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# TOWARDS SMARTER SERVICE PROVISION FOR SMART CITIES: ACCOUNTING FOR THE SOCIAL COSTS OF URBAN SERVICE PROVISION

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## EXECUTIVE SUMMARY

As one of the world's fastest growing countries, India is facing both opportunities and challenges presented by rapid urbanisation. How India responds will have major implications for the country's development and for the rest of the world. One crucial issue in India's urbanising future is the provisioning of basic urban services for its citizens. Through case studies of four Indian cities, this work examines the current unmanaged growth (business as usual urbanisation) and the costs associated with it.

Using a social cost accounting (SCA) methodology, it estimates the market and non-market costs associated with the delivery of urban water and sanitation, transport and energy services. The study goes beyond often discussed issues of access to services and the direct costs involved and emphasises attention to often ignored social costs (indirect costs, health costs and environmental costs). Each type of service provision is categorised into public, private and self-provision across the three sectors and explored further. The study highlights that despite high levels of coverage in the four cities, the quantity and quality of services are inadequate in many respects, especially in the case of water and transport, and have high associated social costs. This work makes three key recommendations for India's urban future: (1) use of social cost accounting to plan services; (2) integrated service planning to generate efficiencies across sectors and (3) leverage new models for service provision and entrepreneurial schemes.

## CONTENTS



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# 1. INTRODUCTION

India is on the cusp of an urban transformation. In 2015, its urban population reached 420 million, which was 33 per cent of the total population of the nation. This number is expected to reach 600 million by 2031 (HPEC 2011) and roughly double to about 800 million by 2050 when one in every two Indians will live in its towns and cities (UN 2014); (UN-HABITAT 2016). By 2031, 75 per cent of India's national income is expected to be generated in cities, up from the current 66 per cent, and the majority of new jobs will be created in urban areas (Ellis and Roberts 2016); (HPEC 2011). In terms of absolute numbers, urbanisation in India is occurring on a scale second only to China. Between 2000 and 2014, India added nearly 127 million new residents to its towns and cities; and over the next 15 years its urban population is projected to grow by a further 177 million (Ellis and Roberts 2016). Between 2001 and 2015, the number of cities in India with a population of a million or more increased from 35 to 53.

As India progressively urbanises, there is no guarantee that cities will necessarily evolve in ways that maximise net agglomeration effects and productivity. Instead, market failures, weak institutions and ineffective policies could impede the ability of cities to provide critical public goods, ensure planned and serviced urban growth, and manage industrial growth. This in turn could result in a massive increase in informal settlements, along with excessive congestion and decreased productivity.

India's cities not only face severe infrastructure bottlenecks and service level deficits that undercut economic performance, but their poorly managed urban growth also directly impacts health and quality of life. Worsening air pollution in Indian cities is estimated to have caused 620,000 premature deaths per annum (Cohen 2010). It also adds significantly to overall carbon emissions and close to half of India's net greenhouse gas emissions originate in urban areas.

Recent evidence shows that the cost of environmental degradation is enormous, reducing India's GDP by 5.7%, or about $80 billion annually (M. S. Mani 2014). A significant portion of this degradation arises from urban activities. It is estimated that health damages from urban outdoor air pollution (primarily from the growth of private motorized vehicles) amounts to 1.7% of the country's GDP. This accounts for the largest share in the overall cost of environmental degradation (Beard, Mahendra and Westphal 2016). These costs are exacerbated by the ongoing real-estate boom in peri-urban areas, fuelled by demand from the residential sector. This rapid expansion is not only unplanned, but also almost entirely lacking in public goods provision (namely water, sewer, power infrastructure) and reasonable access to transit infrastructure. This reinforces the vicious cycle of ever-deeper reliance by firms and households on groundwater, private vehicle ownership and polluting diesel power generation to meet basic needs. The costs of business as usual urban development are clearly unsustainable.

Good policies and institutions to deliver the needed infrastructure and services are therefore crucial in both managing and achieving the most out of the ongoing urbanisation of the country (NCE 2014); (Gouldson, et al. 2015); (Jedwab and Vollrath 2015).

## 1.1 India's urbanisation: investment estimates and proposed programmes

The Government of India has recognised the huge challenges facing Indian cities. To influence the urbanisation trend, it has launched a slew of urban focussed missions, programmes and projects to tackle issues of urban growth and liveability, including: Metro Rail, 100 Smart Cities, Swachh Bharat Mission, Atal Mission for Rejuvenation of Urban Transformation (AMRUT), Housing for All, Heritage Cities, and National Urban Livelihoods Mission. This urban focus is timely and appropriate given the increasing rate and intensity of urbanisation seen across India.

These programmes have been developed based on estimates and forecasts from various reports, the major one being "The Report on Indian Urban Infrastructure and Services" by the High Powered Expert Committee (HPEC), established by the Ministry of Urban Development. This HPEC report estimates the amount of investment in urban infrastructure and services in the period 2012-2031 to be around 39.2 trillion rupees at 2009-10 prices (USD $830 billion) (HPEC 2011). Another estimate by McKinsey Global Institute (2010) has estimated that India's urban infrastructure capital requirement till 2031 will be approximately 53.1 trillion rupees (USD $1.2 trillion) at 2008 prices.

In 2016, as part of the Atal Mission for Urban Regeneration and Urban Transformation (AMRUT) all states submitted their State Annual Action Plans (SAAPs), forecasting their urban infrastructure and service needs. The SAAPs data provides a third estimate for the investments in the water supply, sewerage, and storm water management sectors in urban areas. These estimates correspond to the range reported in the HPEC report.

All these reports focus exclusively on the financial requirements to implement and improve infrastructure and services in urban areas. There is no reference to the potential social or environmental costs arising from the lack of services, low quality of services, or impacts of heavy infrastructure.

### 1.2 The social costs of growth

**The social costs of growth include those arising from activities that are unplanned and sectors that are not provided with public services.**

To understand the impacts of the actual pattern of urbanisation, an especially close look at how urban residents access services when public provision is absent, and the associated cost of such actions is critical. For example, when residents lack affordable public piped water supply, they access it through borewells, water tankers or other private vendors. There are significant costs to these *coping activities* both directly, to individuals or households, and indirectly to the environment or society at large. Similarly, the deficit in electricity access drives residents to rely on costly and carbon-intensive diesel generators. As a result of lacking reliable public transit, communities turn to private vehicle ownership or, if that is unaffordable, they face limitations in their access to labour markets and economic opportunities. Such coping activities take place both in poor, underserved neighbourhoods, as well as exclusive gated communities often built either within or on the peripheries of cities.

With rapid unplanned growth spreading across Indian cities, continued public interventions seem unable to stem the tide of negative externalities that arise, such as air pollution, contaminated water and consequent health crises, which are accompanied by broader socio-economic and institutional repercussions[1]. There is a great need for a body of work that can aid cities to assess their current conditions and assess possibilities of change. As municipal agencies are charged with the provision of basic services such as water supply, sanitation services, transport, energy, health and education, this research approaches the problem from the aspect of assessing delivery mechanisms of selected services at that level, looking in-depth at four case study cities. Using a Social Cost Accounting (SCA) methodology, the research described in this paper estimates the market and non-market costs associated with the delivery of water, sanitation, transport and energy services. The SCA method was used to establish a multi-sectoral systemic analytic framework for cities, which integrates the often ignored indirect costs, health costs and climate costs into the accounting process.

The four cities of Bangalore, Indore, Pune and Surat were studied in detail to quantify the extent of key services people receive from public utilities, from private providers, and the extent of self-provisioning, as well as the social cost of service provision by these different modes using the SCA method. A review of municipal utilities in these cities was conducted to assess their extent of current delivery and capacity to expand in the future. This helped develop a baseline for assessing service provision in cities and the social costs associated with each provisioning type. Such a baseline can also allow cities to compare the potential benefits of alternate innovations and practices as they move towards smart and sustainable urban service delivery.

## 2. THE SOCIAL COST ACCOUNTING APPROACH

Economic activities undertaken by cities, industries or commercial enterprises have financial, social and environmental implications at both local and global scales. While conventional accounting practices (financial accounting, cash-flow accounting etc.) are widely used to account for monetary flows into and out of an institution, they are not designed to capture indirect impact, health impact and climate impact which generally do not have a cost or price assigned to them. Decisions based on results of financial accounting, which ignore social costs, may improve financial returns in the short-term but are likely to have prolonged social and environmental consequences (Bebbington, et al. 2001).

In a world impacted by climate change, and in cities where air and water quality are becoming matters of serious concern, ignoring social costs creates serious vulnerabilities to future climate and environmental shocks. It is vital that accounting methods incorporate environmental and social accounting for long-term sustainability to be achieved (Ditz, Ranganathan and Banks 1995).

In recent times, sustainability has also become a key component globally of regional and city development strategies. Municipal utilities are modifying infrastructure and service delivery mechanisms to achieve sustainability targets, and new accounting tools for environmental assessment, which include social costs, are essential to support this shift towards sustainability practices (Xing, et al. 2007).

The growth of cities in developing countries involves all these considerations as they struggle to achieve basic levels of service delivery to all citizens for services such

as water, sanitation, transport and energy. Overlapping institutional structures, lack of inter-departmental collaboration, and limited public engagement impede the creation of comprehensive and systematic plans for urban services (World Bank 2013). Instead, cities remain dependent almost exclusively on discrete, disconnected infrastructure projects to provide services which can have high costs associated with them. Furthermore, wherever municipal services are absent or of low quality, citizens undertake alternate practices to gain access to basic services. A critical missing link continues to be a comprehensive understanding of the current landscape of service provision and the alternate coping activities that households employ when public supply is absent or limited.

Recognising the extensive presence of coping activities this research brings these alternate practices into the ambit of this study by classifying service provision in the four study cities as: public, private and self-provision[2]. Public provision defines services provided by public utilities or municipal agencies as per the mandate that governs these bodies, such as water supply and sanitation or electricity provision. This also includes services that a public agency contracts out/outsources to private companies (such as solid waste management, water supply etc.) but that it is ultimately accountable for. Private provision pertains to those services that may be entirely provided by a private company, such as bottled water service or taxi cabs and auto-rickshaws for mobility. And finally, self-provisioning encompasses systems and solutions that an individual household engages in to meet basic needs not sufficiently fulfilled by either public or private provision[3], such as individual borewells for water access (refer to Appendix A for various provisioning types).

Social Cost Accounting (SCA) is then used to bring into an accounting framework not only the cost of access, but also other externalities arising from such access, including health and climate costs, as well as the opportunity cost of the differently provisioned urban services.

## 2.1 Research methodology for Social Cost Accounting

As noted, the national government in India has initiated multiple programmes to improve urban services and amenities across cities[4], many of which are aimed at putting in new or upgraded infrastructure for water supply, sanitation, wastewater treatment, mass transit and other services. For these initiatives to be successful, and enable the growth of smart and sustainable cities, these systems need to be designed and operated based on the social costs of providing the associated services in the areas of water, energy and transport.

While Social Cost Accounting can aid municipal agencies in decision making across a range of issues including pricing of services, **this research does not extend to an analysis of pricing strategies or methods to develop full cost pricing.** The SCA approach adopted in this research paper provides a lot of the essential information necessary for the design of urban services but it does not exhaustively cover all the components of cost. However, this approach is still useful as it focuses on the most commonly ignored (and most important) indirect costs, health costs and climate costs while at the same time including direct market costs. The SCA approach also does not deal with elements such as taxes and subsidies that would be considered in a full cost accounting approach.

Relevant data for Bangalore, Indore, Pune and Surat has been gathered to determine the costs of current unmanaged growth (business as usual urbanisation) by:

- Identifying service level deficits in public supply in each city
- Identifying coping activities undertaken by households to access services
- Estimating the social costs of public, private and self-provisioning of these services

Service levels for the four cities are extracted primarily from the 2011 Census data, which provide details on household access to services such as electricity, cooking fuels, water and sanitation at the city level. Census data disaggregated to ward level indicates highly inequitable access to services across various wards but does not reference other service benchmarks such as quality of service supply or frequency and duration of supply.

It is likely that this study based primarily on Census data understates the issues that arise from absent or deficient service provisioning. To increase the robustness of the data studied, the Census data is supplemented with sample surveys and annual reports of utilities in the four case study cities to develop a comprehensive view on the state of urban services in each city.

The SCA method used in this study estimates the social cost of services as the sum of direct cost, indirect cost, health cost and climate cost of service provision

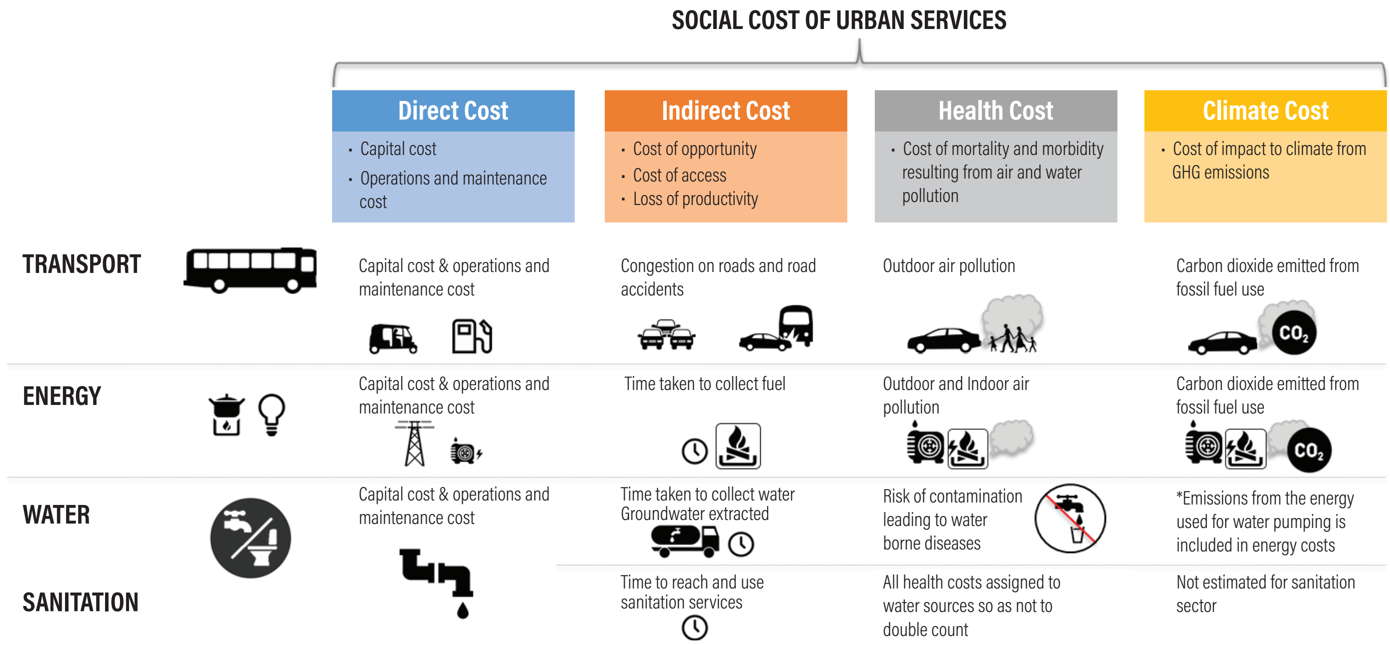
across various sectors (Figure 1). The costs are defined as follows:

- Direct costs are those costs borne by an organization or individual to procure the resource/service from the point of origin until it is delivered to consumers. Depending on the sector and type of provision the components of direct cost would include capital costs, operations and maintenance costs. The costs of procurement and transmission, and personnel costs are also included when reported by utilities providing public provision of services.
- Indirect cost encompasses such costs that impact an individual's and societal productivity either as a function of time, safety or opportunity. For example, time spent in congestion or time spent to access water or firewood could instead have been spent in productive work and is hence a cost to individuals and society. In the water sector opportunity cost of groundwater is estimated as the benefits from agricultural production if groundwater were not diverted through self-provision for domestic and urban use and this is an indirect cost to society.
- Health cost is estimated as the impact on health of individuals as a result of exposure to pollutants in the environment. In the water and sanitation sector, health cost is estimated as the cost of mortality and morbidity due to exposure to contaminated water. While in the transport and energy sectors health costs are a function of the emissions from the use of fossil fuels.
- Climate cost accounts for the global impact of carbon dioxide emissions from the use of fossil fuels in the transport and energy sectors.

This report highlights social costs that are currently not considered during infrastructure project appraisal. However, owing to lack of data, it does not account for subsidies or hidden costs such as cost of land to provide transport infrastructure that are embedded in the transport service provision.

The report provides evidence on several aspects of service provision: (a) overall size of the deficit in supply (i.e., un/under-served population); (b) social costs by sub-sector (example: energy supply from LPG, kerosene or firewood; transportation by cars, 2-wheelers, buses; water supply from public network, tankers, etc.) and finally (c) costs to the entity providing these services (public, private, self).

Figure 1 | **Framework to account for social cost of urban services**




Source: Graphic by authors

# 3. URBAN SERVICE PROVISION: CASE STUDIES OF FOUR CITIES

In India, where state and city authorities are tasked with ensuring basic levels of service to all people, access to urban services is the most used metric for measuring level of service. A key deficiency of access as an indicator, however, as has been noted, is that it does not measure the quality of service provided, in terms of frequency and duration for which the service is available, among other aspects. If for instance, there are four hours of 'load shedding' per day, residents who require uninterrupted electricity might start accessing alternate sources to fill the electricity demand gap, and some of these alternate sources are associated with high health and climate costs. Through this research, we fill those gaps that are prevalent in studies of urban service provision and identify not just household access to urban services, but also the quantity and quality of each service provided by different sources; be it public, private, or self. Using the SCA framework detailed in the sections above, we have also estimated the social costs of each type of service by source. By comparing the four cities of Bangalore, Indore, Surat, and Pune, two broad issues emerge:

- Inadequate public provision forces many citizens to resort to private or self-provision
- The social costs of private and self-provision are often much higher than public provision

## 3.1 Public provision of services in case study cities

All the four case study cities have been urbanising rapidly and have seen an increase in both population and municipal boundaries. While these four cities report high aggregate levels of access to public services, there is significant variation within and between them. In Surat, for instance, 100% of the households have access to piped tap-water in some wards, whereas in other wards it could be less than 10% (Census of India (f) 2011). Households in these areas are forced to provide for services through private or self-provisioned options.

One of the more extreme cases of such coping mechanisms is seen in Bangalore. Despite high aggregate levels of access in Bangalore, more than 50% of the total water demand is met by groundwater from private tube wells and boreholes, and vended water (refer Appendix B: Water and sanitation). In the case of energy, commercial and residential diesel generators provide 16% of the annual electricity consumed and use over 900 million litres of diesel to generate this energy (refer Figure 12, Appendix E: Energy).

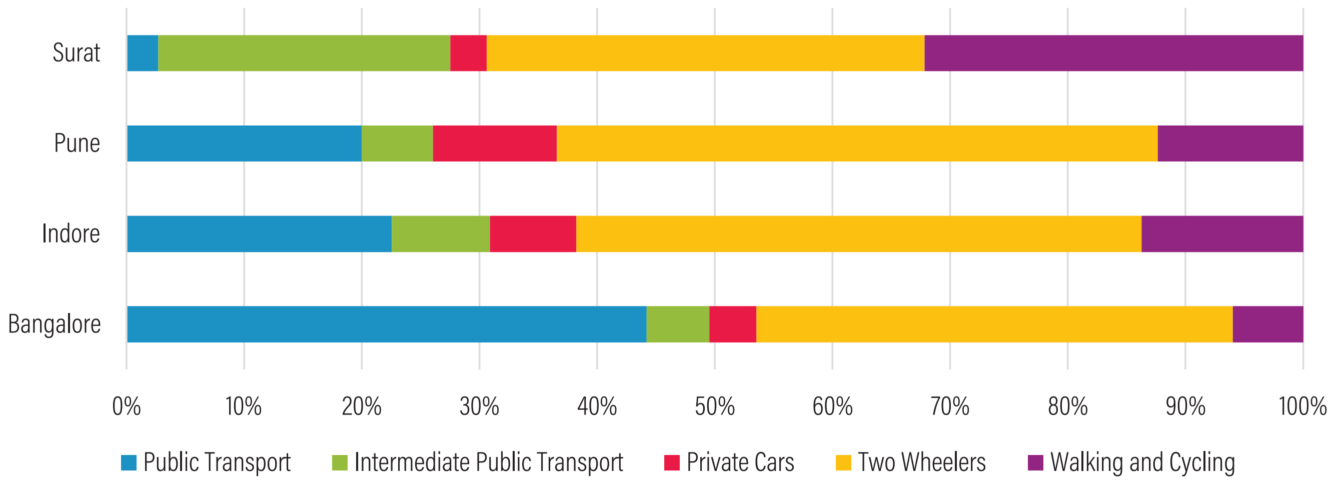
There are many reasons for these coping activities; intermittent supply and inability of the public utility to increase coverage or improve service quality are just some of them. The inability of public utilities to increase coverage and serve new growth areas has significant social costs.

Inequitable distribution of public provision of services is also a function of the political economy in a city. The inequitable distribution is particularly visible in the case of informal settlements where residents may lack formal or legal tenure over their properties (Ranganathan 2014). Such areas depend on the largesse of local political actors whose interventions are piecemeal and does not form part of an overarching water management plan (Zerah 2006). Spaces such as these are often overlooked when proposals for formal and 'legal' service upgrades and improvements are considered. And even when such improvements are negotiated with public service delivery agencies the connection and monthly charges to be paid by the users creates barriers for the community to connect to the city's water supply.

In other cases, where public utilities have improved supply as in the case of the Bus Rapid Transit (BRT) system in Surat, Pune and Indore, we still see a significant portion of the residents travelling by private modes (Figure 2). Of these, two-wheelers account for the largest share of motorised travel (except in Bangalore, where it has the second largest share after public transport). Bangalore is a good example of how a strong public transport agency can positively impact urban travel. Continuous addition of buses, categorisation of services by user groups, and route rationalisation initiatives to improve operational efficiency are some of the reasons for Bangalore Metropolitan Transport Corporation (BMTC) to maintain such large mode shares.

Public utilities' inability to meet increasing demand is also a function of their limited ability to raise revenue for all services supplied. In each of the four cities, non-revenue water (NRW) accounts[5] for a significant portion of the total water supplied (from a low of 20% in Surat[6] to a high of 48% in Bangalore (Saldanha 2016)). Compare this with developed cities where only 15% of the total water is NRW (Kingdom, Liemberger and Marin 2006, 3). By not raising revenue for all the water supplied, the utilities in these cities are falling into significant debt, thus hampering their ability to meet even existing demand.

Figure 2 | **Percentage of passenger kilometre (per mode) in the four cities**




Source: Data from City Comprehensive Mobility Plans (2008-2012) and mode share surveys analysed by authors

Clearly, alternate models of service provision are required in Indian cities to ensure access to basic services to all. Some examples of alternate models do exist. Surat, for instance is exploring means to divert tertiary treated wastewater for industrial use. A pilot project is underway in Surat to meet the water needs of the Pandesara Industrial Units through treated wastewater. For this project a tertiary treatment plant of 40 million litres per day (MLD) capacity has been operationalised at a cost of INR 850 million. It is estimated that the treated wastewater can be supplied at a 20% lower rate (INR 18.20/ kilolitre) than providing fresh water to the industry (INR 23/ kilolitre) (SMC 2014).

In Pune, we see waste-to-energy systems and energy-efficiency measures being adopted to tackle service provision deficits. Currently, the city has 25 bio-methane to power generation plants, several waste composting facilities and a plant producing Refuse Derived Fuel (RDF) from municipal wastes (MNRE 2012). The city is also planning to use bio-CNG produced from waste processing in Pune Mahanagar Parivahan Mahamandal Limited (PMPML) city buses. The city also has relatively high rates of waste segregation at source (~ 55%) compared to other Indian cities and is expected to achieve 100% segregation by 2019. The Pune Municipal Corporation has also introduced an environmentally friendly housing policy in 2007 to improve the energy efficiency of buildings. This allowed developers to voluntarily adopt environment-friendly building practices and gain a certificate from the municipal corporation for completed buildings which adhere to the assessment criteria.

Compulsory solar water heating for certain buildings in the municipal area and a green rating system to evaluate building designs to promote energy efficiency are other measures being explored in Pune (PMC n.d.). Another potential option for improving service provision is to involve the private sector. Private solution providers can achieve change at a speed faster than public utilities which are in many cases grappling with legacy solutions. This is most evident in the transport sector where new mobility solutions are emerging at a fast rate and offer urban travellers an array of travel options. Through careful regulation, cities can ensure that societal goals can be met through private investments.

## 3.2 Costs of private and self-provision

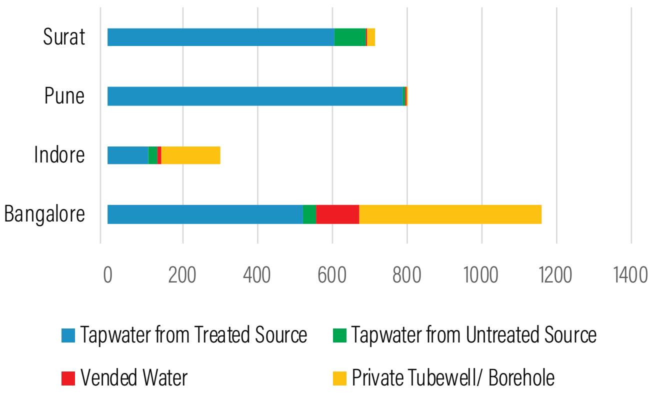
In this section, we present the social cost analysis for water and sanitation, energy, and transport for the four case study cities. All costs reported in this study have been normalised for 2011 which is the study year considered for the four case study cities[7].

### Water and sanitation

Some residents in each of our four case study cities adopt private sources or provide for themselves due to a lack of (access to) public services (Figure 3). These private and self-provisioned options have the highest cost. In the case of water for example, we found that vended water and borewell water can have 2-68 times the social cost of public provided water (Figure 4)[8]. In Pune and Surat where public provided water accounts for 98% and 97% of the total quantity of water supplied, this might not pose as much a problem as in Bangalore

and Indore (where public water accounts for 48% and 42% respectively). Breaking down these costs by component (refer Appendix B: Water and sanitation for details on cost components), we see that the direct cost accounts for the largest share of the social cost (except for vended water in Indore, where cost of access accounts for the largest share)[9]. Considering a large portion of the residents in Indore and Bangalore access non-public water, the high costs of private and self-provisioned water can have equity issues related to it as well (Grönwall, Mulenga and McGranahan 2010, 65).

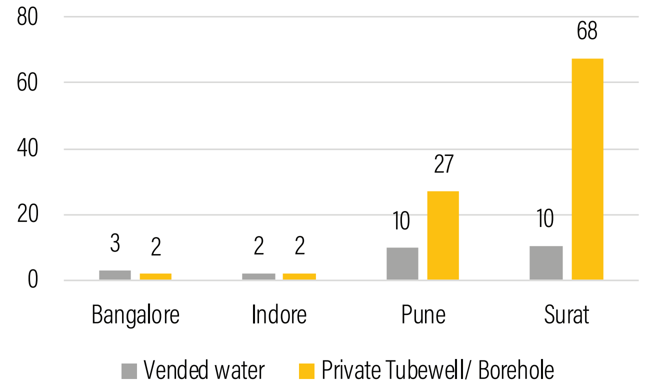
Figure 3 | **Daily consumption of water from various sources in the 4 study cities in 2011**




Source: Demand estimation based on the household coverage reported in Census 2011 and the Central Public Health and Environmental Engineering Organisation standards (CPHEEO 2005, 37) as suggested for each class of city in this study. Daily consumption of water reported in million litres per day (MLD).

Note: The various categories of water supply are considered as per Census 2011 definitions (Census of India (a) 2011, 7). This study assumes all tap water from treated source is public water supply as water treatment at large scale and provision of a piped water supply is typically done by public agencies by tapping freshwater sources. Tap water from untreated sources is also considered to be public provisioning (groundwater extracted from municipal borewells and supplied via piped networks). Both of these assumptions are supported by the definitions mentioned in the District Census Handbooks of the 4 states where the study cities are located.

Figure 4 | **Social cost of private and self-provisioned water supply as a ratio of public water supply (piped network)**

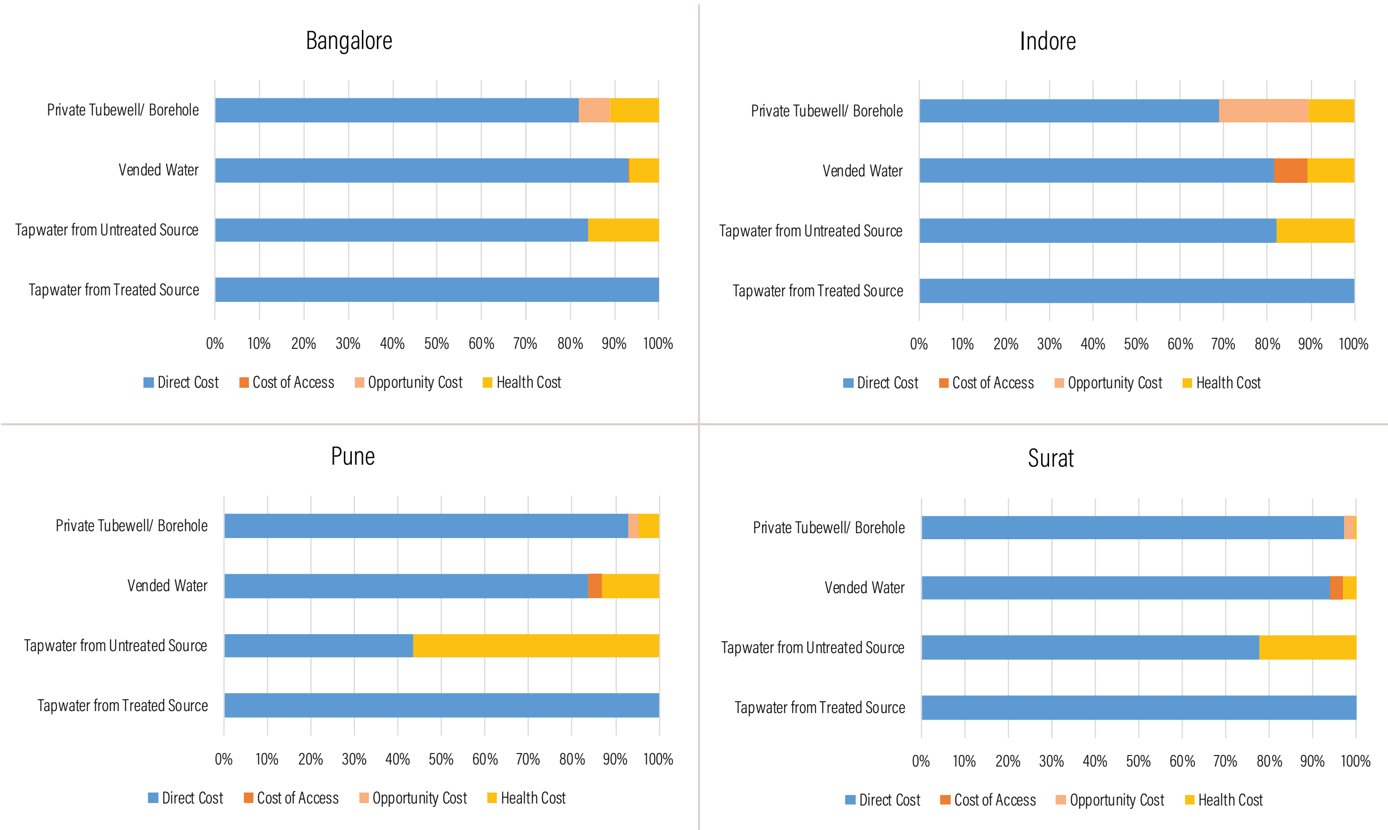



Source: Authors' estimate

A more detailed break-up of the social cost of water by component (refer Appendix B: Water and sanitation for details on each component) for each of our four case study cities is shown in Figure 5. One caveat is that, when estimating the direct cost of water, we have not included the ecological cost of reservoirs and dams. We have estimated the net present value of the direct cost based on financial statements submitted by the utilities (this includes the pumping costs, the cost of infrastructure, operations cost, and depreciation). We also observe that the direct cost is the highest in each of the four types of provision (refer Appendix B: Water and sanitation for details).

The opportunity cost of water (for groundwater extracted using private tubewells/ boreholes) in the four cities was estimated as the potential agricultural revenue that might be gained if the same volume of water were diverted to agricultural purposes instead of domestic urban use. The agricultural revenue is dependent on open areas available for cultivation and the prevalent crops in the district.

Figure 5 | **Social cost of water per source by component**




Source: Authors' estimates

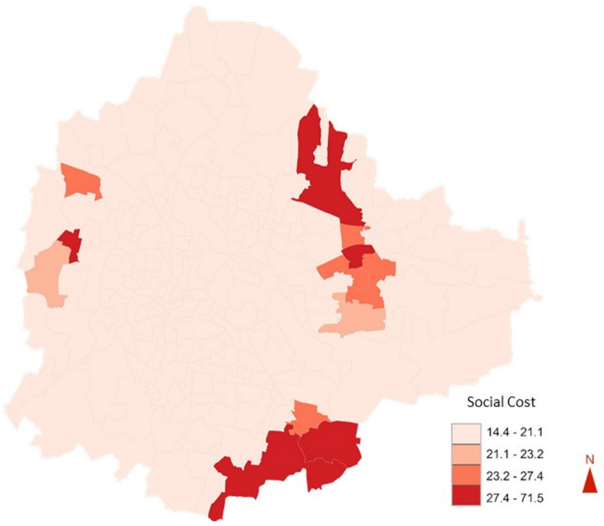
Note: The opportunity cost of groundwater depletion is applied to only the water extracted by private tubewells/boreholes. As described in this study, such self-provisioning occurs as a coping mechanism in the absence of, or inadequate presence of, publicly provisioned services. In all the case study cities, the municipal utility also owns and manages a certain number of borewells which supply water to low income or slum communities. The opportunity cost of groundwater depletion is not applied to the water extracted from these borewells as the supply of water to such households for domestic purposes would be the highest and best use of the groundwater as per the National Water Policy 2012 (refer Appendix B: Water and sanitation).

Since data on water quality are not available for these four cities, the health cost estimated in this study is based on the approach used in the study by (M. S. Mani 2014) to account for the cost of morbidity and mortality associated with water borne diseases based on Disability Adjusted Life Years (DALYs) lost (Crettaz, et al. 2002); (Pennington, et al. 2002); (Mani, et al. 2012). The idea is that unclean water and inadequate sanitation leads to diarrheal and related diseases, such as typhoid and paratyphoid, which bear a direct mortality cost. Another expenditure is the cost of procuring health services and the loss of working days due to ill health, which is estimated as a morbidity cost. According to our estimates, the health cost of water provision varies from 2-10% of the social cost; except for the case of tap water from untreated sources in Pune where health cost is about 43% of social cost.

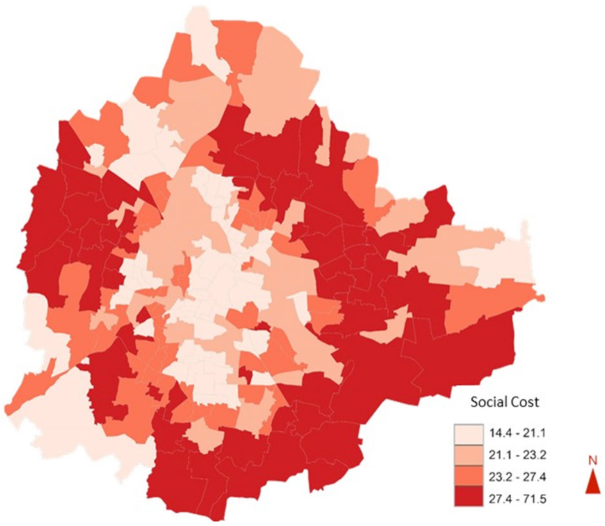
Another important issue with public water supply in Bangalore is the climate cost resulting from energy consumed for pumping water from the Cauvery River (Figure 6). In the analysis of social costs, such pumping costs are included under the energy sector (electricity) and not in the water sector calculations. If instead, we include them as part of the social cost of water and overlay the climate costs of pumping water from the Cauvery onto the ward level maps of the city, we would see that sustainably managed groundwater[10] extraction and aquifer recharge might be a complementary solution to meet water demand and mitigate climate emissions. Clearly, choosing one type of service provision over another depends on the objectives a city is trying to achieve, and such a social costing approach is important for cities making decisions about providing sustainable urban services to their residents.

As urban populations expand, improved sanitation coverage is a critical responsibility of city agencies. Where the public utility is unable to meet the needs of residents, households increasingly depend on septic tanks and pit latrines. Households from lower income backgrounds may even practice open defecation due to

## Figure 6 | Social cost of water in Bangalore (with and without climate costs) in 2011




Social cost of water in INR per litre (without climate costs)



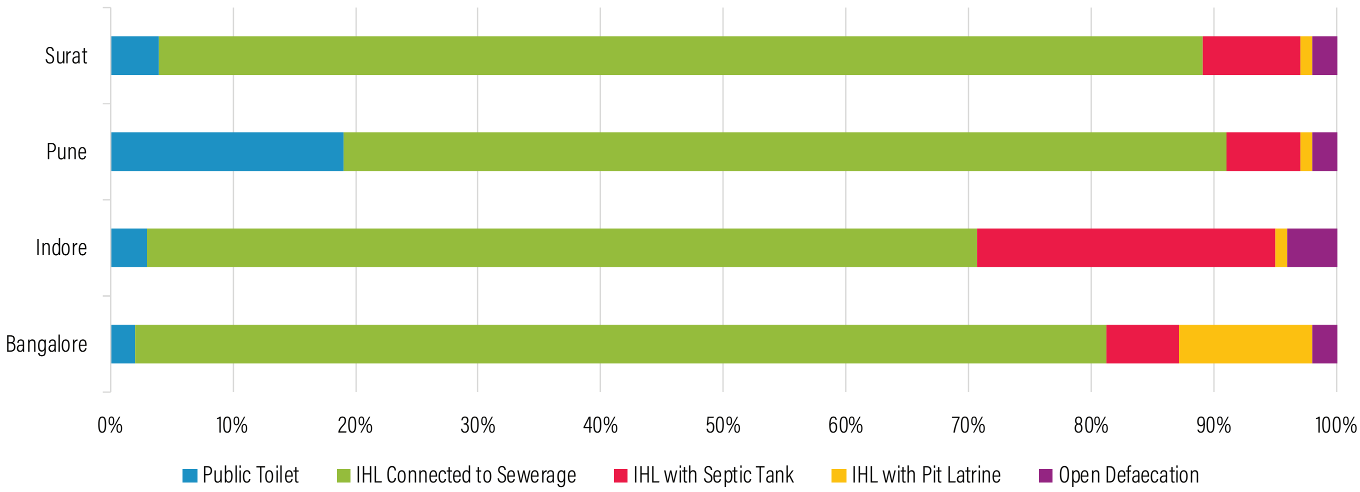

Social cost of water in INR per litre (with climate costs of energy used for pumping)

Source: Authors' estimates

lack of access to individual household latrines (IHL) and public toilets. Sanitation services are critical in urban areas as they help manage water contamination risks and decrease health costs associated with water borne diseases.

In terms of coverage, we observe that all the four case study cities have a large percentage of households within the municipal limits with access to publicly provided sanitation (Figure 7). In Bangalore, about 80% of households in the Bruhat Bengaluru Mahanagara Palike (BBMP) area have access to the public sewer system. Use of public toilets and practice of open defecation are both less than 2% and the remaining households provide sanitation services in the form of septic tanks and pit latrines (Census of India (f) 2011). In Indore we see that around 24% of the households use septic tank for sanitation purposes, which is the highest among the four cities (Census of India (f) 2011).

## Figure 7 | Households by access to various types of sanitation service



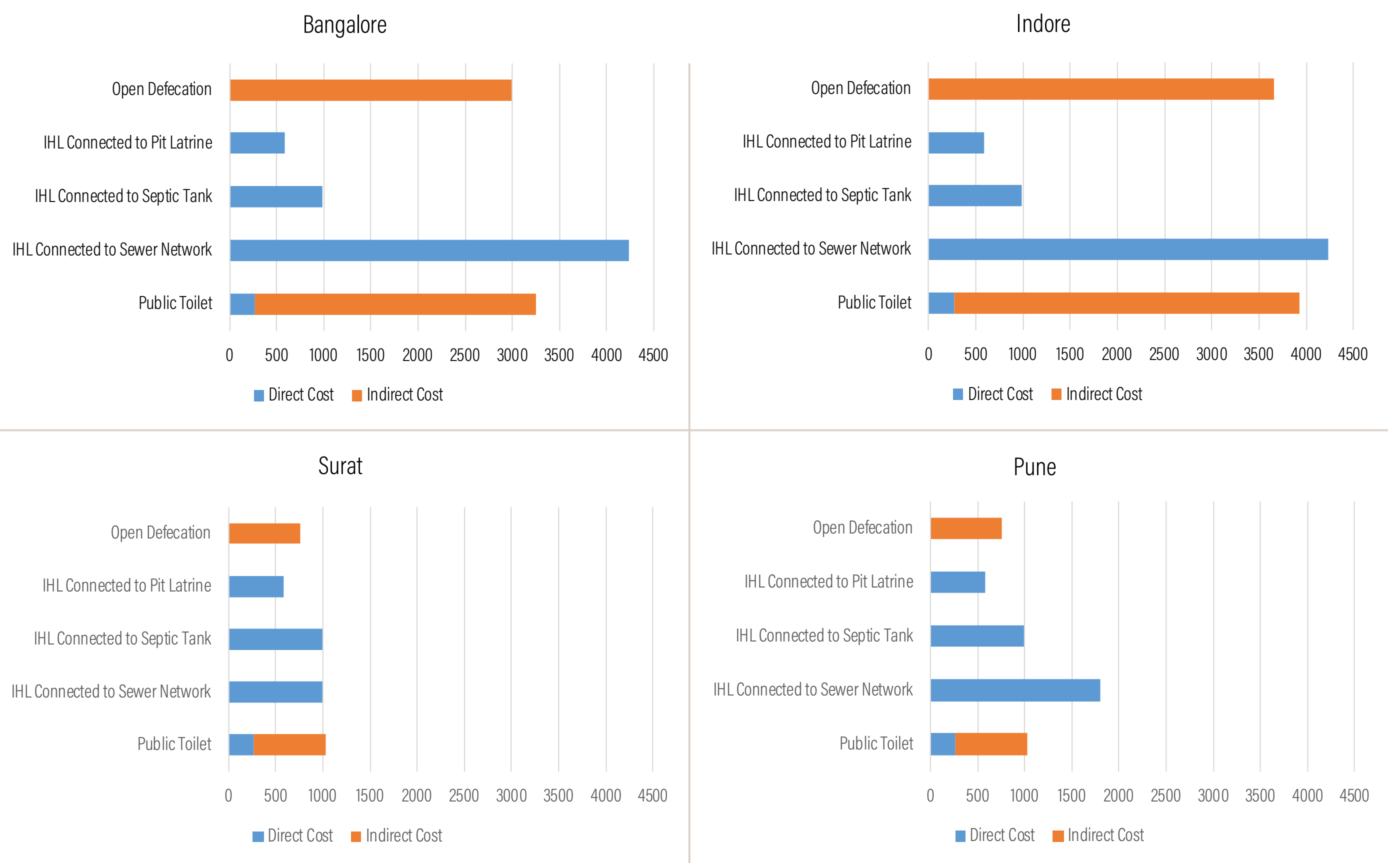

Source: Census 2011 – Household access to amenities reported in percentage

In Figure 8 we show the annual cost of sanitation per user for various options. The figure does not show associated health costs since the cost of inadequate sanitation and the health costs arising out of water contamination due to poor sanitation have been included in the water section. In all our case study cities, public toilets have the least direct cost but have a significant indirect cost (the time value attached to accessing publicly provided toilets). Publicly provided sewerage connections have higher direct cost associated with it which includes the cost of building and maintaining a toilet. Even though open defecation only seems to have an indirect cost, it does not take into account the associated health costs that may arise from the consumption of contaminated water. Therefore, it should be noted that even if health costs associated with open defecation from water contamination are hard to capture they should be considered.

## Transport

In order to estimate the social cost of transport, we classify the various modes into the following groups – walking, cycling, two-wheelers, cars, intermediate public transport (IPT)[11] and buses[12]. In Figure 9 we show the breakdown of costs by component for each mode in the four cities. We observe some variation in the four cities. In the case of Pune and Surat, indirect cost, which is measured as the value of time spent in travel that could be spent on productive work, has a large share. On the other hand, in Bangalore and Indore, health cost accounts for a large share of the social cost for most of the motorised modes (refer Appendix D: Transport, Health Cost). It could be inferred that the problem of congestion is more evident in Pune and Surat as compared to Bangalore and Indore. It is possible that this is due to the high rate of self-provisioned mobility (two-wheelers and private cars) in Surat and Pune.

Figure 8 | **Annual cost of sanitation provision in 2011**




Source: Authors' estimates; costs reported in INR per user

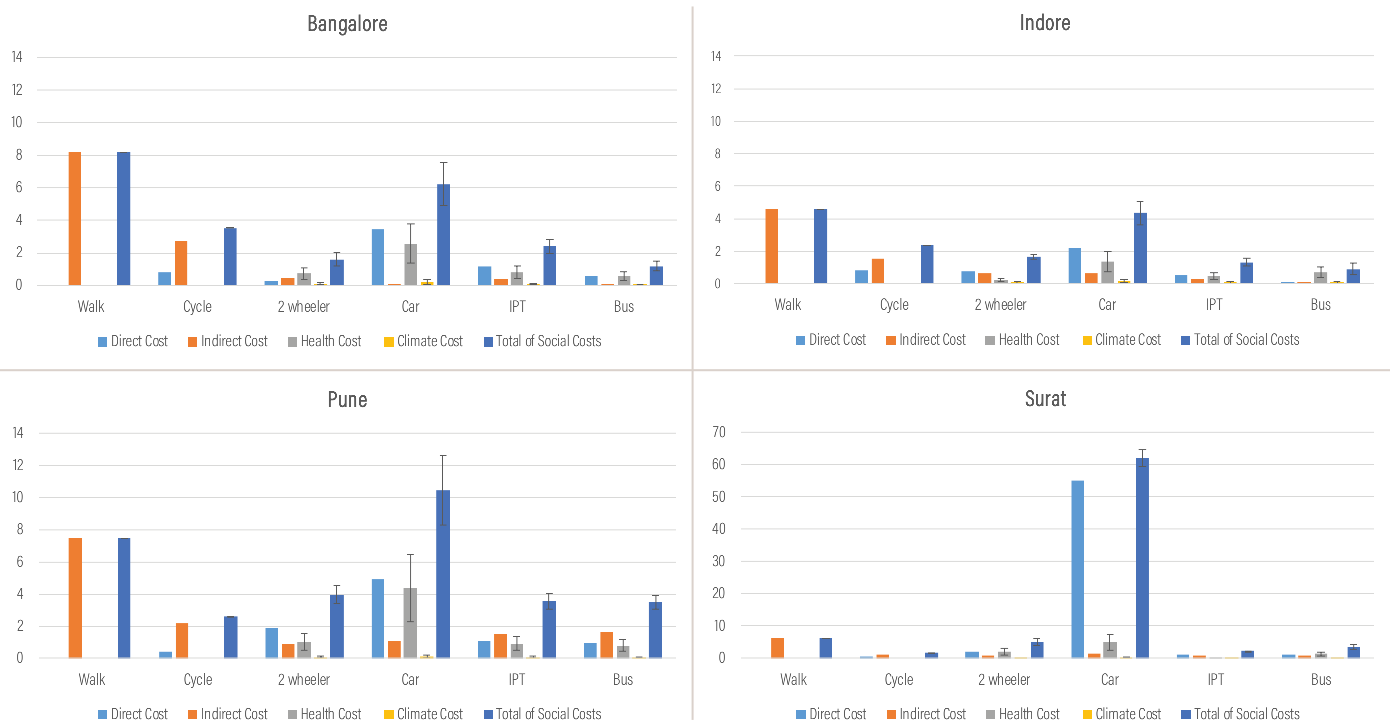
Two-wheeler engine technology in India is quite advanced with high fuel economy and lower direct costs, which in most cases make them cheaper than public transport. Only when we consider the social costs associated with using two-wheelers can we see that public transport is a more viable option.

The social cost of using cars is high across all four cities with Surat showing significantly higher costs than the other three study cities. The direct cost per passenger kilometre travelled (PKT) in Surat is more than 11 times the next highest (Pune). This large difference is explained by the fact that cars are driven far fewer kilometres in Surat as compared to other cities. In our methodology, we have taken the full capital and operating costs of the vehicle and distributed it across the actual vehicle kilometres travelled by that vehicle and then using vehicle occupancy estimated passenger kilometres travelled. If the number of kilometres travelled increases, the direct cost per PKT will reduce (refer Appendix D, High direct cost of cars in Surat). Most studies use the average cost per km (Barnes and Langworthy 2003); (Lemp and Kockelman 2008) whereas this study does a disaggregate calculation based on the actual vehicle and passenger kilometres travelled.

The entire cost of walking is associated with the time taken for commuting which might otherwise have been spent engaged in paid work. Cost of walking in Indore is almost half the value estimated in the other three study cities due to the lower wage rate reported in Indore. Walking has no climate or health impacts associated with it and cities must look at ways to encourage and incentivise walking trips. Investing in safe pedestrian infrastructure networks as well as planning walkable communities with amenities and services in proximity will be key to improving pedestrian mobility in Indian cities.

In conclusion, buses have the lowest per passenger kilometre costs within motorised modes (Figure 9). While vehicle kilometre costs for public transport are high, the fact that they are distributed over a larger number of people, based on typical average occupancy of buses, helps bring down the average costs per passenger (for details on occupancy assumptions for each mode refer Appendix D). High vehicle occupancy brings down costs associated with motorised modes as more trips are contained within a limited use of these modes. Efforts to promote use of public transport,

Figure 9 | **Citywide costs of transport services in the 4 study cities in 2011**




Source: Authors' estimates; costs reported in INR per PKT

carpooling and shared auto-rickshaws should thus be encouraged. Reduction of congestion and corresponding air pollution may be some of the additional co-benefits of such efforts.

## Energy

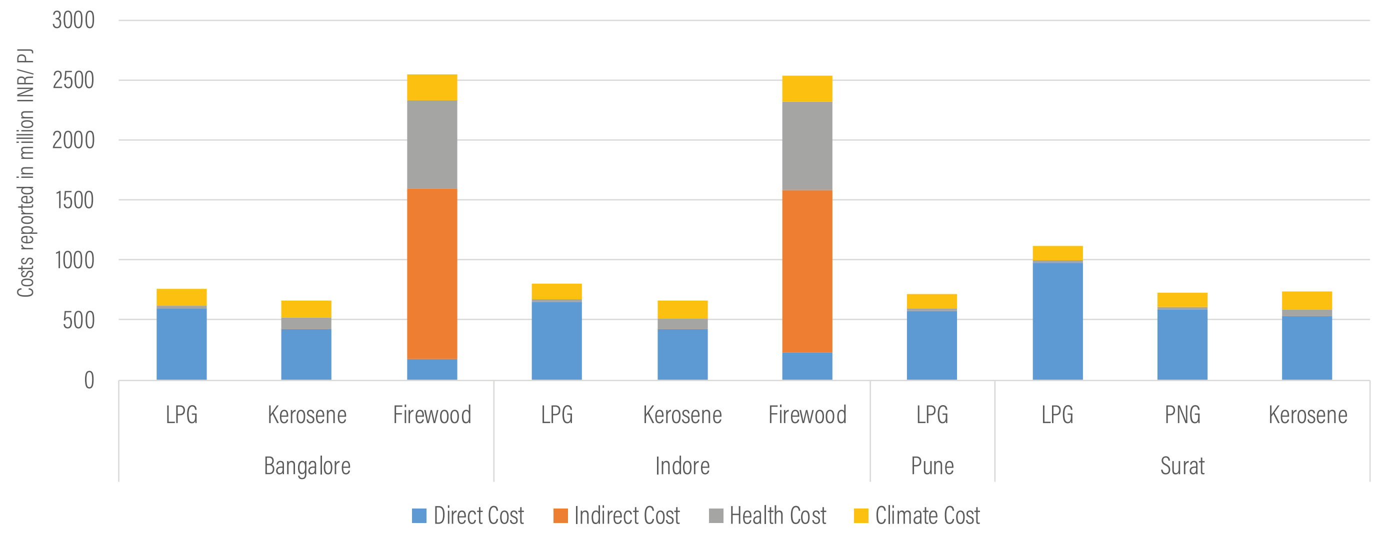
Energy in each of the four cities is primarily provided by public utilities. Other sources such as furnace oil in Pune's industries, firewood for a small portion of households in Bangalore and Indore are also accessed in these cities.

Figure 10 shows that fuels distributed through public networks (LPG, PNG and kerosene) have direct costs, as the highest component, with health and climate costs making up a significant but smaller share. In the residential sector, the use of firewood is the costliest in terms of time and health impact. Health cost of firewood use accounts for about 30% of the social cost and cost of access is about 55%. Similarly, for kerosene, health costs range from 7% to 14% of social cost and LPG emerges as the least polluting fuel with health costs ranging from 2-3% of social costs[13]. The continued use of firewood, despite the high social costs of firewood estimated in this report, suggest that targeted actions addressing household energy consumption patterns are required to shift all households to cleaner fuels. A blanket policy around subsidies and public distribution schemes for more efficient and cleaner fuels (kerosene and LPG) will remain insufficient to address energy access and energy poverty issues in India (Ganesan and Vishnu 2014).

In the case of the electricity sector, publicly provided electricity is the predominant supply[14] stream. The generation of electricity varies across the four cities and hence separate methods are used to estimate the social costs of the electricity supplied. Pune and Surat's electricity production happens within municipal limits and there are health impacts as well as climate impacts of this urban service. In the case of Bangalore and Indore, however, the production happens outside the municipal limits and health impacts to city residents from production processes are not included due to unavailability of relevant data. For all four cities, the direct costs are estimated based on the procurement and transmission costs borne by the electricity utility.

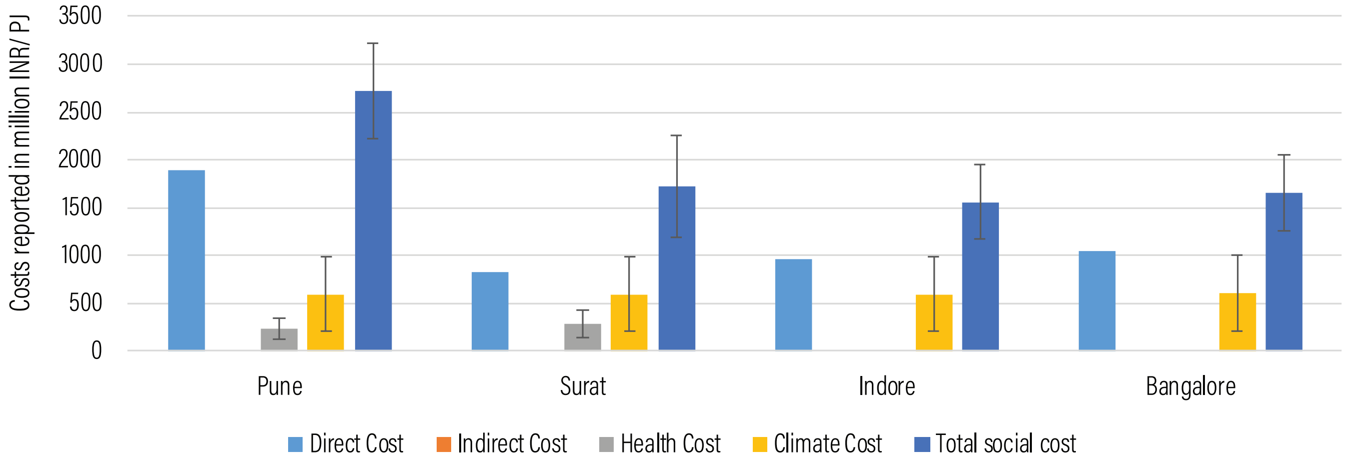
Figure 11 compares costs by component of public electricity supply in all 4 study cities. The higher health costs in Surat can be attributed to the presence of larger coal-based power plant within the city municipality. As Indore and Bangalore do not have generation within the city no health costs are attributed to grid supply electricity in these two cities. Climate costs across all 4 cities are estimated using emission factors for the integrated Northern, Eastern, Western, and North-Eastern (NEWNE) regional grids and the Southern grid[15] as reported by the Central Electricity Authority, India (CEA 2014).

Figure 10 | **Social cost of domestic energy use (other than electricity) in the 4 study cities in 2011**




Source: Authors' estimates

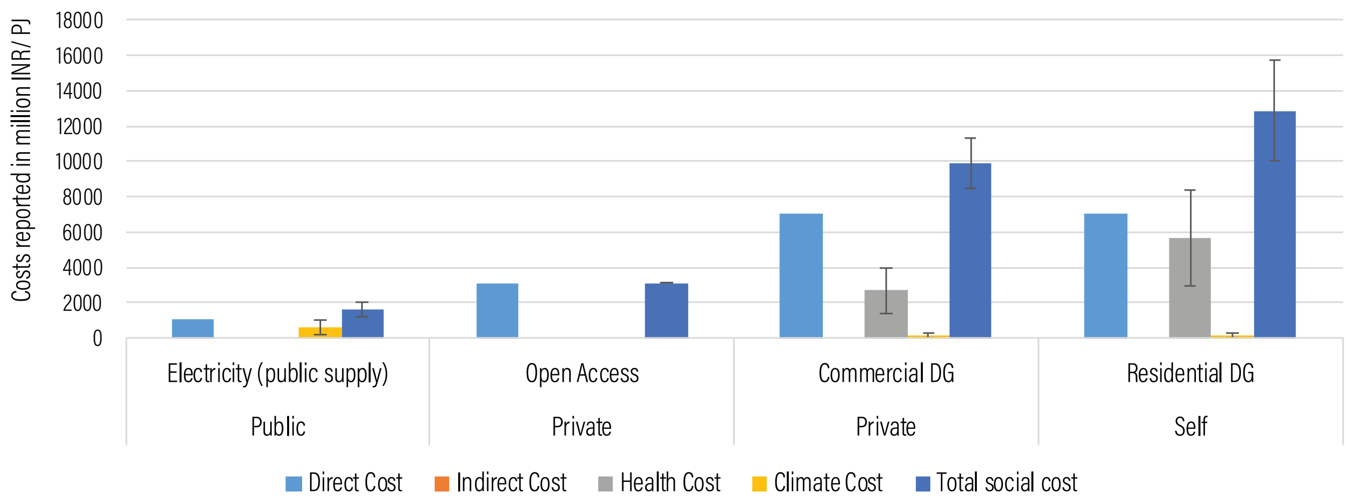
Figure 11 | **Social cost of electricity from public sources in the 4 study cities in 2011**




Source: Authors' estimates

Comparing the costs for electricity supply from different sources in Bangalore in Figure 12 we see that public supply of electricity costs less than alternate strategies such as use of DG sets[16]. This indicates that the issues with service delivery, particularly in terms of inadequate quantity of supply, have pushed consumers to opt for other strategies despite higher costs. While all sources of electricity considered here have climate costs associated with them, the use of diesel generator sets also has high health costs and the continued dependence on such polluting systems leads to deterioration of local air quality. Figure 12 also lists open access electricity[17] as a source of electricity supply in Bangalore. The independent power providers (IPP) in the Bengaluru Electricity Supply Company Ltd. (BESCOM) region, supplying open access electricity, generate electricity from wind or mini hydel systems thus there are no health and climate costs associated with this electricity supply (refer Appendix E: Energy).

Figure 12 | **Social cost of electricity from different sources in Bangalore in 2011**




Source: Authors' estimates

### Analysis of the case study results

Through these case studies we have compared the current levels of service provision in the four cities and followed it with a comparison of some of the key social costs of service provision. We observe that despite high coverage statistics in the four cities, the quantity and quality of services provided does not match up to demand, especially in the case of water and transport. Some of the coping mechanisms opted by residents have high associated indirect, health and climate costs. The Social Cost Accounting framework adopted for this research helped to determine baseline levels of services and to estimate inefficiencies in the network. Indian cities that are rapidly expanding will be able to use our methodology to evaluate and design policies and thus improve the levels of service provided to their residents. Adopting a systems approach to resolve issues related to service provision, will also help cities reap the productivity benefits of urbanisation. A systems approach entails considering service provision in an integrated manner, that leverages cross-sectoral efficiencies, versus operating in silos.

## 4. GOING FORWARD

This study highlights certain issues in service provisioning that have arisen due to existing patterns of urbanisation in Indian cities. As urban populations rapidly increase, the demand for services also increases leaving public service provision lagging and currently highly inadequate. This has resulted in households using coping mechanisms by resorting to private or self-provision of essential services.  Such mechanisms also create inequities in access to services as those who can afford the relatively higher costs of good quality private and self-provision have better access to services[18]. Furthermore, existing service provisioning systems (be they public, private or self-provision) have high costs when indirect, health and climate costs are also accounted for.

The government response to the crisis of urban service provision and delivery has been to initiate a series of missions to increase and/or improve service provision and delivery (AMRUT, HRIDAY, Smart Cities Mission, Swachh Bharat Mission). But various challenges hinder the successful implementation of these programmes.

Social costs of services such as indirect cost, health and climate impacts are not included in infrastructure planning. Not accounting for these costs as externalities has far-reaching consequences[19].

Existing evaluation metrics for these initiatives focus primarily on the supply-side of public service provision, in terms of network coverage and do not account for quality of service. So, while government initiatives envision progressive urban infrastructure projects, the continued focus on supply-side management using these indicators leads to business as usual solutions to be adopted. There is limited uptake of practices which can enhance sustainability outcomes such as demand management[20], reduced resource use and shift to renewable resources.

The nexus between sectors is not charted, which causes hidden and unaccounted for costs in the budgets of multiple service agencies[21] and also leads to legal tussles between service agencies regarding unpaid dues.

Finally, a fragmented institutional landscape with overlapping roles and responsibilities of state and multiple local agencies has long been a critical challenge for effective urban service delivery (Rao and Bird 2010, 18); (Vaidya 2009, 16). The new missions (AMRUT, Smart Cities Mission) do not address the multiplicity of decision makers but rather have added new actors in the decision making, planning and implementation space for urban services such as a separate special purpose vehicle (SPV) to implement smart cities (HLRN 2017, 27).

This study has used Social Cost Accounting (SCA) to analyse existing provision of services in the four case study cities. This accounting approach integrates externalities associated with different types of provision of urban services by including cost of access and opportunity (indirect costs), health and climate costs along with direct costs in the framework. Based on the findings of this study there are three key recommendations proposed to enable cities in India to shift to sustainable and equitable service provisioning models.:

1. Use of SCA framework in service planning
2. Integrated service planning with institutional cohesion to generate efficiencies across sectors (such as water and energy)
3. Leveraging new models for service provision and entrepreneurial schemes

## 4.1 Use of SCA framework in service planning

Many national and sub-national programmes have been established to improve quality of service to urban residents, but the policies and initiatives of different levels of government continue to prioritise supply-side metrics. For instance, the "Atal Mission for Rejuvenation and Urban Transformation" (AMRUT) expects proposals from cities to ensure universal service coverage in the water supply, sanitation and sewerage sectors. Thus, universal coverage will be the first priority of urban local bodies (ULBs) under the AMRUT mission and other benchmarks (such as assured 24 hours supply) will be achieved later in an incremental manner (MoUD 2015).

Urban water supply volumes continue to be derived from supply side standards set by the CPHEEO, wherein a minimum per capita per day must be supplied (the minimum standard is based on the class of city). Water supply agencies supply potable water to meet the entire estimated demand as actual demand numbers for potable and non-potable water are not collected. Further these standards do not distinguish between the sources of water and nor do they provide a framework to assess the social costs of water withdrawal and supply.

Assessing social cost of water supply will allow water supply agencies to make more informed choices as the impact of externalities can also be included in the cost analysis. As we saw in the case of Bangalore, when the climate costs of pumping water from the Cauvery River are included in the social cost of water, sustainable local ground water recharge and extraction turns out to be the more cost-effective and climate mitigating option[22].

National policies and guidelines suggest that ULBs look to alternate solutions such as recycling and reusing of wastewater streams as increasing water demand has stressed finite natural resources. While some projects for sale of treated wastewater for industrial use are being considered in various cities, little or no guidance exists on ways to integrate such practices into the overall water supply planning for urban areas.

We have demonstrated in our research the benefit of using the Social Cost Accounting (SCA) framework and comparing services for not just the direct economic costs, but the health, climate, and access costs as well. Social cost analysis can provide data and estimates that can help policy makers evaluate policies by accounting for their broader impacts. In addition, it is also possible to identify effective prices and ensure effective uses of resources.

## 4.2 Integrated Service Planning

A consistent challenge for Indian cities is the fragmented institutional landscape and lack of comprehensive multi-sectoral planning frameworks to enable integrated service planning. In each sector there are a multitude of actors with differing mandates who are unable to collaborate and thus increase efficiency in the respective sectors. For instance, in a city the transport sector may have a mass transit authority, a public bus agency and private operators for taxi cabs and auto-rickshaws. All these entities provide mobility options to commuters but exist in competition with each other to increase their ridership and revenue. This limits their ability to function cohesively and provide high quality service in the form of a seamless mobility experience for commuters. Furthermore, existing policies ignore the nexus between different sectors which reduce the effectiveness of policies and programmes and/or leads to hidden costs to various agencies.

It is critical that the inter-linkages between various sectors be acknowledged, and a long-term planning perspective be adopted. Integrated service planning, with a systems approach, can be a key step in providing more efficient services and managing the associated demand. But for such a system to function efficiently, robust institutional frameworks must be in place which can enable collaboration between various agencies. We present two examples wherein an integrated approach to urban service provision can be beneficial:

**Land use and transport planning:** The spatial extent of the city is closely linked to the type of transportation options available in the city (Rode, et al. 2014). Cities with a large spatial footprint and large urban blocks present higher dependence on motorised modes and, when inadequately serviced by public transit, there is higher use of individual motorised modes (Cervero 1998). Furthermore, in Indian cities infrastructure spending for non-motorised modes is ignored in favour of road infrastructure such as bridges, expressways and flyovers, which privileges users of motorised modes (Tiwari and Jain 2013).

As cities in India grow, increasing their spatial extent and population, an increase in individual motorised modes is seen (Tiwari and Jain 2013). This has led to increased congestion and travel times, reduced road safety and growing air pollution. Recognising that robust transit services can mitigate many of the problems arising from high dependence on individual motorised modes, the national government has

introduced various programmes and plans. Alongside financial support for mass transit systems (JnNURM) and public bus services (AMRUT) there is growing interest in developing integrated land and transit plans (National TOD policy)[23].

Local and global cases illustrate high land value increments in properties that are in proximity to transit stations. Increasingly city agencies are employing innovative mechanisms to benefit from these land value increments that are brought about by transit services (Suzuki, Cervero and Iuchi 2013). In 2010 the Ministry of Urban Development reported that investments of up to 15 billion USD in urban rail and bus rapid transit systems had already been made that cities could leverage to implement appropriate urban codes and create the right incentives to accelerate transit oriented development (Lohia 2010); (Shah, et al. 2015).

**Water-energy nexus:** The water-energy nexus offers a conceptual framework within which the various interactions between the water and energy sectors can be established[24] across institutions, resources and physical infrastructure (Scott, Crootof and Kelly-Richards 2015). Recognising the nexus is a first step for utilities and households to improve service provision for water. In the context of urban water supply, be it through public supply system, private tanker water or individual borewells, there is high energy dependence for pumping and treatment of water.

In the case of Bangalore, the water utility Bangalore Water Supply and Sewerage Board's (BWSSB) high energy dependence and constrained finances has led to unpaid dues to BESCOM for an amount of INR 730 million (Senthalir 2011). This unpaid amount implies a revenue deficit for BESCOM; at the same time, it adds to BWSSB's debt profile and limits their financial flexibility to undertake new works.

Assessing service provision of water, from a water-energy nexus perspective, can help identify more sustainable and cost-effective measures - be it use of energy efficient systems for water pumping, demand management measures to reduce water usage or use of treated wastewater to meet non-potable water needs.

## 4.3 Leveraging New Models and Entrepreneurship for Service Provisioning

Public utility institutions suffer from weak institutional structures and financial burdens rendering them unable to expand the spatial extent of service networks or improve quality of service. Most public utilities are under significant debt and do not function as financially sustainable entities. The necessary large-scale service expansion or infrastructure upgrades required to meet the needs of growing urban populations is not implemented due to lack of resources and technical capacity. For the growing needs of urban areas to be met, the traditional model of 100% centralised public provision followed in Indian cities must be revisited. Innovative ways of cost recovery that allow services to be affordable while ensuring financial sustainability for the providers need to be developed so that options with the lowest social costs are realised.

To improve sustainability and reduce social costs of service provisioning, cities must assess their resource consumption (particularly water and energy) and revisit the current service provision models which continue to operate on a take-make-dispose principle[25] (EMF 2015). Cities need to develop and enforce regulations that improve environmental and social outcomes for urban services as well.

All four cities have demonstrated the ability to innovate and adopt new service and business models for service delivery, though in separate sectors and not necessarily as a city level strategy. Understanding whether alternate service models can meet societal, equity, environment protection and public health concerns is crucial.

For alternate service models to be piloted and implemented, cities need to create enabling environments or ecosystems that encourage innovation. A Social Cost Accounting (SCA) approach, as demonstrated in this paper, should be adopted as a city tool to analyse services in cities so that interactions between different services across multiple sectors are mapped and better understood. Alongside policy and planning changes, new financing tools to fund urban infrastructure and services should be made available. Regulatory environments involving right pricing of services and incentives that encourage innovation and discourage high-carbon, high resource using alternatives should be enabled.

# APPENDICES

Appendix A | **Types of Provision**

In this study, service provision is categorised into public, private and self-provision across the three sectors studied. Public provision alludes to all services wherein a public utility or municipal agency provides services to users (either directly or through sub-contracting or by licensing a private body). Under private provision are all services which are provided by private agencies who operate to gain a profit. Under self-provision are all strategies employed by individual households to access basic services. Table 1 categorises the services studies into the 3 provisioning types.

Table 1 | **Services in 3 study sectors tabulated as per different service provision**

| SERVICE | PUBLIC | PRIVATE | SELF-PROVIDED |
|---|---|---|---|
| Water and sanitation | Public water supply (tap water from treated and untreated supply);<br>Public toilets, Individual household latrines (IHL) w/ sewerage connection | Tankers and bottled water | Tubewells/borewells<br>Individual household latrines (IHL) w/ septic tank, IHL w/ pit latrine, open defecation |
| Transport | Public bus (BMTC/ PMPML Bus/ I-Bus/ Surat City Bus/ Surat BRTS)* | Auto-rickshaw, taxi, corporate buses, school buses, Tata Magic, contract van | Private car, two-wheeler, bicycle, walk |
| Energy (lighting and cooking) | Public supply electricity<br>LPG, PNG, PDS Kerosene | Open access electricity, commercial diesel gensets etc. | Domestic diesel gensets<br>Firewood |

*BMTC: Bangalore Metropolitan Transport Corporation
*PMPML: Pune Mahanagar Parivahan Mahamandal Limited

Appendix B | **Water and sanitation**

Water demand in the four cities is estimated based on the household coverage reported in Census 2011 and the Central Public Health and Environmental Engineering Organisation standards (CPHEEO 2005, 37) as suggested for each class of city in this study.

The classification of water supply and sanitation services from various sources in this study are based on the definitions reported in the census. Tap water from treated and untreated sources are water supply from public utilities; also tap water from untreated sources refers to groundwater extracted from public borewells.

Water consumption in the four cities is estimated using different methods to account for the various provisioning types. Volumes of publicly provisioned water consumed, which includes treated and untreated water supply, are as per the records of water utilities. The volume of tanker water and groundwater consumed is estimated based on consumption of households' dependent on these sources and the demand-supply gap of public provision that is met through these coping activities.

Sanitation services are estimated as per household coverage reported in Census 2011.

In this study, the social cost of water does not include climate costs due to pumping activities undertaken by water utilities. However, the energy used for pumping is included in the total energy consumed in the city and thus the energy sector estimates captures the costs of pumping by the water utility.

## Direct Cost

Direct cost of water supply represents the cost borne by the organisation in procuring the resource from the point of origin and delivering it to the consumers. This includes the backend cost of water treatment, pumping and distribution, and all other associated cost of supply to the end user. Since only a part of the direct cost is recurring in nature, such as administrative expenses, electricity charges etc., we have broken down the direct cost into (annualised) capital and O&M expenditure,

wherever data permits, for the four cities[26]. Costs of public provisioning are estimated using values reported on utilities website and/or the annual reports detailing revenue. To incorporate the capital cost that is invested over a period of time, to run these services, we have included depreciation cost based on a certain percentage of the total revenue expenditure. Our consultation with city officials puts this figure at 16-17% of the total expenditure. To account for the worth of current investment in these services, we consider a discount rate of 6% over a period of 30 years[27], which is considered as the average life of water services infrastructure. The total financial cost incurred by the city water and drainage departments, is thus the sum of revenue expenditure, depreciation cost and a discount rate.

For private provisioning, direct cost is taken as per values reported in surveys or online sources. For self-provisioned water, costs of digging borewells and O&M costs are derived from surveys and secondary sources and a lifetime of 20 years is considered for equipment to estimate the net present value.

$$\textit{Direct cost of water (INR per kl)} = \frac{\textit{Capital cost in (INR)} + \textit{O\&M Cost in (INR)}}{\textit{Total volume of water supplied (kl)}}$$

Table 2 | **Cost break up for borewells in the 4 study cities for 2011**

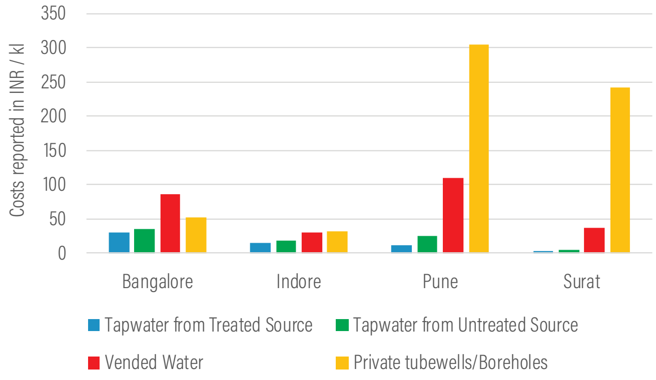
| | CAPITAL COST | LIFE YEARS | O&M | DISCOUNT RATE |
|---|---|---|---|---|
| Pune | 35000 | 20 | 1750 | 6% |
| Surat | 85000 | 20 | 5000 | 6% |
| Indore | 223333 | 20 | 5000 | 6% |
| Bangalore | 223333 | 20 | 5000 | 6% |

Source: Phone survey of local contractors and online sources

## Cost of borewells in Pune and Surat

In Pune and Surat, the cost of water from borewells is extremely high (Figure 13). The social cost for all cities is calculated based on the same formula. Since we have calculated the social cost per unit of water extracted, and the volume of water extracted in Pune and Surat are quite low, there is a large variation in per unit costs.

Figure 13 | **Total social cost of water supply from various sources in the 4 study cities in 2011**




Source: Authors estimates; costs reported in INR per kilolitre

## Indirect Cost

Indirect cost accounts for the opportunity cost of water in two different ways. One cost is in terms of the productivity loss with respect to the income forgone when time is spent on collection of water. The other part is in terms of opportunity cost of groundwater depletion wherein the water could have been put to a different and paying use rather than being diverted exclusively for domestic and urban use.

$$\textit{Cost of access (INR per kl)} = \frac{\textit{Time spent to access or collect water} \times \textit{Wage rate of lowest quintile}}{\textit{Total volume of water collected}}$$

Time spent to collect water is as per National Sample Survey Office (NSSO) Survey results for urban areas in each state in India.

Wage rate[28] is estimated from a report on India's spending patterns (Shukla 2010). To estimate cost of access for water and sanitation services wage rate of the lowest quintile is considered[29].

Opportunity cost of water for groundwater depletion was estimated as the potential agricultural revenue that could be generated by the amount of groundwater that is diverted for urban use. The Central Ground Water Board has developed national and state level mapping of underground aquifers which indicate that for the 4 case study cities the underlying aquifers extend well beyond the urban boundaries (CGWB 2012). As per the mapping

information available in this study it is considered that the urban area and the administrative district around it share the same aquifer. Hence water from this aquifer, if unused for urban needs, could potentially be pumped out directly (with no additional need for piped conveyance) and used for adjoining agricultural practices.

Cropping information reported by each state's agricultural department helped identify the principal crop(s) grown in the said region and available agricultural land in the district of the study city was used to estimate yield. The potential yield estimate is a function of the land available for agriculture, water requirements per kilogram of crop and the volume of groundwater extracted.

$$\textit{Opportunity cost of water (INR per kl)} = \frac{\textit{Total yield of certain crop in tonnes} \times \textit{Minimum support price of yield in INR per tonne}}{\textit{Volume of water required for irrigation for the total yield in kl}}$$

$$\textit{Total yield of crop in tonnes} = \textit{Area available for agriculture in hectares} \times \textit{Yeild in tonnes per hectare}$$

Minimum support price is a market intervention by the Government of India to protect farmers' revenues against excessive price falls by introducing a minimum price guarantee for certain crops (Government of Maharashtra n.d.).

| CITY | BANGALORE | INDORE | PUNE | SURAT |
|---|---|---|---|---|
| Crops | Rice, maize | Wheat, maize soybean | Rice, jowar | Rice, wheat |

When estimating the opportunity cost of groundwater depletion this cost is applied to only the water consumed by those households that report dependence on self-provisioned borewells. As per this distinction made in this study, self-provisioning occurs as a coping mechanism in the absence of, or inadequate presence of, publicly provisioned services. In all the case study cities, the municipal utility also owns/manages a certain number of borewells which supply water to low income or slum communities. The opportunity cost of groundwater depletion is not applied to the water extracted from these borewells as the supply of water to such households would be the highest and best use of the groundwater[30].

Some additional caveats with regards to groundwater extraction are as follows. There is one cost relating to the extractive value/cost to the water user, and another relating to its stock or in situ value, particularly when the extraction rate is much higher than the recharge rate. The latter includes a set of costs that when monetised could be substantial but are not considered in the study due to data limitations. These include a) opportunity costs of engendering future shortages, b) possible subsidence of land because of excessive ground water extraction (as seen in the case of Jakarta (Abidin, et al. 2015)), c) habitat and ecological diversity costs, d) loss of inflows to wetlands and lakes that affect quality of life in the city, and e) deterioration of groundwater quality because of fecal contamination from on-site sanitation systems.

### Health Cost

The health cost estimated in this study is based on Mani's (2014) approach of accounting for the cost of morbidity and mortality associated with water borne diseases using Disability Adjusted Life Years (DALYs). The idea is that unclean water and inadequate scope of sanitation might lead to diarrheal diseases – such as typhoid and paratyphoid which bears a direct mortality cost when there is a loss of a healthy life. Another expenditure is the cost of procuring health services and the loss of working days due to ill health which is estimated as morbidity.

The estimated DALYs are calculated using the baseline data as reported in (M. S. Mani 2014, 30) which also disaggregates mortality and morbidity rates based on age groups (children below 5 years being particularly vulnerable to waterborne diseases). City level population and age data was considered to estimate DALYs while mortality and morbidity numbers were estimated based on reported health cases for each city. When city level health data was unavailable, district level health statistics were considered and reduced to the city.

Table 3 | **Baseline data for estimating health impacts**

| | BASE LINE | SOURCE |
|---|---|---|
| Child mortality rate for those younger than age 5 years in 2006 | 52-82 (per thousand live births) | National Family Health Survey, India (NFHS) -3 |
| Diarrheal mortality in children younger than 5 years (% of child mortality) | 14% | Office of Registrar general (2004) |
| Diarrheal two-week prevalence in children younger than 5 years | 8.9%-9% | National Family Health Survey, India -3 |
| Estimated annual diarrheal cases per child younger than 5 years | 1.85-1.87 | Estimated from NFHS-3 |
| Estimated annual diarrheal cases per persons older than 5 years | 0.37-0.56 | International Experience (Krupnick et.al,2006) |
| Hospitalisation rate (% of all diarrheal cases) for children younger than 5 years | 0.15% | National Sample Survey (2004) |
| Hospitalisation rate (% of all diarrheal cases) for the population older than 5 years | 0.3-0.6% | |
| Percent of Diarrheal cases attributable to inadequate water supply, sanitation and hygiene | 90% | WHO (2002b) |
| DALYs per 100,000 cases of Diarrhea in children younger than 5 years | 70 | Estimated from WHO tables |
| DALYs per 100,000 cases of Diarrhea in population older than 5 years | 100-130 | |
| DALYs per 100,000 cases of typhoid in the entire population | 190-820 | |
| DALYs per case of diarrheal and typhoid mortality in the entire population | 32-34 | |

Source: Greening India's growth: Costs, valuations, and tradeoffs (M. S. Mani 2014)

$$\textit{Cost of mortality (INR per kl)} = \frac{\textit{Total cost of mortality estimated for urban population using DALYs in INR}}{\textit{Total volume of at risk water consumed in kl}}$$

$$\textit{Cost of morbidity (INR per kl)} = \frac{\textit{Total cost of morbidity estimated for urban population using DALYs in INR}}{\textit{Total volume of at risk water consumed in kl}}$$

The cost for morbidity and mortality are reported as follows in (M. S. Mani 2014)

Annual Cost of Morbidity due to inadequate water, sanitation & hygiene 105 Billion INR
Annual Cost of Mortality due to inadequate water, sanitation & hygiene 50 Billion INR
Total DALY's for Mortality 1384000
Total DALY's for Morbidity 197000

Cost per DALY estimated in this study:
Mortality 36127 INR annually
Morbidity 532995 INR annually

## Appendix C | Social Cost of Carbon

The costs associated with carbon dioxide ($CO_2$) emissions for each unit of fuel consumed in a city are estimated using global prices for each ton of carbon dioxide emitted, which have been converted into Indian Rupees to estimate the prices in the local currency. Although the $CO_2$ costs are in US dollars (US Government 2013), the final figures used for this study are presented in Indian Rupees. The associated costs are usually a range, with a lower bound and an upper bound for the potential costs arising from $CO_2$. For this study, both the lower and upper bound of the costs have been used to present the possible range of costs.

| SOCIAL COST OF CARBON | |
|---|---|
| Lower Bound | Upper Bound |
| USD 12 converts to INR 754 | USD 55 converts to INR 3556 |

*Conversion rate is taken as USD 1 = INR 65 across the study for the four case cities

## Appendix D | Transport

Travel demand is estimated based on existing research and surveys on the mode share, vehicle kilometres travelled (VKT) and passenger kilometres travelled (PKT) in the four study cities. In some cases, in the absence of more recent data, we have relied on older data sources to provide rates for estimating current travel demand, assuming them to be similar to those in the current scenario. For Surat that now has two bus systems in the city – the City Bus and BRTS, in the absence of current data, the mode share of 1% was split evenly between the two – 0.5% each. The occupancy assumptions for the different modes in the 4 cities are listed in Table 4.

$$\textit{Total number of trips} = \textit{Population} \times \textit{Trip rate}$$

$$\textit{Passenger kilometers travelled (PKT) per mode} = \textit{Total trips} \times \textit{Mode share} \times \textit{Average trip length by mode}$$

$$\textit{Vehicle kilometers travelled (VKT) per mode} = \frac{\textit{Passenger kilometers travelled}}{\textit{Average mode occupancy}}$$

Table 4 | **Average occupancy per mode in the 4 study cities**

| | BANGALORE | INDORE | PUNE | SURAT |
|---|---|---|---|---|
| Walk | 1 | 1 | 1 | 1 |
| Bicycle | 1 | 1 | 1 | 1 |
| Two wheeler | 1.5 | 2.34 | 1.56 | 1.1 |
| Car | 2 | 3.14 | 2.91 | 1.25 |
| Taxi | 2 | - | - | - |
| Auto-rickshaw | 2.5 | 2.20 | 2.32 | 3 |
| Contract Van | - | 4.03 | - | - |
| Tata Magic | - | 6.27 | - | - |
| Company/ School Bus | 40 | 32.44 | - | - |
| Public Bus | 60 | 32.44 | 35 | 40 |
| BRTS | - | - | - | 20 |

Source: City Comprehensive Mobility Plans for study cities (2008-2012)

## Direct Cost

### Investment Costs

Investment per vehicle includes the on-road price. To estimate the net present value, we assume a varied rate of depreciation for each mode of transportation based on quality of assets and frequency of operations. For cars, we take an average life of 7 years, buses: 15 years, two-wheelers: 10 years, auto-rickshaws: 15 years, and for bicycles: 5 years. The annualised cost of the asset is calculated using constant depreciation and a 6% imputed interest cost.

The following equation is used to estimate daily investment costs for each traveller:

$$\textit{Daily investment cost INR per PKT} = \frac{\textit{Annualized cost of investment per vehicle over expected years of service at 6\%}}{365} \times \frac{1}{\textit{Daily VKT} \times \textit{Average vehicle occupancy}}$$

$$\textit{Daily PKT} = \textit{Daily VKT} \times \textit{Average vehicle occupancy}$$

### Operational Costs

For operational costs we have considered only the fuel costs associated with running of the various modes. Information regarding fuel type and mileage for various modes is derived from secondary data sources. The following equation is used to estimate fuel costs per passenger:

$$\text{Fuel cost INR per PKT} = \frac{\text{Fuel used per kilometer of travel} \times \text{Price rate per unit of fuel}}{\text{Average vehicle occupancy}}$$

### Maintenance Costs

Rates for maintenance costs for all modes are based on estimates provided by the local consultants and city reports.

$$\text{Maintenance cost in INR per PKT} = \frac{\text{Daily amount spent on maintenance}}{\text{Daily VKT} \times \text{Average vehicle occupancy}}$$

### High direct cost of cars in Surat

When compared with other cities such as Pune, Surat's mode-share for cars is quite low (Surat's 1.5% vs Pune's 6.3%). This indicates low usage of cars in the city. Hence, the total VKT for cars in Surat is much lower than other cities like Pune.

For establishing the average daily km travelled by cars in Surat, census numbers on vehicle ownership and VKT were used. The resulting average daily VKT for cars was quite low (4.20 km compared with Pune's much higher 26 km). Against similar investment costs for cars across cities, the low usage of the mode in Surat results in relatively high per unit costs.

## Indirect Cost

### Accident Costs

#### CALCULATING COST OF ACCIDENT RISK IMPOSED ON USERS

The value of statistical life (VSL) derived from Bhattacharya et al. (2006), adjusted for 2016, is roughly 3 million INR. For estimation of daily PKT costs we take the number of deaths by each mode and value them using VSL. The resulting figure is then divided by the number of passenger kilometres to get an accident cost per kilometre by mode of travel. The number and mode share of road accident deaths in 2014 was taken from (NCRB 2014).

$$\text{VSL cost in INR per PKT per day by mode} = \frac{\text{VSL} \times \text{Number of fatal accidents by mode}}{365 \times \text{PKT}}$$

Table 5 | **Break up of capital, O&M costs and life years per transportation mode in this study for 2011**

| | CAPITAL COST | | | | O&M COST | LIFE YEARS | DISCOUNT RATE |
|---|---|---|---|---|---|---|---|
| | SURAT | PUNE | INDORE | BANGALORE | | | |
| City Bus | 3000000 | 3000000 | * | ** | Avg of ~INR 10,400/ week (for Pune and Surat) | 15 | 6% |
| BRTS | 3000000 | NA | NA | NA | 8250/ week | 15 | 6% |
| Auto | 224647 | 224647 | 176751 | 165000 | 250/ week | 15 | 6% |
| Car | 507443 | 507443 | 507443 | 507443 | 7000/ year | 7 | 6% |
| Two-wheeler | 55000 | 55000 | 35000 | 35000 | 1000/ year | 10 | 6% |
| Cycle | 3650 | 3650 | 5000 | 5000 | 500/ year | 5 | 6% |
| | For Bangalore and Indore disaggregated capital and O&M costs were not available. | | | | | | |
| | * Value taken directly from Comprehensive Mobility Plan for Indore | | | | | | |
| | ** Value taken directly from Comprehensive Traffic & Transportation Plan for Bengaluru | | | | | | |

Source: City Comprehensive Mobility Plans, phone and online surveys

## Cost of Commuting

The cost of commuting is based on the Brueckner and Sridhar (2012) study where commuting time is valued at 60 percent of the wage[31]. Average hourly wage figures are derived from the respective States' Economic Statistics Department. Average commuting speeds for various modes is based on data provided by local consultants and local studies.

$$\text{VTTS cost per PKT per day by mode} = \frac{\text{60\% of wage rate per hour}}{\text{Average speed in kilometers per hour}}$$

## Health Cost

Health costs for different modes of travel are estimated based on the emissions from the use of different fuel types in motor vehicles. Emissions are calculated based on emission factors derived from the IIASA Gains Model. The health costs associated with each type of pollutant is calculated based on the ranges reported in the OECD study (2012).

$$\text{Health cost in INR per PKT} = \frac{\text{Total emissions from fuel used in tons} \times \text{Cost per ton of emission}}{\text{PKT}}$$

$$\text{Total emission from fuel used in tons} = \text{Fuel needed per kilometer of travel} \times \text{VKT} \times \text{Emission factor for fuel for specific pollutant}$$

Note: The health cost has been calculated based on the quantity of tail pipe emissions and the carbon cost has been calculated based on the carbon emissions per kilometre travelled. Hence, we do not see any health cost associated with walking and cycling. We do recognise that there is a significant health cost associated with air pollution; and pedestrians and cyclists who breathe the same air also have associated health costs, which is a limitation of this study.

## Climate Cost

Climate cost in the transport sector is estimated as the cost of carbon dioxide emissions from the use of fossil fuels to power various motorised vehicles and are estimated based on US Government estimates for social cost of carbon for 2013 (refer Appendix C: Social Cost of Carbon). $CO_2$ emissions are estimated as per IPCC emission factors for each fuel type (IPCC 2006) and supplemented by factors from the UK's Department for Environment, Food and Rural Affairs $CO_2$ benchmark.

$$\text{Climate cost in INR per PKT} = \frac{\text{Total } CO_2 \text{ emissions from fuel used in tons} \times \text{Cost per ton of } CO_2}{\text{PKT}}$$

## Emission factors (health) for fuels used in transport sector

Table 6 | **Transport sector emission factors in Karnataka for 2011 (emissions in kt/PJ)**

| MODE | FUEL | PM 2.5 | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|
| Bus [BMTC] | Diesel | 0.5237 | 11.31 | 0.11 | 0.944 | 0 |
| Company/school bus | Diesel | 0.5237 | 11.31 | 0.11 | 0.944 | 0 |
| Auto-rickshaw | CNG | 0.001 | 0.419 | 0.001 | 0.226 | 0 |
| Taxi | | | | | | |
| | Diesel | 0.806564 | 3.007081 | 0.105204 | 0.420816 | 0 |
| | Petrol | 0.29916 | 6.1494 | 0.25484 | 4.99708 | 0.06648 |
| | LPG | 0.001 | 0.419 | 0.001 | 0.226 | 0 |
| Car | | | | | | |
| | Diesel | 0.806564 | 3.007081 | 0.105204 | 0.420816 | 0 |
| | Petrol | 0.29916 | 6.1494 | 0.25484 | 4.99708 | 0.06648 |
| | LPG | 0.001 | 0.419 | 0.001 | 0.226 | 0 |
| Two-wheeler | Petrol | | | | | |
| | 2s | 1.237509 | 0.296156 | 0.034753 | 6.989886 | 0.001511 |
| | 4s | 0.064464 | 0.813858 | 0.185334 | 9.967746 | 0.104754 |

Source: IIASA Gains Model

Table 7 | **Transport sector emission factors in Madhya Pradesh for 2011 (emissions in kt/PJ)**

| MODE | FUEL | PM 2.5 | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|
| Bus/City Bus | Diesel | 0.3359 | 7.2588 | 0.0720 | 0.6059 | 0.0000 |
| Tata Magic * | CNG | 0.0010 | 0.4190 | 0.0010 | 0.2260 | 0.0020 |
| Contract Van * | | | | | | |
| | CNG | 0.0010 | 0.4190 | 0.0010 | 0.2260 | 0.0020 |
| | LPG | 0.0010 | 2.1667 | 0.0010 | 0.2260 | 0.0020 |
| Auto * | | | | | | |
| | Petrol | 0.1054 | 2.1667 | 0.0898 | 1.7607 | 0.0234 |
| | LPG | 0.0010 | 0.4190 | 0.0010 | 0.2260 | 0.0020 |
| | CNG | 0.0010 | 0.4190 | 0.001 | 0.2260 | 0.0020 |
| Company/School Bus | Diesel | 0.3359 | 7.2588 | 0.072 | 0.6059 | 0.0000 |
| Car | | | | | | |
| | Petrol | 0.2577 | 5.2969 | 0.2195 | 4.3043 | 0.0573 |
| | Diesel | 0.5174 | 1.9290 | 0.0675 | 0.2700 | 0.0000 |
| Two-wheeler | Petrol | | | | | |
| | Moped** | 1.0655 | 0.2550 | 0.0299 | 6.0184 | 0.0013 |
| | Motorcycle** | 0.0555 | 0.7010 | 0.1596 | 0.0285 | 0.0902 |

Source: IIASA Gains Model

Table 8 | **Transport sector emission factors for Maharashtra for 2011 (emissions in kt/PJ)**

| MODE | FUEL | PM2.5 | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|
| Bus | Diesel | 0.70 | 15.09 | 0.15 | 1.26 | 0.00 |
| | CNG | 0.01 | 0.46 | 0.00 | 3.25 | 0.00 |
| Auto-rickshaw | CNG | 0.00 | 0.42 | 0.00 | 0.23 | 0.00 |
| | Petrol | 0.26 | 14.38 | 0.60 | 11.68 | 0.16 |
| Car | Diesel | 0.70 | 4.01 | 0.14 | 0.56 | 0.00 |
| | Petrol | 2.89 | 14.38 | 0.60 | 11.68 | 0.16 |
| Two-wheeler | Petrol | 0.28 | 1.90 | 0.26 | 19.82 | 0.12 |

Source: IIASA Gains Model

Table 9 | **Transport sector emission factors for Gujarat for 2011 (emissions in kt/PJ)**

| MODE | FUEL | PM2.5 | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|
| City Bus | Diesel | 0.74 | 15.91 | 0.16 | 1.33 | 0.00 |
| BRTS | Diesel | 0.74 | 15.91 | 0.16 | 1.33 | 0.00 |
| Auto-rickshaw | CNG | 0.00 | 0.42 | 0.00 | 0.23 | 0.00 |
| Car | Diesel | 1.13 | 4.23 | 0.15 | 0.59 | 0.00 |
| | Petrol | 0.50 | 10.37 | 0.43 | 8.43 | 0.11 |
| Two-wheeler | Petrol | 2.09 | 1.37 | 0.06 | 11.78 | 0.00 |
| Two-wheeler | Petrol | 0.28 | 1.90 | 0.26 | 19.82 | 0.12 |

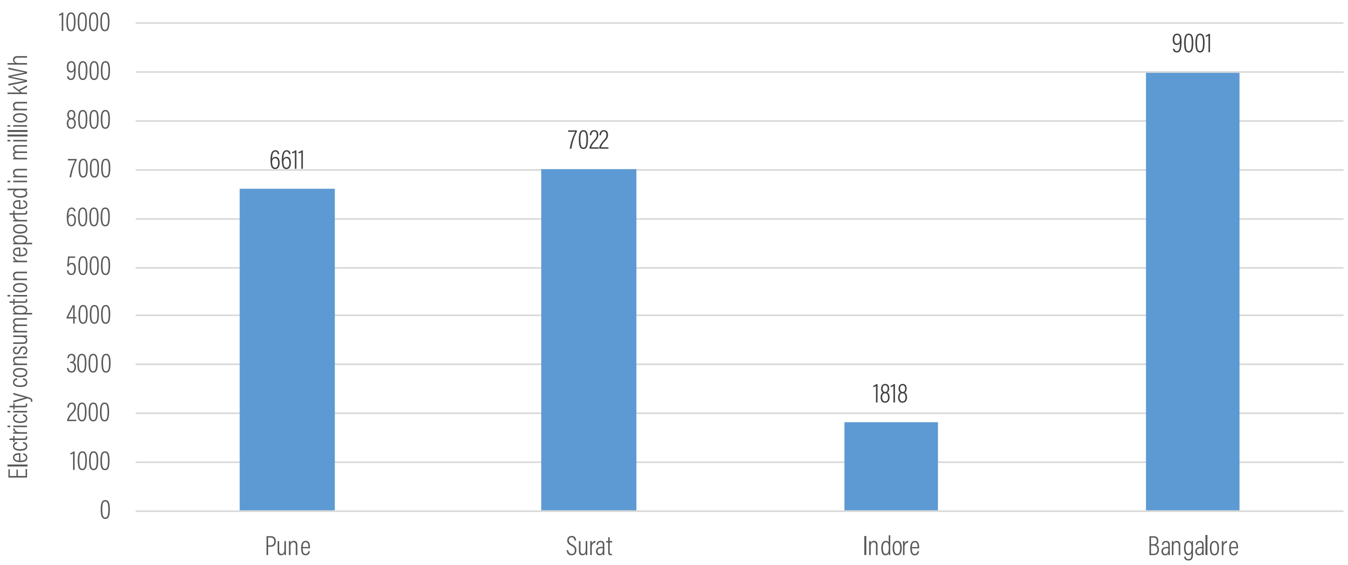
Source: IIASA Gains Model

## Appendix E | Energy (lighting and cooking)

Energy used for lighting is derived from numbers reported by the electricity utility. Cooking fuels are estimated based on the Census 2011 numbers on household coverage and consumption rates from Ministry of Statistics and Programme Implementation (MOSPI) reports on use of household commodities per state. To be able to compare the use and costs across fuel types, all fuel consumption is converted to petajoules (PJ) of energy using standardised conversion factors (UCB n.d.).

The electricity sector, in the four cities, differs slightly and therefore different methods are used to estimate costs. In the case of Surat and Pune some energy production by public utilities happens within the city limits; in Bangalore and Indore the energy production is outside of municipal limits.

Figure 14 | **Annual electricity supply by public utility in the 4 case study cities in 2011**



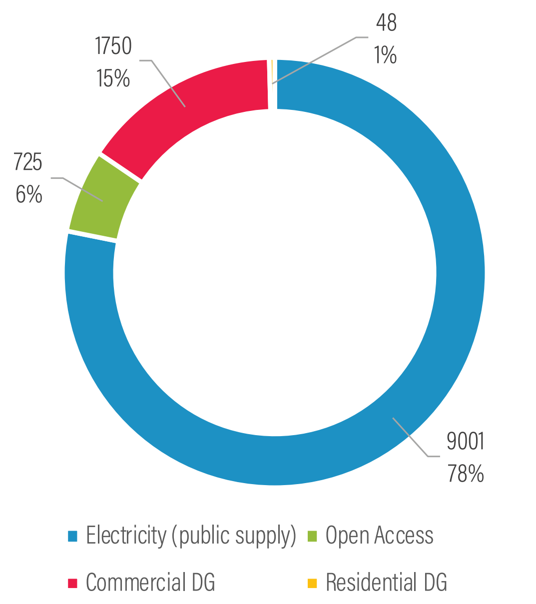

Source: Electricity supply in million kWh as reported by electricity utilities for each city.

Electricity supply from public utility, open access sources and self-supply using diesel generation sets (gensets) was also considered for the city of Bangalore. Other sources of electricity considered in this study are 'open access electricity' which connects private generators to private consumers and the electricity utility only provides transmission services through the grid. A total of 725 million kilowatt hours (kWh) of electricity was supplied through open access provision in 2011 as disclosed on BESCOMs website. Alternatively, diesel gensets (DG sets) also provide power back-up for commercial use and residential/domestic use in case of power outages. The electricity consumed from DG sets is estimated as 1750 million kWh from commercial DG and 48 million kWh from domestic DG sets using 953 million litres and 26 million litres respectively.

Diesel consumption by gensets in Bangalore was extrapolated based on diesel genset usage in India and the reported numbers of gensets in Bangalore[32].

Given lack of similar data in the other study cities diesel consumption in gensets was not estimated for them.

Figure 15 | **Annual electricity supply from various sources in Bangalore in 2011**




Source: Data from electricity distribution utility - Bangalore Electricity Supply Company Ltd.; electricity supply from various sources reported in million kWh.

## Direct Cost

The direct cost of electricity is estimated for the four cities based on the procurement and transmission costs as reported by the electricity utilities.

The direct cost of cooking fuels in all 4 cities is considered to be the same as the tariff charged directly to users. This cost reflects the market price of fuels in the study year and includes possible taxes and subsidies levied on the fuel.

## Indirect Cost

Indirect cost in the energy sector is estimated as the productivity loss with respect to the income forgone when time is spent on collection of fuel (in this study only firewood).

$$\text{Cost of access (INR per PJ)} = \frac{\text{Time spent to access or collect firewood} \times \text{Wage rate for lowest quintile}}{\text{Total volume of energy generated from the fuel source in PJ}}$$

The wage rate used is for the bottom quintile, same as used to estimate the cost of access of water and sanitation services in this study (Shukla 2010).

## Health Cost

Health costs, for different fuels used, are estimated based on the emissions from each fuel. Emissions are calculated based on emission factors derived from the Gains Model (IIASA n.d.). All emission factors are reported in kilotonnes per Petajoule (kt/PJ). The health costs associated with each type of pollutant is calculated based on the cost ranges reported in the OECD study in 2012.

$$\text{Health cost in INR per PJ} = \frac{\text{Total emission for fuel in tons} \times \text{Cost per ton of emission}}{\text{Total energy from fuel in PJ}}$$

## Climate Cost

Climate costs for electricity consumed are estimated using $CO_2$ emission factors reported in the baseline inventory released by the Central Electricity Authority, India (CEA 2014) and based on US Government estimates for social cost of carbon for 2013 (refer Appendix C: Social Cost of Carbon). The report provides $CO_2$ emission factors for the Integrated Northern, Eastern, Western, and North-Eastern (NEWNE) regional grids and the Southern grid. The 'simple operating margin' factor is considered for both the grids which accounts for all existing power plants. The $CO_2$ emission factor is reported in tons-$CO_2$/ MWh.

$$\text{CO}_2 \text{ emitted in tons} = \text{CO}_2 \text{ emission factor per MWh of electricity consumed} \times \text{Total electricity consumed in MWh}$$

$$\text{Climate cost in INR per PJ} = \frac{\text{Total CO}_2 \text{ emission for fuel in tons} \times \text{Cost per ton of CO}_2}{\text{Total energy from fuel in PJ}}$$

Climate emissions ($CO_2$) are derived for all fuels using IPCC standards (IPCC 2006) and supplemented by factors from the UK's Department for Environment, Food and Rural Affairs $CO_2$ benchmark.

Note: Grid electricity reports higher climate costs than DG sets due to the predominance of coal based thermal generation in the public grid supply which is a higher emitter of $CO_2$ as compared to diesel.

## Emission factors (health) for fuels used in energy sector

All emission factors in tables below are derived from GAINS Model.

Table 10 | **Energy sector emission factors for Karnataka for 2011 (emissions in kt/PJ)**

| ENERGY SOURCE | PM2.5 | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|
| LPG domestic | 0.0070 | 0.0600 | 0.0000 | 0.0030 | 0 |
| Kerosene | 0.0073 | 0.08 | 0.233 | 0.004 | 0 |
| Diesel [RES] | 0.096 | 1.16 | 0.233 | 0.16 | 0 |
| Diesel [COMM] | 0.131 | 1.16 | 1.814 | 0.16 | 0 |
| Firewood | 0.505 | 0.05 | 0.023 | 0.789 | 0.008 |

Source: IIASA Gains Model

Table 11 | **Energy sector emission factors for Madhya Pradesh for 2011 (emissions in kt/PJ)**

| ENERGY SOURCE | PM2.5 | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|
| LPG domestic | 0.0020 | 0.0600 | 0.0010 | 0.0030 | 0 |
| Kerosene | 0.0073 | 0.0800 | 0.2330 | 0.0040 | 0 |
| Firewood | 0.505 | 0.05 | 0.022 | 0.789 | 0.008 |

Source: IIASA Gains Model

Table 12 | **Energy sector emission factors for Maharashtra for 2011 (emissions in kt/PJ)**

| | USE | EMISSIONS FACTORS FOR COAL FOR POWER GENERATION | | | | |
|---|---|---|---|---|---|---|
| | | PM2.5 | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
| Electricity* | Domestic | 0.045 | 0.230 | 0.455 | 0.006 | 0.000 |
| | Commercial | 0.045 | 0.230 | 0.455 | 0.006 | 0.000 |
| | Industrial | 0.045 | 0.230 | 0.455 | 0.006 | 0.000 |
| | Public Lighting | 0.045 | 0.230 | 0.455 | 0.006 | 0.000 |
| | Agriculture | 0.045 | 0.230 | 0.455 | 0.006 | 0.000 |
| | Other | 0.045 | 0.230 | 0.455 | 0.006 | 0.000 |
| LPG | LPG -Residential | 0.007 | 0.060 | 0.001 | 0.003 | 0.000 |
| | LPG -Industrial | 0.007 | 0.060 | 0.001 | 0.003 | 0.000 |
| Furnace Oil | Furnace Oil | 0.001 | 0.007 | 0.076 | 0.000 | 0.000 |

Source: IIASA Gains Model

Table 13 | **Energy sector emission factors for Gujarat for 2011 (emissions in kt/PJ)**

| FUEL | PM2.5 | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|
| Electricity (coal) | 0.0603 | 0.2127 | 0.5666 | 0.0052 | 0 |
| LPG | 0.007 | 0.060 | 0.001 | 0.003 | 0 |
| PNG | 0.002 | 0.050 | 0.001 | 0.002 | 0 |

Source: IIASA Gains Model

## Appendix F | $CO_2$ emission factors for fuels used in energy and transport sectors

Table 14 | **$CO_2$ emission factors for fuels used in energy and transport sectors**

| FUEL | $CO_2$ EMISSION FACTOR | UNITS | SOURCE |
|---|---|---|---|
| Petrol | 69.3 | kg per GJ | (IPCC 2006) |
| Diesel | 74.1 | kg per GJ | |
| LPG | 63.1 | kg per GJ | |
| CNG | 56.1 | kg per GJ | |
| Kerosene | 70 | kg per GJ | |
| Firewood | 1610 | Grams/ kilogram | (Edwards, et al. n.d.) |

## Appendix G | Cost factors for emissions in energy and transport sectors

### Table 15 | Cost factors for emissions in energy and transport sectors

| EXTERNAL COST OF PM2.5 (USD/TON) | | EXTERNAL COST OF NOX (USD /TON) | | EXTERNAL COST OF $SO_2$ (USD /TON) | | EXTERNAL COST OF VOC (USD /TON) | | EXTERNAL COST OF $NH_3$ (USD /TON) | | CLIMATE COST PER TON OF $CO_2$ (USD/ TON) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LB | UB | LB | UB | LB | UB | LB | UB | LB | UB | LB | UB |
| 10568 | 30485 | 1788 | 4878 | 2276 | 6504 | 386 | 1138 | 4471 | 12601 | 11.6 | 54.7 |

For this study all USD values were converted to INR using an exchange rate of INR 65 to 1 USD. Cost factors in the Table 15 are derived from the OECD report (OECD 2012). [Lower Bound (LB); Upper Bound(UB)]

# ENDNOTES

1. Choosing private or self-provisioning systems for urban services leads to an opting out by socio-economic groups who otherwise might act as a pressure group insisting on higher quality services, more accountability and reforms from government agencies. Instead, wherever possible, such groups are politically appeased through narrow "deal-making". But such short-term solutions, for the benefit of select user groups, undermine trust in public agencies and impede the urban economy. The number of the urban underserved population continues to grow, and service level deficits persist deepening urban poverty, undermining sustainable growth and reducing productivity.
2. The three service provision types in this study arise from the various Census classifications for household access to services. Community service provision through collective action may be listed as a separate provisioning alternative, as it is done by a group other than public or private entities or individual households and does not function on a for-profit basis. For the purpose of this study though, community provisioning is not included, as the available Census data does not offer disaggregated data for this typology. It can be considered that in the Census, community provisioning is conflated with public toilets and public taps/hand pumps.
3. Self-provision may also occur in combination with either or both public and private provision. For instance, a household may have public water supply, may depend on tanker water and also have a borewell; and use these 3 provision mechanisms simultaneously to meet their water needs.
4. These programmes are to be implemented across a wide range of cities so that the benefits from planned cities and urban service provision are distributed across all urban populations and not limited to metropolitan or Tier I cities only.
5. Non-revenue water (NRW) is reported as 30% in Pune (PMC 2013, 103); in Indore NRW is estimated to be 42% (WSP 2009).
6. Surat's NRW is reported to be 20% and while better than the situation in the other cities, Surat has taken the lead to minimise NRW by instituting an NRW cell (NIUA 2015).
7. To normalise the data, we relied on Census 2011 data for population and service levels for the four cities; 2011 prices for commodities are used to estimate costs and conversion from USD to INR for carbon costs uses 2011 exchange rates.
8. The wide range (2-68 times) presented for the cost of private and self-provisioned water as a ratio of public provisioned water is clarified in Appendix B: Water and sanitation, Notes.
9. Direct cost for vended water and private borewells accounts for 77% and 94% of the social cost in Bangalore and 28% and 89% in Indore.
10. The authors suggest only that the utility may consider sustainable groundwater management and aquifer recharge as an additional component in their water supply portfolio. Water balance estimates (Hegde and Subhash Chandra 2012); (Sawkar 2012) record Bangalore's rainfall to be about 1800 MLD which can be used to significantly recharge groundwater aquifers and indicates a path to a water secure future for the city. At present though (in the absence of robust rainwater harvesting and recharge practices) groundwater in the Bangalore region is over-exploited and is at a stage of development of 128% to 176% (CGWB 2013) meaning that extraction (pumping) exceeds recharge from rainfall.
11. Intermediate public transport (IPT) includes auto-rickshaws, taxis, contract vans, corporate buses, and school buses.
12. Buses include both city bus services and BRT systems.
13. Existing literature indicates the disparity of health impacts across age groups and gender for various fuels used. Women and children particularly bear the burden (health and time) of fuel collection and cooking activities (M. S. Mani 2014); (Global Alliance for Clean Cookstoves 2013). This study estimates the social costs for the urban energy sector per unit of energy consumed and does not look at exposure rates or at-risk populations. But the social costs estimated in this study can be overlaid with age and gender census data to estimate health costs to specific population groups.
14. Electricity distribution in Surat has an additional component in that the Surat city is serviced by two distribution companies; one is a state owned (public) agency Dakshin Gujarat Vij Company Limited (DGVCL) and the other is a private entity Torrent Power. While Torrent Power is a private entity, it is licensed by the Gujarat Electricity Regulatory Commission (GERC) in the same way that DGVCL is licensed to provide services to certain parts of Surat city and functions in a manner similar to a state-owned distribution company. Thus, due to the similarity of the service mechanism this study catalogues electricity supplied by both DGVCL and Torrent Power as public provisioned electricity.
15. India's electricity supply system is divided into two grids, the Integrated Northern, Eastern, Western, and North-Eastern regional grids (NEWNE) and the Southern grid.
16. DG sets refers to diesel generator sets that are used for generating electricity. In many cases they are used as a coping mechanism in the absence of public provision of electricity or when supply is not continuous. We have further split DG sets into residential and commercial based on the scale of system. Battery run inverters are also used as a coping mechanism, but we have not included these as data on usage is difficult to obtain.
17. Open access electricity refers to the provision in the Electricity Act 2003 in India which allows large consumers of electricity (typically consuming 1 Megawatt (MW) or above) to procure electricity from the open market. Essentially, such consumers are able to choose from various competing power companies at better rates instead of being forced to depend on the local/regional utility which has a monopoly on electricity supply. This provision was particularly aimed at industrial and commercial enterprise to give them the opportunity to procure power at competitive rates and boost their bottom line. Transmission still occurs through existing transmission lines set up by either the transmission company or the distribution company and a separate tariff is applied when only transmission services are availed (Kumar n.d.).
18. The city of Surat stands out in this research as an example of good practices in most sectors with high household access to services such as water supply and sanitation. But in the transport sector personal motorised modes (with high social costs) are increasing to rapidly replace non-motorised and shared modes such as walking, cycling and IPT.
19. For example, in the case of Surat and Pune, the decision to locate thermal power plants within/near the city boundary has health impacts on residents (Figure 11) but relocating such services to mitigate their impact is not easily accomplished due to (a) the fixed location and (b) the locked-in expenses of constructing such heavy infrastructure systems.
20. Since the reforms in the electricity sector, in 2003, there have been various initiatives for demand management (subsidy to households to install solar water heaters) and efficiency improvements (free LED lights provided to households based on monthly electricity consumption), but ever-increasing demand from industries and urban areas has meant that supply has not yet equalled demand.

21. Case in point is the water-energy nexus in Bangalore exemplified in the form of BWSSBs unpaid dues to the tune of INR 730 million to BESCOM (Senthalir 2011).
22. Localised efforts of groundwater recharge through rain water harvesting on individual properties and tank and lake recharge have shown positive outcomes in rural and peri-urban settings (Sohoni 2015); (Vishwanath 2014) and such sustainable groundwater management efforts can supplement the total water supply (Sawkar 2012) and reduce the overall volume of imported Cauvery water.
23. Government of India's urban reforms have focussed extensively on service improvement of urban transport systems. Financial support for new mass transit systems was provided under the Jawaharlal Nehru National Urban Renewal Mission and to public bus systems under the Atal Mission for Rejuvenation and Urban Transformation. More recently the National Transit Oriented Development Policy (2017) aims to integrate land use and transport planning to optimise benefits for residents and businesses in proximity to mass transit systems.
24. A recent national level policy in India recognises this water-energy nexus and requires thermal power plants, which have sewage treatment plants within a 50 kilometre radius, to source treated wastewater from such facilities in order to meet their water needs (PIB 2016).
25. The 'take-make-dispose' model is the predominant global economic model which relies on an abundance of cheap raw materials and resources such as water and energy for production of goods and advances excessive consumption to enhance growth and development (EMF 2015).
26. While this study attempts to account for all direct costs to the utility, it is difficult to attain a 'full cost' of service provision as energy subsidies of various types (to public utilities) often masks the full cost of services.
27. These numbers are based on consultations with water utility officials and phone surveys of service providers for individual borewells.
28. It should be noted that there are two limitations in using these wage rate numbers: (a) the original data estimates the numbers using data from surveys conducted in 2004 – 2005 across quintiles, and (b) the estimated wage rate is not disaggregated between rural and urban populations.
29. The use of the wage rate of the lowest quintile to estimate cost of access for water reduces the overall cost associated per kilolitre of water consumed. But is also reflective of the disproportionate distributional impact wherein lower income households' ability to participate in income generating activities is curtailed by the need to access services such as water.
30. The National Water Policy 2012 states that safe water for drinking and sanitation be considered a pre-emptive need when allocating water for different purposes (MoWR 2012).
31. Cost of commuting considers only 60% of the wage rate and varies from estimates for cost of access for water and energy (fuelwood) where 100% of the wage rate is considered. This variation is due to the fact that commuting time is estimated as a function of work-time and leisure-time which are valued differently (Brueckner and Sridhar 2012). While surveys indicate that time cost for water and energy are valued at around the full wage rate (Hutton and Haller 2004).
32. Number of diesel gensets and diesel consumption in India was derived from the ICF report (2017) on diesel generators in India; reported numbers of gensets in Bangalore was extracted from a 2010 publication on air quality, emission inventory and source apportionment for Bangalore city (TERI 2010).

## LIST OF FIGURES

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## ABOUT WRI

WRI India is a research organization that turns big ideas into action at the nexus of environment, economic opportunity and human well-being.

**Our Challenge**

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

**Our Vision**

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

**Our Approach**

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.