India's Natural Gas Future Amid Changing Global Energy Dynamics

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Working Paper | August 2021

Abstract

Deep decarbonisation and diversification of the energy mix are priorities to combat increasing emissions and climate change in India. Becoming a natural gas-based economy by increasing its share to 15 per cent in the primary energy mix by 2030 is important to India's energy strategy. Historically, India and other countries have faced high gas prices. High prices and shortages in domestic gas supply have dampened the pace of gas infrastructure addition in the country and necessitate the formulation of a priority sector allocation policy. With the discovery of shale gas reserves in the US, there has been an observable global shift from a high to low gas price regime in the last few years; this is likely to continue in the long term. In this context, our study aims at answering the following research questions: (i) How will natural gas penetration evolve in India in high versus low gas price regimes? (ii) What would be the implication of removing the gas allocation regime? (iii) Would a high penetration of natural gas impede India's progress towards becoming a low-carbon

economy? and (iv) What are the monetary and non-monetary benefits of high gas penetration in India? We answer these questions through the application of the Global Change Assessment Model (GCAM, CEEW version). We explore the high gas price, low gas price, uniform pricing policy, and decarbonisation scenarios in the study. **Based on the analysis, we argue that the optimal long-term (by 2050) fuel share target for natural gas in the Indian economy is around 18 per cent, with reference to the adopted carbon budget to stay on 2 °C pathway.** This would ensure that India can reap the benefits of low natural gas prices without locking itself down with potentially stranded assets and staying on low carbon pathway.

1. Background and motivation

India, an important constituent of the global energy market (Sokołowski 2019), is the third-largest consumer of primary energy across the globe, with a growth rate of 5.2 per cent over the last decade (BP Statistics 2020). An expanding economy, rapid urbanisation, and a growing population are fundamental drivers of India's energy demand, pushing the nation to become one of the most significant energy markets by 2040 (PIB 2019). However, India's primary energy mix remains coal-dominated, which has been an impediment to the deep decarbonisation objectives of the country. The government has already recognised this issue and has adopted a multipronged approach to promote diversification of the primary energy mix with fewer carbon-emitting energy sources (IEA 2020). Indeed, India aims to become a natural gas-based economy by increasing its share to 15 per cent of the primary energy mix by 2030 (PIB 2020). But the share of natural gas in India's energy basket has been increasing at a much slower rate than anticipated, from 5.6 per cent in 2012–13 (MOSPI 2014) to 6.2 per cent in 2018–19 (MOSPI 2020), despite a 6 per cent increase in its consumption during the same period (PPAC 2020). With a steady decline in domestic production because of limited availability of gas that can be extracted economically (under current market conditions) (Ratner 2017), consumption growth has been satisfied through liquified natural gas (LNG) imports whose share in the country's natural gas consumption crossed 50 per cent in 2019 (EIA 2020).

India's natural gas market is mired in three specific challenges: a lack of pipeline infrastructure to transfer natural gas across (Corbeau, Hasan and Dsouza 2018) and to major demand centres, while unlocking the latent demand; the mandated domestic gas allocation policy for priority sectors; and the regulated wellhead prices of domestic gas production.

The gas allocation policy classifies consumer sectors in two tiers. Tier one includes priority sectors such as the city gas distribution (CGD) sector for piped natural gas (PNG, domestic) and compressed natural gas (CNG, transport), fertiliser, power, LPG, etc. which receive the larger share of cheaper domestic gas. In contrast, tier two sectors have to rely on expensive LNG. The prioritisation is based on either the price-sensitive nature of consumers or because this fuel has been recommended as a solution to a long-term problem. For instance, fertiliser production is a priority considering the sensitivity of the agriculture sector, whereas the CGD sector is included as a consequence of a Supreme Court ruling to curb increasing air pollution in cities (Corbeau, Hasan, and Dsouza 2018; PRS 2013).

In addition, as opposed to market-driven discovery, the gas market in India is governed by a controlled pricing mechanism. Currently, there are four major gas pricing regimes in the country: (i) The Nomination regime (administered pricing mechanism or APM); (ii) The Discovered Field regime (Pre-New Exploration Licensing Policy regime or Pre-NELP); (iii) The New Exploration Licensing Policy (NELP); and (iv) The Hydrocarbon Exploration and Licensing Policy (HELP) (GoI 2014; Sen 2015).

Multi-billion USD planned investments towards establishing 'one nation one gas grid' indicate the government's commitment to building a gas-based economy (MOPNG 2020). Also, considering the fast adoption of LNG in India, the focus on LNG infrastructure has become as important as that of the national gas grid. Overall, there is a 'chicken and egg' dilemma regarding natural gas uptake and the construction of supporting infrastructure. But infrastructure development is not the only factor that could accelerate gas penetration in India.

The price of natural gas in consumer sectors is an equally critical variable that influences gas uptake (Corbeau, Hasan, and Dsouza 2018; Amanam 2017; Sen 2015). Historically, gas prices have been high in countries worldwide, but a paradigm shift towards a low gas

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price (LGP) regime is being observed. This shift can be attributed to several reasons such as the discovery of shale gas reserves in the United States of America (USA) in 2015 and the global supply glut (EIA 2020; PPI Energy and Chemicals Team 2013). International gas prices started crashing in 2019 due to the supply glut, and amid the coronavirus (COVID-19) pandemic, the LNG price dropped to as low as USD 2/MMBtu (Fulwood 2020). LNG's low prices, especially for the spot, have triggered renegotiations of long-term (LT) contracts in India (Deb and Shabaneh 2019). Consequently, the LGP regime has bolstered discussions on the future of gas in the country.

Low gas prices offer great potential for uptake and corresponding benefits across sectors. But multiple associated nuances need to be explored before making a decisive push towards gas adoption. It is important to evaluate what a gas-based economy could offer in terms of jobs, growth, and sustainability. Also, high gas demand in India could facilitate the further expansion of gas infrastructure in the country. The growing availability of infrastructure would increase employment opportunities. But gas will also replace other fuels, which could trigger job losses in associated value chains. Hence, the net impact of gas penetration on the jobs front remains uncertain. High gas penetration could also reduce oil import bills by substituting gas for oil in the primary energy mix. But, conversely, it could also increase the expenditure on gas imports. Hence, an LGP regime would have implications for imports, but it is crucial to examine the net impact while planning for import reductions and increasing energy security.

With increasing gas penetration, the role of natural gas in deep decarbonisation would impede India's arguments for becoming a gas-based nation. The conversation surrounding natural gas as a' 'bridge' or 'transition' fuel consists of two views. One side of the debate advocates natural gas adoption for decarbonisation, while the other opposes it due to its carbon-intensive nature. Hence, it is crucial to explore the role of the fuel in India's long-term decarbonisation strategy and understand if becoming a gas-based economy would impede India's progress towards becoming a low-carbon economy. Moreover, the expanding gas infrastructure might end up as stranded assets and investments if the government takes specific measures to meet its decarbonisation targets. Thus, there is a need to explore these aspects and assess the impact of gas penetration in the long term to be better informed while leveraging the opportunity that low gas prices offer.

> **Multi-billion USD investment and low gas prices are making a favorable ecosystem for gas adoption in India.**

The present study intends to answer the following questions within this larger context: (i) How would natural gas penetration evolve across sectors under high and low gas price regimes? (ii) What would be the implication of removing the gas allocation policy regime? (iii) Would a high penetration of natural gas impede India's progress towards becoming a low-carbon economy? and (iv) What are the monetary and non-monetary benefits of high gas penetration in India? We aim to provide insights that could address the complexity and uncertainty of the natural gas debate in India.

The remainder of the paper is structured as follows. In the next section, we review the relevant literature and gaps in it. Section 3 details the methodology, encompassing the modelling approach, scenario framework, and data used in the study. Subsequently, in Section 4, we present key insights across various scenarios. In Section 5, we offer a discussion, policy recommendations, and directions for future research.

2. Literature review

The role of natural gas in India's energy mix is pertinent, and, consequently, it has sparked a range of research on different aspects of it. Guo and Hawkes (2019) highlight two types of approaches to understanding future gas markets: (i) examining economic principles and various uncertainties, and (ii) modelling the energy system to enable quantitative evaluations. While analysing the natural gas market in India, gas prices and infrastructure (pipelines and LNG terminals) are the two broad areas of research discussed widely.

The first approach is used extensively in studies focusing on India's gas market challenges and opportunities, especially while evaluating the implication of prices on-demand across sectors. Corbeau, Hasan, and Dsouza (2018) discuss the critical challenges in the natural gas sector such as the 'chicken and egg' situation between gas infrastructure and demand and high gas prices in consumer sectors. The study argues for a liberalised gas market and measures to safeguard price-sensitive sectors (also allocated as priority sectors) such as fertiliser and CGD. Sen (2015) highlights that CGD sectors (transport and households) can afford a reasonably high gas price, ranging USD 12–16/MMBtu. Nevertheless, Corbeau, Hasan, and Dsouza (2018) and Amanam (2017) make it evident that gas prices are regulated to safeguard specific prioritised and price-sensitive sectors such as fertilizer; and plunging gas demand, which is likely to be met by expensive LNG in non-prioritised sectors. However, the country-level analysis provided by EIA (2020) highlights that declining domestic production and insufficient import capacity have restricted gas demand over the years.

The second approach, which involves modelling the energy system, focuses more on projections and scenario analyses to understand India's possible evolution of the natural gas market. This approach builds on the information and perspectives presented through the first approach to bring policy insights based on various scenarios related to the demand and supply of alternative fuels in the energy market. A collaborative study, 'Energising India', by NITI Aaayog, India, and The Insititute of Energy Economics, Japan (2017), explores the natural gas demand in the long term, up to 2047. The study compares the output from two models; namely, the India Energy Security Scenarios (IESS) 2047 and World Energy Projection Systems Plus (WEPS+), to explore various scenarios, such as high gas price, low RE (renewable energy) achievement, immediate market-driven, etc. Both models project high gas penetration under favourable conditions for natural gas. IESS projects 12 per cent and WEPS+ up to 17–18 per cent of the total primary energy in 2040.

In the business as usual (BAU) case, the International Energy Agency (IEA) and BP Statistics project the share of gas to be around 7–8 per cent of total primary energy by 2030 (IEA 2019; BP 2019). As highlighted in their studies, the potential for gas penetration and associated prices would differ across sectors. Despite being on the non-prioritised list, the industrial sector presents considerable potential for gas penetration. According to estimates by the International Gas Union (IGU) (2020), by 2040, natural gas could make up around 18 per cent of the industrial energy demand. As per the estimates of NITI Aayog and IEEJ (2017), the iron and steel sector could be a promising consumer of natural gas; it has the potential to use natural gas to meet around 27 per cent of its total energy requirement by 2047. CGD (gas used in households and transport) is another sector with great potential to accommodate a high gas share in its energy mix. Nearly 45 per cent of urban households could potentially rely on gas by 2047, and gas adoption is expected to increase across different vehicle categories in the transport sector.

> **Existing studies highlight higher prices and lack of infrastructure as major barriers to gas adoption.**

> **The rapidly declining prices of RE technologies such as solar and wind make it more challenging for gas to increase its share in the electricity generation mix.**

Moreover, the power sector has always been a focus on natural gas. Despite the sector's position on the prioritised list and multiple other efforts such as reduced taxes on gas consumption for electricity generation, gas penetration in the sector is limited. Sen (2015) highlights the uncompetitiveness of gas compared to coal power as a critical reason impeding gas demand in the power sector.

The rapidly declining prices of RE technologies such as solar and wind make it more challenging for gas to increase its share in the electricity generation mix. According to the optimal generation mix[1] suggested by the Central Electricity Authority (CEA) (2020), the share of natural gas in electricity generation is expected to be limited to around 2 per cent, whereas solar and wind are collectively expected to generate approximately 35 per cent of all electricity in 2029–30. Thus, based on qualitative and quantitative assessments, it can be concluded that some sectors in the Indian economy have immense potential for gas adoption. Still, affordability remains the key reason for limited penetration.

Since the USA's shale gas discovery in 2015, there has been a paradigm shift in global gas prices, and in late 2019, gas prices dropped to their lowest. Fulwood (2020) acknowledges the possibility of the price of gas, reaching as low as USD 2/MMBtu. Lower gas prices could increase gas penetration in price-sensitive markets such as India, which is explored in detail in this study. However, high gas penetration is also associated with debates such as the implication of gas on its decarbonisation goals.

The role of natural gas in deep decarbonisation is a highly debated topic within the natural gas discourse. The conversation surrounding natural gas as a bridge or transition fuel has both sides of the argument. Though active at the global level, the debate has started impeding India's arguments for a gas-based economy. Weissman (2016) highlighted natural gas

1 The optimal mix is based on the least cost principal to projected peak energy demand and total electricity requirement by 2029-30.

Debate on role of natural gas as a 'bridge' or 'transition fuel is still unsettled in Indian context.

as a cheap, plentiful, versatile, and comparatively clean fuel, making it a viable option as a transition fuel between coal and renewables. On the contrary, Stockman, Trout, and Blumenthal (2019) and Loomis (2018) argues against gas penetration because of various reasons such as gas overshooting carbon budget and not a necessity for the stable electricity system. In the Indian context, Dsouza (2019) highlights that this argument is in its nascent stage and requires more exploration to understand the tradeoffs.

3. Methodology

As we discussed in the beginning, the future of natural gas in India is a function of various aspects such as infrastructure, policy outlook, and the gas price at the consumer end. Overall, consumer prices are the most critical factor influencing choice and demand in the price-sensitive Indian energy market (Corbeau, Hasan and Dsouza 2018). Scenarios are practical tools to help understand this uncertainty, necessary policy interventions, and their implications in the long term (Dhar, Pathak and Shukla 2020).

Scenarios can be created using various models with specific strengths and weaknesses. Various models such as WEPS+, IESS 2047, Model for Energy Supply Strategy Alternatives and their General Environmental Impacts (MESSAGE), Global Change Assessment Model (GCAM), etc. have been used to explore energy scenarios for India (Chaturvedi, Nagar Koti, and Chordia, 2018; NITI Aayog and IEEJ 2017; Thambi, Bhatacharya, and Fricko 2019). In the Indian context, to assess natural gas demand, NITI Aayog and IEEJ (2017) used the IESS 2047 and WEPS+ models to explore various scenarios for the future of natural gas. But neither the IESS 2047 nor the WEPS+ is an integrated assessment model (IAM). The IAMs belong to a category of models that simulate human decision-making around the energy system while considering interactions with other systems (Edmonds, et al. 2012). IAMs are well established to explore mitigation pathways and are utilised globally for comprehensive analyses (IPCC 2018; Gambhir et al. 2019). As the debate on natural gas penetration in India is about mitigation and decarbonisation towards becoming a low-carbon economy, IAMs are well-placed models for exploring research questions.

The GCAM model operates with an IAM framework used to build scenarios and address research questions for this study. The scenarios and base assumptions for understanding alternative futures for natural gas in India are described in Section 3.2.

3.1 The IAM framework: the Global Change Assessment Model (GCAM)

In this study, GCAM is used as an energy modelling tool (Bishkek 2018) to explore the future of natural gas in India. GCAM is an energy sector focused IAM operating on the principle of partial equilibrium, with details on both the supply and demand of energy sources (Chaturvedi et al. 2020; Brenkert et al. 2003). Energy and emissions are modelled in five-year time step up to 2050 for India, a separate region within the larger global energy system. For this study, the whole energy system is modelled on the idea that natural gas is used in the electricity generation sector to supply electricity to other end-use sectors. Meanwhile, natural gas is also used directly in end-use sectors, such as in the building sector in the form of PNG, in transport in the form of CNG, and industry in the form of wholesale gas.

As discussed in Section 1, since natural gas is available to consumers at different prices, energy and emissions are also examined at the end-use service level. Some of the services considered are cooking (rural, urban, and commercial) in the building sector, different modes in the transport sector, and type of use (energy use and feedstocks) in the industry sector. The fuel prices in each sector are also calibrated for 2015 based on offtake prices collected from various sources (details in Section 3.2). The future prices of fuels are endogenously modelled, with growth applied to the base prices.

3.2 Scenario frameworks and assumption

The vision for natural gas in India is evolving. The key variable that influences the outlook for the future of natural gas is its price. Taking this as the core of our analysis, this study explores four scenarios for natural gas in India: (i) 'High Gas Price' (HGP) scenario; (ii) 'Low Gas Price' (LGP) scenario; (iii) 'Uniform Pooled Price' (UPP) scenario; (iv) 'Low-carbon 2-degree' scenario. Figure 1 describes the overall scenario framework considered for the study.

Figure 1 Scenario framework followed in the study

Scenarios	Prices	Infrastructure improvement	Gas allocation policy
High Gas Price (HGP) scenario	High price of gas persist in long-term	Considered	Considered
Low Gas Price (LGP) scenario	Low price of gas regime would continue in long-term	Considered	Considered
Uniform Pooled Price (UPP) scenario	Low gas price regime would continue in long-term	Considered	Not-Considered
2° carbon contrained scenario	1. High gas price scenario 2. Low gas price scenario	Considered	Considered

- Natural gas adoption across sectors
- Emission Reductions
- Import Bills Reductions
- Employment potential
- Carbon price (incase of 2° scenarios)
- Infrastructure & investment requirement

Source: Authors' compilation

The HGP scenario considers a high price for LNG based on the signed LT contracts between India and supplier nations. Recent trends indicate the increasing share of spot and short-term contracts for LNG in India due to declining prices (International Gas Union (IGU) 2020). But the HGP scenario assumes that these low gas prices cannot be sustained in the long term. The gas prices vary significantly across sectors in India due to allocation policy. However, the natural gas price in HGP scenario is considered to be approximately 80 per cent higher than that of the LGP scenario in 2030 and nearly 70 per cent higher in 2050. In contrast, the LT contracts will remain a priority to assure supply security, which implies that gas prices will remain high in the long term in India (Guo and Hawkes 2019). The real prices for end-use sectors are taken from different sources—industrial gas prices from the Annual Survey of Industries, MOSPI; and CGD gas prices from market sources for PNG and CNG for the building and transport sectors, respectively. The gas price for the power sector is taken from tariff orders and stakeholder consultations. The HGP scenario further assumes continued existence of a gas allocation policy, and the final prices for sectors are based on the shares of volumes of domestic gas and imported LNG pooled as per priority allocations.

In the year 2015, the industry and commercial gas sectors being in tier-II of gas allocation policy faced 15.0 and 14.3 2015 USD/MMBtu respectively. However, the fertilizer being a priority sector faced around 10.1 2015 USD/MMBtu. In contrast, tier-I CGD sectors, transport and residential gas faced CNG and PNG prices as 11.5 and 11.3 2015 USD/MMBtu respectively. Also, the power sector faced a relatively lower cost of gas at 9.0 2015 USD/MMBtu. Detailed assumptions for NG prices faced by end use sectors for the HGP and LGP scenarios in 2030 and 2050 are presented in Annexure 1. Essentially, we assume that the prices faced by end use sectors in the LGP sc would be half of the prices these sectors face in the HGP sc.

The LGP scenario explores a shift in the gas price regime from high to low. The existing supply glut has created a low price environment that is expected to persist in the near- to medium-term future (Cocklin 2020). Moreover, because of declining spot prices, there has been a surge in demands to renegotiate LT contracts in India. In addition to the COVID-19 pandemic, there are other factors influencing the paradigm shift to an LGP regime: the shale gas discovery in the USA, mild winters in European regions resulting in lower consumption of gas, and excessive availability of the fuel. The low gas price trajectory has been applied from 2025 onwards and is likely to be impacted by low prices as per the modelled time steps. The LT contract price is considered to be USD 9/MMBtu for LNG, whereas the spot prices are assumed to be USD 3/MMBtu (average prices based on Kanoi and

Abreu 2020 and Jaganathan 2020). Also, this scenario accounts for the continual increase in the share of spot LNG in total consumption. The existence of the gas allocation policy is considered for this scenario as well; it implies overall low gas prices from previous years but differentiated prices among end-use sectors.

The third scenario is the UPP, which is a progressed version of the LGP scenario. The scenario envisages the abolition of the gas allocation policy (discussed in Section 1) and offers a common pooled price of natural gas to all consumer sectors. The final price offered to the sectors will be the result of the volume-weighted average applied, following the pooling of LT contracts for LNG, spot LNG, and domestic gas.

The study implicitly assumes a gradual improvement in gas infrastructure based on historical and proposed developments. Infrastructure improvement is kept constant across scenarios to rule out its implication on gas adoption. In addition, the study explores carbon constraint scenarios in the form of a 2-degree scenario (reference w.r.t. IPCC). The 2-degree scenario assumes a fixed carbon budget required to maintain the 2-degree global temperature trajectory (Chaturvedi, Nagar Koti, and Chordia, 2018). The carbon constraint is applied to both the HGP and LGP scenarios to understand the implication of an LGP regime on decarbonisation efforts and the cost of mitigation.

> **Despite infrastructure improvements, the gas share would only be 6% by 2030 in high gas price regime.**

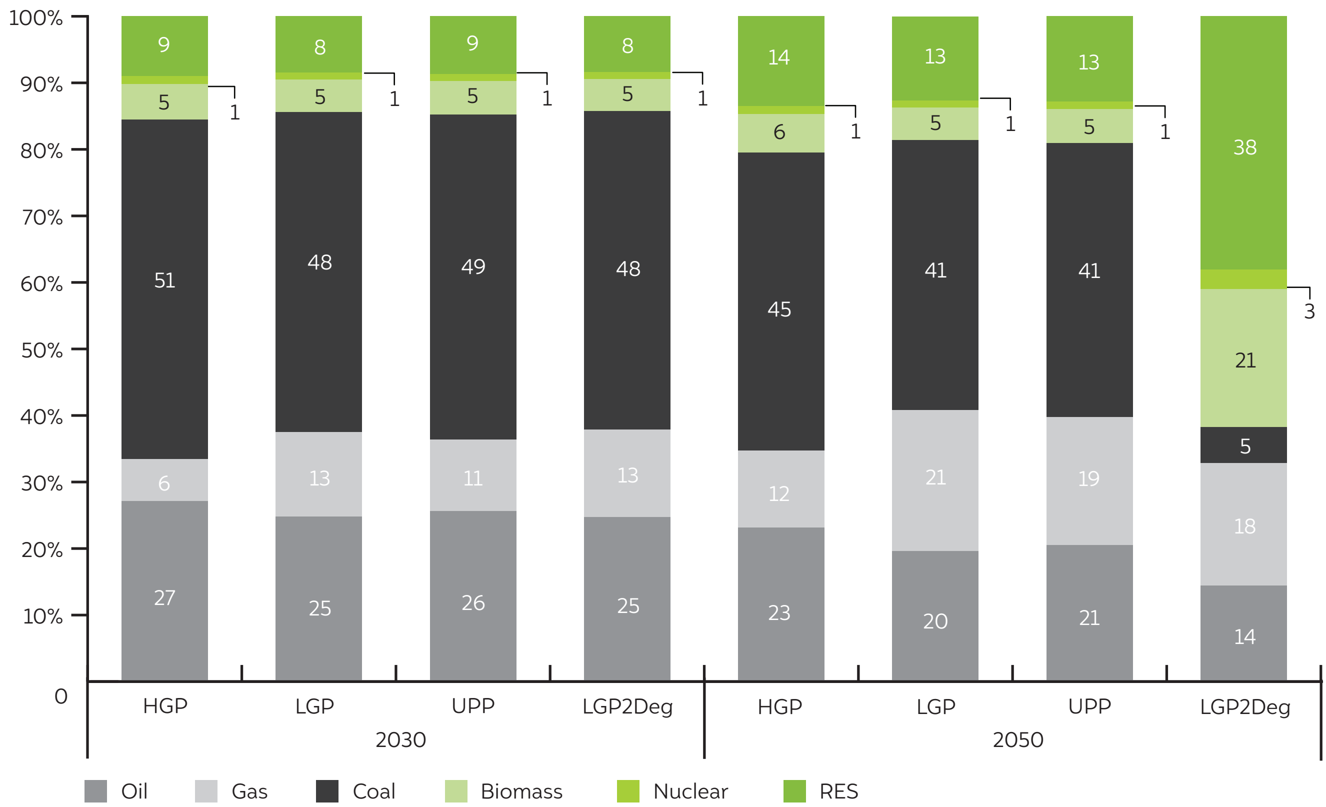
The increasing adoption of gas is expected to lead to a reduction in emissions and oil import bills as compared to HGP scenario and to generate opportunities. More information on the estimation of these factors is provided in the relevant results section.

4. Results

4.1 High gas price regime

This study aims to identify the pathway towards the target proposed for natural gas penetration in India, i.e., 15 per cent of the primary energy mix by 2030. Figure 2 shows the primary energy mix for 2030 and 2050 in the HGP and LGP scenarios. Figure 2 demonstrates that in the HGP scenario, the share of natural gas in the primary energy mix reaches only 6.4 per cent by 2030

Figure 2 In low gas price scenario, by 2050, natural gas could support one-fifth of the total primary energy demand



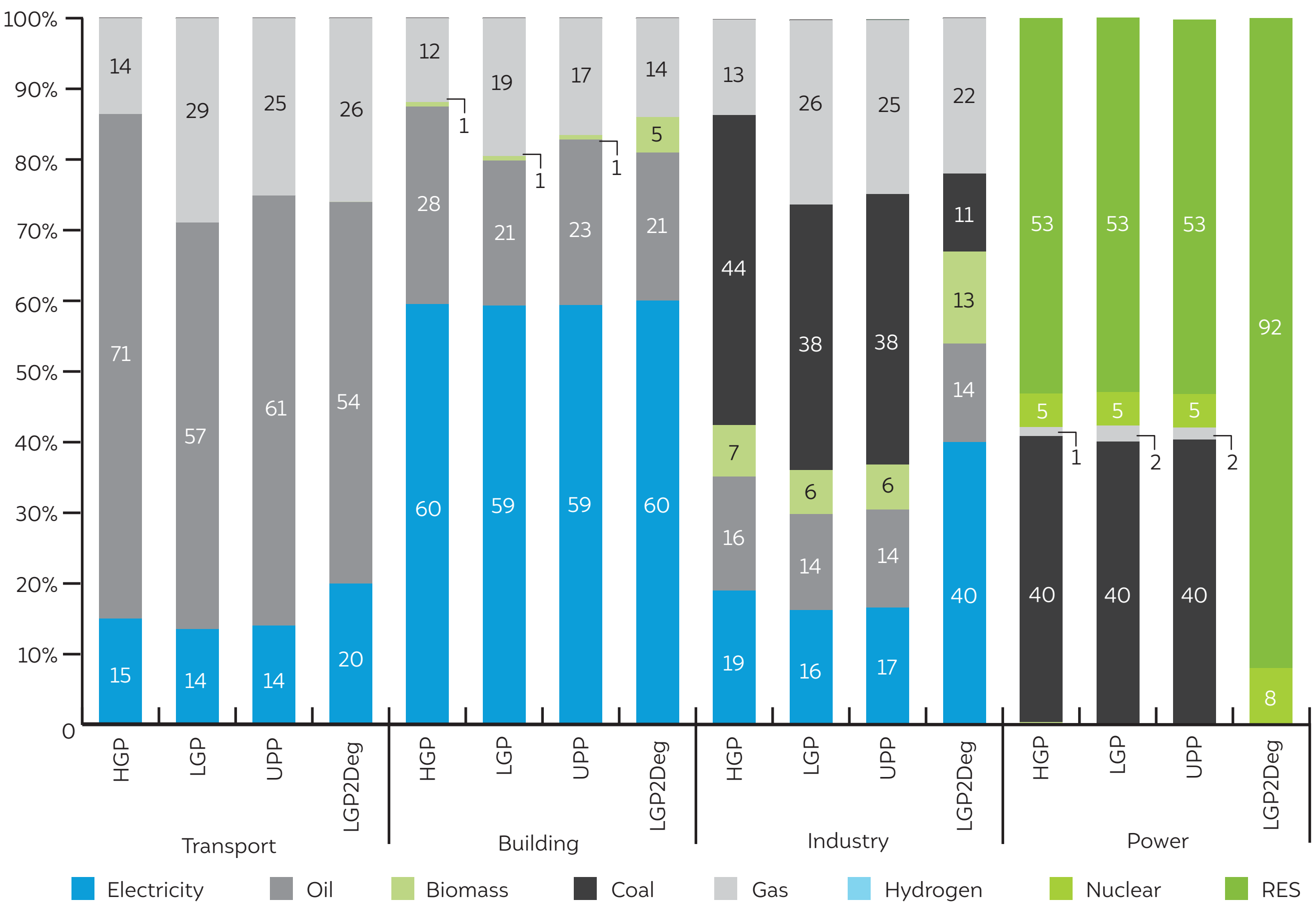
Source: Authors' compilation
Note: RES refers to the summation of energy provided by RE sources, namely solar, wind, hydro, and geothermal

and 12 per cent by 2050. This clearly implies that if high gas prices along with the continued price regulation by gas allocation policy continue, India will miss its target by a considerable margin of 9 per cent. This result aligns with other projections such as that by the IEA, in which the share of gas in the primary energy mix is projected to touch 7 per cent in 2030 (IEA 2019) and by BP Statistics, which projects an 8 per cent share in 2040 (BP 2019). Thus, the HGP regime also corresponds to the low penetration of gas in Indian economy. The primary energy mix in the HGP scenario remains coal-dominated in the long term as well, at 51 and 45 per cent in 2030 and 2050, respectively.

Figure 3 describes the sectoral energy mix for the HGP and LGP scenarios in 2050. It is evident from Figure 3 that in the HGP regime, even priority sectors are expected to have limited penetration of natural gas and to remain dominated by other fuels. Gas penetration in the transport and building sectors, which are part of the CGD network and the highest priority, is expected to be 14 and 12 per cent by 2050, respectively. In the building sector, cooking service is the key consumer of gas, due to which it is a priority sector for domestic gas supply. In contrast, the commercial gas supply is a non-priority tier. A significant increase in the adoption of natural gas is observed in the urban residential cooking sector (44 per cent in 2050), whereas the rural cooking sector reflects the adoption of LPG because of a lower population density, which renders natural gas pipelines unfeasible. The commercial cooking sector, despite being on the non-priority list, is expected to have a 34 per cent share in 2050. In the transport sector, the penetration of gas is expected to be similar to that of electricity, which reveals the coexistence of two low-carbon visions for the sector, i.e., electric vehicles (EV)–based and natural gas-based fleets.

In this scenario, natural gas gets priced out and becomes uncompetitive for power generation as compared to other fuels. Hence, only 1 per cent of the power sector's total generation is expected to come from gas in 2050, even though the absolute consumption of gas will increase. Although electricity generation is on the priority list of the gas allocation policy, its gas share gradually declines over time, reflecting the un-

Figure 3 **Low gas prices results in double of gas share in transport and industry and a 50 per cent increase in the building sector**



Source: Authors' analysis

> **The target of having 15% natural gas in primary energy by 2030 will be missed even in low gas price scenario.**

competitiveness of gas as compared to other cleaner sources of generation such as solar which is also expected to have declining cost trajectory in future. This decline in gas penetration is described in the 'optimal generation capacity mix' report by the Central Electricity Authority (CEA); it reflects a 2 per cent share of gas in the gross generation in 2029–30 (CEA 2020). The industry sector will also remain coal-dominated in 2050, and gas penetration is expected to make up about 13 per cent of its total energy consumption.

4.2 Implications of a low gas price regime

There has been a global shift in price regimes from high to low, and India could harness this variation across sectors. The high and low gas price regimes each show a different vision for the future of natural gas in the country. While high gas prices are widely discussed as a hurdle to gas penetration in India, the LGP regime could potentially allow for overcoming this hurdle. Figure 2 shows that the natural gas share nearly doubles in the LGP scenario as compared to the HGP scenario, to 13 and 21 per cent in 2030 and 2050, respectively. Though the 15 per cent fuel share target will not be achieved even in the LGP scenario, the gap between the target and penetration reduces significantly to a margin of 2 per cent. In the long term (by 2050), natural gas could support nearly one-fifth of the total primary energy requirement in an LGP regime. Moreover, the increase in the share of gas for the HGP and LGP scenarios is compensated by the decline in the share of coal and oil, however, the availability of cheap gas will also be competing with non-fossil sources such as solar and biomass.

Natural gas penetration increases significantly across all sectors in this scenario except for power generation. In the LGP regime, sectors which are on the non-priority list, such as industry and commercial gas supply, are likely to observe a significant increase in the share of natural gas in their energy mixes. In the industrial sector, the share of natural gas increases from 13 per cent in the HGP scenario to 26 per cent in the LGP scenario in 2050 (see Figure 3). Simultaneously, commercial cooking demonstrates an increase of 27 per cent in penetration, from the HGP (34 per cent) to the LGP (61 per cent) regimes. Priority sectors, such as transport and residential urban cooking, also show a significant penetration of natural gas in their energy mixes. The transport sector has great potential for gas penetration, at 29 per cent in 2050. The power sector remains broadly unaffected in the LGP regime. This could be attributed to the uncompetitiveness of gas in the electricity generation sector. Other sources of energy, such as conventional coal and fast-rising renewables, solar and wind, are much cheaper, making them economically more viable sources of generation. The other reason could be the unpriortised supply of gas as a fuel to gas-based power plants because of increased demand in other sectors., which makes operating with a fluctuating supply of fuel difficult Though the share of gas increases from 1 to 2 per cent in 2050, it remains negligible as compared to the other sources of generation. The power sector is expected to be dominated by RE sources, followed by coal.

The domestic production of natural gas in India has been declining since 2011-12, which in turn has increased the country's dependence on LNG imports. The share of LNG imported in 2018–19 in India stood at around 47 per cent (28.7 billion cubic metres (BCM)) (PPAC 2020); this share is expected to grow nearly 11 times between 2020 and 2050, to around 470 BCM, in an LGP regime, assuming domestic production remains stagnant at the current level. Increasing imports could pose a threat to energy security if import sources are not harnessed strategically. LT contracts are usually strategies to ensure uninterrupted gas supply but, at the same time, can be difficult to renegotiate in changing gas price regimes. However, India has already taken steps towards signing new contracts at low gas prices (Deb and Shabaneh 2019; Financial Express 2020). Going forward, diversification of import sources could be a strategic move to ensure energy security as well as to avoid being stuck with a monopoly supplier with few windows for renegotiation.

4.3 Sectoral impacts of withdrawing the gas allocation policy

Both scenarios, HGP and LGP, consider the impact of the gas allocation policy, which sets differentiated prices across sectors. Whereas, in the UPP scenario, the low gas price regime remains, however, the gas allocation policy is revoked. Overall, the share of gas in the primary energy mix for the UPP scenario reduces to 19

> **Non-priority sectors such as industry consumes twice the gas in low gas price scenario than that of high gas price scenario.**

The high penetration of gas in Indian economy does not mean huge emission reductions and ease in decarbonisation efforts.

per cent as compared to 21 per cent in the LGP scenario. Broadly, the decline in the share of gas in the primary energy mix implies that withdrawing the gas allocation policy is not beneficial to gas penetration in the country. But it is more important to assess the impact of withdrawing this kind of policy on sectors that were previously classified as priority ones.

As Figure 3 shows, the share of gas in the transport sector declined by 4 per cent, and in the building sector by 2 per cent, as compared to the LGP scenario, given the prioritisation of these sectors under the gas allocation policy. The reason for this decline is the increase in prices for the priority sectors in the UPP scenario. Meanwhile, the abolishment of the gas allocation policy is shown to marginally impact non-priority sectors such as industry because the change in prices for these sector is minimal as compared to the ones being faced earlier.

The priority sectors are much more likely to be affected by a change in allocation policy. The power sector will remain unaffected by the change in prices due to the withdrawal of its priority status, but an increase consumer gas prices for households and transport in the CGD network would endanger profitability for CGD companies (ICRA 2019) and inhibit their interest in expanding their networks and operations. However, the other perspective is that the final pooled price should ensure that overall protiftability should not be impacted. There are multiple reasons for keeping the gas allocation policy in place; for instance, safeguarding vulnerable and price-sensitive sectors, such as farming, and promoting gas-based vehicles to curb air pollution in cities. There are multiple options available for withdrawing the gas allocation policy without impacting these segments; for instance, direct benefit transfers for farmers and the promotion of EVs as primary transport vehicles. But all these require further in-depth exploration to clearly understand the implications of withdrawing the gas allocation policy from across the value chains of consumer sectors.

4.4 The role of natural gas in deep decarbonisation scenario

We examine the potential role of gas in India's decarbonisation strategy by analysing an emissions constraint scenario for both HGP and LGP futures. Figures 4 (a) and 4 (b) present the emissions trajectories and cost of mitigation, respectively, in the 2-degree carbon constraint LGP and HGP scenarios to provide insights to facilitate the debate in the Indian context.

The analysis reveals two exciting insights. First, the results dismiss the possibility of natural gas being a transition fuel for India's low-carbon trajectory. The reduction in economy-wide emissions with increasing gas penetration in the LGP scenario is only around 2.8

Figure 4a. Increasing penetration of natural gas yield lesser emission reduction than anticipated

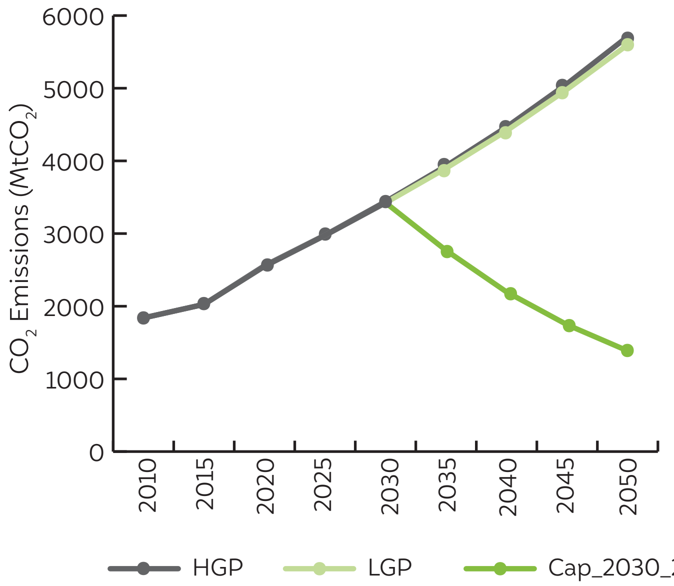
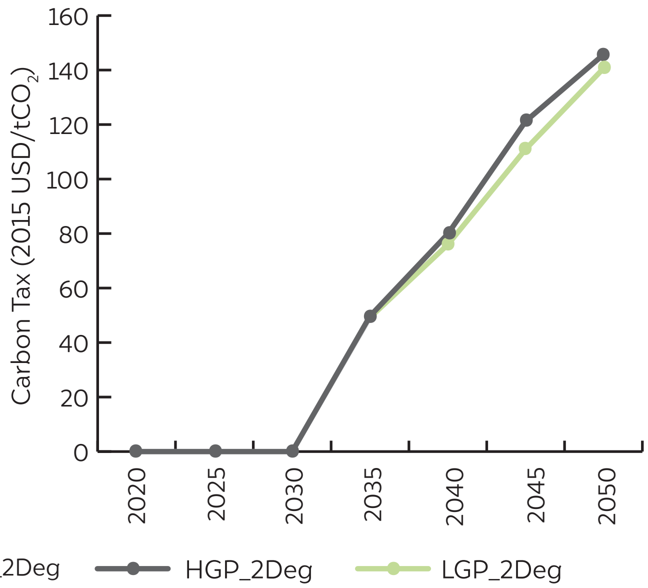


Figure 4b. High gas penetration increases overall fossil share in economy leading to 4% higher carbon price.



Source: Authors' analysis

per cent as compared to the HGP scenario (see Figure 4 [a]). The key factor contributing to this negligible decline is that the increasing penetration of natural gas would be at the cost of non-fossil energy (nuclear, solar, wind, etc.), along with a reduction in coal and oil. Replacing the cleaner energy sources resulted in compensating the emission reduction occurring due to the replacement of coal and oil. As such, in the LGP scenario, the share of energy supported by fossil sources is around 2 per cent higher than that of the HGP scenario. Also, with increasing gas penetration in the LGP scenario, the emissions from gas processing are nearly doubled as compared to that in the HGP scenario. The overall emissions for India are similar in a high or low gas price scenarios. Thus, **our analysis rejects the argument that a high share of natural gas in India would make decarbonisation easy for the country**.

Second, to achieve deep decarbonisation goals when natural gas prices are low, the carbon price increases only by 4 per cent (see Figure 4 [b]) relative to that in the high gas price scenario coupled with emissions constraint. As the average cost of fossil energy declines due to globally low natural gas prices, decarbonising the economy becomes slightly more challenging. Another widely discussed aspect is methane emissions from pipelines. This argument is valid for old pipeline systems like those in the US. But India is in the initial stage of gas pipeline infrastructure, and these leakages would be negligible from its relatively newer infrastructure. Additionally, the practice of gas flaring is not prevalent in India which further defies the argument of methane leakage emissions in Indian context.

In the 2-degree decarbonisation scenario, emissions peak in 2030 and then start declining to achieve the climate goal. Due to the carbon constraint, energy mixes across sectors will change significantly (refer Figure 3). The 2-degree scenario pushes for a reduction in gas penetration across sectors while promoting the adoption of electricity as the primary source of energy. In the LGP2Deg scenario, the share of gas in 2050 declines by 3 and 5 per cent in the transport and building sectors, respectively, as compared to the LGP scenario. Meanwhile, the industry sector also shows a decline of 6 per cent in 2050. Since electricity adoption increases across sectors, the total generation of electricity increases by 33 per cent. In the power sector, the maximum share of generation is from RE sources (91 per cent), whereas the share of gas declines to zero.

> **1.2 lakh new employment opportunities could be generated across the value chain corresponding to high gas penetration.**

> **There is a potential of reducing the import bill by 46% between 2020 and 2050 if low gas price opportunity is harnessed.**

Carbon capture and storage (CCS) is a highly debated option in case of deep decarbonisation (Reiner 2012). However, it is also argued that CCS is critical for the world to stay below 1.5- and 2.0-degree pathways (Global CCS Institute 2019). We explored the sensitivity of our results to the availability of CCS for the power sector under the carbon constraint scenario. As presented in Annexure 2, we see the combined share of coal and natural gas in the primary energy mix of the Indian economy increasing by 5 per cent points if CCS is available for the power sector. Nevertheless, the electricity is expected to dominated by the RE sources (around 86 per cent), in contrast to 93 per cent in LGP2Deg scenario without CCS feasibility. Availability of CCS for industrial decarbonisation could give an additional fillip to fossil energy, but the extent of its penetration would be determined by a host of factors going beyond the additional cost of CCS. In absence of fast decline in the cost of CCS, however, fossil energy sources would effectively have to go out of favour in the Indian economy.

4.5 Jobs, growth, and sustainability

The trilemma of jobs, growth, and sustainability is crucial for fast-growing countries like India. Countries facing this trilemma try to provide employment opportunities while balancing the growth and sustainability of the country. High gas penetration in India would initiate the development of gas infrastructure in the country. With growing infrastructure development, employment opportunities will increase. As per the analysis, in the high gas penetration, i.e., low gas price scenario, 1.2 lakh new employment opportunities could be generated across the natural gas value chain by 2050; this includes pipelines, terminals, and CGD. Though high gas penetration could offer employment opportunities, it would also replace other fuels, which could trigger job losses in coal and oil value chains. Hence, the net impact of gas penetration in the Indian economy could be either neutral or detrimental on the jobs front. However, in terms of import bills, high gas penetration in the LGP regime could have economic benefits of a significant magnitude. Since oil and natural gas prices are linked, lower prices for both fuels are considered in the LGP regime. The analysis reveals that in the LGP Scenario, the country could benefit from an economic gain of 723 billion (2015 USD) sum of undiscounted cost from 2020 to 2050, which is a 46 per cent reduction as compared to that in the HGP scenario.

Although the difference in CO2 emissions between the HGP and LGP scenarios is negligible, the reductions in NOx and SO2 emission are significant in the LGP regime. As per the analysis, the NOx emissions from LGP regime in 2050 are 9 per cent lower than those of HGP regime. However, the SO2 emissions from LGP scenario are 5 per cent lower than those of HGP scenario. This reduction in NOx and SO2 emissions would have a positive impact on local air pollution, which India is currently struggling with. There are multiple documented health issues associated with these pollutants, and high gas penetration would help to curb these impacts.

5. Discussions

5.1 LGP regime: harnessing the opportunity through investments

The benefits mentioned in Section 4.5. are subject to high gas penetration in India. The study highlights that the LGP regime offers great potential for gas demand in the country across sectors, but a lack of infrastructure could be a hurdle. The analysis revealed that the current infrastructure plans are not even enough to cater to the gas demand in an LGP regime in 2030 and, moreover, the infrastructure deficit increases significantly in 2050.

Figures 5 (a) and (b) represent the infrastructure deficit and the investment required to build capacity to cater to the gas demand across scenarios, respectively.

As domestic production has been declining over since 2011-12, Figure 5 (a) reflects the massive requirement for LNG terminals to cater to the demand potential expected in the LGP regime. To have this extensive infrastructure, an estimated total investment of 96 billion (2015 USD) (refer Figure 5 [b]) is required from 2020 to 2050, to build the capacity required of an LGP regime. There is a multi-billion USD investment that has been announced for gas infrastructure in India. Still, the timeline of the infrastructure development needs to be expedited in order to harness the opportunity of an LGP regime. Delays in infrastructure development could increase the risk of missing out on high gas adoption in the country. Additionally, delayed infrastructure development could prevent potential consumers in the country from being connected to the gas grid. Moreover, LNG terminal capacity development should grow significantly to meet the increased reliance on imported gas in the future. Currently, the pipeline proposed for the country is 30,000 km long, and the proposed LNG capacity is around 96 BCM. The current capacity to harness the LGP opportunity in 2050 is short by 54,000 km of pipeline and 368 BCM of LNG capacity. However, with increasing conversation for promoting hydrogen in the economy, the gas infrastructure's reusability is another possibility that is not explored in this study because the competitiveness of hydrogen in the future internationally and especially in the Indian context is still unclear.

Figure 5a The infrastructure deficit in terms of pipeline and terminal requirements in the HGP and LGP scenarios

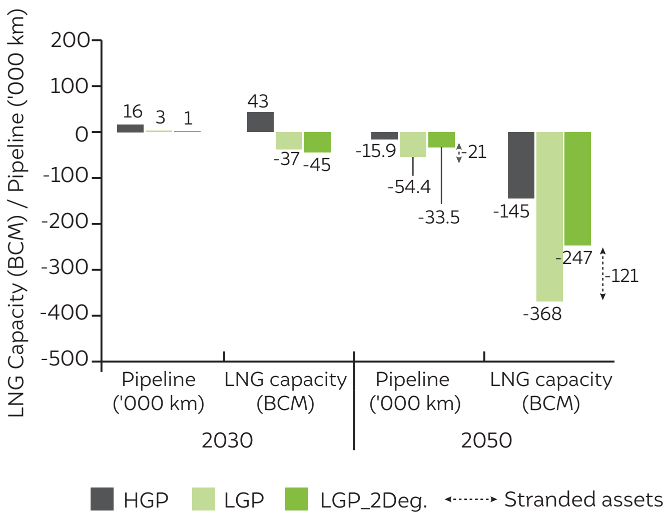
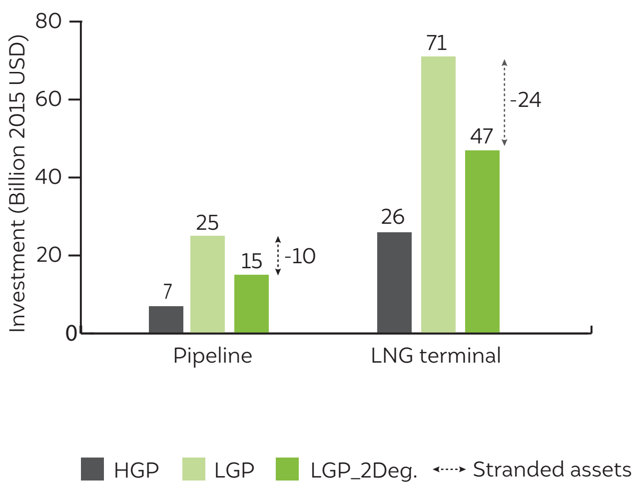


Figure 5b Investment requirement to build capacity to cater to the demand across scenarios



Source: Authors' analysis

5.2 The risk of stranded assets

The carbon-constrained scenario favours a reduction in gas penetration across sectors. In the 2-degree scenario, there is a huge risk of stranded assets associated with high gas penetration. For the LGP regime, infrastructure requiring massive investment needs to be built (discussed in Section 5.1.). But the proposed 2-degree climate goal across the globe would be detrimental for the gas future in India. As per Figure 5 (a), in the LGP2Deg scenario, nearly 21,000 km of pipeline and 121 BCM of LNG capacity of the terminal could be stranded in an LGP regime along with the carbon constraint of 2 degrees. The investment required to build these potentially stranded assets, i.e., around 34 billion (2015 USD), would also go in vain in the 2-degree scenario.

5.3 Deep decarbonisation versus a high natural gas share: Is there an optimal point?

Section 4.4. imply that there is some inconsistency between the LGP regime, i.e., high gas penetration, and the deep decarbonisation scenario. To harness the opportunity of the LGP regime, large infrastructure investments need to be expedited. But in the deep decarbonisation scenario, there is a massive risk of stranded assets in the form of gas pipelines and terminals. Nevertheless, it is evident that an optimal point needs to be explored so as not to miss LGP opportunities and benefits associated with high gas penetration while adhering to the carbon budget proposed for the 2-degree deep decarbonisation scenario.

> **Increasing gas adoption above 18% in Indian economy could derail us from the 2-degree pathway.**

Indeed, the optimal point could be investing in infrastructure to the extent that is required to cater to the gas demand in the LGP2Deg scenario. As per Figure 5 (b), the investment required from 2020 to 2050 would be around 15 and 47 billion (2015 USD) in pipeline and LNG terminal infrastructure, respectively. As per the analysis, this level of infrastructure in the LGP regime with a 2-degree carbon budget could yield a gas share of around 18 per cent in the primary energy mix in 2050. This is definitely much lower than that of the LGP scenario (21 per cent in 2050), but it would mitigate the risk of stranded investments and contribute to achieving deep decarbonisation and remaining within a 2-degree carbon budget.

This level of gas penetration could also offer 90,000 employment opportunities by 2050 and import bills savings of around 835 billion (2015 USD) sum of undiscounted costs from 2020 to 2050. Moreover, the emissions benefits are massive because of the restrained carbon budget. Since climate change induced by anthropogenic CO2 emissions poses huge risks to lives and livelihoods, the optimal point could help achieve a more sustainable pathway for the future of natural gas in India.

Table 1 **Summary of findings across scenarios (for the year 2050)**

Scenario	Share of gas in PE mix (%)	2-degree carbon budget	Infrastructure deficit		Investment requirement		Co-benefits	
			Pipeline ('000 km)	LNG terminals (BCM)	Pipeline (billion 2015 USD)	LNG terminals (million 2015 USD)	New employment (lakhs)	Import bills (billion 2015 USD)
HGP	12	NA	-15.9	-145	7	26	0.49	1577.84
LGP	21	NA	-54.4	-368	25	71	1.20	854.76 (723.1)
LGP_ 2Deg	18	145 $GtCO_2$ from 2010 to 2100	-33.5 (-21)	-247 (-121)	15 (-10)	47 (-24)	0.90	742.44 (835.4)
UPP	19	NA	-46.3	-321	23	59	0.97	831.14 (746.7)

Source: Authors' analysis

Note: The negative sign in the infrastructure deficit column indicates the requirement to fulfil the expected demand in the respective scenario. In the LGP_2Deg scenario, the numbers in brackets for infrastructure deficit and investment requirement are stranded assets and investments. In the case of the import bills, the numbers in brackets are the import bill savings with reference to the HGP scenario.

The main findings of this research are as follows: the share of gas in the primary energy mix increases significantly by 9 per cent in 2050 due to a shift in gas price regimes from high to low. The LGP scenario requires huge investments to develop the infrastructure necessary to cater to the demand induced by low gas prices. But switching to gas could offer huge benefits in terms of jobs and import bills reduction. The carbon-constrained scenario acts against gas penetration; a reduction in the gas share would leave the country with stranded assets in the form of pipelines and terminals and corresponding stranded investments.

6. Conclusions and policy implications

This study traces the potential evolution and adoption of natural gas in the Indian economy, across sectors. The insights are crucial to understanding alternative pathways which natural gas could take under different price regimes and the 2-degree carbon-constrained scenario. India has been historically facing high gas prices across sectors. Additionally, the nation has adopted a gas allocation policy to support some priority sectors such as CGD, fertiliser, and power. Due to globally declining natural gas prices, India is shifting from an HGP to an LGP regime. It is clear from Section 4.1. that while remaining **in the HGP regime, India does not fulfil its goal of being a gas-based economy**. Though the target of 15 per cent natural gas in the primary energy mix would not happen **under an LGP regime, the margin is as low as 2 per cent in 2030, and the penetration would be around 21 per cent in 2050**. Hence, it is evident that low gas prices offer great potential for gas adoption, but infrastructure remains a hurdle. **However, the increasing share of gas doesn't mean that the importance of coal diminishes for the Indian economy**. In the LGP regime, the share of coal remains to be around 40 per cent in the primary energy mix. As already highlighted, the electricity generation sector does not uptake gas in a big way and, hence, has to rely on coal and renewable sources such as solar. Due to this, the Indian economy could have a high share of gas, but remain coal dominated irrespective of the global gas scenario.

Section 5.1. highlights that the massive deficit of infrastructure in terms of pipelines and LNG capacity could restrict the gas adoption potential of the Indian economy in the LGP regime. Hence, **the key is to expedite infrastructure development to harness the LGP opportunity**. Our findings align with those of Sircar, Sahajpal, and Yadav (2017), who have highlighted various regulatory challenges that need immediate attention in order to facilitate the expansion of gas infrastructure. Another way to expedite infrastructure development could be more frequent bidding on geographical areas to expand the area under coverage and increasing investments.

Whether a gas allocation policy should exist in India has been debated on numerous platforms. The results of this study show that the withdrawal of the gas allocation policy would lead to a decline in the gas penetration in the Indian economy and across sectors. Priority sectors would have to give up their share of natural gas in the uniform pooled price scenario due to the higher price of gas that would be faced by these sectors as compared to the current policy regime. Having said that, **we argue that market reforms are critical, and there are many potential benefits to the economy in the move towards a market friendy structure for the allocation of natural gas**. A potential decline of gas use in sectors that are currently in the priority list should not be used as a rationale to scuttle market reforms which could be counter-productive. While in theory, it is simple to withdraw or retain this policy, the Indian economic system is highly complex, and the impact of a withdrawal needs a separate, detailed analysis. The reason for the existence of this policy is also linked to the volatility experienced by end consumers, such as farmers in the case of the fertiliser sector. Thus, the study only highlights the implications of withdrawing the gas allocation policy on gas penetration but not the other related aspects that are important to consider while making a decision on this policy.

The role of gas penetration in decarbonisation goals has been highly debated, and this study tries to provide insights to further and inform some aspects of the discourse. The global scenarios talk about two extremes: either that gas is a transition fuel that helps with decarbonisation or that it impedes low-carbon transitions and makes deep decarbonisation much more difficult. **The study highlights that the high penetration of gas (as in the LGP scenario) in the Indian context would neither have a significant positive impact on the emissions trajectory nor make deep decarbonisation much more difficult**. The LGP scenario shows that the cost of mitigation also increases marginally by 4 per cent with high gas penetration. But **high gas penetration would also include employment generation potential—approximately 1.2 lakh new job opportunities—**

and provide significant savings in import bills of around 723 billion (2015 USD) sum of undiscounted cost from 2020 to 2050. The deep decarbonisation scenario supports the penetration of electricity across sectors but reduces gas penetration. In this case, the infrastructure built to cater to the demand in an LGP scenario, requiring massive investments, could get stranded. The possibility of a restricted carbon budget could increase the risk of investments, and stranded assets would harm investors in the long run. Thus, it is crucial to establish an optimal balance point between deep decarbonisation and high gas penetration. This study argues that the LGP scenario in a carbon-constrained world can significantly benefit the economy. **We find that 18 per cent natural gas share in India's primary energy mix by 2050 is an optimal to reap benefits of low gas price opportunity while meeting country's decarbonisation objectives**.

Like any study, our research is not without its limitations, which we foresaw and propose that future researchers consider. Aspects such as the implication of withdrawing gas allocation policy for downstream consumers, such as farmers, in a low gas price regime are yet to be examined. In this study, we did not explore changes in tax regimes, but with upcoming dynamic changes in the taxation system, it becomes relevant to consider the implications of different tax options for the competitiveness of natural gas across sectors. Additionally, the role of gas in hydrogen feasible world can also be explored considering the optimistic developments in hydrogen breakthrough.

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Annexures

Annexure 1: Prices of natural gas across sectors and scenarios

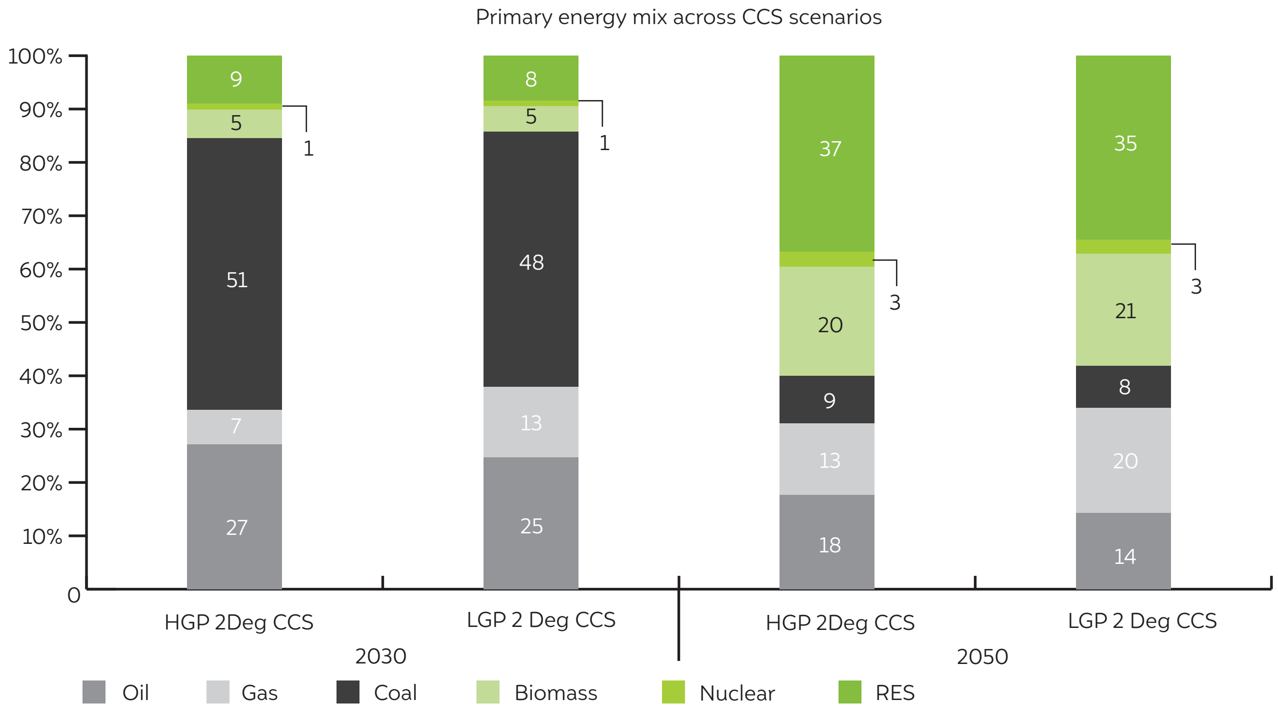
Table A.1.1. Prices across high and low gas price scenarios across sectors

Scenarios	Allocation Tier	End-Use Sectors	2030	2050
HGP	Tier-II	Industry	15.28	16.23
	Tier-I	Fertilizer	9.77	9.57
	Tier-I	Power	9.02	9.72
	Tier-I	Transport	15.07	15.72
	Tier-I	Residential	11.58	12.88
	Tier-II	Commercial	14.66	16.25
LGP	Tier-II	Industry	7.72	8.28
	Tier-I	Fertilizer	7.12	6.96
	Tier-I	Power	5.43	5.85
	Tier-I	Transport	6.74	7.39
	Tier-I	Residential	6.51	7.86
	Tier-II	Commercial	7.77	10.70

Note: The unit of the prices described in the above table is 2015 USD/MMBtu

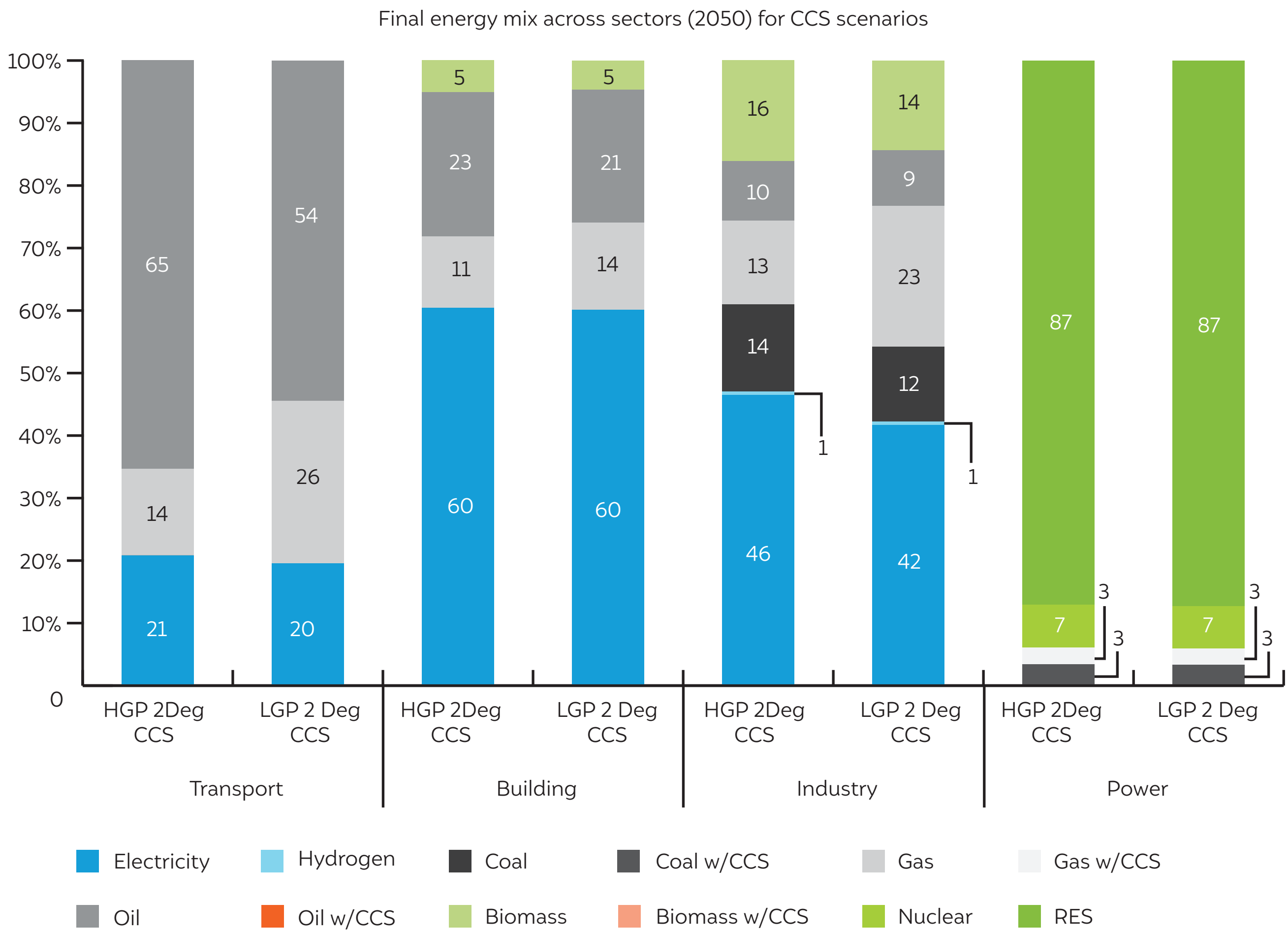
Annexure 2: Primary energy mix in Indian economy and final energy mix across sector in low gas price 2 degree carbon constraint scenario with CCS feasibility

Figure A.2.1. LGP 2Deg CCS scenario has slightly higher gas share as compared to LGP 2Deg scenario without CCS feasibility



Source: Authors' analysis

Figure A.2.2. **In CCS scenario, there is some uptake of fossil energy sources such as coal and gas in power sector**



Acknowledgment

We thank colleagues from ExxonMobil, Gas Authority of India (GAIL) Ltd., Oxford Institute for Energy Studies (OIES), King Abdullah Petroleum Studies and Research Center (KAPSARC), National Foundation for India, Royal Dutch Shell, TOTAL, ICF International, and IIM-Sambalpur for their observations and suggestions during the stakeholder discussion held on 21 January 2021. We would like to thank Dr Anupama Sen, Senior Research Fellow & Executive Director, Electricity Programme, Oxford Institute for Energy Studies (OIES), Dr Kaushik Deb, Research Fellow, Markets and Industrial Development, KAPSARC and Mr Tirtha Biswas, Programme Lead, Council on Energy, Environment and Water (CEEW) for being the reviewers of the study and providing their details comments and suggestions for improvement. Their valuable inputs have shaped the research piece significantly. We would also like to thank our colleagues from Industrial and Sustainability (ISC) team at CEEW for insights throughout the course of the study. Discussion with them improved our understanding of different aspects associated with future of gas in Indian economy. Authors' take full responsibilities for any errors in the document.

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Suggested citation: Malyan, Ankur, Poonam Nagar Koti, Nitin Maurya, Diptiranjan Mahapatra, and Vaibhav Chaturvedi. 2021. *India's Natural Gas Future Amid Changing Global Energy Dynamics.* New Delhi: Council on Energy, Environment and Water.

Peer reviewers: Dr Anupama Sen, Senior Research Fellow & Executive Director, Electricity Programme, Oxford Institute for Energy Studies (OIES); Dr Kaushik Deb, Research Fellow, Markets and Industrial Development, KAPSARC; and Tirtha Biswas, Programme Lead, CEEW.

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