# Appendix A

प्रयास

आरोग्य, ऊर्जा, शिक्षण आणि पालकत्व
या विषयांतील विशेष प्रयत्न

# Contents

# Appendix A: Description of Scenarios

This appendix describes the storylines defining the four scenarios that are used in the analysis. Each scenario is primarily defined by its fuel penetration assumptions, i.e. assumptions about the percentage of households using a particular fuel as the primary cooking fuel.

For all fuels except LPG, the penetration of a fuel is the same as the penetration of connections for that fuel. That is, all households that have a 'connection' for a fuel (say, PNG) use that fuel as the primary fuel. Because of programmes such as the Pradhan Mantri Ujjwala Yojana (PMUY) which targets disbursing large number of subsidised connections, the increase in the percentage of households with connections is greater than the increase in the percentage of households using LPG.

This follows from an interesting anomaly in the available data regarding penetration of LPG connections (not primary fuel users). The penetration of LPG connections was well in excess of 100% in urban areas of many states in November 2015 as per data submitted by the government to the Indian parliament (Lok Sabha 2016). For example, urban LPG connections in Himachal Pradesh exceed 300%; in urban Uttarakhand, Assam and few other states they exceed 200%; while the all-India urban LPG connection coverage is 111%. Rural LPG connections in many states are also quite high — for example, 86% in Tamil Nadu, 95% in Kerala and 60% in Andhra Pradesh. Given this high base of connections in 2015 and the government's announcement of aggressive targets for disbursing LPG connections in 2016, the penetration of urban LPG connections reaches 114% in 2030 in our scenarios, though the penetration of connections will actually fall in many states in the latter years due to faster increase in the number of urban households as compared to new connections.[1] The penetration of rural LPG connections also reaches 113% by 2030, with states such as Tamil Nadu, Chattisgarh, Maharashtra, Punjab, Uttar Pradesh, West Bengal and Andhra Pradesh all having over 100% rural LPG connections.

## A.1 Baseline scenario

This scenario represents our best guess of the path the country is likely to follow until 2030 in the absence of any new major policy push, with fuel prices following expected trajectories. The scenario accounts for a significant increase in LPG connections and some increase in use driven by the government's Pradhan Mantri Ujjwala Yojana (PMUY), a programme for subsidised LPG connections to poor households. There is a significant uptick in penetration of LPG as a primary fuel compared to past trends as a result of PMUY, with greater usage in urban areas as compared to rural areas where penetration is low due to issues such as unreliable supply and unaffordability of the fuel. National penetration of LPG doubles from 31% in 2015 to 62% in 2030, with 90% of urban India and 38% of rural India using LPG in 2030. States with high penetration of LPG as a primary cooking fuel according to the census of 2011 continue to have higher LPG penetration in 2030 as compared to

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1. Note that connection penetration may exceed 100% due to multiple reasons such as multiple connections in a household, past aggressive connection drives which did not result in sustained use, usage of LPG connections for purposes such as gas-based heaters, and diversion of domestic connections for commercial or other purposes. Some increase in urban connections beyond 100% may also be because of some rural households having connections with distributors in urban areas.

those with low LPG penetration in 2011. The states with the highest rural penetration of LPG in 2030 are Punjab (63%), Himachal Pradesh (61%) and Tamil Nadu (58%). Chhattisgarh (28%) Bihar and Madhya Pradesh (29% each), Odisha (30%) and Uttar Pradesh (31%) are the states that lag behind.

The absence of specific policies to encourage or promote other fuels results in very modest increases in penetration of other clean fuels, namely PNG, biogas and electricity. Together, the penetration of these fuels will increase from 1% in 2015 to 2% in 2030.

Penetration of biomass, which is the residual fuel in this scenario, falls from 65% in 2015 to 36% in 2030 across the country. The rapid uptake of LPG means that in urban areas, biomass users fall from 22% of all urban households in 2015 to just 5% in 2030. In rural areas, it goes down from 84% in 2015 to 61% in 2030, with the states having high LPG penetration having low biomass penetration and vice-versa.

## A.2   PMUY scenario

This is the scenario that represents the outcome of an aggressive and successful implementation of PMUY augmented by measures to boost LPG use. Thus, the number of LPG connections in this scenario is only slightly more than that in the Baseline scenario because of better implementation of PMUY. However, the real difference between the Baseline and PMUY scenarios is how many of these connected households use LPG as their primary source of cooking fuel.

Thus, in this scenario, there is specific attention given to ensuring that households use LPG as a fuel beyond just obtaining a connection. To achieve this, increased attention is given to rural LPG distribution infrastructure and networks. Steps are taken to improve quality and reliability of supply, addressing consumer grievances and improving affordability of LPG through well-designed subsidy programmes, all of which lead to a significant increase in penetration of use of LPG. As a result of these measures, national penetration of LPG use reaches 78% in 2030 from just 31% in 2015. While the penetration in urban areas at 93% in 2030 in this scenario is marginally higher than the 90% in the Baseline scenario, the real change is seen in rural areas due to the measures mentioned above, with LPG penetration reaching 65% in rural areas in 2030, compared to just 38% in the Baseline scenario. As with the Baseline scenario, the states with the highest rural LPG penetration are Tamil Nadu, Punjab, Himachal Pradesh and Uttarakhand. Policy measures targeted at states with low LPG usage lead even states such as Bihar, Odisha and Uttar Pradesh, which lag considerably in the Baseline scenario, to achieve LPG penetrations in the range of 64% to 75%.

Because of the exclusive focus on LPG in this scenario, there is hardly any difference in penetration of other modern fuels in this scenario and they continue to contribute only 3% at the national level even in 2030 which is comparable to the Baseline scenario, with PNG barely reaching a penetration of about 4% in urban areas in 2030. The prices of PNG, biogas and electricity are assumed to be the same as in the Baseline scenario.

The rapid increase in LPG penetration also means that biomass penetration at the national level plummets from 65% in 2015 to 20% in 2030, with urban usage of biomass almost disappearing by 2030 (at 3% in 2030 from 22% in 2015) and rural usage of biomass coming down to 34% from 84%. Less than 25% of rural households in Tamil Nadu, Punjab, Uttarakhand and Himachal Pradesh use biomass in 2030 in this scenario, while rural biomass penetration even in states such as Bihar, Jharkhand, Chattisgarh, Odisha and Uttar Pradesh comes down to the 30% to 40% range.

## A.3  Multi-Fuel scenario

This scenario also sees a significantly greater push for modern cooking fuels than observed in the Baseline scenario. However, the major difference between this scenario and the PMUY scenario is that LPG is no longer the single focus of policy attention. Instead, encouragement is given to all the modern fuels with households choosing a suitable fuel depending on local realities and their preference. Thus, piped gas networks are expanded aggressively in many more cities to provide PNG as a viable option for urban households. Similarly, greater support is provided to biogas, in particular through development of technology and business models which result in lower capital costs for biogas, development of dung markets and targeted subsidies so that many more rural households opt for this fuel. More community sized plants, economies of scale and bulk procurement of dung by biogas using families and communities also help to bring biogas fuel costs down.  An increased attention to household electrification, investment in rural electricity distribution networks and improved reliability and affordability of electricity supply encourages many households to switch to electricity as the primary cooking fuel. Penetration of PNG, electricity and biogas depends on resource and infrastructure availability for these fuels in states. Thus penetration of PNG is higher in states with more existing and upcoming city gas distribution networks, that of biogas is higher in states with greater bovine population relative to human population, and the use of electricity as cooking fuel is higher in states with better electricity networks and supply. This also results in the spread of PNG, biogas and electricity as cooking fuels, in areas where it is difficult to deliver LPG or where it is relatively more expensive.

An interesting fall-out of juxtaposing this scenario with the reality of PMUY being rolled out in the initial years of the model (2016–2019) is the spurt in LPG connections (and to a lesser extent, usage) in the initial years, especially in urban areas, after which there is a shift to other fuels that households find more convenient. However, though other fuels are also provided as an option, LPG remains the dominant modern fuel even in this scenario albeit with a lesser role than in the PMUY scenario.

In 2030, nationally, LPG reaches a penetration of 69% in this scenario as compared to 62% in the Baseline scenario and 78% in the PMUY scenario. PNG, electricity and biogas together are now used in about 18% of households across the country compared to just 2%-3% in the Baseline and PMUY scenarios. Thus, 87% of households use modern fuels in 2030 in this scenario, with only 13% using biomass (compared to 80% and 20% respectively in the PMUY scenario).

In urban India, LPG penetration reaches 73% in 2030 with PNG reaching a significant 18% of households and 7% of households using electricity as their preferred fuel. Thus, only 2% of urban Indian households use solid fuels in 2030 in this scenario.

22% of rural India uses biomass in 2030 in this scenario, compared to 61% in the Baseline scenario and 34% in the PMUY scenario. The increased penetration of modern fuels in this scenario is because a broader range of choices are provided to households, which allows them to choose a convenient option. In particular, 7% of rural households opt for biogas and 6% opt for electricity in this scenario, with LPG being the choice of 65% households, which is comparable to the PMUY scenario. Thus, greater penetration of electricity and biogas as cooking fuel options in rural areas is primarily responsible for the reduction of biomass use in this scenario as compared to PMUY.

As many cities and towns lay down city gas distribution networks for PNG along with compressed natural gas for transport, PNG penetration increases. PNG penetration reaches significantly higher proportions in states that already have a good PNG network or states that have ambitious plans for city gas networks. This is based on current plans for expansion of PNG networks (Petroleum and Natural Gas Regulatory Board n.d.). Thus in 2030, 55% of urban Gujarat households use PNG with the corresponding figures being 40% for Uttar Pradesh, 35% for Haryana, 30% for Punjab and 20% for Maharashtra. PNG is used in rural areas only marginally (0.05% in 2030).

Penetration of electricity in urban areas has a significant reach across the country with the highest penetrations occurring in states such as Kerala and Tamil Nadu (11%), which have good electricity supply and are already seeing some penetration of induction-based cooking. States with relatively poor electricity supply such as Bihar, Chattisgarh, Jharkhand, Madhya Pradesh and Uttar Pradesh achieve electricity penetrations of around 4% in urban households in 2030. Rural areas of states with good electricity supply see a faster uptake of electricity with many states such as Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab and Tamil Nadu reaching penetrations around 10%-11% in 2030. States with poor supply such as Bihar, Jharkhand, Odisha, West Bengal and Uttar Pradesh reach rural electricity penetrations of around 3% in 2030.

Biogas is predominantly a rural option, and states with high per-capita bovine populations move towards this fuel. Thus, states such as Assam, Chattisgarh, Gujarat, Jharkhand, Haryana, Madhya Pradesh, Rajasthan, Uttar Pradesh and Punjab have rural biogas penetrations in the range of 8%-10% in 2030, while other states have penetrations around 5% in 2030. Penetration of biogas is also facilitated through development of better business models that make community biogas plants (in contrast to household-sized plants) more viable, which reduces the cost of biogas. While the share of community biogas plants in the total number of biogas plants is only about 3% in 2030 in the Baseline and PMUY scenarios, it is around 30% in this scenario.

## A.4   SDG scenario

This scenario is designed with the objective of achieving SDG goal 7 by 2030, which requires all Indians to have access to modern, clean cooking energy. Thus, this scenario is deliberately designed to have 0% households using biomass and other traditional fuels as their primary cooking fuel by 2030. The drivers of this scenario are similar to the Multi-Fuel scenario in that all the possible alternative modern fuels are supported, with development of technology, improved quality of supply, better delivery mechanisms, better consumer grievance redressal, improved business models, and consumer price signals that encourage switching to modern fuels. Increasingly scarce availability of biomass (and associated increase of prices), a greater valuation of women's time and labour, and a greater understanding of the pitfalls of using solid fuels because of concerted efforts on the part of the government are other drivers for people to switch to modern fuels. As with the Multi-Fuel scenario, in the SDG scenario also LPG penetration increases rapidly in the initial years backed by policy drivers such as PMUY before falling in later years due to the availability, affordability and convenience offered by alternatives such as PNG, electricity and biogas. This fall in penetration arises due to two factors: a) households using biomass who would switch to a modern fuel in later years opting for a fuel other than LPG and b) some households using LPG switching to other options that are more attractive.

There is also a high penetration of PNG in urban areas building upon the success in rolling out city gas networks. The high urban PNG penetration means that a portion of the PNG supply is from imported gas either in the form of LNG or international pipelines. It is assumed that India is able to access more natural gas through international pipelines which helps to keep PNG prices low and make it price-competitive with other fuels, in addition to its being more convenient and safe to use. Also, regulation, oversight and competition in the PNG sector are assumed to be significantly better than today, which helps to keep prices down.

Community based biogas plants, which are assumed to have much greater penetration in this scenario compared to the Multi-Fuel scenario, reach 40% of the total households using biogas by 2030. This, along with technology improvements and economies of scale, are assumed to lead to lower cost of biogas making it a preferred fuel for more rural households. The big mover in this scenario is electricity as a preferred option driven by various factors such as convenience of use, the fact that it that can be used for a variety of purposes, affordability and reliability of supply even in rural areas, a robust transmission and distribution network and universal reach.

These policy, technology and market drivers cause 100% of Indian households to use modern fuels for cooking by 2030. The shares of the various modern fuels at the national level in 2030 are 58%, 13%, 11% and 18% for LPG, PNG, biogas and electricity respectively. Thus, LPG has the highest penetration among all fuels in 2030 even in this scenario, though it is much lesser than that in the PMUY and Multi-Fuel scenarios. Indeed, it is even less than the 2030 penetration of LPG in the Baseline scenario due to the availability of other competing options.

In urban areas, LPG retains its pole position in 2030 with a penetration of 45%, with electricity and PNG being the preferred choice of 27% households each. In rural India, 69% households prefer LPG in 2030, while the rest are divided between biogas (20%) and electricity (11%). Thus, this scenario sees an interesting inversion in the role of LPG, which changes from its current role of being a predominantly urban fuel of choice to a predominantly rural fuel of choice.

Urban penetration of LPG is high, unsurprisingly, in states with low likelihood of PNG networks developing or where electricity supply is unlikely to be very reliable. Thus, Assam, Bihar, Chattisgarh, Himachal Pradesh, Jharkhand, Uttarakhand, Odisha, West Bengal and the North East have urban LPG penetrations greater than 60%. The rapid uptake of PNG based on ambitious plans results in urban LPG penetration in 2030 of less than 35% in Gujarat, Haryana, Punjab and Uttar Pradesh, with the urban LPG penetration in 2030 in Gujarat being just 10%.

States that have poor biogas potential (due to low bovine population) or unreliable electricity have high rural LPG penetrations. These include Bihar, Kerala, West Bengal, Uttarakhand and the North East, all of which have rural LPG penetrations greater than 70% in 2030. The states with relatively low rural LPG penetrations in 2030 are Gujarat, Punjab and Haryana which have both good electricity supply as well as good biogas potential.

PNG, which is an urban fuel, achieves a penetration of 60% in Gujarat by 2030 based on the extensive network already in place in that state. It also reaches a penetration of 50% in Uttar Pradesh, a state for which there are ambitious plans of rolling out new networks. The other states with large PNG shares among urban households are Haryana (47%) and Punjab (40%). Hilly states such as Himachal Pradesh, Uttarakhand and the North East have low PNG penetrations of less than 10%, as do states such as Bihar, Chattisgarh, Jharkhand and Odisha.

Biogas, which is a rural fuel, achieves a penetration of 30% or more by 2030 in Chattisgarh, Gujarat, Haryana and Punjab. It reaches a very low penetration of just 2% in Kerala due to its limited bovine population, while it is in the range of 10% to 15% in Himachal Pradesh, Maharashtra, Tamil Nadu, Uttarakhand and the North East.

Use of electricity for cooking spreads in both urban and rural areas by 2030, with a greater spread in urban areas. The states with urban electricity penetrations of 30% or more in 2030 include Andhra Pradesh, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab and Tamil Nadu. Its spread as a preferred fuel is evident from the fact that the lowest urban penetration of electricity for cooking in 2030 is 19% (Bihar, Jharkhand, Uttar Pradesh and West Bengal). The states with rural penetrations for electricity in 2030 at 20% or above are Gujarat, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab and Tamil Nadu, while the states with rural electricity penetrations below 10% are Assam, Bihar, Chattisgarh, Jharkhand, Odisha, Uttar Pradesh, West Bengal and the North East.

Figure 1 and Figure 2 show the transition in the modern fuel penetrations in rural and urban areas of the country respectively from 2015 to 2030.

**Figure 1: Modern fuel penetrations in rural areas of various states in 2015, 2022 and 2030**
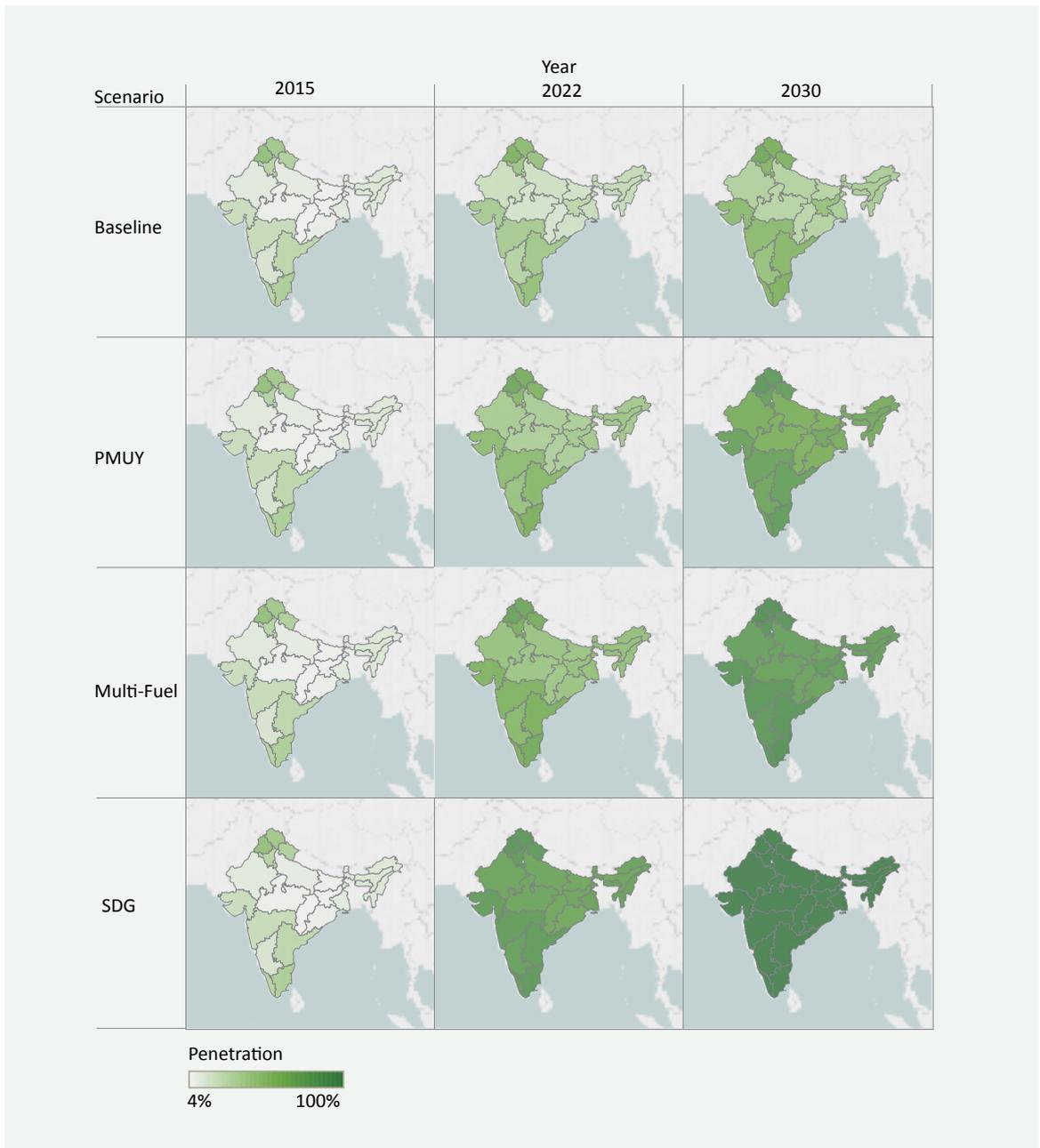
**Figure 2: Modern fuel penetrations in urban areas of various states in 2015, 2022 and 2030**
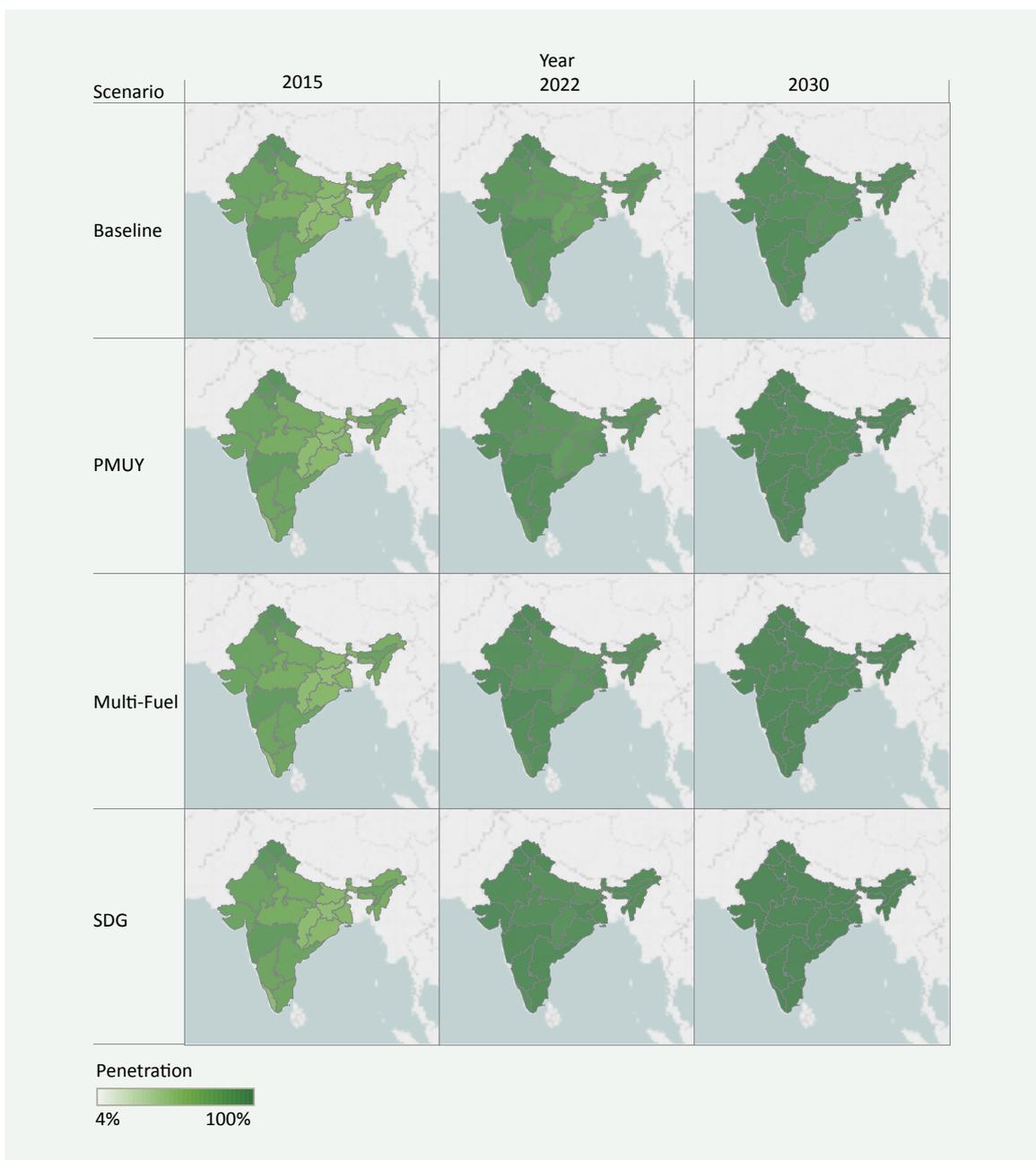


Based on the penetration of fuels in 2015, the states under analysis can be roughly grouped into three categories: high traditional fuel usage, moderate traditional fuel usage and low traditional fuel usage, as described in Table 1.

**Table 1: Grouping of states based on penetration of traditional fuels**

| Category | | 2015 | Baseline 2030 | PMUY 2030 | Multi-Fuel 2030 |
|---|---|---|---|---|---|
| High (>=75%) | Bihar | 89% | 62% | 35% | 24% |
| | Odisha | 85% | 56% | 31% | 21% |
| | Chhattisgarh | 84% | 50% | 28% | 19% |
| | Jharkhand | 84% | 37% | 22% | 13% |
| | Madhya Pradesh | 78% | 47% | 26% | 17% |
| | Uttar Pradesh | 77% | 47% | 27% | 18% |
| | West Bengal | 76% | 40% | 22% | 15% |
| | Assam | 76% | 51% | 27% | 18% |
| | North East | 75% | 45% | 25% | 16% |
| | | | | | |
| Medium (55% - 75%) | Rajasthan | 74% | 46% | 26% | 17% |
| | Kerala | 65% | 32% | 18% | 11% |
| | Karnataka | 61% | 23% | 13% | 8% |
| | Andhra Pradesh | 60% | 29% | 16% | 9% |
| | | | | | |
| Low (<=55%) | Gujarat | 55% | 19% | 10% | 6% |
| | Himachal Pradesh | 54% | 33% | 17% | 10% |
| | Uttarakhand | 52% | 25% | 14% | 8% |
| | Haryana | 50% | 22% | 12% | 7% |
| | Maharashtra | 49% | 15% | 8% | 5% |
| | Tamil Nadu | 42% | 11% | 5% | 3% |
| | Punjab | 36% | 13% | 7% | 4% |

A few facts stand out from this table:

- States with higher penetration of traditional fuels in the initial year by and large remain worse than other states even in 2030 across all scenarios (except SDG where traditional fuel use reduces to zero by 2030 for all states).

- Penetration of modern fuels (which is the complement of traditional fuels) increases significantly in all states from the Baseline scenario to the other scenarios.

- In absolute terms, the states dependent on traditional fuels for over 80% of their needs in 2015 (Bihar, Chattisgarh, Jharkhand and Odisha) are the ones to see the sharpest falls in usage of traditional fuels, particularly in the PMUY and Multi-Fuel scenarios, as special attention is given to such states. States whose urban areas use traditional fuels for less than 15% of their needs see slower falls in their traditional fuel consumption in all scenarios, since it is harder to bring reliable supply of modern fuels to those who switch to them last — the poorest, marginalised people and those most reluctant to switch — without significant effort.

While no state has a traditional fuel use of less than 10% in 2030 in the Baseline scenario, there are three such states in the PMUY scenario (Maharashtra, Punjab and Tamil Nadu) and eight such states in the Multi-Fuel scenario (Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu and Uttarakhand).

Figure 3 (for urban areas) and Figure 4 (for rural areas) show the penetration mix of fuels in different states as assumed in the Multi-Fuel and SDG scenarios in 2030. The figures also highlight the dominant fuel in that state. It is interesting to note that LPG is the dominant fuel in the urban areas of most states with the exception(s) being Gujarat in the Multi-Fuel scenario and Gujarat, U.P, Haryana and Punjab in the SDG scenario, where PNG is the dominant fuel. Nevertheless, PNG and electricity have significant penetration in urban areas of states in the SDG scenario. In the SDG scenario, Maharashtra, Karnataka and Punjab are interesting in that the three modern urban fuels (LPG, PNG and electricity) play roughly equal roles.

**Figure 3: Penetration of fuels in urban areas of different states in 2030**
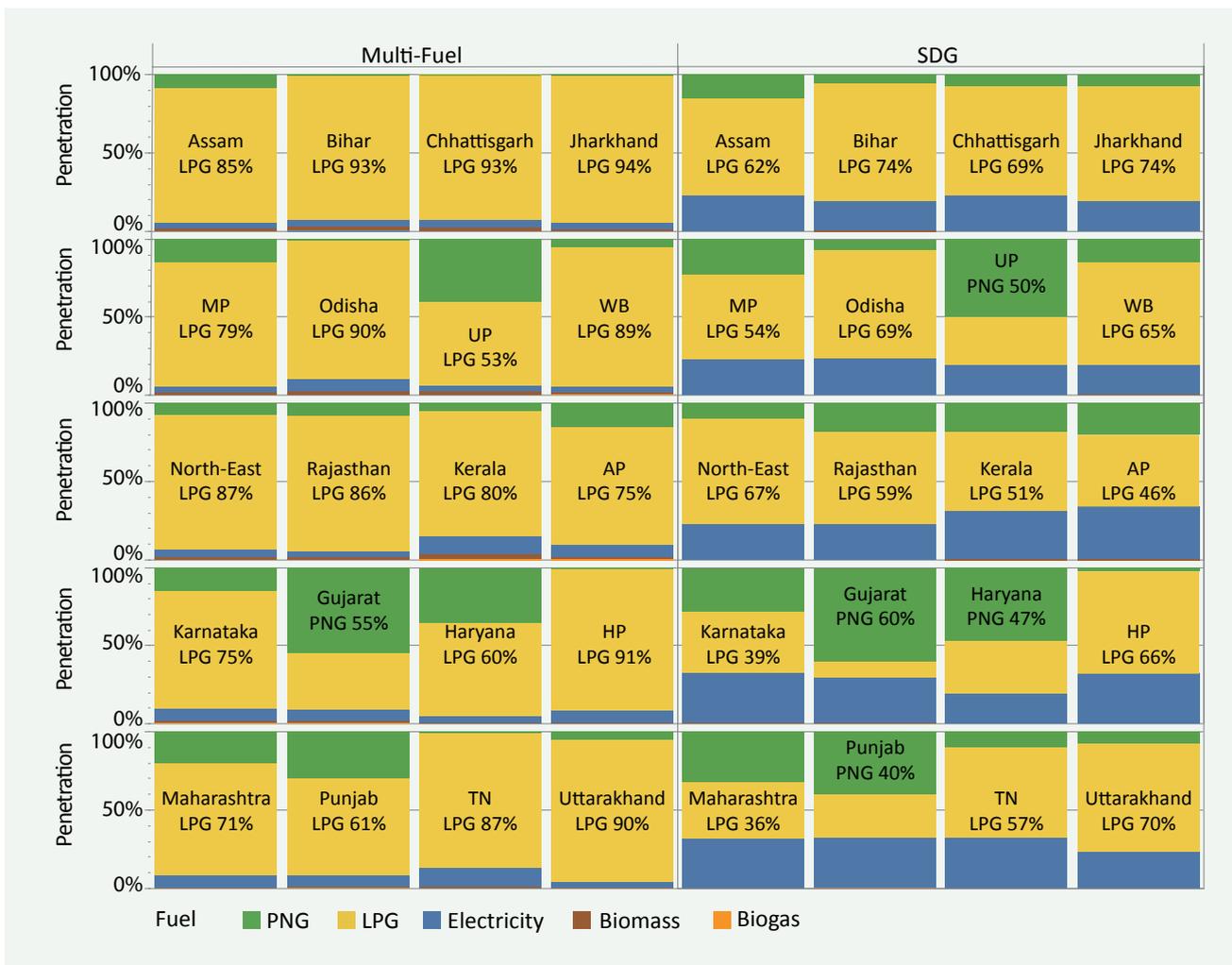


In the Multi-Fuel scenario, biomass use in 2030 is 22% in the rural areas of the country, but no state has biomass as the dominant fuel in rural areas because of the focus on reduction in solid fuel use. LPG is the dominant fuel in the rural areas of all states in both scenarios while biogas use is significant in the SDG scenario. Indeed, LPG is used in more than 50% of rural households in all states in 2030 in both these scenarios, with the exception of Gujarat and Punjab in the SDG scenario where it is used by 45% to 49% rural households respectively.

## Figure 4: Penetration of fuels in rural areas of different states in 2030



Figure 4: Penetration of fuels in rural areas of different states in 2030
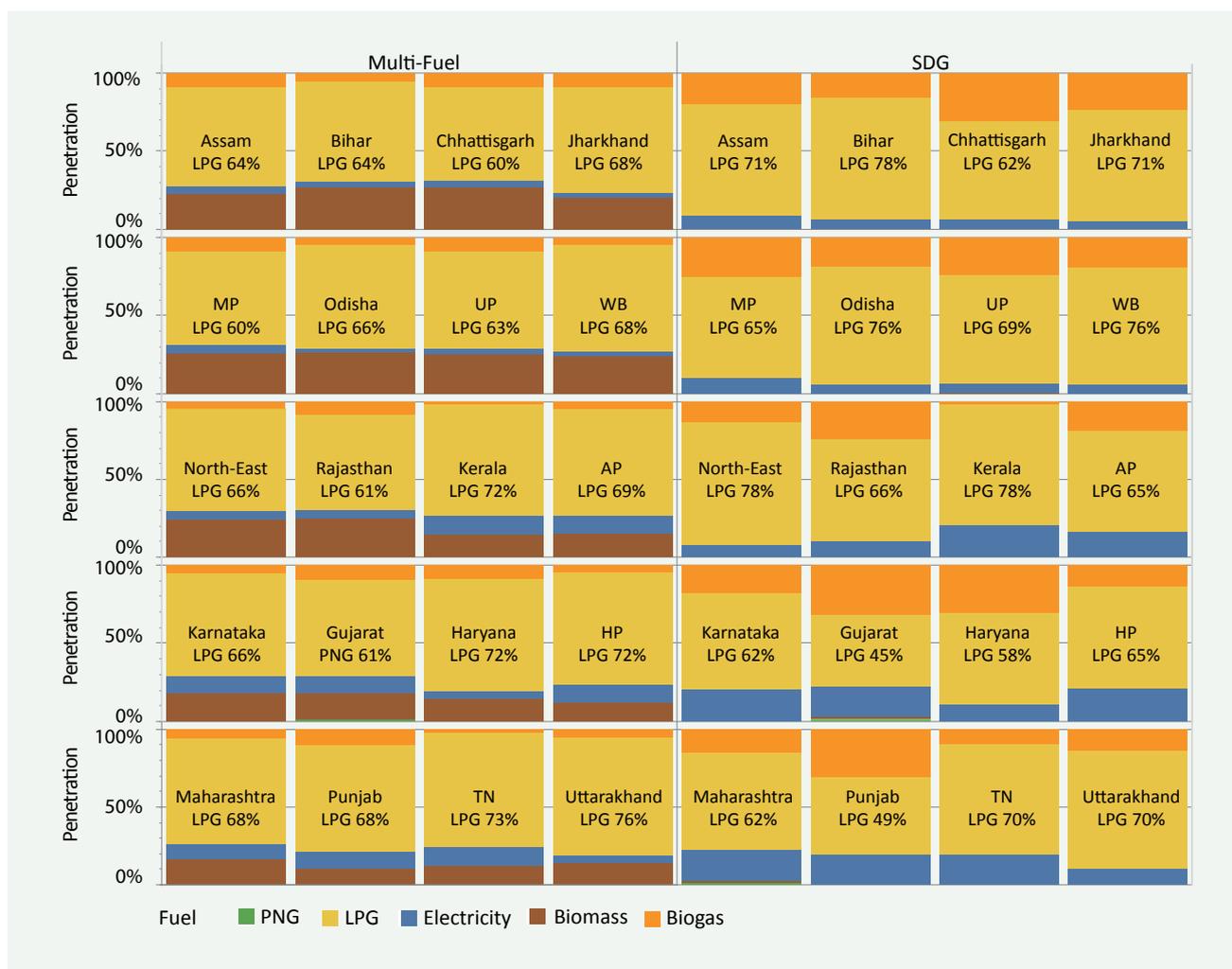
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