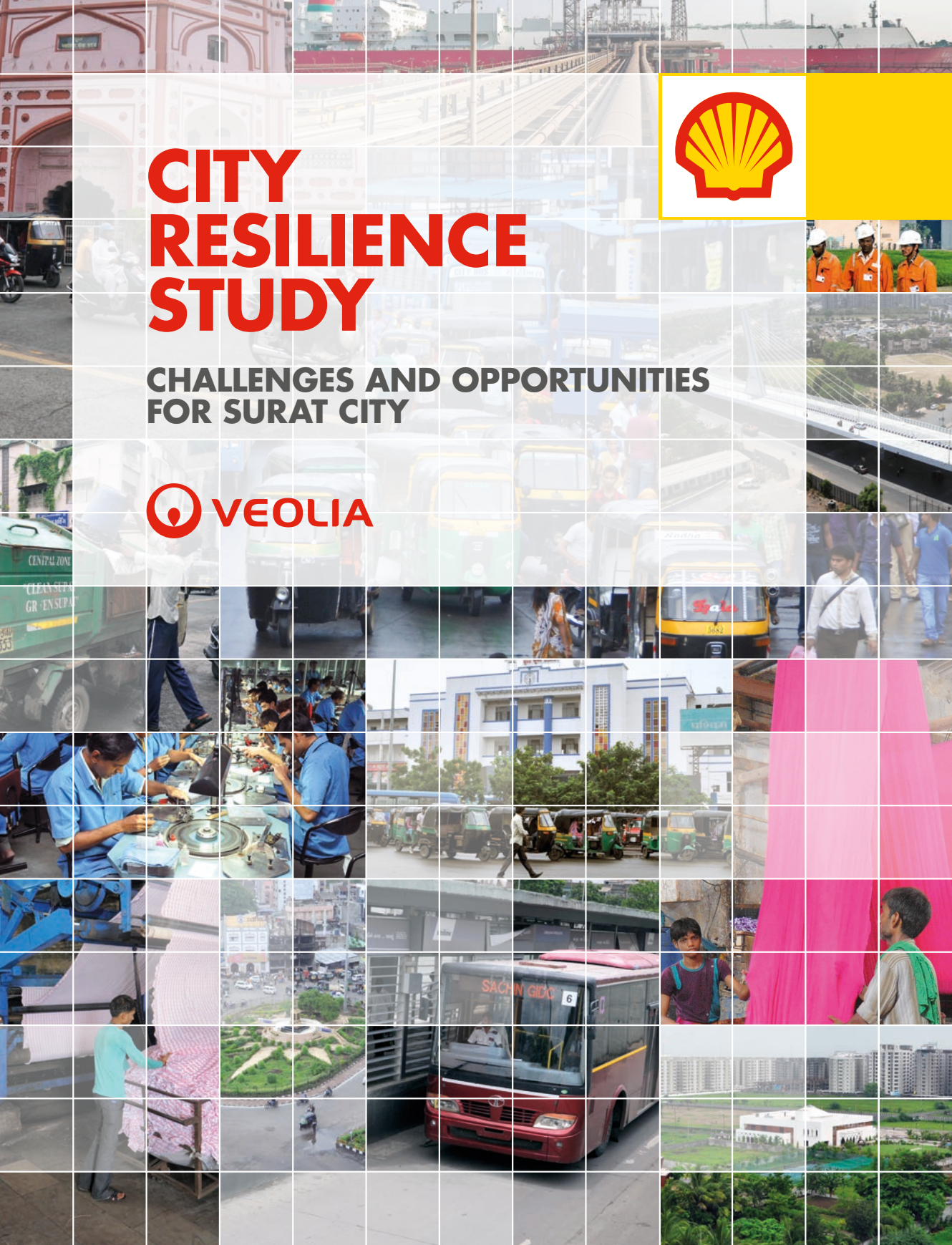


CITY RESILIENCE STUDY

CHALLENGES AND OPPORTUNITIES
FOR SURAT CITY

 **VEOLIA**





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APPROACH AND LIST OF PARTNERS

This study has been co-created together with key stakeholders and municipal leaders in Surat.

The approach to this study has been to engage and collaborate, with the objective of understanding the infrastructure challenges and opportunities the city faces as a result of urbanisation and identifying innovative and credible solutions. To understand how Surat

sees the future, a set of meetings was held with key stakeholders in the city such as the Surat Municipal Corporation (SMC), the South Gujarat Chamber of Commerce and Industry (SGCCI), TARU, local business leaders and Torrent Power.

WE ARE GRATEFUL TO ALL OUR PARTNERS IN THIS STUDY, ESPECIALLY:

PARTNER	FUNCTION/AFFILIATION
Mr Milind Torawane	IAS, Surat Municipal Commissioner, Surat
Mr Jatin Shah	City Engineer, Surat Municipal Corporation and Managing Trustee, Surat Climate Change Trust, SCCT
Mr Kamlesh Yagnik	Past President, Southern Gujarat Chamber of Commerce and Industry, SGCCI
Mr GK Bhatt	President, TARU Leading Edge Pvt Ltd
Mr Mahesh Rajasekar	Director, TARU Leading Edge Pvt Ltd
Mr Girish Luthra	Textile Expert, Luthra Dying and Printing Ltd
Mr Mehul Patel	Senior Associate, TARU Leading Edge Pvt Ltd

AND WE ARE ALSO GRATEFUL TO THESE INSTITUTIONS FOR THEIR CONTRIBUTION:

Surat Municipal Corporation
 Surat Climate Change Trust
 The Southern Gujarat Chamber of Commerce and Industry
 Sarvajani College of Engineering and Technology, Surat
 The Energy and Resource Institute, New Delhi

PREFACE FROM SURAT MUNICIPALITY

Surat city has embarked on a mission to take pre-emptive adaptation measures to mitigate the impacts of processes associated with climate change and variability at the city level. The process of building resilience to the impacts of climate change is being spearheaded by the Surat Municipal Corporation (SMC) with support from various stakeholders. This document 'City Resilience Study : Challenges and Opportunities for Surat City' helps to focus attention on the key issues associated with energy and infrastructure sectors of the city.

As Commissioner for the SMC I am pleased that the City Resilience Study has identified a range of energy and infrastructure issues and believe it can help to stimulate concerted efforts to tackle them through focused measures with support from Shell, Veolia, The Southern Gujarat Chamber of Commerce and Surat's Textile Industry.

In today's world the phenomenon of rapid urbanization and issues of pollution, availability of resources, infrastructure development and economic growth opportunities are constantly under review. Urban centers are also centers of innovation, creativity and culture, as well as focal points for government, finance, business, services and corporate headquarters and thereby growth engines for the national economy.

Shell and Veolia have a strong interest in city development and are investigating new ways to develop and maintain sustainable infrastructure. It is gratifying to note that all stakeholders involved in this study actively and passionately contributed to the process to ensure that the document becomes a live and vibrant strategy which is owned and acted upon by all through a convergence of approach and action.

I am sure the city of Surat, its enlightened citizenry and stakeholders will be able to offset the adverse impacts of climate change on energy through convergence of approach and synergies of action. Surat has already displayed its inherent resilience by overcoming the scourge of plague to become the cleanest city in India as also by recovering from the the worst flood in a century. I am confident that Surat and its citizens will once again chart a new course and set an example by achieving the ability to remain Energy Resilient in the face of processes of climate change for other cities to emulate.

This study has been a successful shared experience and has provided relevant learning on resilience and energy issues to city stakeholders. It has promoted Resilience literacy, learning and sharing of knowledge on urban climate change resilience.

I take this opportunity to acknowledge the support and guidance of various departments of Surat Municipal Corporation, other organisations and individual experts in contributing to the preparation of this document.



MILIND TORAWANE

IAS Commissioner, Surat Municipal Corporation

PREFACE

BY SHELL AND VEOLIA

Royal Dutch Shell is one of the largest and most diversified international investors in India's energy sector. Shell businesses in India span retail transport fuels, lubricants, aviation fuels, technology development and gas and power through our Hazira LNG Joint Venture, close to the city of Surat.

Veolia designs and deploys circular economy solutions for water, waste and energy management to improve efficiency for cities, industry and citizens (96 Million people supplied with water, 529 heating and cooling networks managed, 655 waste-processing facilities operated). As a world leader in environmental services, Veolia works with both municipalities and industrials. Veolia is deeply committed to helping Indian Cities optimize their environmental public services. In Nagpur and in Delhi, Veolia provides safe and potable water to more than 4 million people.

In this collaborative study, Veolia and Shell provide an assessment of the key infrastructure challenges and potential solutions regarding sustainability for Surat local stakeholders (air quality, resilient energy infrastructure and providing, waste and

water management systems, transport, etc.). The work in this report reflects the significance Shell and Veolia place on working with local communities to help tackle their challenges, particularly in fast-growing cities like Surat.

It has been an honour to work with the Surat municipality, including the Municipal Commissioner, Mr Torawane, and his team, in developing this study, which was a genuinely interactive and collaborative approach to identifying key infrastructure resilience issues and ways to tackle them. We also appreciate the strong engagement and support we have received from a wide range of local stakeholders, including the South Gujarat Chamber of Commerce and Industry, the government of Gujarat and business leaders in the city.

The issues and ideas in this report are very much a joint effort and we have learnt much from the achievements and aspirations of the people of Surat. We hope that this study provides a modest contribution to the considerations of the municipality as it works to ensure a positive and sustainable future for the city.



YASMINE HILTON

Chairman, Shell Companies in India



PATRICK ROUSSEAU

CEO and Managing Director Veolia India

EXECUTIVE SUMMARY

Today, about half of the world's 7 billion inhabitants live in cities. This will approach about three-quarters by 2050 as the urban population grows from 3.6 to 6.3 billion. Shell and Veolia estimate that by 2040, almost 80% of global energy will be consumed in cities. Similar to the global trend, India is observing the rapid growth of its urban population. The latest census showed that the urban population of India increased from 286 million in 2001 to 377 million in 2011. Surat, located in Gujarat state in North West of India, is one of the fastest-growing cities in the world, experiencing rapid industrialisation and migration.

Shell and Veolia worked together during 2014/2015 to provide a series of focused solutions to key challenges and opportunities for Surat. The study has been co-created with a range of stakeholders using a three-step process to Understand, Identify and Collaborate. This report reflects the output from the collaborative work and aims to give the city authorities a set of options to improve the resilience, liveability and economic potential of the city. These solutions are the result of discussion and feedback from many people associated with living working in, administering and guiding the city.

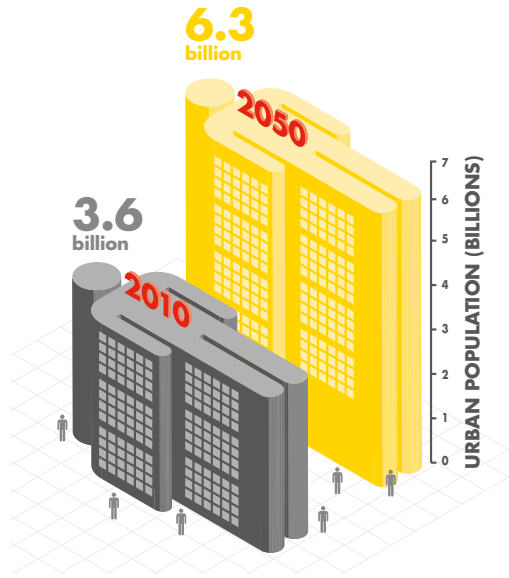
The opportunities include:

1. Implementing a Combined Heat and Power system in the textile clusters to provide clean, efficient and affordable power and heat to this key area of the Surat economy.
2. Putting in place a resilient, green clean power micro-grid that complements the existing grid.

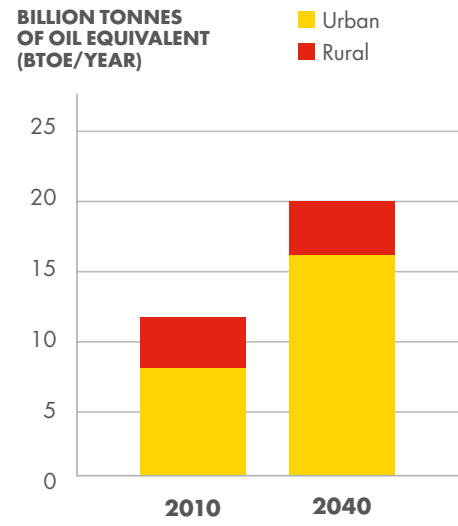
3. Reducing water consumption through the implementation of effective water recycling measures, particularly in the industrial sectors.
4. Developing further waste to energy solutions by increasing the use of biogas in power production.
5. Expanding efficient transport systems using cleaner fuels that could leverage micro-grid infrastructure.
6. Using green infrastructure systems that complement the existing flood management solutions for the River Tapi.
7. Building on and further developing the excellent management and governance systems that Surat already is respected for.

As such these solutions belong to Surat. Individually, each solution has potential. However, the real value to Surat is in their integrated implementation. The proposed solutions are achievable, but much needs to be done to further assess detailed engineering feasibility, commercial viability (investor funding, project economics), local and federal regulatory support, environmental fit and to ensure community support. We hope that the results of this study will help to build the roadmap for Surat.

GLOBAL URBAN POPULATION GROWTH



WORLD ENERGY CONSUMPTION



WHERE WILL THESE EXTRA 2.7 BILLION PEOPLE COME FROM?



INTRODUCTION TO CITY RESILIENCE STUDY

“THE 21ST CENTURY IS THE ERA OF CITIES”¹

Rapid urbanisation is one of the most significant dynamics affecting the future, presenting both opportunities and risks. Today, about half of the world’s seven billion inhabitants live in cities. This will approach about 70% by 2050 as the urban population grows from 7 to 9 billion. Shell estimates that by 2040 almost 80% of the global energy will be consumed in cities. Urbanisation is also a key dynamic for the future of Asia, as almost 50% of urbanisation occurs there. Cities are also places of opportunity. They are the engines of economic growth as well as being cultural and historical hubs and centres of social mobility.

understand the implications and opportunities for the inhabitants and governments of cities. Shell’s first insights were published in “New Lenses on Future Cities”.

To further deepen the understanding of the patterns of urban growth and develop our insights into potential options for sustainable development, Shell has been working with a number of major cities to understand their challenges and opportunities and collaborate in helping to identify potential solutions. Surat is one of the first of these cities and reflects Shell and Veolia’s commitment to India and, through Shell’s joint venture at nearby Hazira, to the state of Gujarat.

However, the percentage of the population living in urban areas in India is only 31% (lower than China, Indonesia and Brazil), indicating that there is plenty of capacity for further growth. India’s urban population is expected to increase to 600 million (40% of the population) by 2031, with a 75% contribution to the nation’s GDP (up from 66% today).

We appreciate the commitment of the Surat Municipal Corporationer, Mr Torawane, the Surat Municipal Corporation (SMC), the South Gujarat Chamber of Commerce and Industry (SGCCI), the consulting bureau TARU, and Mr Luthra from Luthra Industries, who agreed to work with Shell and Veolia on this project.

City growth will be accompanied by increased demand for natural resources, such as energy, water and food. As a result there will be greater pressures on current infrastructure and supply systems as well as increased societal and political challenges. To be a resilient, liveable and prosperous city of the future, municipal services will need to plan carefully to integrate the use of resources in an efficient and sustainable way. Urban design and planning will be essential to our future well-being. However, what that might look like is very different for every city. It depends on the current state of the city, the history and the different challenges and aspiration a city has. Shell and Veolia have explored urbanisation with a number of private and public partners to

SURAT CITY CHARACTERISTICS

Surat is a city in the West Indian state of Gujarat, on the bank of the River Tapi.

The city is located approximately 300 km south of the state capital, Gandhinagar. It had a population of 4.6 million at the 2011 census, making it the second largest city in the state of Gujarat, after Ahmedabad and the eighth largest city in India.

Out of 35 cities in India with a million-plus population, four of them (Ahmedabad, Vadodara, Surat and Rajkot) are in Gujarat.

The city registered an annualised GDP growth rate of 11.5% over the seven fiscal years between 2001 and 2008. Surat was awarded “best city” by the Annual Survey of India’s City-Systems (ASICS) in 2013 and is one of the fastest growing cities in the world, experiencing rapid industrialisation and migration.²

Surat is a compact city and has been expanding along transport corridors. A moat divides the older parts of the city, with their narrow streets and historical houses, from the newer suburbs.

The growth trends indicate sprawl tendency towards the South and North-East, with growth extending towards the northern side across the river. The residential development in the city covers about 57% of the total land use developments in the city. Peri-urban growth is also a feature of the city, especially along the Surat-Hazira corridor, which has led to associated growth in the periphery. Surat has the highest percentage migrant population in India (more than 50%).

The city has experienced 6+% annual population growth since the 1960s. In recent decades Surat has emerged as a major centre for trade and commerce in the region.



SURAT CITY PROFILE^{3,4}

Area	327 sq km	Population	4.6 million
Temperature	Mean 35 °C	GDP (approx)	\$40 billion
Air Quality Index (PM10)	70–110 ppm	GDP Growth 2008	12% approx
		Energy Consumption (Mtoe)	4.3
		Energy per Capita (toe)	0.96

Tonne of oil equivalent (toe) is a unit of energy defined as the amount of energy released by burning one tonne of crude oil, approximately 42 gigajoules. Multiples of the toe are used, in particular the megatone (Mtoe, one million toe).



INFRASTRUCTURE

Gujarat has an extensive transportation network encompassing national highways, state highways, district highways, district roads and rural roads (sugar cane roads and Panchayat roads). The state consists of more than 300 state highways covering a distance of 19,761 km and 13 national highways covering a distance of 3,245 km. The public transport bus system has been privately operated since August 2007. The buses handle 1% and autorickshaws handle about 21% of the total trips made in the city. Transport in the city is dominated by personal

modes such as cars and motorbikes (51%). Being a commercial city, peak traffic volumes are observed throughout the day and are especially high in the industrial areas.

Wastewater management is organised in drainage zones, including the walled city. This network covers 91% of the population, though there is a need for replacement and renewal of old pipelines, particularly in the walled city (Athwa and Umra areas). Sewage water is treated by the Gujarat Pollution Control Board, in a 100 million litres per day (mld)

capacity sewage treatment plant at Karanj, and treated sewage is disposed into the Karanj Khadi. Untreated sewage from the remaining areas, along with wastewater generated from the local small-scale industries, is discharged into the Karanj Khadi through storm water drains.

The present drinking water system covers 95% of the population, with 145 liter per capita per day (lpcd) water supply. The current average yield to supply ratio for SMC's four major water works, Katargam, Sarthana, Varachha and Rander, is 57%.

With the implementation of the Master Plan, Surat aims to achieve a 100% coverage target as well as to address issues of contamination in areas where the pipes need to be replaced.

ECONOMY

Surat is known for its textile manufacturing, diamond cutting and polishing industries, complex zari (silver) works, chemical industry, engineering and related activities (including equipment manufacturing) and petrochemical industries within and beyond the city limits. Surat has been very successful in attracting a sizeable amount of Foreign Direct Investment in various sectors such as energy, oil, and petroleum.

TEXTILES⁴

Surat is well known as one of the textile hubs of India. It hosts over 600,000 power looms and the textile industry provides over 1,200,000 jobs. It contributes 18% to the total manmade fibre exports and 40% of manmade fabric production in India. Surat is renowned for its synthetic sarees and dress materials and there are about 400 different small and medium industries located in the city's textile clusters at Palsana, Sachin, Pandesara and Surat city Industrial Areas. The saree and dress materials produced in the Surat clusters are marketed in India and also exported globally.

The cost of energy as a percentage of the overall textile manufacturing cost varies anywhere between 12% and 15%. The majority of the textile units located in Surat involve wet processes such as the dyeing and washing of cloth. Wet processes require a high amount of thermal energy in the form of hot water and steam, making it a high proportion of the overall energy cost.

DIAMONDS⁵

Gujarat accounts for almost 80% of the diamonds processed in India. Of this, 90% are processed by the units located in and around Surat. Like textiles, diamond cutting and polishing is also a labour-intensive industry, employing about 700,000 workers in about 25,000 units of varying sizes. To take forward the Indian Government's vision of building 100 smart cities in the country, a foundation stone has recently been laid for the Diamond Research and Mercantile (DREAM) City, to be located on an area of about 2,000 acres (around 8 km²) on the outskirts of Surat. The DREAM City will mainly house an international diamond trading hub, Surat Diamond Bourse (SDB), on 579 acres (2.3 km²) of land. The SDB will house around 10,000 offices for diamond traders from India and abroad.

OTHER INDUSTRIES

The Hazira LNG Terminal and Port is a JV between Shell and Total, known collectively as Hazira Group Companies (HGC). Hazira is situated at a distance of 25 km from Surat and approximately 300 km from Mumbai. The Hazira regasification plant started operations in 2005. It procures LNG in the international market to meet the commercial needs of customers in the West and North of India.

CHALLENGES

Surat is a fast growing city, experiencing rapid industrialisation and migration. According to World Bank Sustainable Development Network, it's also one of the world's most climate change-affected cities.

In the past 100 years, Surat has experienced 23 floods, including a significant one in 2006 when almost 75% of the city was inundated, and an outbreak of the plague in 1994. It has a forward-thinking municipal government and proactive public and private sector stakeholders who have made significant strides in recent years to improve the health and resilience of the city for all of its population.

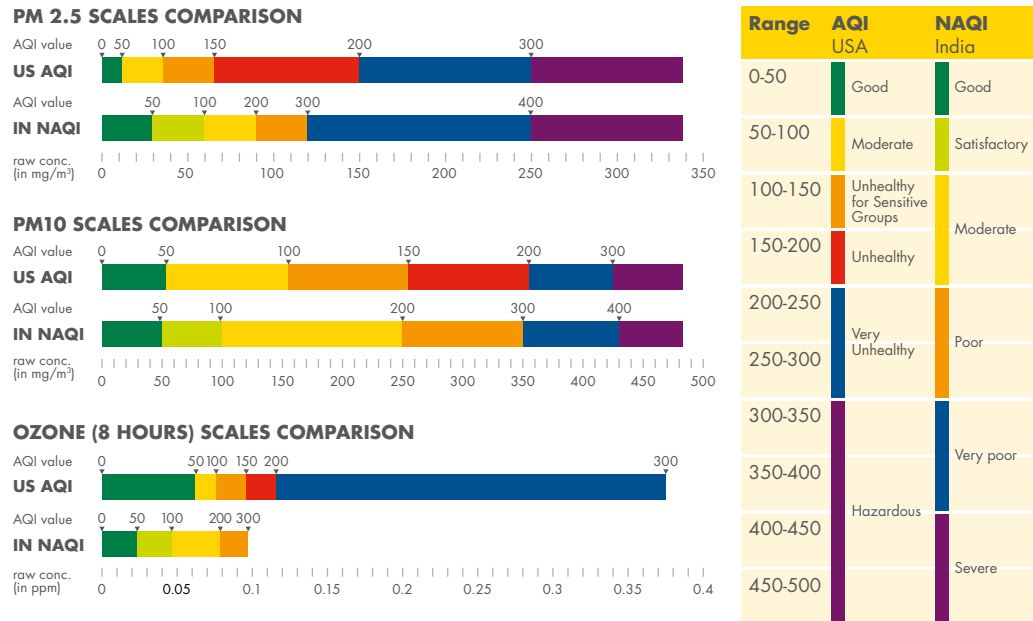
Looking forward, this study has identified a number of key challenges in further improving the infrastructure resilience of the city. Recognising these challenges helps us to identify some of the main solution areas.

1 AIR POLLUTION

As defined by the World Health Organization (WHO), air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide. Outdoor and indoor air pollution cause respiratory and other diseases, which can be fatal.

Air pollution is becoming a hot topic in India, due to exponential urban growth. Air pollution kills over 620,000 people a year in India and millions across the world, according to the WHO. A National Air Quality Index (NAQI) has been launched in early 2015 in order to give real-time concentrations of major pollutants (PM10, PM2.5, ozone).

AIR QUALITY INDEX COMPARISON (UNITED STATES AND INDIA)



The new index will initially cover 10 cities (Delhi, Agra, Kanpur, Lucknow, Varanasi, Faridabad, Ahmedabad, Chennai, Bangalore and Hyderabad). The aim is eventually to cover 66 Indian cities, according to the government.

In Surat, in 2012, the Central Pollution Control Board reported that PM 10 annual average emissions were 94 µg/m³, whereas the National Ambient Air Quality Standard limit is 60 µg/m³ (as annual value – 100 µg/m³ over 24 hours).⁶

As estimated by the Surat Municipal Corporation, industrial and vehicle discharges are the main

contributors to the decrease of ambient air quality in the city. The current infrastructures (energy supply, water supply, wastewater treatment, transportation) are no longer adequate to sustain the needs of a fast-growing city. That is why finding innovative solution for the industrial sectors to optimize their energy consumption (in terms of energy efficiency, clean sources of energy etc.) and improve the water and waste services (e.g. with biogas recovery from municipal waste and wastewater sludge) will help these industries decrease their impact on ambient air.

2 ENERGY INFRASTRUCTURE

India is the fourth largest consumer of energy in the world after USA, China and Russia. India does not have abundant energy resources and has to meet its development needs by using all available domestic resources of coal, uranium, oil, hydro and renewables. Meeting the energy needs of a growing economy with 7% or 8% economic growth and the energy requirements

of the population at affordable prices presents a major challenge. There are continuous efforts to increase energy efficiency and at the same time to increase domestic production as much as possible to keep import dependence at a reasonable level.⁷

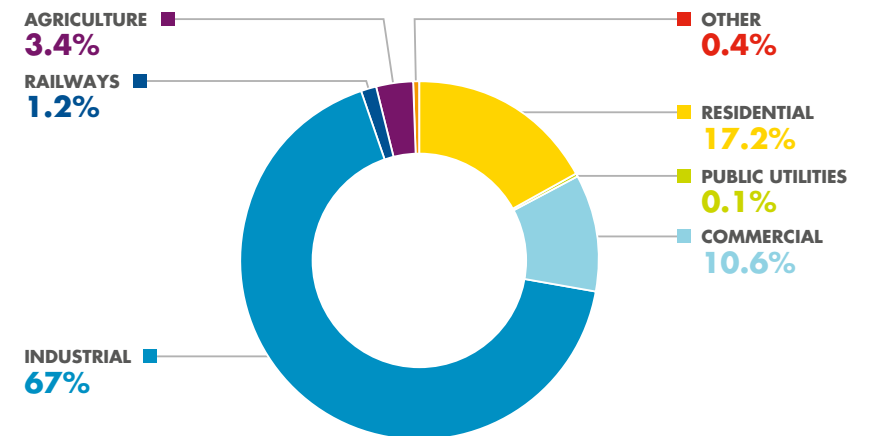
One of the global challenges of urbanisation is the development and planning of energy supply, transmission and distribution infrastructure. In this study key stakeholders highlighted the supply of affordable and dependable energy as one of the major challenges to the growth of Surat. The recent population growth (more than > 50% of the total population are migrants) of the city is mainly due to the growth of two labour-demanding industries: textiles and diamond cutting and polishing.

Population growth and an expanding economy are reflected in a significant growth in energy demand. The 2013 Indian Central Electricity Authority survey of electricity consumption in Indian mega-cities showed a steady growth rate of 4–5%. The peak electric load of the city was 1,014 MW and 1,145 MW during the years 2003–04 and 2009–10 respectively. During the previous five years, the compound average growth rate of peak electric load of the city was 2.26%.

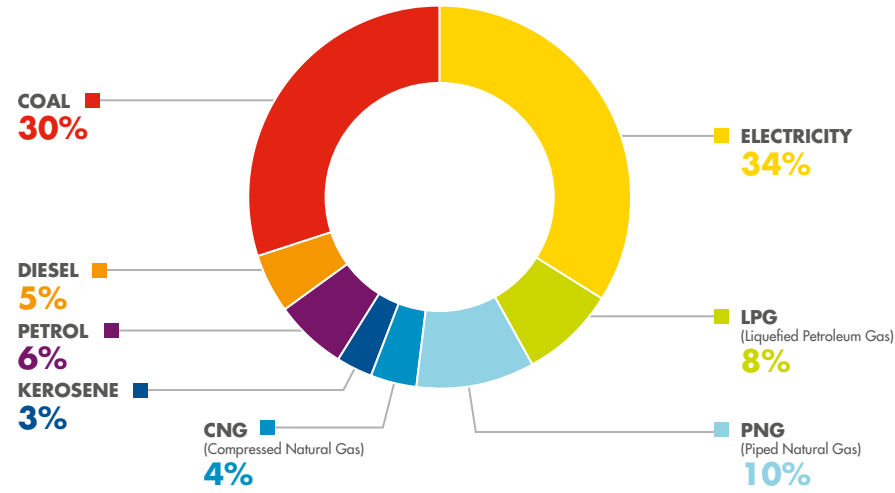
Surat mainly relies on fossil fuels for power generation, with industrial consumption representing the majority of overall consumption in the city (> 65 %).⁸ Though the general reliability of electricity provision in Surat is good, there were many concerns expressed by stakeholders at the pollution levels from some of the smaller-scale energy generation, particularly in industrial sectors such as textile mills, where large volumes of coal are used on a unit by unit basis for the generation of steam in the dyeing and washing of cloth. There were also concerns about the city’s ability to provide sufficient generation capacity in the future, given the expected increases in demand due to the expanding economic base.

In the Surat solar city master plan⁹ it was identified that the Surat Municipal Corporation and local industries are very keen to use renewable sources of energy generation such as wind, biogas, municipal solid waste etc. More than 50 MW capacity of wind power plants have already been installed in Surat by industries during 2011–12 to 2012–13.

ENERGY CONSUMPTION PER SECTOR IN SURAT⁸



ENERGY CONSUMPTION IN BASE YEAR IN SURAT, 2010-11⁹



Units in the Surat textile clusters require a significant quantum of thermal energy in the form of steam and electricity. At present, the steam is generated in low-pressure boilers and coal is used as fuel, which is relatively cheap in comparison to other fuels, whereas electricity is either imported from the grid or generated in natural gas generators (about 5% to 10%).

The particulate pollution from coal use is high and there are also concerns about the disposal of wastewater used in the textile production processes. Finding less polluting and yet efficient and cost-effective energy generation methods in the industrial sector in Surat is a major challenge for ensuring a resilient and sustainable energy system for the city.

DIFFERENT FORMS OF ENERGY CONSUMPTION IN CLUSTER UNITS (2010 DATA)⁴

S. No.	FUEL TYPE	PRICE RANGE (Rs.)
1	Lignite	2,500 – 2,800 per ton
2	Imported coal	3,500 – 3,800 per ton
3	Natural gas	11.5 per SCM
4	Biomass (Groundnut husk briquettes and wood)	3,500 per ton
5	Grid electricity	5.6 per kWh

ENERGY PRICES (2014 DATA)

Electricity	7	INR/kWh
Natural gas	48.3	INR/Nm ³
Coal	5800	INR/tonne

Fixed exchange rates: 1€ = 1.25 USD and 1 INR = 0.016279 USD

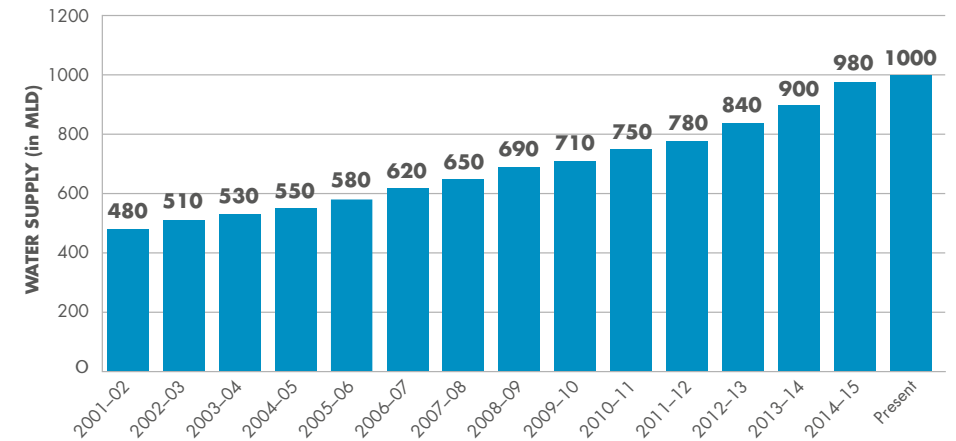
3 WATER MANAGEMENT

WATER SUPPLY FOR DOMESTIC AND INDUSTRIAL USE

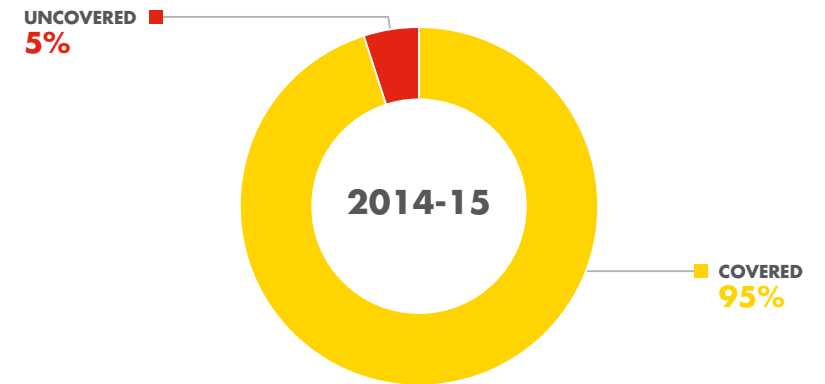
The water needs of Surat are managed by the Surat Municipal Corporation. The major source of water supply for the city is from the River Tapi.

The water supply network was commissioned in 1898. A total of 95% of the population have access to potable water, while in the last 15 years the water supply has been doubled and now reaches 1 million m³ per day in 2015, with a current installed capacity of 1.3 million m³.

INCREASE IN DAILY AVERAGE WATER SUPPLY IN SURAT¹⁰



POPULATION COVERAGE FOR EXTENDED CITY AREA IN YEAR 2006¹⁰

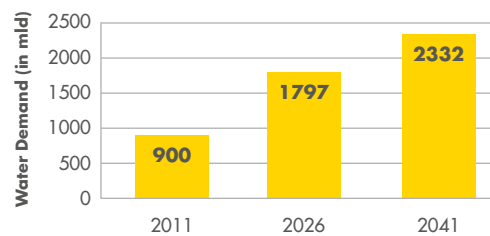


In Surat water demand from the industrial sectors is significant. Clusters of textile units consume more than 450 million litres per day¹¹ (mld) of fresh water for their processes, of which there is 100 mld demand for the Pandesara cluster alone. The Surat Municipal Corporation supplies a part of these needs, e.g. 60 mld of potable water and 40 mld of recycled water from a tertiary treatment plant to address the 100 mld water demand from textile processing units in Pandesara cluster.

Similar to other cities in India, Surat has its own share of poor areas and informal settlements where migrants, unable to afford formal housing, mainly live. In 2006, about 20% of the population was living in these locations. Since the late 90s, the Municipal Corporation has provided free water and sewage connections to the households living in these areas. In addition, paving of internal streets, street lights and toilets (public and private) have been provided. However, the arrival of migrants or semi-skilled workers in response to the needs of growing industries is a continuous challenge for the SMC.

Given these factors it is a significant challenge for the city to manage increasing demand for water for domestic and industrial purposes, which is estimated to more than treble from 2011 levels by 2041.¹²

SURAT CITY WATER DEMAND PROJECTION¹²



FLOOD MANAGEMENT

According to the World Bank Sustainable Development Network, Surat is also one of the world's most climate-change-affected cities. In the past 100 years, Surat has experienced 23 floods. The River Tapi passes through Surat City via the Ukai Dam built in 1972. It is situated 100 km upstream of Surat. The main purpose of the dam was irrigation, power generation and partial flood control. However, heavy rainfall in the catchment area of the Ukai Dam (in Maharashtra) leads to heavy inflow into the reservoir and in the past has resulted in significant discharges of water, causing flooding in Surat.

Surat faces flood risks from heavy precipitation in and around the city but also from heavy precipitation upstream and from high tides downstream. Flooding has a number of consequences. There are risks to the safety of the population and damage to property. The city's transport systems are disrupted, stopping commuters going to work. Also, the power supply to the city may be cut, causing business and commercial enterprises to lose productive time. In the case of more severe flooding, evacuation of large parts of the city may be required and there is a significant risk to the population.

Since joining the Rockefeller Foundation's Asian Cities Climate Change Resilience Network (ACCCRN) in 2008, the city authorities are now learning best practices from other cities facing similar challenges and also bringing lessons back to test in their own waters. As one of ten cities in the network, Surat has developed a climate change resilience strategy, ensuring that they are better equipped to plan, finance and implement timely interventions to potential flooding problems.

WASTEWATER AND SEWAGE TREATMENT

Sewage treatment is also a SMC responsibility. Eight Sewage Treatment Plants (STP) with a treatment capacity of 640 mld¹³ receive wastewater collected through the 1,500 km network in Surat, covering 91% of the population. In anticipation of the increasing amount of wastewater generated in this area, additional capacity will be added (580 mld).¹³

Plant	Capacity (mld)
Existing	
Anjana STP	82.5
Behesan STP	100.0
Bhatar STP	120.0
Karanj STP	100.0
Singapore STP	100.0
Bamroli-Vadod STP	100.0
Asarma STP	15.0
Khajod STP	25.0
Ongoing STP Projects	
Dindoli STP	66.0
Vairav-Kosad STP	84.0
Proposed STP Projects	
Bhatar (extension)	120.0
Karanj (extension)	80.0
Singapore (extension)	100.0
Bamroli-Vadod (extension)	60.0
Behesan (extension)	70.0

As part of its commitment to sustainable resource management and green energy the Surat Municipal Corporation has installed biogas-based power plants using sewage to generate biogas which is used in gas engines to generate power on four Wastewater Treatment Plants (Capacity: 3.5 MW).⁹

The current electricity production is approximately 46.5 MWh/day (half of the maximum production potential). In addition to these existing biogas-based power plants the Surat Municipal Corporation has commissioned three more sewage-based biogas power plants with 0.55, 0.6 and 0.7 MW capacity.

SUMMARY OF CHALLENGES

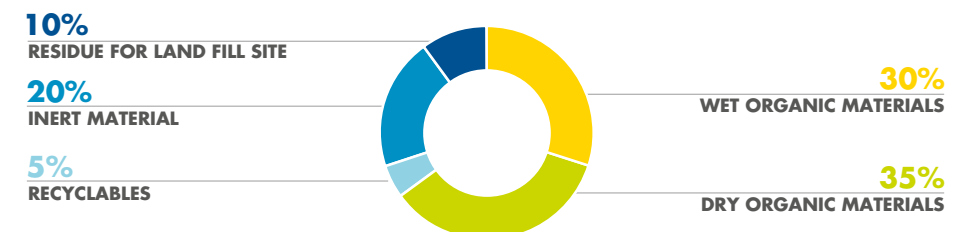
Over recent decades, the city has invested in the water supply and sewage networks and now has a well-managed system. It has also made significant progress with the management and early warning systems for flood risk. However, with the high population growth rate and the industrial water demand increasing, water shortage is clearly defined as a future concern and there is room for improvement in the volume of water recycled in order to more sustainably manage this precious resource.

4 WASTE MANAGEMENT

The Surat municipality is in charge of collecting, transporting, sorting, processing and disposing of municipal solid waste (MSW). This is a continuous challenge for the city. Today, approximately

1,575 metric tons of MSW¹⁰ are generated per day in the Surat municipality, with approx. 4.5 million inhabitants.

THE COMPOSITION OF WASTE IN SURAT¹⁴



Waste management has improved significantly since the plague event in 1994 and the SMC has made huge progresses to improve the situation and to comply with the MSW Rules 2000,¹⁵ which state that it is obligatory on the part of all the municipal authorities to arrange for collection, segregation, transportation and suitable disposal of municipal wastes of the municipal towns/cities.

Surat has had privatised contracting and participation in solid waste management for more than 10 years. For waste management the city is divided into seven zones covering almost the whole area of the city. Each zone is managed by a waste agency. The city effectively manages the entire waste resource chain:

- **Waste collection** is managed through two systems: a door-to-door system (since 2004) and roadside containers (75 containers located in the city). Treatment and disposal are managed effectively across the city.
- **Waste treatment:** Waste collected is sent to transfer stations (six transfer stations running today and four being considered).
- **Disposal:** From these transfer stations, all waste is sent to the disposal site located in Khajod, which is composed of a compost facility (for organic waste recovery) and a landfill:

- 600 metric tons Per Day (TPD) of Municipal Solid Waste (MSW) sent to a composting facility; and
- 900 TPD of MSW sent to landfill.¹⁴

In recent years the SMC has also taken a number of supporting measures to transform the waste management systems in the city:¹⁶

- introduction of daily monitoring system for better waste collection efficiency;
- posting of sweepers for round the clock duty at nuisance spots;
- engaging private contractors for collection and transportation of waste to the disposal site, as well as sweeping and scraping all major streets during the night;
- slum improvement operations with the assistance of NGOs;
- revamping of the entire administrative and financial management system of SMC; and
- policy decisions to create a responsive waste management system by introducing a system to address complaints.

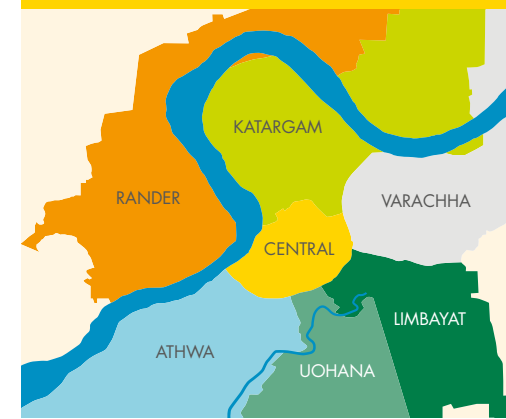
WASTE TRUCK FOR DOOR-TO-DOOR COLLECTION



WASTE TRUCK FOR CONTAINER LIFTING



SURAT CITY: SEVEN ZONES FOR WASTE MANAGEMENT



In recent decades the SMC has made significant strides in improving waste collection and disposal throughout the city, which has resulted in real benefits to the population in terms of improved public health and reduction in environmental pollution. However, with a growing population and economy, maintaining a good standard of waste management will continue to be a challenge. Considering the potential to increase the amount of materials being recycled, introducing innovative methods of waste treatment and disposal, such as more composting facilities, and implementing proposed energy from waste facilities can help to ensure the city can build on its existing strong progress.

5 TRANSPORTATION

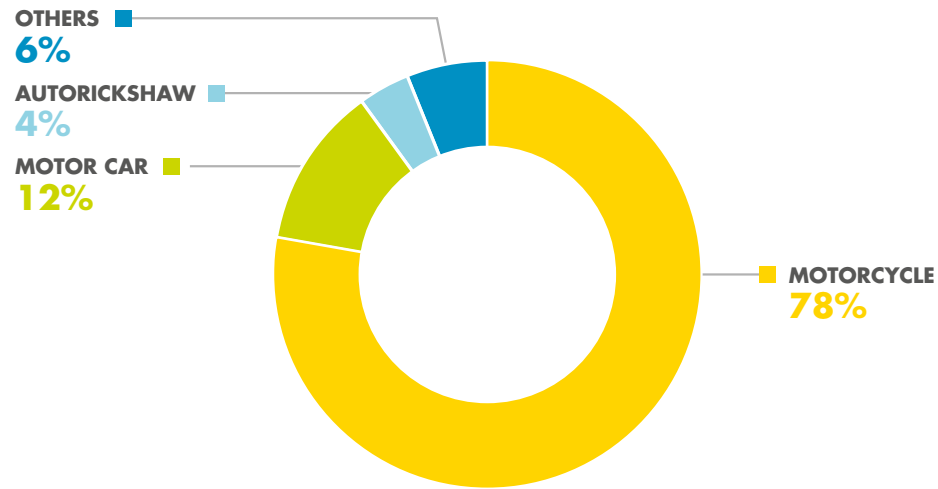
PRIVATE VEHICLES

SURAT CITY TRAFFIC



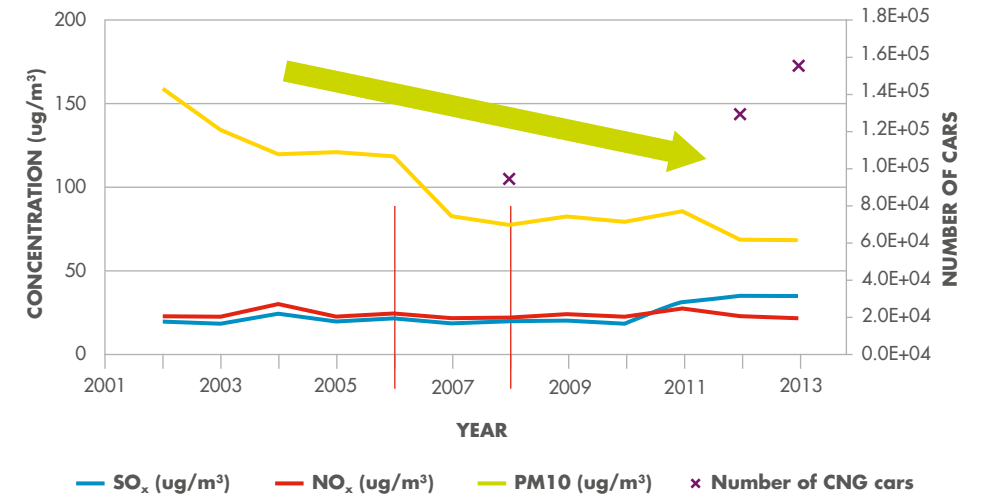
Private vehicle usage in the city has grown at a fast pace, reflecting the overall expansion in the population, changing lifestyles and improving personal wealth. The number of vehicles registered in the Surat Regional Transport Office (RTO) area has increased from 0.4 million in 1994 to almost two million in 2012, accounting for a growth rate of 12%. Two- and three-wheelers

(motorbikes and autorickshaws) account for nearly 80% of the number of vehicles while cars constitute around 10% of the fleet.

DIFFERENT CATEGORIES OF VEHICLES IN SURAT (2012 DATA)¹⁷

Traffic congestion across Surat has been recognised as an escalating problem that creates an increasing economic burden and decreases the quality of life for Surat citizens due to pollution and loss of time. According to the Rockefeller Foundation research, 60% of air pollution in the city comes from transport. According to the Gujarat State Pollution board, Surat's Air Pollution Index API is 100 ppm of PM 10 (which is yellow on a traffic light colour coding, with green being acceptable and red being at risk for people's health). In addition, while the peripheral areas in the West, East, South and South-West zones of the city have grown considerably, the connectivity of these roads with the main corridors needs improvement. While nearly 80% of the city area is well connected, the rest lacks good linkages.

Despite these increases in traffic volumes, the air quality trend in Surat has improved overall since the beginning of the 21st century. This is largely due to a significant increase in the number of vehicles running on compressed natural gas (CNG) in the last 10 years. Approximately 92,000 cars currently run on CNG (40% of the total number of cars run on CNG – 2012 data) and, the vast majority of the autorickshaws run on CNG. There are 130 CNG retrofitters registered with the RTO and there are 50 CNG refuelling stations.

AIR QUALITY TREND IN SURAT (INDIA)^{18, 19}

IMPORTANT FACTS:

2006 switch to CNG cars. 2008/2009: mandatory CNG for public transport (3 wheelers, buses).

A majority of vehicles run with CNG because of the relative price of fuel, though in recent years there has been some reversal of this trend with the decreasing price of petrol and diesel fuels.

Auto Liquefied Petroleum Gas (LPG) is the third largest automotive fuel used in the world, with approximately 500 million of passenger cars fitted with LPG combustion kit.

Autogas contains octane derived from natural gas by fractionation and from crude oil refining. It also contains propene and butene. Autogas is kept in the form of gas at ambient pressure and normal temperatures, whereas it can be liquefied while pressurised or when the temperature is reduced enough.

Autogas contributes to 5% of the total market share in the entire world. Autogas is not so popular in India, but the market is catching up and growing remarkably, which is low-cost compared to gasoline or diesel and more environmental-friendly, with CO₂ emission reduction of 13–18% compared to liquid petrol.²⁰

PUBLIC TRANSPORT

Public transport availability is principally through 126 buses which ply 44 routes across Surat City. The city has recently made meaningful steps to further improve the availability of public transport by the introduction of a Bus Rapid Transit System (BRTS), "Sitelink". The BRTS is a passenger-oriented rapid transit system designed to deliver fast, comfortable, economical and eco-friendly mobility to urban dwellers. Specially designed BRT buses travel on dedicated lanes along with special provision for other modes such as cyclists, pedestrians and mixed traffic. The BRTS is also intended to provide world-class physical infrastructure such as bus stations, control centres, terminals, depots and also an Intelligent Transportation System which includes electronic fare collection, automatic vehicle tracking systems and public information systems.

The first phase of the BRTS programme, providing services to 30 km of road corridors, began operation in 2014, and three further phases are planned to open over the coming years.

In addition, there are plans to build a Metro rail rapid transit system for Surat. If completed on schedule, the four-line, 100 km (62 mile) metro will enter operation in 2018. These additions will help to meaningfully reduce congestion and improve connectivity to key areas of the city.

SUMMARY OF CHALLENGES

Surat has a fast-growing transport market driven by population and economic growth. The city has made positive strides with the growth of less-polluting CNG fuels in private transport and the increasing provision of public transport through a range of bus services. However, given the pace of growth of private vehicle usage, there are significant challenges to keep a good standard of air quality and keep the population moving around the city. Areas of focus for this study that stakeholders identified included:

- further improvements to main bus route penetration and feeder routes to the main networks to reduce reliance on two- and three-wheelers;
- support for further growth for less-polluting fuels by reducing waiting times to refuel a CNG vehicle and identifying ways to reduce the cost of diesel to CNG conversion, which is currently three times more expensive than gasoline to CNG conversion;
- investigating how to provide more green space around transport routes to lessen the environmental impact and reduce flood risk from over-building of natural soakways.

6 GOVERNANCE AND IMPLEMENTATION

Surat has considerable strengths in strong and transparent governance and has implemented positive changes to the city through more efficient waste management and increased provision of public transport. To further improve its capacities there are a number of potential areas of challenge to focus on:

- The ability to co-ordinate and implement projects and services across clusters and economic zones. All the infrastructure challenges described here require the effort to co-ordinate with adjacent cities and a range of public bodies, whether it is energy supply or waste management. Integrated planning and managing of systems across network boundaries are important to get the maximum economic and resilience benefits.

- The pace of implementation of major projects and the ability to collaborate with the private sector to drive delivery.
- Availability of funding and financing for projects and improvement works.
- Ensuring strong consultation with the local population on proposed improvements.
- Reinvigorating investment to further develop Surat as a city to visit, to work in and to live in.

SURAT BRTS



OPPORTUNITIES

Given the major challenges highlighted during the study and based on our discussions with key municipal stakeholders, we have identified a range of solutions and assessed them against six key criteria:

SIX ASSESSMENT CRITERIA



Reliability



Sustainability



Cost-effectiveness



Environmental footprint



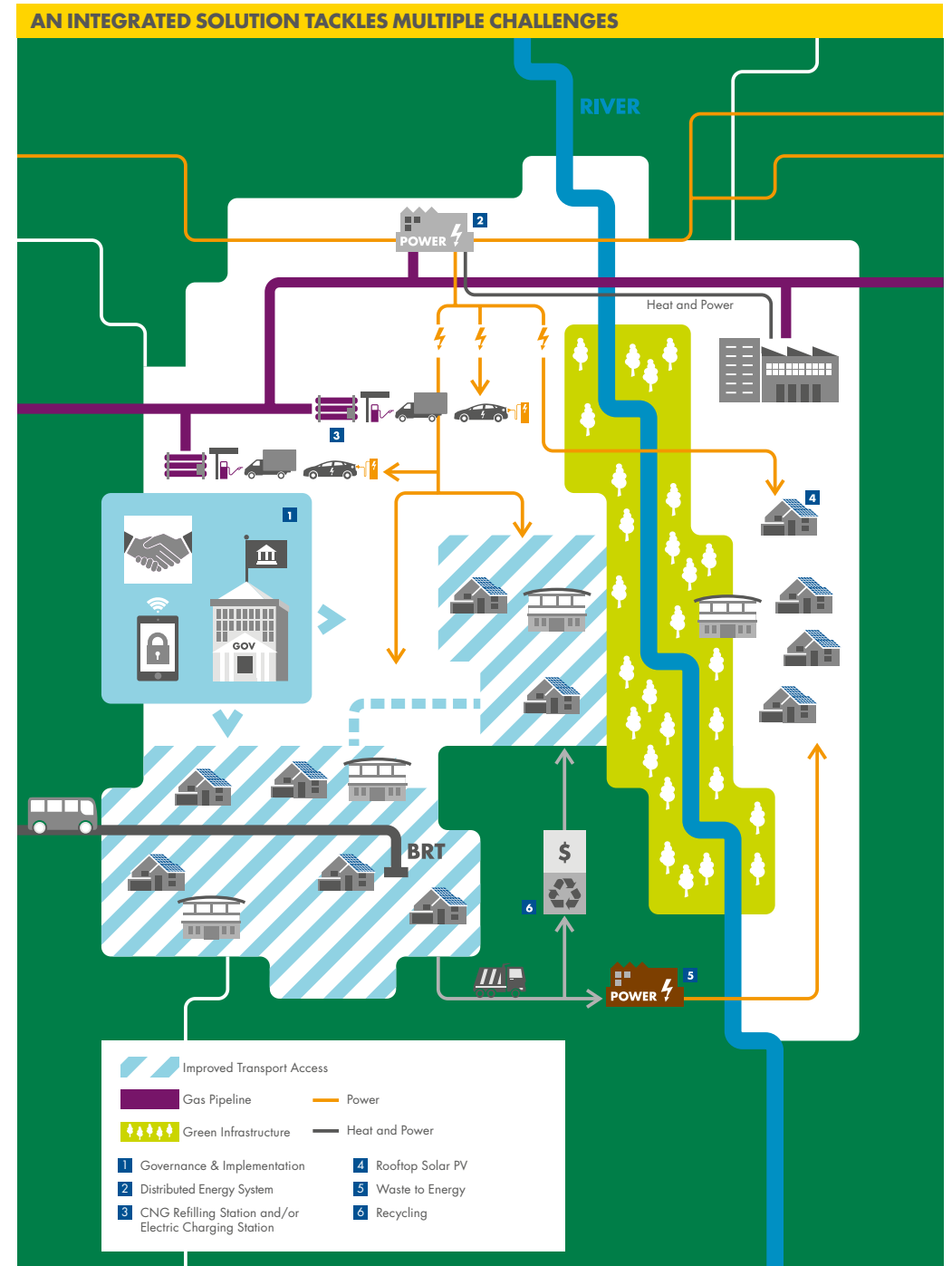
Energy efficiency



Innovative technology

The challenges identified in this report are interconnected and one solution can form an integrated solution to tackle multiple problems. For example, a waste-to-energy option is a solution for waste management as well as creating affordable and dependable electricity.

Integrated solutions enhance the resilience of the city. For a city, resilience is the capacity of its infrastructure to resist disturbance, be reliable and respond and recover in a timely and adequate manner.



This is a stylised image of a city that shows how the various solutions can be integrated. It is not intended to specifically resemble the geography of Surat or any other city.

OPPORTUNITY 1 RESILIENT ENERGY SYSTEMS

COMBINED HEAT AND POWER FOR TEXTILE UNITS

Surat forms part of the backbone of the Indian textile industry and is one of the largest centres in the world.

In the Surat textile clusters, out of 400 units, about 70 units are only dyeing facilities, while 330 units are an integrated type (both dyeing and printing).⁴

The textile industry in Surat has significant energy demand for power and heat. The sources of energy used such as coal/lignite can be inefficient and can create negative externalities

such as high levels of particulate pollution. While evolving towards being a smart city in the future, the energy system for the industry needs to be resilient and reduce these externalities while ensuring low-cost energy to help support the local economy. While some of the textile units within the city are energy-efficient and technically sophisticated, this report has tested the possibility of transforming the energy system in the textile sector to make it more structurally resilient, socially responsible and economically efficient and environmentally friendly.

To develop these options we concentrated on one specific textile cluster in the Pandesara area of the city.

Case study: Pandesara Cluster Pandesara has approximately 113 textile units in its cluster. The units in the cluster are of various sizes from 800 sq m to 30,000 sq m. Seventy-five per cent of the units are engaged in both the dyeing and printing of cloth while the rest are principally involved in dyeing. The cluster is spread across 0.65 sq km of land.

These units have two major types of energy demand – heat and power. Electricity for the power looms and printing machinery is supplied from the existing Gujarat grid while heat for the dyeing, forming and washing of cloth is locally produced at the premises in steam-generating boilers, mainly domestic coal, lignite and pet-coke²¹ or imported coal. In total the cluster has an overall energy demand of approximately 27 MW of power and 500 tonne per hour (TPH) of steam. Individual steam boilers in each unit create negative externalities to the environment and fail to gain advantage of higher economies

of scale that could come from a wider community solution. Also, grid dependence and the overall environmental footprint of the grid power may create problems in achieving wider resilience objectives.

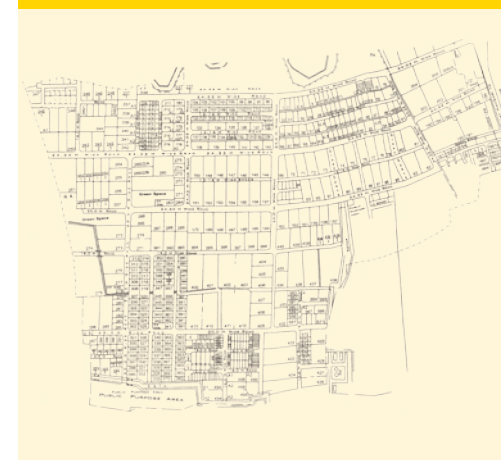
For the Pandesara Cluster case study, two complementary approaches have been assessed:

- A top-down approach, taking into account the whole cluster needs, and in which the solutions have been designed based on the power demand of the cluster.
- A bottom-up approach, in which solutions have been designed for a limited number of units and based on the steam demand.

LOCATION OF INDUSTRIAL CLUSTERS IN SURAT



MAP OF PANDESARA



Number of units	113
Nature of industry	Textile dyeing and printing
Total steam consumption	500 TPH approx
Total electricity consumption	27 MW
Source of energy – steam	Domestic coal, lignite, imported coal
Sources of energy – electricity	Grid power

TOP-DOWN APPROACH: POWER-BASED SOLUTIONS

Based on the current requirements for the cluster and the challenges it faces we looked at a range of options to change the existing unit by unit power and heat supply to a community “Combined Heat and Power (CHP)” solution covering the whole cluster.

CHP is widely used in the world to make energy systems more efficient by generating electricity from gas engines and steam through waste heat recovery from those engines. A community CHP can improve energy resilience by:

- making power provision self-sufficient, thereby increasing reliability of supply and unit up-time;
- reducing the overall energy footprint and increasing efficiency by using waste heat;
- including new energy sources, such as gas or renewables; and
- creating better economics and economies of scale by supplying a large number of units with a cost-effective approach.

With this multi-layered resilience objective, we looked at three options for how to implement a community CHP approach:

1. **Gas-based CHP with coal boiler:** A gas engine provides the full 27 MW of electricity required for the cluster. However, with current CHP/gas engine technology, using a waste heat recovery method there would be five tonnes per hour (TPH/MW) of steam generated, a small proportion of the total 500 TPH demand. Therefore, alongside the CHP, most of the units still have to continue to use the coal-based individual boilers to generate steam, though they become independent of grid electricity. Long-term LNG pricing could make this solution competitive with current electricity prices and it is technically more straightforward to execute. However,

the other objective of resilience building in terms of building economies of scale in steam production and reducing the environmental footprint largely remains unaddressed.

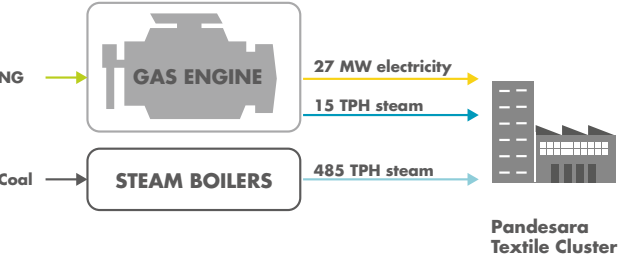
2. **Gas-based CHP and gas-based community boiler:** This option is the same as option 1 for electricity generation, but instead of retaining individual coal-fired boilers for steam generation they are replaced with a larger-scale community gas boiler for the 495 TPH demand that cannot be met through the CHP unit. This creates the opportunity to move to a cleaner fuel for steam generation and can take advantage of economies of scale by building a gas-based community boiler along with the CHP. However, due to both affordability and availability factors related to natural gas in India, the overall solution for Pandesara is costly for the cluster units, even though the fuel mix, independence, economies of scale and overall energy footprint situation improves.

3. **Gas-based CHP combined with Concentrated Solar Thermal (CST) and an intermittent gas-based community boiler:** As with option 2, a gas-fired CHP unit is installed, but instead of being purely a gas-based community boiler for steam generation it is possible to include Concentrated Solar Thermal technology for 50% of the steam requirement alongside the gas boiler for the other 50% of demand. The West of India, particularly Gujarat and Rajasthan, has high solar irradiation levels, which helps the viability of the CST component. CST is a relatively new technology but is being used at scale in industrial settings for enhanced oil recovery in the Middle East, which are more complex and with tougher²² steam pressure and temperature requirements than would be needed in textile mills. The CST component helps to reduce the operating cost of steam

generation so that, combined with gas CHP and an intermittent-use community boiler, it is the most efficient and cost-effective option. In terms of resilience objectives this option gives economies of scale, reduces the environmental footprint of energy use in the cluster and gives the unit a potentially cost-competitive and independent energy solution using innovative technology. This solution combined with energy efficiency

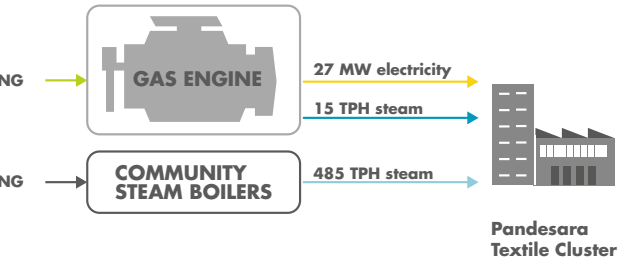
solution as suggested in the recent Bureau of Energy Efficiency (BEE) report⁴ can also make additional savings in energy cost and environmental impact. However, we do need to bear in mind that this solution is technically more complex and experimental than other options and therefore ultimate proof of viability and implementation would be more challenging.

OPTION 1: GAS-BASED CHP WITH COAL-BASED BOILERS



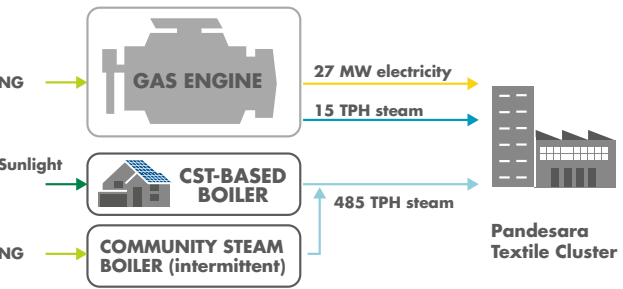
Advantage: Lower capex, easy execution, moderate gas volume, viable for 5% steam and long-term LNG price.
Disadvantage: Technical constraints. Only 5% of steam can be produced, coal for 95% steam hence highest environmental footprint.

OPTION 2: GAS-BASED CHP WITH GAS-BASED COMMUNITY BOILER

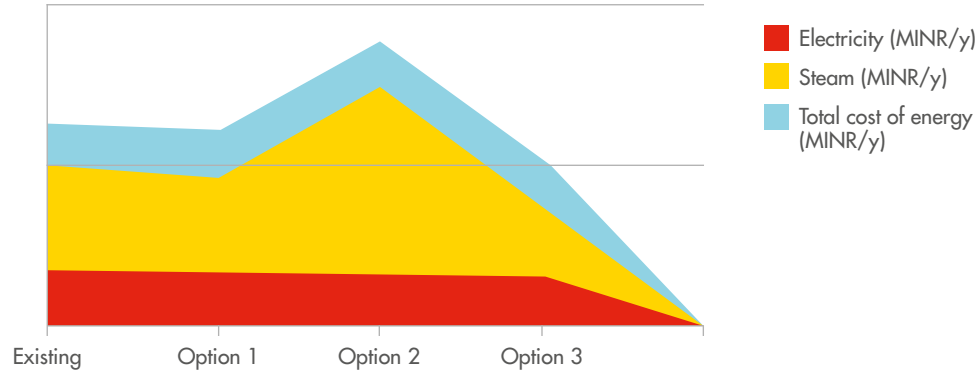


Advantage: Moderate capex, easy execution, community boiler reduces O&M cost, establishes economies of scale with reduced externality cost.
Disadvantage: Not viable for end user in comparison to coal.

3: GAS-BASED CHP COMBINED WITH CONCENTRATED SOLAR THERMAL WITH INTERMITTENT GAS-BASED COMMUNITY BOILERS



Advantage: Lowest environmental footprint, most economic for end user from fuel opex, futuristic renewable integrated with gas intermittent, advantage from new solar policy, most sustainable solution.
Disadvantage: Very high capex, parallel high cost infrastructure, land resources, not viable from business side without fiscal and policy support.

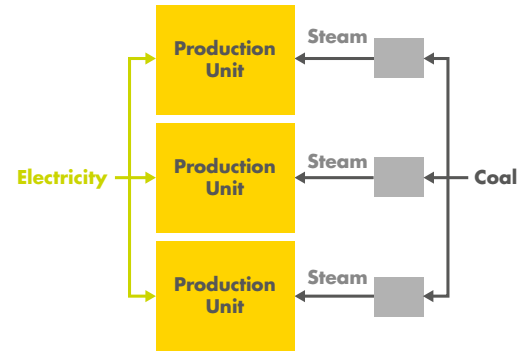


Overall, therefore, we believe option 3 is the most attractive for Surat to consider. However, it should be borne in mind that this is a high-level assessment of potential options. If there was interest in pursuing any of these options then detailed technical, commercial and economic analysis would need to be carried out using a much higher level of granular data on energy use in the cluster than has been available so far. Any further analysis would also need to look at issues such as the operational challenges to

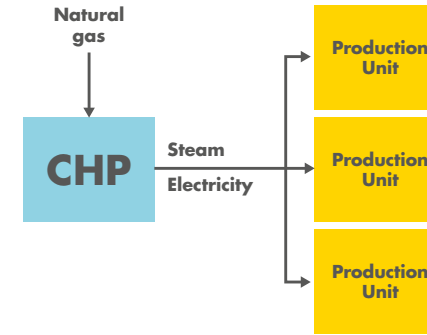
implement a community business model that would work for a large number of individual companies and the regulatory and practical considerations of installing the equipment required, as well as sources of funding and financing. This further work would need the involvement of state and national government, municipality, local textile industry bodies and a consortium of industries who will implement this solution on the ground.

BOTTOM-UP APPROACH: STEAM-BASED SOLUTIONS

It should be borne in mind that it may be logistically complex to bring together a whole cluster of individual units in a community based project as identified above. An alternative is to develop a small-scale pilot for a small number of units and duplicate if it is successful. In this approach, we looked at a Combined Heat and Power unit (CHP) implementation for 1–10 units. The other difference with the previous approach is that the CHP system is designed on the steam demand for the textile units. In this case, the CHP solution will produce more electric power than needed by the units. Thus, extra electricity production can be sold to the network/grid and generate additional revenues for the unit owners if the mechanisms exist for doing this.



In the CHP scenario, the coal-fired steam boilers are replaced by a mutualised natural gas-fired CHP unit that is designed for several units. More precisely, we looked at the minimum number of units that need to be provided with steam to make the CHP competitive with the current situation.



For this case study, we took all data from literature, e.g. for the power/heat generation ratio with the CHP: 0.7 (1 kWh thermal and 0.7 kWh electric).⁵ We also took into account the steam demand of 2 tonnes/hour per boiler being supplied with coal.⁴ The results show that the impact of the implementation of a CHP Unit on the annual production cost could be neutral for a small number of units. There are also meaningful environmental benefits (reduction of CO₂ and PM10 emissions). However, it should be noted that the smaller scale of this option reduces the efficiency of the CHP equipment. In addition, the high price of natural gas and the low price of electricity may create significant barriers to the viability of this option, which would have to be investigated further.

HOW DOES THE CHP OPTION 3 SCORE AGAINST OUR ASSESSMENT CRITERIA?

Reliability

- Even though grid power is reliable in Gujarat, the solution will allow the cluster to manage its own requirement, peak load and seasonality more effectively.
- As a part of wider urban responsibility, when the grid electricity is no longer required it can be diverted to the other part of the city and/or country.

Sustainability

- There is an abundant supply of natural gas and solar irradiation levels are good. Hence the combined solution can be made reliable by ensuring cost-effective compatible availability.
- There are two parallel infrastructures for electricity and steam generation, hence there is the smallest chance of failure, even during environmental disasters like floods.

Cost-effectiveness

- While the cost saving in electricity is not substantial, the combined system has the potential to reduce the operating fuel cost by 30–40%.
- The capital cost can be substantially reduced by taking advantage of government renewable policies and green financing.

Environmental footprint

- Removing coal and including solar and natural gas can reduce the environmental externality substantially.
- Also, captive generation of electricity from gas reduces the overall footprint as some of the grid electricity is also generated using coal or lignite.

Energy efficiency

- Enhancing energy mix and optimising daytime usage of solar thermal makes the solution more energy-efficient.
- Other equipment-level efficiency measures as suggested by BEE should be implemented alongside.

Innovative technology

- Irrespective of the complicated operating model, the proposed option 3 uses an innovative combination of technologies for the textile sector.

MINI AND MICRO SMART GRID DEVELOPMENT ACROSS SURAT

In order to provide a more resilient energy system to meet the challenges faced by Surat, improve the economic opportunities for businesses and inhabitants in the city and contribute towards wider electricity requirements in Gujarat, we have looked at two main options:

- a micro-grid providing decentralised electricity generation within the city; and
- rooftop solar PV as an addition and complement to the micro-grid, which together form a smart grid.

MICRO-GRID

A “micro-grid” is a small-scale grid with various distributed energy technologies – such as solar panels, small-scale wind, biomass boilers, plug-in electric cars and more. This connects renewable energy sources with the wider large-scale utility grid so that it can dynamically deal

with supply and demand while efficiently and cost-effectively managing and improving the fuel mix of the system.

Historically, economies of scale have dictated a preference for centralised power generation in most places in the world, including India. It has been necessary to build a large power plant to get high fuel efficiency. Therefore the current electricity infrastructure is set up with large centralised power generation and control outside local boundaries. To supply electricity to the city there is a network of high-voltage transmission and low-voltage distribution lines.

Though this arrangement is efficient, it has resilience weaknesses with little redundancy in the system, so that if an individually significant part of the network is taken out of action (e.g. a power station or main transmission line) it can cause power failures in a wide-ranging area and be expensive and difficult to recover from. In a city such as Surat which can face extreme weather events and environmental stresses, this could be a problem.

PLANNING THE FUTURE CITY GRID POWER SUPPLY AS COMBINATION OF SMART MINI- AND MICRO-GRID, CONTINUOUSLY INTERACTING WITH THE EXISTING GRID POWER



SMART GRID

A Smart Mini-Grid (SMG), or Micro-Grid, is an intelligent electricity distribution network, operating in order to provide electricity to a community

Energy System of Surat

The grid power supply across various types of consumers

Mini smart grid

in localities with residential commercial and industrial combination

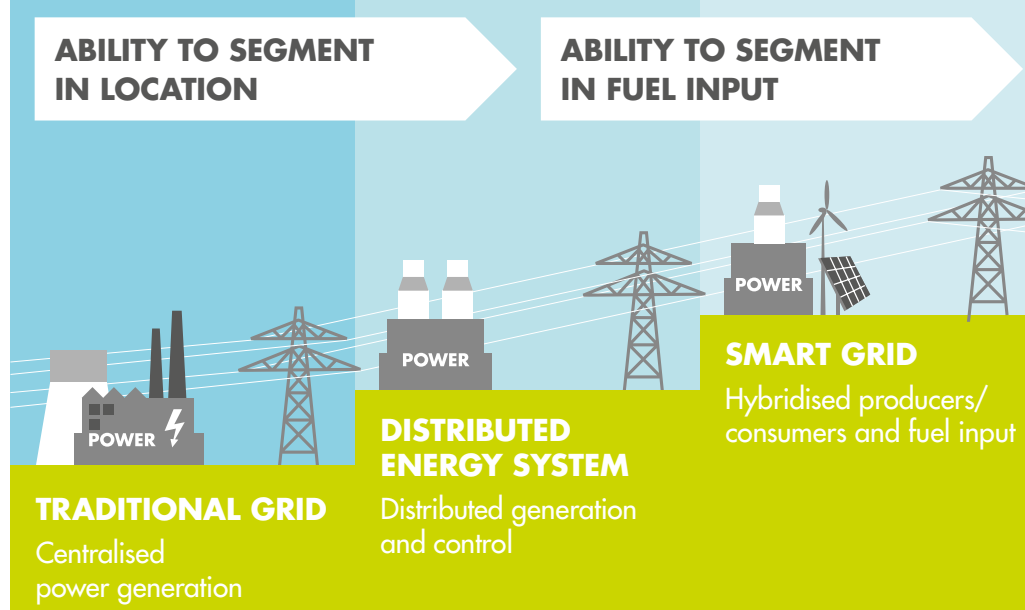
Micro smart grid

in housing complexes, malls or small-scale industrial units

INDUSTRIAL LOCATIONS

	Industrial Area		NH Road
	City Boundary		Major City Road

SEGMENTATION IS KEY FOR BOTH A DISTRIBUTED ENERGY SYSTEM AND A SMART GRID



The traditional grid operates as one unit, while the decentralised grid operates as a collection of (semi-)independent modular systems, each with their own control. Due to the partitioning of the power generation, the generation facilities of a micro-grid do supply a smaller amount of electricity compared to the traditional grid but may still provide a meaningful MW load. The major benefits of this approach are:

- It is more resilient to disruption (e.g. from natural causes) because the modular system has some redundancy, which allows a limited amount of modules to switch off/on according to the location of any source of disruption. Moreover, it has inherent back-up connections to other modules, which enhances recovery. Therefore the modularity of both control and power generation is key for a more responsive system.
- The modular set-up allows the city to plan smaller-scale investments instead of planning more complex and expensive infrastructure projects. Decisions about large-scale infrastructure projects have to be taken while future developments are uncertain. As these projects are implemented over long periods of time, there are many factors that can change in the meantime: increased demand, technological advances and economic fluctuations. A micro-grid gives the city more dynamic flexibility and an ability to build capacity incrementally. The city can also replicate the facilities to other districts/regions as appropriate.
- In times of peak demand it can help power companies to balance load and increase capacity ("peak shaving ability").
- The costs for small-scale power generation units have reduced substantially in recent years, and these options are increasingly cost-competitive and complementary with centralised generation options.
- A micro-grid can also have a "Smart" dimension, with information technology managing demand peaks intelligently and switching between different fuels such as gas and renewables.

The benefits of a micro-grid were demonstrated when Hurricane Sandy hit the East coast of the US in October 2012. The resulting power disturbance affected 8.5 million people, and kept more than 1.3 million in the dark for a week. However, the gas-fired micro-grid system at Long Island was able to generate power for over 15 days, providing power to the North Shore Health System facility and 400 other homes and allowing for a 24-hour emergency operation. Today, 20 states in the US are planning micro-grids for some of their power supply.

A key part of the solution is that the power systems utilise natural gas as the fuel source (as opposed to coal). A gas-fired power plant produces less SO_x, NO_x and particulate matters per kWh as compared to coal-fired plants.²³ Moreover, natural gas-fired plants produce around half the greenhouse gas emissions per kWh compared to burning coal. Continued use of coal in power

plants is exacerbating the air quality issues that India is already grappling with. Based on World Bank studies on China, it is estimated that the health cost of air pollution in emerging Asian countries amounts to 1–4% of its GDP.

Utilising natural gas as the backbone fuel in power generation also helps in achieving the full benefits of integrating other low-polluting alternative energy systems such as rooftop solar PV, wind and transport electrification and CNG. To improve the energy resilience across the city both the residential and commercial sectors have to evolve and integrate with renewable energy and cleaner hydrocarbon fuels such as gas. However, it is still important to retain the connection to the wider grid as the reliability of renewables can be affected by seasonality and energy storage technologies are still evolving.

SURAT RAILWAY STATION



Gas can easily be supplied to Surat. The first option is via the existing pipeline system. The other possibility is to transport LNG from a site

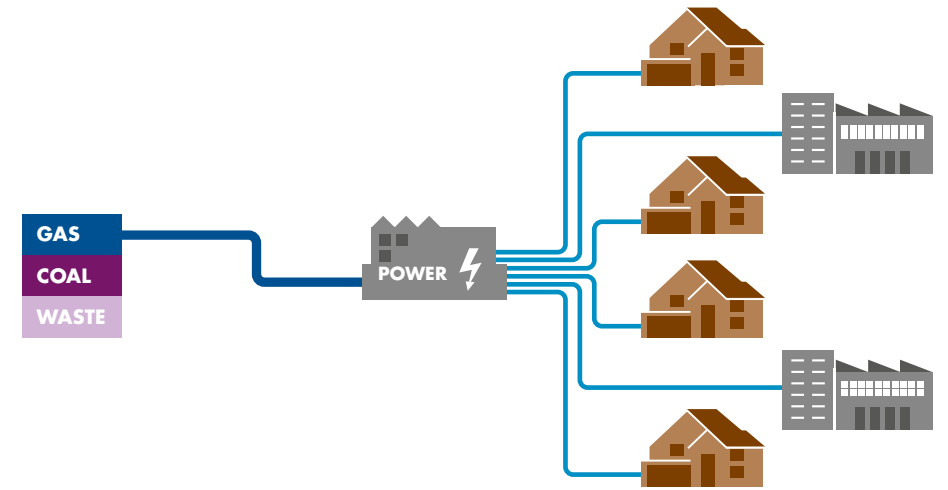
such as the Hazira re-gas terminal. The type of generating equipment that could be applicable in Surat includes:

PRIME TECHNOLOGY	PROS	CONS
1. Reciprocating engines (RE)	<ul style="list-style-type: none"> Higher flexibility Fast ramp up/down (10 min) Highest fuel efficiency (~45%) Regular maintenance could be done by local crew Can accept larger range of fuel composition "fuel flexibility" 	<ul style="list-style-type: none"> More emissions compared to turbines, including ppm level methane slip Lower power density (higher footprint) Higher noise levels More frequent maintenance Highest down time
2. Aero-derivative turbines	<ul style="list-style-type: none"> High fuel efficiency (~35%) Lower emissions compared to RE Lowest down time On-site maintenance time is limited because the core of the engine is substituted 	<ul style="list-style-type: none"> Specialist needed for maintenance Maintenance costs will be relatively higher
3. Industrial turbines	<ul style="list-style-type: none"> Option to boost efficiency by integrating a steam cycle. However, ramp up/down is decreased dramatically (hours) 	<ul style="list-style-type: none"> Lower fuel efficiency (~30%) Specialist needed for maintenance Slow ramp up/down (40 min)

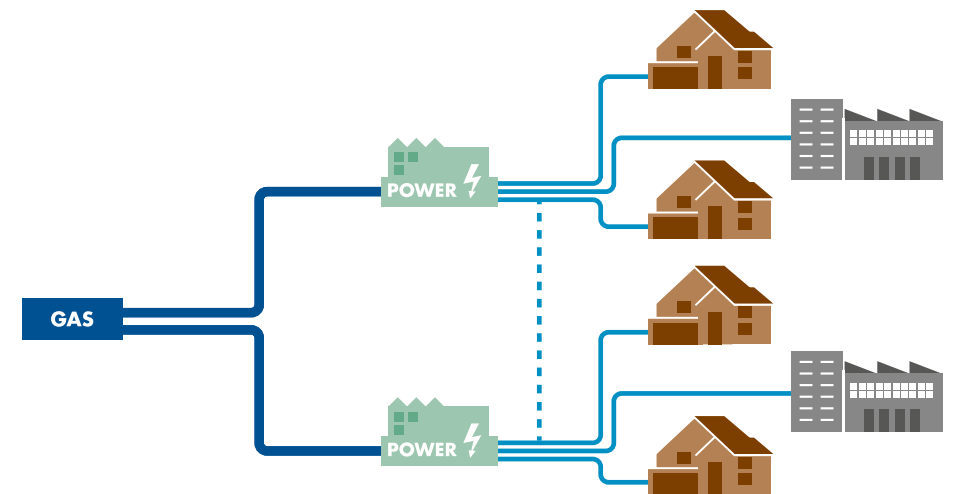
Given resilience requirements, any power generation equipment should be able to provide electricity quickly to recover from periods of environmental pressure and in times of peak demand (i.e. "black start" and "peak shaving ability"). Therefore, looking at the options above, reciprocating gas-fuelled engines may be the

most effective option for the city given their high level of flexibility and fuel efficiency. A micro-grid of this nature could also be configured with renewable generation capacity such as solar PV to jointly be part of the existing electricity grid via Smart technology integration.

TRADITIONAL GRID: CENTRALISED POWER GENERATION AND CONTROL OF SUPPLY TO ALL END USERS



GAS-FIRED DISTRIBUTED ENERGY SYSTEM, CLUSTERED DECENTRALISED POWER GENERATION AND CONTROL, SUPPLYING CLUSTERS OF END USERS



The benefit to Surat from hosting its own distributed power system is the ability for the city to provide reliable, clean and green electricity at all times, including at times of environmental pressure (e.g. during floods or storms). The system could also be used to provide additional electricity to the Gujarat grid during peak demand periods. Power outages close schools, shut down business

and impede emergency services, ultimately costing millions of Rupees in lost productivity, and disrupting the lives of the city's inhabitants. For Surat, having the ability to guarantee power grid resilience not only becomes a key defence against natural disaster but it also provides a critical resource to increase business and investor confidence in the infrastructure of the city.

ROOFTOP SOLAR PV

A key part of developing new energy solutions for Surat is to review options to introduce alternative energy systems (e.g. wind, solar). High urban density suggests that options such as wind power and large-scale solar farms in the city are not feasible. There is, however, potential scope for rooftop solar to be installed on suitable buildings. Solar PV power supply is increasingly cost-competitive with fossil fuel power systems. Integrating alternative energy supply as part of a city's overall power mix is important to residents, the municipality, with solar energy regarded as one of the most preferred future energy sources.

Most of India has a rich solar resource base due to its equatorial location. The daily average solar energy incident over India varies from 4 to 7 kWh/m², with about 2,300–3,200 sunshine hours per year, depending upon precise location. The daily average global radiation varies from 5 kWh/m² in north-eastern and hilly areas to about 7 kWh/m² in western regions and desert areas. The monthly average global insolation for all the states is more than 5.25 kWh/m²/day for three months – March, April and May.

The available solar radiation in Surat is sufficient to utilise it efficiently for various applications across all the sectors: residential, commercial, institutional, industrial and municipal. The two most important applications of solar energy are solar thermal and solar photovoltaic (PV) electricity generation. Solar thermal can be used for water heating, space heating, process heat generation and solar cooking in the city. Residents, hotels, hospitals and institutes need hot water for bathing, laundry and other purposes, with demand increasing during the winter season. While solar thermal is already proposed in the textile cluster CHP model mentioned previously, solar energy can be harnessed all across the city by building integrated solar and rooftop solar PV.

The role of solar technologies in fast-growing cities such as Surat has also been supported by the Indian government at a national level. "Development of Solar City" is a programme launched by Ministry of New and Renewable Energy (MNRE) in 2011.²⁴ The programme assists urban local governments in:

- preparation of a master plan for increasing energy efficiency and renewable energy supply in the city;
- setting up institutional arrangements for the implementation of the master plan; and
- awareness generation and capacity-building activities.

The main focus of the programme is to reduce power demand across different sectors in fast-urbanising cities in the country. The programme aims at a minimum 10% reduction in projected demand against the "business as usual" scenario of conventional energy at the end of five years, which can be achieved through a combination of energy efficiency measures and enhancing supply from renewable energy sources.

A city-wide rooftop solar system could also be integrated with a fully distributed micro-grid that maximises and complements the efficiency of an integrated Smart system by using information technology to dynamically manage demand and supply. Making the system "Smart" is key to improving the efficiency of electricity demand and supply, ultimately leading to more reliable power availability and an overall reduction in charges to consumers. Achieving a smart grid requires building in new technical infrastructure, and the application of digital processing and communications technology to the power grid. This will enable sophisticated data collection and integration of systems which manage consumption patterns, direct local power production and control the integration of the local grid with existing utility systems.

SUMMARY

These solutions are not an overnight transformation but a planned transition towards a secure and resilient energy infrastructure that further enables the improvement of the energy mix by transforming every energy user into an energy producer, with the following objectives:

- self-sufficiency in the energy system;
- efficient and optimum energy resource management;
- the introduction of more environmentally benign fuels in the overall electricity mix of the

energy system, i.e. integrating solar, wind, gas and micro-grid benefits;

- minimising outages; and
- reducing environmental footprint.

It should be noted that assessing the economic and commercial viability of these options in Surat requires a more detailed cost/benefit analysis of all elements of the fuel and infrastructure supply chain, an electricity distribution impact study, as well as an environmental and community impact assessment.

HOW DOES THE SMART MINI- AND MICRO-GRID OPTION SCORE AGAINST OUR ASSESSMENT CRITERIA?

Reliability

- An interactive grid includes parallel sources of energy and hence gives redundancy in energy systems and is more reliable.

Sustainability

- Provides options to integrate renewable sources with cleaner gas-based grid power and hence is more sustainable.

Cost-effectiveness

- Solar PV, solar thermal in the form of building integrated solar and rooftop solar, provides energy which is almost free of incremental cost. It also has the potential for future integration of other forms of energy such as hydrogen fuel cells.
- With the right regulatory mechanisms, every residential and commercial establishment can also sell its excess power to the grid and hence offset the cost of their own consumption.

Environmental footprint

- Solar, wind and geothermal can all be integrated through a smart grid. The primary objective is to integrate a system of renewable sources and cleaner fossil fuels and hence the overall footprint can be improved overall as technologies progress.

Energy efficiency

- Other equipment level efficiency measures, as suggested by BEE, should be implemented alongside.

Innovative technology

- Making the city a combination of smart grids is indeed an innovative way to save energy and improve the fuel mix with more renewable sources.

OPPORTUNITY 2 WATER MANAGEMENT

WASTEWATER AND BIOGAS GENERATION

Based on several engagement sessions with SMC and local stakeholders, there were two main opportunities identified regarding improvement of the water management systems in the city.

WASTEWATER (WW) REUSE FOR INDUSTRIAL USAGE

This study identified a high level of water consumption in the industrial clusters in the city, particularly as part of textile manufacture processes. More than 450 mld of freshwater is consumed by textile clusters, adding to the water stress faced by the city.

To reduce water consumption and reduce the environmental impact, the city could implement tertiary treatment of biologically treated wastewater using innovative technologies (reverse osmosis membranes, ultra-filtration, nano-filtration). This treated water can then be reused in the different processes of industrial companies (boilers, cooling towers, floor washing...). This solution can be provided through long-term supply arrangements to industrial companies.

Veolia has implemented such a wastewater beneficial reuse solution in North America, in Honolulu (USA). The city and county of Honolulu have undergone a significant amount of development in the last 40 years (numerous residential, commercial and industrial developments including refineries and several power stations). The consequences: increased demand for potable water, reduction of local aquifer recharge and limited available water resources for continued growth.

In 1995, the US Environmental Protection Agency (EPA), the state of Hawaii Department of Health and the city of Honolulu entered into an agreement known as the a Consent Decree, which required a significant commitment by the city to improve its wastewater system. The city had to develop a wastewater reuse system that would recycle 38,000 m³/d of water by July 2001. One solution was for the city to find a partner to design, build and operate the new water recycling plant in order to meet the Consent Decree. Veolia developed a 20-year partnership with the Board of Water Supply to design, build, own (and transfer to the Board of Water Supply at startup) and operate a multifaceted 49,210 m³/d water reclamation facility to help preserve the City's area's limited potable water resources and to meet the Consent Decree requirements.

The Design-Build-Operate (DBO) model covers a new reclamation plant at the existing wastewater treatment plant to generate two quality levels of water: High-purity water sold to industrial users for power and petrol-refining uses, and R1 water used for irrigation along a 24 km (15 miles) distribution system. The contract also includes process guarantees, marketing and distribution of the treated wastewater.

HONOLULU WASTEWATER TREATMENT PLANT



BIOGAS PRODUCTION OPTIMISATION AT SEWAGE TREATMENT PLANTS (STP) FOR POWER GENERATION

At present, the four biogas plants at sewage treatment plants at Anjana, Karanj, Singanpore and Bhatar have a power generation capacity of 3.5 MWe, as described in the table below.

Based on several engagement sessions with SMC and local stakeholders, there were two main opportunities identified regarding improvement of the water management systems in the city.

ELECTRICITY PRODUCTION UNTIL MARCH 2013²⁵

Sr. No.	NAME OF STP	INSTALLED CAPACITY OF POWER PLANT (MWe)	YEAR OF COMMISSIONING	GWh UNITS GENERATED	GENERATION (MILLION RUPEES)
1	Anjana	0.5	Oct 2003	16.1	71.6
2	Singanpore	1.0	Mar 2008	7.3	34.7
3	Karanj	1.0	Mar 2008	12.1	58.5
4	Bhatar	1.0	Aug 2008	3.7	17.7
Total				39.3	182.6

The table shows that the STP have been producing 39 GWh of electricity since their start, which represents less than the half of their total electricity production capacity. Thus, there is a margin of possible improvement and the municipality could identify and implement efficiencies across every aspect of the city's Sewage Treatment Plants, with a goal of realising savings and revenues enhancements due to biogas production optimisation.

In Urumqi, Xinjiang Province (China), Veolia is responsible for the operation, maintenance and expansion of the wastewater treatment plant that serves 1.5 million people. With the dynamic development of the city, especially in the Xin Shi, Sha and Ian Shan districts, water demand increased tremendously, which led to stronger demand in wastewater treatment as well. The municipal government of Urumqi saw the need to enhance the city's wastewater treatment services and reform the existing wastewater plants. Veolia uses innovative technologies in order to raise and stabilise the quality of treated wastewater. In addition, to provide quality wastewater treatment services, Veolia is committed to reducing the carbon footprint of its operation by using green energy. The plant is designed with digestion and co-generation systems and a biogas holder. The benefits for Urumqi Municipality are safety conditions improvement and implemented initiatives (e.g. process optimisation, performance and quality audits, preventative maintenance) to increase the plant's productivity. Moreover, the plant has started to operate six sludge digesters

URUMQI WASTEWATER TREATMENT PLANT



capable of treating more than 80,000 m³ of sludge per month, producing 930,000 m³ of biogas. The gas is then used to heat the plant and to generate 800,000 kWh of electricity. The new biogas holder is currently the largest double membrane in Asia and is well equipped with facilities to turn biogas released from sludge treatment into energy. Treated water is used for irrigation in the plant's green areas to reduce water consumption.

ACCESS TO DRINKING WATER

Both Shell and Veolia have implemented projects that have helped Indians to obtain better access to drinking water. Examples include:

HAZIRA REVERSE OSMOSIS PROJECT

India's growing population is putting a strain on the available water, with many sources under threat due to contamination from sewage and agricultural run-off. The highest risks are felt in rural, village areas of the country. Near to Surat, the area of Hazira²⁶ has no fresh water source and only salty ground water due to its coastal location. To tackle the problem, Shell and its partner Total at the neighbouring Hazira LNG

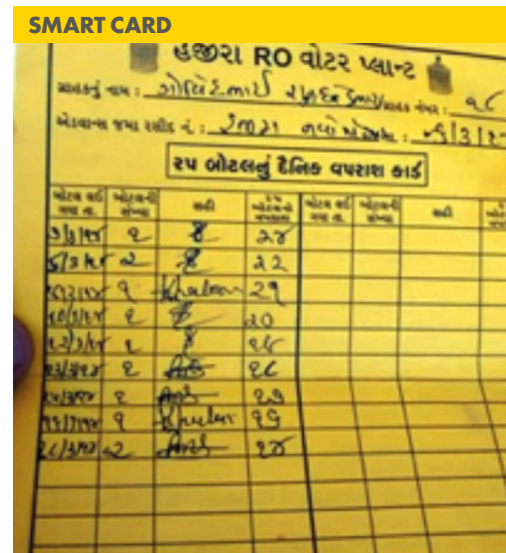
Terminal and Port helped install new infrastructure to provide clean tap water.

The Hazira Group of Companies (HGC) supported the Village of Panchayat (a local self-governance institution) in building a reverse osmosis (RO) drinking water plant. It uses an historic well as a source of raw water and has a storage capacity of 4,000 litres. Each family is given a standard 20-litre water bottle which is exclusively used for collecting water from the RO plant.

NEW DELHI – IMPROVEMENT OF THE DRINKING WATER NETWORK

In 2012 Veolia Water India was awarded a contract by the Delhi Jal Board, the water and wastewater authority for the Indian capital, to manage drinking water production and distribution infrastructure, as well as the water department, for the Nangloi neighbourhood in the West of New Delhi. Under the terms of the 15-year contract, the joint venture set up by Veolia Water India and its local partner, Swachh Environment, will supply drinking water 24/7 to one million people in Nangloi.

Now in the process of implementation, the project forms part of an initial pilot phase for the improvement of the drinking water service in the Indian capital before rolling out the service across greater New Delhi (population of 18 million). This project has also highlighted the importance of engaging with stakeholders through social mediation. Nangloi is the largest public-private partnership ever to be formed by New Delhi in the water sector.



FLOODING

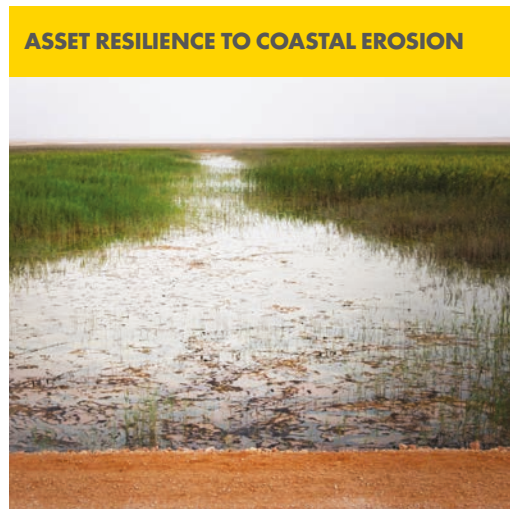
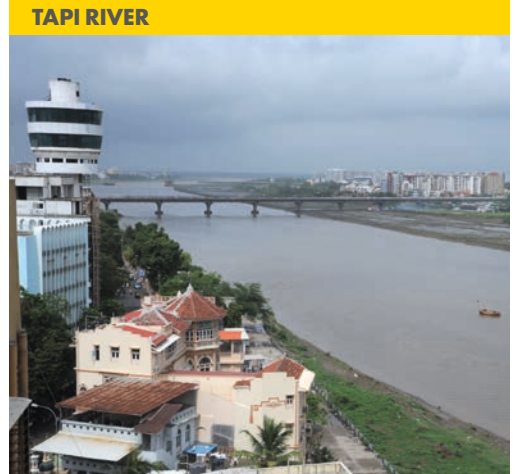
Significant progress has been made by the Surat authorities in reducing the risks associated with flooding. In recent years there has been more efficient water management of the Ukai reservoir and the implementation of a proper warning system in the catchment area of the Tapi basin.

The water system infrastructure, including the drainage and control system, is governed by regional and federal authorities. Flood management engineering and controls require co-ordination across several states. The interfaces between these bodies need to be managed carefully to ensure the efficient management of the overall system.

Though the implementation of the flood management master plan is the key to reducing flood risk in Surat, resilience can also be improved through cost-effective incorporation of "green infrastructure" into the flood management landscape for Surat. This is a set of natural solutions to help solve urban and climatic challenges particularly focused on using natural features and materials to reduce flood risk.

Opportunities to do this in Surat include restoration and enhancement of river bank systems and spillways and the development of open green recreation spaces that can assist in absorbing heavy rains. Rooftop and vertical gardening, planting of trees on walkways and roadways could also be considered.

There is some cost associated with maintenance of these green spaces, but it is significantly less than the cost of heavily engineered solutions. Results in other locations have shown that, when implemented correctly, high-performing green spaces provide real economic, ecological and social benefits.



HOW DO THE WATER MANAGEMENT OPTIONS SCORE AGAINST OUR ASSESSMENT CRITERIA?

Reliability

- The filtration technologies referred to in the waste and drinking water solutions are proven and robust.
- Green infrastructure development is low-cost and needs light levels of maintenance that makes it potentially more reliable than other flood mitigation measures.

Sustainability

- Re-use of wastewater is a strong way to decrease fresh water usage and intake in the river.
- RO technologies have a low environmental footprint, as do green infrastructure solutions.

Cost-effectiveness

- The economic benefit needs to be worked through but green infrastructure can be lower-cost, as can some of the technologies shown here.

Environmental footprint

- The water footprint will decrease with greater recycling and more reliable drinking water systems.

Energy efficiency

- Green infrastructure as a natural defence against flooding is inherently energy-efficient. Modern drinking water systems can also use less energy than older, less reliable systems.

Innovative technology

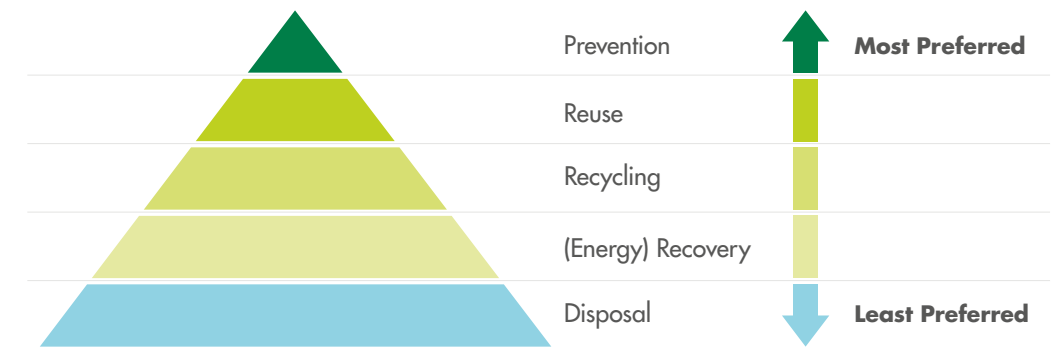
- Wastewater tertiary treatment enables high water quality standards for industrial reuse.

OPPORTUNITY 3 WASTE MANAGEMENT

Waste can be a valuable resource (via recycling or as fuel). However, it is not always easy to realise this potential because the ability to optimise waste management can be constrained by local physical and governance issues (e.g. policies, regulatory frameworks, financing, education etc.). This makes the associated challenges complex. In this section, a selected number of opportunities are highlighted.

One way of looking at waste is by using the “waste hierarchy”, which is the cornerstone of most waste minimisation strategies: it aims to extract the maximum practical benefits from products and to generate the minimum amount of waste. In this study we have looked at a range of waste management options across this hierarchy.

THE WASTE HIERARCHY²⁷



RECYCLING

Materials such as paper, plastics, glass and metals are recyclable. To be recovered, these materials need to be separated and collected. In the past decade recycling rates around the world have dramatically increased – in many cases recycling well over 50% of all waste produced. Surat could increase its recycling potential by the installation of roadside or underground collection points for segregated materials.

The municipality could also lead by example in its own offices and facilities by:

- discouraging the use of non-recyclable products and materials by employees and contractors;
- buying recycled products, such as recycled office paper; and
- requiring the composting of food waste and plant material generated at government facilities.

OPPORTUNITIES IN MUNICIPAL SOLID WASTE (MSW) MANAGEMENT

Even if high levels of recycling are achieved, there will always remain a fraction of waste that has to be disposed of safely and economically. Much of this non-recycled waste is currently sent to landfill sites throughout Surat. Landfill is a sub-optimal way to dispose of waste. Sites lack capacity to deal with the demands of an expanding city, they are dangerous places for those who work there (formally and informally), can be breeding grounds for disease and are highly polluting to the environment. Another way of dealing with waste is to use it as fuel to produce power, e.g. waste-to-energy. This option works for hazardous waste that should not end up in landfill such as medical and toxic waste.

There are three routes for waste-to-energy:

- **Via (co-)incineration:** burning waste (potentially with gas, coal or biomass) and using the generated heat to produce steam, or electricity:
 - **Mass-burn incinerators** are fed with untreated waste after basic removal of organic matter, glass, metals, batteries etc. (which can be recycled).
 - **Refuse-derived fuel (RDF)** incineration, where waste is processed into a uniform “fuel”. RDF feed stream usually consists of plastics and biodegradable waste – products that are combustible with the potential to deliver energy.
- **Via gasification:** various technologies are available to produce methane from waste and then burn the methane.

In the Netherlands it is common practice to burn unrecyclable waste as a fuel to generate power and heat. For example, the incinerator near Amsterdam (ca. 750,000 people) supplies the city with an average of 64 MW in 2014, using both RDF and bio-gasification technologies.²⁸ In Asia, similar-sized systems exist in Singapore, Japan, South Korea and Taiwan. However, most of them are mass-burn incinerators.²⁹

Focusing on Surat, the main opportunities are to find solutions for material and energy recovery from the high organic content of MSW (up to 65%). There are two main ways in which this could be done:

Biogas from organic waste collected separately. If an at-source waste segregation system can be implemented in Surat, material and energy recovery of organic waste (biowaste) could be more effective. A biogas production plant designed for 500 tonnes per day (tpd) of municipal organic waste could treat 50% of the potential organic feedstock generated by Surat City. The potential purified biogas production is estimated at 13 million Nm³/year of natural gas equivalent.

Since 2012, Veolia has been operating a wet anaerobic co-digestion of organic waste facility in the North of France (Artois Méthanisation). This facility offers a large panel of treatment solutions for organic waste and provides a comprehensive service based on anaerobic digestion. Located in the heart of a farming region which supplies the food and beverage industry, the Artois Méthanisation site is a local solution for eco-responsible recovery. The typical waste treated is biological sludge (flotation grease), production rejects, animal by-products (category 3), restaurant grease, collective canteen waste, sewage waste, manufacturing deviations etc. The treatment capacity of the facility is 25,000 metric tons/year of organic waste, and 8,000 MWh of electricity is generated every year (6,500 people supplied).

WET ANAEROBIC CO-DIGESTION OF ORGANIC WASTE FACILITY



PLESSIS-GASSOT LANDFILL SITE



Biogas from landfill gas capture

In Surat, the majority of the MSW collected is sent to landfill. As part of this disposal process, fugitive emissions of biogas occur at the site and can be captured for energy recovery.

Based on a 500-tpd landfill, the potential biogas recovery is estimated at 4.8 million Nm³/year of natural gas equivalent.

These two solutions enable the Air Quality and Waste Reduction challenges of the city to be addressed. Indeed, using waste for biogas recovery and reuse as a substitute of fossil resources (coal and natural) for electricity production will significantly decrease CO₂ emissions and fine particles (PM10 and PM2) emissions in Surat.

Veolia's Electr'Od: Energy to Biogas: the Plessis-Gassot landfill site on the outskirts of Paris (France) processes 950,000 metric tons of non-recyclable waste every year. électr'od facilities (a French acronym meaning “electricity from waste”) produce energy from biogas to deliver an annual 130 GWh, which is enough to meet the electricity needs of 41,200 households, not including heating. The site also generates 30 GWh of thermal energy each year. Part of this energy is absorbed by the site itself, with the rest used in the district heating network – providing heating and hot water for homes and public buildings – in the municipality of Plessis-Gassot. The process is compatible with non-hazardous waste facilities and biogas plants.

HOW DO THE WASTE MANAGEMENT OPTIONS SCORE AGAINST OUR ASSESSMENT CRITERIA?

Reliability

- Continuous production of biogas to generate electricity, proven and robust technology.

Sustainability

- Use of a renewable resource as a substitute to fossil fuels.

Cost-effectiveness

- The first study gives a positive outcome and could be cheaper than existing fuels. The benefits have to be confirmed with further work.

Environmental footprint

- Significant decrease of GHG emissions and PM emissions.

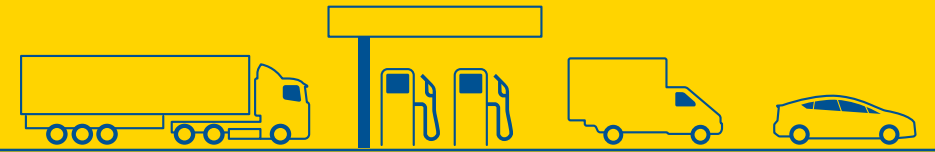
Energy efficiency

- The biogas production is turning waste into a resource. Greater recycling rates reduce the ultimate energy use of producing new materials and products.

Innovative technology

- Innovative processes of biogas capture and use in energy generation can be developed for municipal solid waste treatment.

TRANSPORT



1 CLEANER TRANSPORT FUELS

CNG



LNG



ELECTRIC RICKSHAWS



2 ENHANCED PUBLIC TRANSPORT: BUS RAPID TRANSPORT SYSTEM



3 CONGESTION REDUCTION INCENTIVES



OPPORTUNITY 4 EFFICIENT TRANSPORT

CLEANER TRANSPORT FUELS

COMPRESSED NATURAL GAS

The fleet of vehicles in Surat already contains a high percentage of vehicles running on compressed natural gas: 40% of the vehicles (2012 data).

Increasing the penetration of CNG further could boost a cleaner transportation fuel in the city's energy mix, with significantly lower emissions

compared to conventional diesel vehicles. Dedicated CNG vehicles offer Surat City an opportunity to improve air quality and liveability of the city by decreasing the level of fine particles. There is already a network of 50 CNG retailers and 130 retrofiters in the city.

The retrofit kit starts from Rs 30,000 to convert a gasoline car into a CNG car. The payback time is less than one year for a conversion from gasoline to CNG.

EMISSION BENEFIT OF REPLACING DIESEL WITH CNG VEHICLES ³⁰			
Fuel	CO	NOx	PM
Diesel	2.4 g/km	21 g/km	0.38 g/km
CNG	0.4 g/km	8.9 g/km	0.12 g/km
% reduction	-84	-58	-97



To power a vehicle with CNG, the vehicle owner has three options:

OPTION	PROS	CONS
1. Purchasing a dedicated OEM CNG vehicle	<ul style="list-style-type: none"> Original equipment manufacturer (OEM) guarantee on vehicle quality No integration trouble with existing vehicle 	<ul style="list-style-type: none"> Higher purchase price compared to gasoline and diesel e.g. in India \$6,000–12,000³¹ Redundancy of existing vehicles
2. "Re-powering": replacing diesel/gasoline engines with OEM CNG engines	<ul style="list-style-type: none"> Suitable for large existing fleets of transport e.g. trucks, buses 	<ul style="list-style-type: none"> Technically challenging More expensive compared to retro-fitting
3. Retrofit: converting current existing diesel/gasoline engines to CNG engines	<ul style="list-style-type: none"> Suitable for cars, tricycles and other small vehicles Technically easy to implement – could be done by local shops in a couple of hours Most affordable options for vehicle owner Retrofitting gives the vehicle dual-fuel capability 	<ul style="list-style-type: none"> Generally, infeasible in heavy-duty vehicles like trucks (high maintenance, low efficiency and higher emissions) To install a CNG conversion kit into a gasoline-powered vehicle sacrifices a part of the car trunk or cargo space

All the options above indicate an upfront capital investment from the vehicle owners. However, vehicle owners can recoup their investment (switch over costs) over a period of time through lower input fuel costs.

In order to encourage consumers to switch over to CNG, it is also imperative to ensure adequate supply. A key requirement for this is presence of CNG distribution infrastructure such as refuelling facilities. The necessary refuelling facilities will be determined by the operating characteristics of the vehicles (fleet size, vehicle type, trip lengths, fuel economy etc.).

The CNG refuelling infrastructure consists of a mother station and a number of daughter stations. The mother station is supplied by a continuous supply of natural gas from a pipeline or a large storage facility. The daughter stations can be supplied by the mother station via a pipeline

or via trailer truck delivery. According to a study published by Pacific Northwest National Laboratory for the US Department of Energy, the cost (including installation) of a mother station is \$2 million; smaller fuelling units average around \$10,000. The cost for refuelling infrastructure (as with most transport fuels) is embedded in the fuel pricing.

In order to increase the penetration of CNG the Surat municipality may want to consider accessing low-cost finance for conversion kits, in particular diesel to CNG conversion, which is three times more expensive than gasoline to CNG conversion. In the situation that there is a gas-fired Distributed Energy System, Surat would have the opportunity to leverage the available gas supplied to the city for power generation for CNG provision, potentially at lower cost than if the supply infrastructure was being provided purely for transport fuel purposes

LIQUEFIED PETROLEUM GAS FOR TRANSPORT²⁰

LPG gas is the third largest automotive fuel used in the world, with approximately 500 million passenger cars fitted with an LPG combustion kit. There are about 500 LPG gas/Autogas filling stations across 250 cities in India, which attracts the users mainly because of 25–30 % of the fuel saving.

The Indian government has approved the usage of LPG in vehicles since 2000. The Autogas price is not regulated by the government and it tends to increase or decrease based on the crude oil price/market situations. Another positive aspect of LPG is the significant CO₂ emission reduction compared to gasoline and diesel.

In Gujarat, the Autogas price in Surat is Rs. 51.15/ltr. and there are three fuel filling stations across the state. There is room for improvement in developing the refuelling network.³²

LIQUEFIED NATURAL GAS (LNG) FOR TRANSPORT

Other solutions could contribute to keep emission particle level low while the number of vehicles in the city is growing rapidly. LNG (natural gas chilled to a liquid form) for transport has been proposed as an alternative solution for long-haul trucks and municipal fleets such as buses which conventionally run on diesel. LNG has the potential to offer significant fuel cost savings compared to conventional diesel. It can also reduce greenhouse gas emissions, from production to use, compared to conventional diesel and bio-diesel in new engines. The reduction of particles and NOx emissions is up to 80% compared to diesel trucks. There is no SOx emission for LNG trucks and the CO₂ tailpipe emissions can be improved versus diesel engines.

Burning LNG in spark-ignited engines is also quieter than burning diesel in combustion engines. LNG-fuelled trucks and buses can operate for longer where noise restrictions apply, for example delivering to shops in residential areas.

Shell is working to supply LNG along a truck route in Alberta, Canada, starting with three sites. Shell also intends to work with TravelCenters of America to provide LNG for truck fleets at truckstops across the USA. The first European Shell LNG retail station, near Rotterdam in the Netherlands, was opened in January 2015.

As there are many heavy-duty trucks that ply the highways of Gujarat and Maharastra, there could be significant cost savings and environmental benefits to these states and the city of Surat from fuel switching to LNG. There is also a ready supply of fuel at LNG terminals at locations such as Hazira.

The purchase of LNG trucks can also be cost-effective. In China an LNG truck is about \$15,000 more expensive than a diesel truck, with a cost payback under one year. The India truck manufacturers should be able to produce a LNG truck for similar prices to China. TATA in India has developed an LNG prototype and showcased the Prima 4032.S LNG during the 12th Indian Automotive Expo in March 2014, as the first LNG truck prototype in India with 320 hp tractor.

Indian Railways are also considering plans to retrofit their diesel locomotives for LNG. This will help them conserve fuel cost, increase efficiency and make them more eco-friendly. Pulling an equal load with same speed, an LNG-based locomotive will cut per-unit running cost by 40% compared to the running cost of a diesel engine.



ELECTRIFICATION OF ROAD TRANSPORT

Within the last decade, electrified mobility has been given increasing priority in the US, Japan, China, Korea and EU, and is part of the long-term strategic vision of many of the world's cities. Mass production of electric and hybrid vehicles is under way, and they are becoming increasingly competitive in terms of cost (purchase and running) and utility (range and speed) when compared with conventional combustion vehicles as advances

are made in battery technologies, infrastructure investment and scale production. The advantages of increased electrified road transport include energy savings, improved air quality (reduction in greenhouse gases and air pollution) and a reduction in noise pollution. All of these could have positive impacts in improving public health, economic growth and reducing the impact of climate change, if the electricity was generated from low carbon resources.

COMPARISON OF WELL-TO-WHEEL CO₂ EMISSIONS FOR CONVENTIONAL GASOLINE INTERNAL COMBUSTION ENGINES (ICE) VEHICLES, BIOFUELS ICE AND ELECTRIC VEHICLES (EV) IN RELATION TO THE ELECTRICITY MIX³³

Fuel	WELL TO TANK (BATTERIES)	TANK TO WHEELS (BATTERIES)	TOTAL EMISSIONS
CO ₂ eq. in g/km			
Conventional ICE car	23	120	143
Biofuels ICE car	17–28	97–135	114–163
Battery Electric Vehicle 27% Nuclear 20% Renewable 53% Fossil Fuel	67–84	0	67–84
Battery Electric Vehicle 100% Coal	126–155	0	126–155
Battery Electric Vehicle 50% Wind 50% Photovoltaic	0–4	0	0–4

If Surat hosted a micro-grid power system inside the city limits, it could give encouragement to exploit potential electrification of road transport. Increased electrical power capacity inside Surat would provide confidence to investors (1) to install necessary electrical charging stations across the city and (2) to purchase electric vehicles for personal use and as part of business. It is important to note that the benefit in reducing air pollution is dependent on the primary source of fuel used in generating electricity. Electricity generated

from coal-fired power stations offers little to no overall reduction in CO₂ emissions compared to conventional combustion engines. However, alternatives such as gas or solar (as proposed under Opportunity #1) would provide an electricity source with significant reductions in CO₂ emissions, enabling the full benefits of electrification of road transport to be captured. Another alternative would be electric vehicles, fuelled with hydrogen, delivering emission-free operations.

PUBLIC TRANSPORT

In Surat, the first phase of the Bus Rapid Transport System (BRTS) programme providing services to 30 km of road corridors began operation in 2014 and three further phases are planned to open over the coming years. In addition there are proposed plans to build Metro rail rapid transit system for the city. If completed on schedule, the four-line, 100-kilometre (62-mile) metro will enter operation in 2018. These additions will help to meaningfully reduce congestion and improve connectivity to key areas of the city.

Further improvements to main bus route penetration and feeder routes to the main networks to reduce reliance on two and three wheelers can be made. Intercity transportation between the east, west, north and south areas of Surat is being partly addressed by the plan to

expand the current BRTS lines to reduce traffic congestion and reduce emissions by displacing the use of private vehicles. However, there is an opportunity to improve the ease of access to BRTS stations within the city, enhancing the desirability of Surat City as a place to live, work and visit.

The access to new BRTS stations is just as important as planning the location of the stations, and this is an area that can be controlled by Surat City. An accessible BRTS station can be connected to several other transport options like buses, pedestrian walkways, bike lanes etc. to ensure a smooth flow of passengers moving in and out, and to connect the BRTS to key areas in the city such as restaurants, shopping, employment and recreation locations.

Cleaner fuels such as LNG or CNG can be suitable for long-haul buses. Indian Railways

are also considering the plans to retrofit their diesel locomotives for LNG (see cleaner transport fuels section).

LOWER COST CONGESTION REDUCTION OPTIONS

Efforts to reduce congestion in Surat can also be helped by the use of a range of lower-cost mechanisms to incentivise reductions in car use. There are other solutions from cities around the world that could be considered:

■ **Strict enforcement of traffic rules:**

This can be the cheapest option to implement to reduce congestion on busy roads. Simply ensuring that vehicles are not illegally parked and that signals at junctions are observed can significantly increase the availability of existing road capacity and improve the flow of traffic, while also reducing accidents.

■ **Congestion/road charging:**

Singapore has an Electronic Road Pricing (ERP) scheme for major roads in the city. It charges road users a variable price based on traffic speeds and timing of journeys (e.g. travelling during peak hours on busy roads is more expensive than on other routes at other times). It has been estimated that the ERP has reduced congestion on major expressways during operational hours by around 15%. However, congestion charges can be unpopular, as their calculation can be viewed as unreliable and a cost burden to drivers, particularly at times of high fuel prices. Manila (Philippines) implements the Unified Vehicular Volume Reduction Program (UVVRP), which restricts the types of vehicle that can use major public

roads based on the final digit of the vehicle's licence plate.

■ **Tolling:** Road tolling is an established mechanism for restricting usage of road space and funding the building of infrastructure. They are often associated with public-private partnership models for the construction and operation of these assets. They have been implemented in many places in the Philippines (e.g. North Luzon expressway, Metro Manila Skyway) and in cities across the world (e.g. Delhi, Jakarta). Though they are successful in encouraging the building of new road capacity at lower capital cost to the public purse, they have a mixed record in reducing congestion, largely due to the partial nature of their coverage of the road network, which can result in drivers re-routing onto smaller "free" roads. Tolls collected at booths at the end of the road or bridge can also create congestion at the points that drivers stop to pay.

EMBARQ MODEL FOR SAFE ACCESS APPROACH³⁴



HOW DO THE TRANSPORT OPTIONS SCORE AGAINST OUR ASSESSMENT CRITERIA?

Reliability

- The cleaner fuel options proposed are proven and reliable technologies.

Sustainability

- Investment in new infrastructure and reduction of congestion and pollution can make the city a more attractive place to invest and set up businesses.

Cost-effectiveness

- Costs of congestion are significant so improvements can be cost-effective. Fuel switching can be cost-effective but is dependent on pricing points for existing fuels.

Environmental footprint

- The proposed solutions enhance the resilience and the sustainability of the city by reducing pollution and emission levels.

Energy efficiency

- More efficient fuels reduce pollution and new infrastructure investment increases the competitiveness of the city by making it easier to move around.

Innovative technology

- Cleaner fuels, local investment in refuelling infrastructure and improvements around BRTS stations rely on innovative technology and can enhance the desirability of Surat City as a place to live, work and visit.

OPPORTUNITY 5 GOVERNANCE AND IMPLEMENTATION

Surat has been in the forefront of making positive changes to the infrastructure of the city over recent decades, and is seen as a leader in effective governance to improve the health and well-being of its citizens.

Surat works collaboratively with the Gujarat state government, the Indian national government and local stakeholders such as the South Gujarat Chambers of Commerce and Industry to develop and implement plans for resilient infrastructure in the city.

However, there are still challenges that remain in encouraging and managing development in Surat. Options for improvement that could be considered include:

- Public-private partnerships to design, build, finance and operate key infrastructure assets e.g. for toll roads and bridges, street lighting, public housing development. These can be financed through federal government-backed infrastructure funds or state-backed pension fund investment. National government investment guarantees can also help to reduce project costs. These mechanisms can also help to bring in private sector expertise to implement and manage projects.
- Smart data solutions can make city management more effective. For example:
 - city control rooms such as the Centre of Operations (COR) in Rio de Janeiro, Brazil, which monitors the daily activity of the city using multiple data inputs and allows it to manage potential crisis situations including traffic, major events and natural disasters;
 - smart ticketing e.g. OV chipkaart in Netherlands, which allows all public transport journeys in the country to be paid for on one smart card; and

- smart metering of utilities to allow time of day tariffs and load balancing.
- Localised funding streams and tax retention can help to plan, finance and build infrastructure, e.g. municipal bonds, tax-incremental finance (where the predicted tax revenue increase created by infrastructure investment can be used as a revenue stream to finance that investment, e.g. the London Metro extension to Battersea in the UK). Private developers can also be asked to contribute to building elements of public infrastructure as conditions of planning approval.
- Local consultation and collaboration to build trust and create solutions. Crowd-sourcing solutions using digital tools and making city data publically available online as has happened in Helsinki, Finland. Neighbourhood forums and partnership agreements can also help to build public engagement in plans for the city.
- Consider new forums for collaboration across city agencies and authorities on common Surat and Gujarat issues.
- Master planning and collaboration, e.g. Singapore's Master Plans (most recent plan published in 2014, first published in 1958), which has created a strong vision and pipeline of future investment across several decades. These plans can be developed through international collaboration, such as the work done with the Rockefeller Foundation on the Surat City resilience strategy.

HOW DO THE GOVERNANCE AND IMPLEMENTATION OPTIONS SCORE AGAINST OUR ASSESSMENT CRITERIA?

Reliability

- These measures can help to ensure the delivery of high-quality services to the people of Surat.

Sustainability

- A strong pipeline of investment and improved implementation capacity helps ensure the long-term sustainability of solutions.

Cost-effectiveness

- These measures are designed to reduce implementation costs through smart measures and financing solutions.

Environmental footprint

- Smart management solutions are good ways to reduce the environmental impact of infrastructure solutions.

Energy efficiency

- Smart management solutions and effective implementation strategies reduce waste and can increase energy efficiency.

Innovative technology

- Many of these solutions deploy new ICT technologies or best-practice methods from across the world.

CONCLUSIONS AND NEXT STEPS

This study provides a series of focused solutions to key challenges and opportunities for Surat. These solutions are the result of discussion and feedback from many people associated with living, working in, administering and guiding the city. As such, these solutions belong to Surat. Individually, each solution has potential. However, the real value to Surat is in their integrated implementation. The opportunities include:

A. implementing a combined heat and power system in the textile clusters to provide clean, efficient and affordable power and heat to this key area of the Surat economy;

B. putting in place a resilient, green, clean power micro-grid that complements the existing grid;

C. reducing water consumption through the implementation of effective water recycling measures, particularly in the industrial sectors;

D. increasing the use of biogas in power production;

E. developing efficient transport systems using cleaner fuels and that could leverage micro-grid infrastructure;

F. using green infrastructure systems that complement the existing flood management solutions for the Tapi River; and

G. building on and further developing the excellent management and governance systems that Surat is already respected for.

A visualisation of these potential solutions is shown on page 25.

Taken together, these options can help Surat as it plans for its future development. However, we suggest the results in this report are just the beginning. The proposed solutions are achievable, but much needs to be done to further assess detailed engineering feasibility, commercial viability (investor funding, project economics), local and federal regulatory support, environmental fit and to ensure complete understanding of community support. We hope that the results of this study will help to build the roadmap for Surat.

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