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Can coal-derived DME reduce the dependence on solid cooking fuels in India?

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ABSTRACT

The Indian government is currently promoting and subsidising the replacement of solid cooking fuels with cleaner-burning liquefied petroleum gas (LPG). India is however a growing importer of LPG, the cost of which strongly linked to the prevailing oil price, which makes this program vulnerable to oil price shocks. Dimethyl ether (DME) is a synthetic fuel which may be blended with LPG and, if produced from domestic Indian feedstocks, one way of potentially reducing this vulnerability. A techno-economic analysis of the use of low grade Indian coal for this purpose is described in this paper, and the coal rich state of Jharkhand, where more than 18% of households used coal as a cooking fuel in 2011, was chosen as a study area. Here it was found that, due to higher cooking energy efficiency, the production and use of the DME (together with an associated electricity export) could result in 35% less coal being consumed when compared with a scenario where coal is used for cooking and to generate an equivalent amount of electricity. This analysis further shows that producing DME through this means would likely require oil prices in excess of $72 per barrel to be cost competitive with imported LPG.
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Introduction

Globally, there are approximately 1.4 billion people without access to electricity, and 2.7 billion people who rely on solid fuel (wood, crop residue, dung and coal) for cooking (Johansson et al., 2012). The use of these traditional cooking fuels creates a number of significant problems which includes deforestation and an estimated 4 million attributed deaths annually due to the negative health effects associated with indoor air pollution (Rockall, 2008; Johansson et al., 2012). In addition, the labour and time intensive collection of traditional fuels often occurs at the cost of more productive activities and contributes to gender inequality (Guruswamy, 2011). Improving energy access as a means of addressing these problems in developing countries has been high on the agenda of the international community for some time. Most recently, this resulted in the announcement of the United Nations Sustainability for All (UNSE4All) initiative, with key objectives of achieving global electricity access, and a primary reliance on non-solid fuels for cooking by 2030 (UNSE4All, 2012). In this context, various governments, including China, India, Guatemala, Indonesia, Kenya, Pakistan, Sri Lanka, Albania, Brazil, Mexico and Peru, have instituted programs aimed at replacing solid fuels with liquefied petroleum gas (LPG) (D'Sa and Murthy, 2004; Fall et al., 2008; Kojima, 2011; Khandker et al., 2012; Andadari et al., 2014). These countries currently represent more than 45% of the world's total population.

In 2011, more than 67% (or 165.8 million) of Indian households still relied on the use of solid fuels for cooking, compared with approximately 74% (or 142.6 million) in 2001. Approximately 28.5% of the country's population had transitioned to the use of LPG (and piped natural gas (PNG)), and only 0.2% of the population used electricity for this purpose (India-Census, 2012). The vast majority of India's LPG consumption is supplied through imports (either as final product LPG or as imported crude oil) (MoPNG, 2015) and some studies (TERI, 2012) suggest that the demand for petroleum products is expected to increase more than four-fold between 2011 and 2031, and that by 2031 India would be 90% dependent on oil imports, compared with 74% in 2011.

The price of LPG is strongly linked to the prevailing crude oil price, and the cost is high when compared with traditional fuel alternatives (Kojima, 2011). As a result, the Indian government subsidises the provision of LPG to make it affordable to a greater part of the population and protect them against oil price volatility. The LPG price is regulated by the Government through its controlling share in public oil marketing companies (OMCs) and subsidised through a mechanism by which the OMC's are reimbursed for the difference between the cost price and regulated price (IISD/GSI, 2014). This cost difference is referred to as an LPG under-recovery, the extent of which is depicted in Fig. 1, together with the Saudi Aramco LPG price and the Indian Basket crude oil price.

The impact of oil price volatility on the LPG price and under-recovery is clear to see. At high oil prices, the cost may be significant and in 2012/2013 the total LPG-related subsidy was approximately 2.7% of the total

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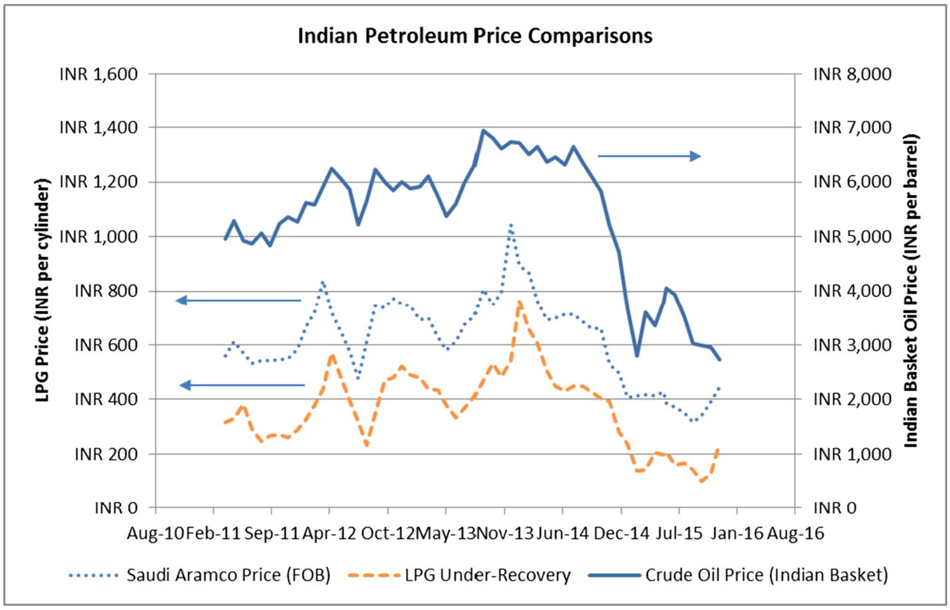

Fig. 1. Indian petroleum price comparisons. The Saudi Aramco price conversion (from US$ per tonne into INR per cylinder) is based on prices published by Gas Energy Australia (http://gasenergyaustralia.asn.au/reports-and-submissions/saudi-aramco-lpg-prices), a LPG blend containing 40% propane and 60% butane, a 14.2 kg of LPG per cylinder and the monthly average INR to US$ exchange rates published by www.xe.com.

budget, and almost twice the (non-plan) amount spent on social services (which included education, health, broadcasting, etc.) (IISD/GSI, 2014).[1]

The uptake of LPG as a cleaner cooking fuel is also dependent on the reliability of supply (Kojima, 2011) and any operational disruption resulting in LPG shortages has a much more immediate effect on households. One of the consequences of these disruptions may also be a return to the use of solid fuels, as evidenced by recent events in Nepal where a blockade on petroleum (and other imports) resulted in a sudden jump in the demand for firewood and an increase in deforestation.[2]

One strategy of reducing the impact of LPG price volatility and supply disruption may include the substitution of imported LPG with a non-crude-oil derived equivalent, produced through the use of domestically available alternative feedstock. Dimethyl ether (DME) has properties similar to LPG and may be produced from a variety of different feedstock types including natural gas, coal, biomass, municipal solid waste (MSW) and CO_2 (Larson and Yang, 2004; IRENA, 2013). It is therefore particularly attractive in this regard. DME is suitable for a wide variety of different applications, which includes use as an aerosol propellant, diesel fuel substitute, gas turbine fuel and a number of studies have shown that the use of LPG/DME fuel blends containing up to 20% are completely compatible with existing LPG cooking devices, without modification (Fleisch et al., 2012).

In 2000, the total global production of DME was estimated at 150,000 t per year (Larson and Yang, 2004) but increased more than 30-fold by 2012, with the consumption of DME amounting to approximately 4.8 million tonne per year (CMAI, 2012).

This growth was largely driven by increased consumption in Northeast Asia, and specifically China, and the production underpinned by the use of coal (primarily) and natural gas (CMAI, 2012). Approximately 90% of the produced DME was blended with LPG, with the remainder used for refrigeration or as a propellant (Fleisch et al., 2012).

Unlike China, there are currently no known commercial DME production facilities operational in India where its use is very limited. India had however, as early as 1998, been identified as a prospective market for DME by a joint venture comprising Amoco, the India Oil Company (IOC) and the Gas Authority of India (GAIL). The joint venture was interested importing DME produced in countries with large gas resources (such as Qatar) and using it to generate power, replace diesel with a cleaner burning alternative and blend it with LPG for cooking fuel use. Amoco merged with British Petroleum (BP) in late 1998 however, after which the resulting company (BP Plc) terminated the project to pursue more favourable gas related ventures (Fleisch et al., 2012).

There has been a resurgence in the interest in DME in recent times and the Indian and Australian Governments are currently engaged in a joint research program aimed at informing the development of small scale plants which may produce DME from remote and stranded natural gas.[3] This research is focused at improving the conversion efficiency of the DME production process to make the use of these gas resources, currently challenged by high capital costs and low economies of scale, economically viable. Broadly speaking, the objective of this initiative is similar to that of an emerging industry which is focused on monetisation of natural gas resources (stranded due to remoteness and/or lack of scale) through small scale gas-to-liquid (or so-called miniGTL) plants (Fleisch, 2014). Once proven to be commercially viable, these plants may not only unlock the value in small scale gas reserves but also improve the chances of producing DME from feedstocks such as biomass and MSW, the cost of which is similarly challenged by economies of scale. This is an exciting development and considered to be an area worthy of future investigation.

A study (Larson and Tingjin, 2003) of the use of DME as a clean cooking fuel determined that LPG equivalent cost[4] of producing DME from coal in the Yanzhou City area (Shandong Province) was comparable with the prevailing LPG wholesale price. An extension to this work (Larson and Yang, 2004) concluded that for China's coal rich provinces, which are mostly located inland and a great distance from sea-borne import terminals, the production of coal-derived DME became cost competitive with imported LPG at oil prices between $20 to $26 per

[1] See http://indiabudget.nic.in/budget2012-2013/glance.asp (accessed 7 May 2016).
[2] See http://www.bbc.com/news/science-environment-34468821 (accessed 7 May 2016).

[3] The joint research program is being conducted through joint collaboration by the CSIRO, Indian Institute of Petroleum (CSIR-IIP), Indian Institute of Technology (IIT-Roorkee), Bharat Petroleum Corporation Limited (BPCL), The Center of Advanced Materials and Industrial Chemistry (CAMIC) at RMIT, and The University of Melbourne (http://australianresources.com.au/988/australia-india-collaborate-clean-fuel-production — accessed 7 May 2016).
[4] The LPG equivalent cost is equal to the actual cost of producing DME multiplied by the ratio of the heating value of LPG (46.6 MJ per kg) to DME (28.9 MJ per kg).

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