act on the use of subsidised LPG under the Ujjwala programme. According to an RTI response from public-sector LPG retailers, out of 95.8 million recipients of LPG cylinders under the Ujjwala programme, 18.4 million did not return for a refill LPG cylinder, and 15 million obtained only one refill LPG cylinder in 2022-23.²¹⁵ According to government response to a question raised in Parliament in early 2023, the average number of subsidised LPG refills obtained by Ujjwala beneficiaries in a year increased from three in 2019-20 to 4.4 in 2020-21 but fell to 3.7 in 2022-23.²¹⁶ Information conveyed in the Rajya Sabha in December 2023 puts the consumption of subsidised LPG cylinders at a much lower level of 2.8 cylinders per household per year. The method used to arrive at these figures is not clear; therefore, in the general procurement of a tradeable subsidised good (such as LPG), the use and actual consumption of LPG by poor households may be lower. In urban households, an average of nine 14.2 kg LPG canisters is estimated to be used per year.²¹⁷ The limited ability of poor households to use LPG as the primary fuel for cooking, notwithstanding initial subsidies, raises the question of LPG affordability for poor households as well as the challenge of affordability of LPG subsidies for the government.

Even at a subsidised price of INR 603 for a 14.2 kg canister in 2023, LPG remained unaffordable for many poor households in India. Additional reasons for the low consumption of subsidised LPG by the poor include limited cooking time for short periods once or twice a day and the availability of biomass-based fuels at low or no cost (except the opportunity cost of female labour).

Smaller canisters may improve the adoption and use of LPG in rural areas. However, the introduction of 5 kg LPG canisters by public-sector oil marketing companies in the early 2010s did not receive encouraging responses. There are limited dealers and retail outlets providing 5 kg “free trade” LPG canisters. Additionally, the price of the 5 kg canister is relatively high for a typical single-income poor household. The small canisters are primarily targeted at young migrant urban populations who lack a proof of address and not the poor in rural areas. If the 5 kg canisters are sold in rural markets at reasonable (non-subsidised) prices, it is likely to be adopted in rural kitchens. Landless agricultural labourers are often paid weekly wages, which limits purchases to small volumes. In this context, small canisters of LPG can prove to be more affordable. Applications of LPG in lighting and power generation can also be introduced in rural areas, which may initiate investment in small-scale industries and create demand for LPG. LPG can also serve as a robust and affordable backup source for villages with off-grid RE solutions. As LPG supply does not require specialised infrastructure, it can be replaced with renewable LPG (rLPG) as it becomes affordable and available. This will require focused policy for the promotion of small LPG canisters with the goal of improving access to clean, unsubsidised cooking fuels, reducing carbon emissions, and preparing for a decentralised green energy future.

FIG. 10: RETAIL PRICE OF LPG IN DELHI (2014-23)



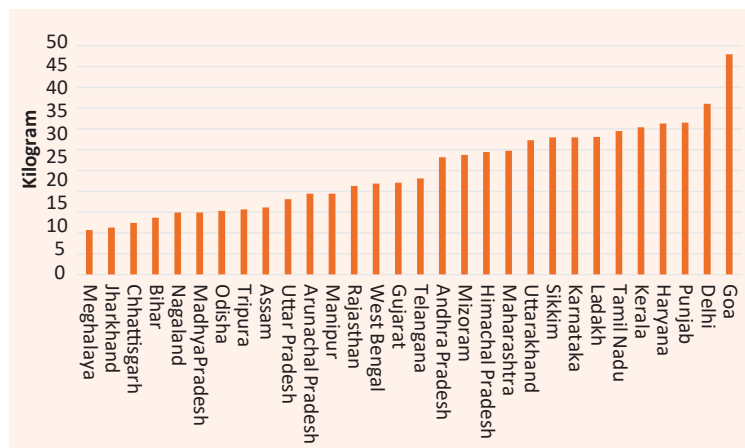
Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India²¹⁸

5.2.2 LPG Sales and Economic Activity

State-level differences in LPG sales, state-level economic value addition, and dealer density (number of dealers per 1000 population) are correlated.

In 2014-15, the per-capita sale of LPG was lowest in Meghalaya, at 5.4 kg, followed by Jharkhand, which had a per-capita LPG sale of 5.9 kg.²¹⁹ Meghalaya had the lowest per-capita LPG sales despite not having the lowest per-person net state domestic product (SDP); in 2014-15, the per-person net SDP²²⁰ of Meghalaya was INR 39,503 which was higher than that of Bihar (INR 16,804) and Uttar Pradesh (UP) (INR 20,057).²²¹ Delhi had the highest per-capita LPG sales in 2014-15, at 43.7 kg—eight times that of Meghalaya—despite a per-capita net SDP that was only three times larger, at INR 129,809.²²²

FIG. 11: PER-PERSON LPG SALES IN SELECT STATES

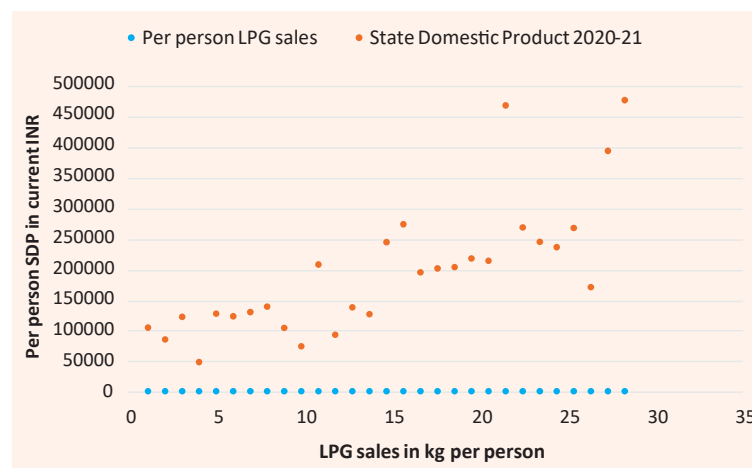


Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India²²³

The per-capita LPG sales in Meghalaya continued to remain the lowest in 2022-23, at 9.3 kg, followed by Jharkhand, with per-capita LPG sale of 9.9 kg.²²⁴ The per-capita SDP of Meghalaya had increased by over 53 percent in 2022-23, to INR 60,606, whereas that of Jharkhand increased by over 32 percent to INR 55,126.²²⁵

One of the probable reasons for low per-capita sale of LPG in Meghalaya despite its economic growth is the relatively low density of its dealer network. Where Jharkhand has over seven LPG dealers per 1,000 square kilometres (km²), there are just two dealers per 1,000 km² in Meghalaya.²²⁶ UP has the largest dealer network, with 4,142 outlets, but per-capita LPG sales in UP amounted to only 16 kg, which is lower than the all-India average per-capita LPG sale of 20.5 kg in 2022-23.²²⁷ UP and Punjab had roughly 17 dealers per 1,000 km², but per-capita LPG sale was 32.6 kg in Punjab, more than twice that in UP, suggesting that the increase in the number of dealers alone cannot increase the consumption of LPG without an increase in incomes. The per-capita SDP of UP had doubled to INR 40,432 in 2022-23 but was still lower than that of Meghalaya.²²⁸ Goa had the highest per-capita LPG sale of 47.4 kg, while the per-capita LPG sales in Delhi fell to 36.7 kg in 2022-23, primarily because of the increase in access to PNG in and around Delhi.²²⁹ Both Delhi and Goa are almost 100-percent urbanised.

FIG. 12: LPG CONSUMPTION AND STATE DOMESTIC PRODUCT (2020-21)



Source: Petroleum Planning & Analysis Cell, Ministry of Oil & Natural Gas, Government of India²³⁰

A comparison of LPG sales and incomes in select states in India shows a strong correlation between per-capita LPG

sales in a particular state and its per-capita GDP, which is a proxy for per-capita incomes. If left to market forces, LPG adoption will increase only when household incomes increase, but this would require postponing action on local pollution, climate change, and the health concerns of women and children in poor households from biomass burning.

A 2023 study on the causes of pollution in India found that, out of annual emissions of 5.2 MT of $PM_{2.5}$, which is the leading cause of pollution, about 82 percent comes from biomass burning and industrial activities.²³¹ Biomass burning by households for cooking and heating in winter in northern India accounts for over 38 percent of total $PM_{2.5}$ emissions. In Delhi, which is among the top ten most polluted cities²³² in the world, the average $PM_{2.5}$ level on 27 November 2023 was 380, which is rated as “very poor” air quality and much higher than the satisfactory level of air quality at 100.²³³ The provision of financial support for LPG use by poor households will not only enhance energy access and use but also reduce $PM_{2.5}$ emissions. While subsidies are important for increasing initial access to LPG and consequently to reduce local pollution, reducing the size of LPG canisters can also increase the affordability of unsubsidised LPG refill canisters.

5.2.3 Sustainability of Subsidies

Until the late 2010s, subsidies for LPG were largely appropriated by relatively affluent urban households, which consumed a large share of LPG, and any suggestion of LPG subsidy reduction was mobilised for protests against the government in power.²³⁴ This changed in the late 2010s, when measures for systematic reduction of LPG subsidies were initiated.²³⁵ Budgetary limits to fiscal subsidies, initiatives for DBT of subsidy benefits to targeted consumers, along with the fall in the international price of oil and LPG, facilitated a reduction of LPG subsidies. However, the increase in the international price of LPG

since 2021 and the fact that subsidies for LPG access do not often translate into use by poor households has resulted in revived interest in the question of LPG affordability.²³⁶

Though the international price of LPG increased after the end of pandemic-related lockdowns, LPG prices have demonstrated a declining trend in the last six years. Between FY 2013-14 and FY 2019-20, the international price of LPG fell by 48 percent, and between 2013-14 and 2020-21, it fell by about 31 percent.²³⁷ The international price of LPG is significant, with the share of LPG imports in total LPG consumption increasing from about 37 percent in 2011-12 to over 64 percent in 2022-23.²³⁸ Despite the fall in international prices of LPG, the retail price of LPG has increased because of the reduction in subsidies.

Between 2013-14 and 2015-16, government subsidies under the burden-sharing programme fell by over 64 percent, from INR 746.1 billion to INR 263 billion, and the oil-company share of the subsidy burden fell by over 98 percent, from INR 691.28 billion to about INR 12.68 billion.²³⁹ DBT payout fell by over 86 percent, from INR 275.7 billion in 2015-16 to about INR 36.58 billion in 2020-21.²⁴⁰ DBT payments peaked at INR 435/cylinder in November 2018, after which it fell to about INR 140/cylinder in July 2019.²⁴¹ DBT payments increased from about INR 260 billion in 2015-16 to a peak of over INR 315 billion in 2018-19 but since fell to about INR 8.5 billion in 2022-23.²⁴² The fall in subsidies may partially explain the marginal reduction in household LPG consumption in 2022-23. The contradiction between the need to make LPG affordable for poor households through subsidies and the difficulty in making budgetary provisions for LPG subsidies highlights the need for international financial assistance for LPG adoption in developing countries.

As pointed out in a 2023 study carried out on behalf of the G20 countries, LPG qualifies for carbon credits.²⁴³

Carbon credits are a market-based carbon offsetting solution. This slightly controversial environmental initiative is popular among businesses.²⁴⁴ Carbon credits for efficient biomass-burning cookstoves that aim to replace the traditional three-stone open stoves common in India are the fastest growing type of voluntary emission reductions, representing 15 percent of total projects in the market.²⁴⁵ However, efficient cookstoves are estimated to be over-credited by an average of 920 percent according to a 2004 study.²⁴⁶ Carbon credits for LPG cookstoves may overcome the problem of accurately measuring carbon reductions through efficient biomass cookstoves. The G20 policy brief mentioned earlier offers clinical calculations of carbon reduction per meal when LPG stoves replace biomass stoves. The upcoming COP29, scheduled in November 2024, opens up an opportunity for developing countries such as India, which have a proven record of improving access to clean modern sources of cooking fuels to seek international financial assistance, including but not limited to carbon credits for LPG use. The additional benefits that accrue mostly to women and children in poor households make LPG a more attractive option.

5.3 Environmental and Energy Security Concerns

Increasing import dependency for LPG can magnify the emissions challenge and undermine the goal of energy security. In India, these challenges embedded in LPG can compromise the achievement of SDG 7, which aims to increase access to clean cooking fuels to all.²⁴⁷ However, it is necessary to place these issues in the context of time and space.

5.3.1 Environmental Concerns

LPG is essentially derived from fossil fuels. As with most fossil fuels, the scope 1 emissions (direct GHG emissions that occur from sources that are controlled or owned by the producer of LPG)²⁴⁸ and scope 2 emissions of LPG

(indirect GHG emissions associated with the purchase of imported energy and external energy inputs used by the producer of LPG) are high.²⁴⁹ The scope 3 emissions of LPG (emissions across the value chain, starting with the procurement of raw materials, through manufacturing, distribution, and finally the customer's use of the end product) are relatively low compared to petrol and diesel.²⁵⁰ Scope 3 emissions comprise the largest share of emissions for oil and gas producers and are typically the hardest for producers to accurately quantify and track. Most of the public-sector producers and importers of LPG (e.g., ONGC, IOC, HPCL, BPCL, and others) have committed to phase out scope 1 and 2 emissions by 2040-50.²⁵¹ This will substantially improve the environmental credentials of LPG in the medium term, but it may limit the import of LPG from sources that have not committed to phase out scope 1 and 2 emissions. Until then, LPG will remain an attractive lower-carbon cooking fuel that can bridge the transition to a low-carbon future. Scaling up LPG use does not involve investment in capital-intensive infrastructure such as pipelines, which will be redundant in the zero-carbon future. Further, replacing LPG with rLPG is straightforward with changes limited to the supply end.

5.3.2 Energy Security Concerns

Energy security may be evaluated in the context of the nation and in the context of the household or the individual. Imported energy has been framed as a threat to the nation's energy security. As over 40 percent of domestic LPG consumption in India is imported, it could be argued that LPG adds to India's energy insecurity. However, in terms of security of supply, LPG is among the most secure conventional forms of energy. As an inevitable byproduct of the oil refining and natural gas extraction processes, LPG will exist as long as society requires these two processes. LPG is freely traded around the world and scores twice as highly as both petrol and diesel on the Organisation of Economic Cooperation and

Development's (OECD) Trade Openness Index.²⁵² LPG is also less susceptible to political instability due to its dual-source origins and the variety of available transportation options, including ships, trains, boats, and trucks. Unlike natural gas and crude oil, which are exposed to high price volatility, the price of LPG is relatively stable and predictable. At the individual or household level, energy security increases with access to fuels such as LPG; when LPG is made affordable, the energy security of the households increases further. Overall, the perceived energy security compromise in importing LPG at the national level is offset by the increase in energy security and health benefits at the household level.

6

Conclusions

In the next two decades, India needs to address the energy trilemma of increasing the availability of affordable energy, increasing the sustainability of energy use by reducing GHG emissions, and ensuring energy security at the individual and national levels. Continued promotion of LPG as a primary fuel for cooking as well as a fuel to meet a wide range of industrial and transportation needs can assist India in successfully navigating the energy trilemma. LPG is not a GHG and is a clean cooking fuel. Additionally, even when imported, LPG is a secure source of energy supply, with a relatively low-price volatility.

In the last four decades, the promotion of LPG use in households as a cooking fuel through government policy initiatives and price incentives has displaced the use of biomass in most urban households and in a significant share of rural households in India. This has reduced deforestation and indoor air pollution, in turn bringing down the incidence of respiratory illness in women and children, reducing the time involved in fuel collection and cooking, and increasing the time available for education and remunerative economic activity for women. No other fuel has contributed to the inclusive development and emancipation of marginalised women as much as LPG. However, in order to accelerate progress in this direction, continued assistance in the form of subsidies will be

necessary. The private sector needs to play a more active role to ensure the widespread availability of LPG in various sizes to suit the needs of households in terms of volume and price, which can increase LPG adoption even in the absence of subsidies.

The upcoming COP29 provides a unique opportunity to introduce LPG as a clean fuel and initiate the prospect of using carbon-credit assistance to fast-track the use of LPG in poor households in India and other parts of the developing world.

The use of LPG in industries and in transportation have been inhibited partly by the overwhelming emphasis on household LPG use and partly by the policy support offered to natural gas in India. LPG can offer the same environmental benefits as natural gas, with the added advantage of substantially lower transportation and storage costs. To increase low-carbon energy choices available to industries and transportation during the energy transition, the regulatory burdens on the use of LPG may be eased without compromising on safety. A greater role for the private sector in sourcing and distributing LPG may facilitate adoption by the transport and industry segments. This may also open up the co-benefit of greater LPG access to domestic and non-domestic consumers who do not require subsidies.

7

Recommendations

- 7.1 LPG is a clean bridge fuel that can complement the role of natural gas in reducing local pollution, lowering carbon emissions, increasing access to clean energy, and paving the way for complete decarbonisation in India. As in the case of natural gas, there is a need to set a clear target for increasing the share of LPG in India's commercial energy basket, and ways and means to achieve the target must be identified.
- 7.2 In the short term, subsidies for the domestic consumption of LPG should be continued through the DBT mechanism. In the longer term, dedicated effort should be made to secure international financial assistance to increase LPG adoption, and continued use must be pursued. The upcoming COP29 creates the opportunity for developing countries with an energy access deficit to secure carbon credits for LPG to meet SDG 7 targets by 2030 and reduce local and global pollution.
- 7.3 Given the problem of affordability of refills of large LPG canisters, the 5 kg LPG canisters that primarily target migrant urban populations could be promoted for adoption by poor rural households. This will increase the use of LPG and reduce the burden of subsidies for LPG use.

- 7.4 Certain industrial segments where LPG offers significant advantages in terms of emission reduction and process quality and efficiency may be mandated to use LPG as fuel, especially if they are not connected to the natural gas grid.
- 7.5 Easing of regulatory burdens on the use of LPG without compromising on safety will create a greater role for the private sector in sourcing and distributing LPG. This will increase the use of LPG in the transport and industry segments, with the co-benefit of reducing local pollution, reducing carbon emissions, and improving the access and availability of LPG to rural households.

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