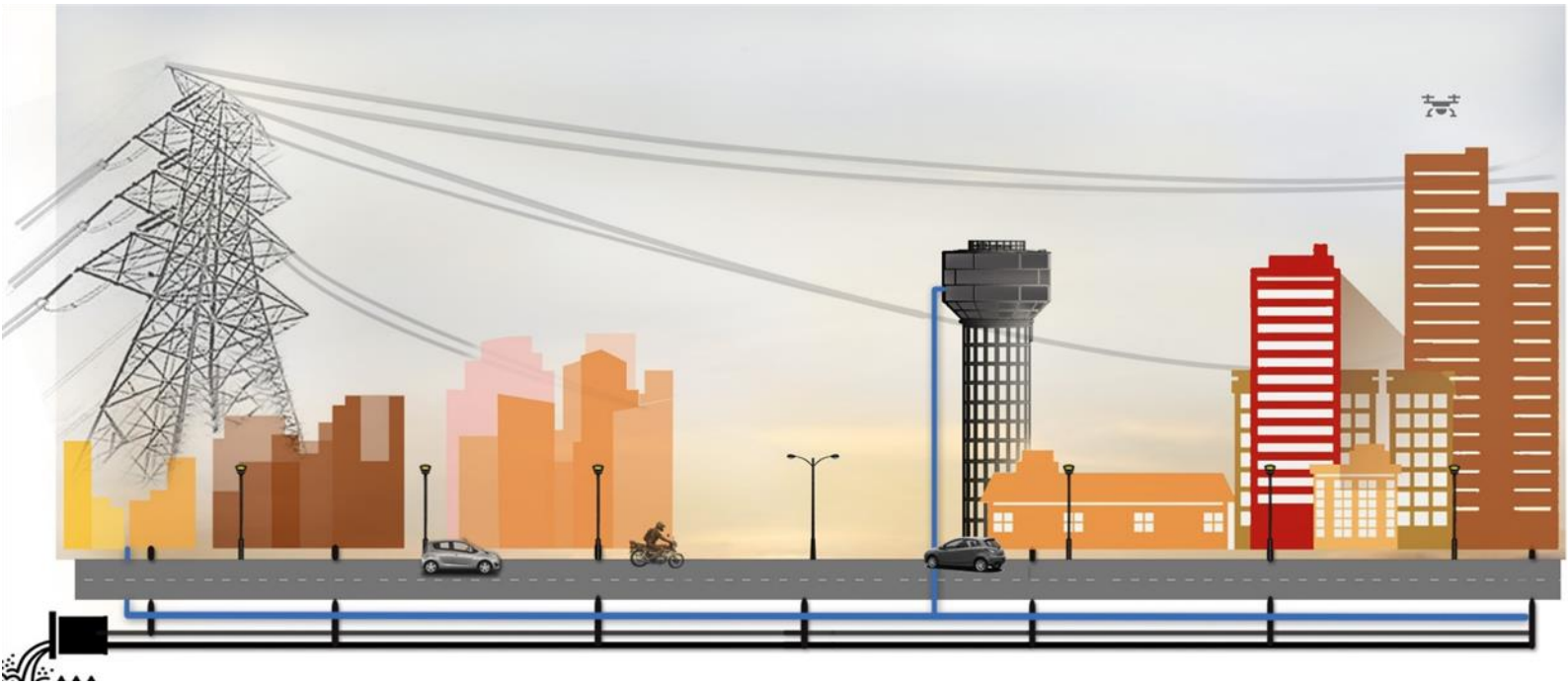


India-UK Joint

Integrated Urban Model for Built Environment Energy Research

(iNUMBER)

Incorporating Municipal Energy Services into the City Energy Model and Developing a Water-Energy Nexus

R&D Partners - India

CEPT University
Ahmedabad

Indian Institute of Technology-
Bombay

R&D Partners - UK

University College
of London

University of Oxford

Industrial and Organizational Partners

Funding Agencies

Department of
Science &
Technology,
Government of
India
सत्यमेव जयते

Newton
Fund

EPSRC
Engineering and Physical Sciences
Research Council

E·S·R·C
ECONOMIC
& SOCIAL
RESEARCH
COUNCIL

Document No: Work Package 2 /17-21

India-UK Joint Integrated Urban Model for Built Environment Energy Research (iNUMBER)

Work Package 2 (WP2): Incorporate Municipal Energy Services

Incorporating Municipal Energy Services into the City Energy Model and Developing a Water-Energy Nexus

January 2019

Authors:

Mona Iyer, Rajan Rawal, Sachin S, Himani Pandya, Asha Joshi

Centre for Advanced Research in Building Science and Energy

CEPT University, Ahmedabad

Kathryn Janda

University College London, London

Research Team:

Kartikay Sharma, Tithi Soladhara, Veeren Poola

Team - India

Rajan Rawal - Principal Investigator
Mona Iyer - Co-Investigator
Krithi Ramamritham - Co-Investigator

Research Team

Himani Pandya
Asha Joshi
Kartikay Sharma
Veeren Poola
Sachin S
Tithi Soladhara
Surbhi Mehrotra
Hareesh Kumar
Vaibhav Kumar

Interns

Shivani Chouhan
Shelly Vaish
Garima Kamra

Team - UK

Paul Ruyssevelt - Principal Investigator
Kathryn Janda - Co-Investigator

Research Team

Ivan Korolija
Phil Steadman
Robert Liddiard
Stephen Evans
Pamela Fennell
Russell Layberry
Phillipp Grunewald
Radhika Khosla

Acknowledgments

The Department of Science and Technology (DST), Government of India, the UK Engineering and Physical Sciences Research Council (EPSRC) and Economic and Social Research Council (ESRC), as part of the Newton Bhabha Fund, provided joint funding to "Integrated Urban Model for Built Environment Energy Research (iNUMBER)". The EPSRC and ESRC support the UK iNUMBER activity to University College London. The DST, Government of India supports the Indian iNUMBER activity to CEPT University under sanction order number DST/TMD/UK-BEE2017/18(C) and DST/TMD/UK-BEE2017/18(G) dated 29 December 2017.

iNUMBER (iNtegrated Urban Model for Built Environment Energy Research) is a four-year (2017-2021) research project to help cities reduce their energy demand and improve their municipal services. This goal is led by CEPT University, Ahmedabad and supported in India by Indian Institute of Technology Bombay, Mumbai. It is led by University College London, London, and supported by the University of Oxford, Oxford.

Authors acknowledge guidance from Dr. Yash Shukla, Technical Director and Mr. Agam Shah, Senior Research Associate at Centre for Advanced Research in Building Science and Energy (CARBSE), CEPT University. Authors also acknowledge Ms. Shelly Vaish, iNUMBER - Direct Research Project student, CEPT University for designing the graphic of the cover image of this report.

Please cite this document as:

Iyer, M., Rawal, R., Sachin, S., Pandya, H., Joshi, A., Janda, K. (2019). *Incorporating Municipal Energy Services into the City Energy Model and Developing a Water-Energy Nexus*, Ahmedabad, India: Centre for Advanced Research in Building Science and Energy (CARBSE), CEPT University. Submitted to the India-UK Joint Integrated Urban Model for Built Environment Energy Research (iNUMBER)

This page is intentionally left blank.

CONTENTS

1. Introduction 1
1.1. About iNUMBER 1
1.2. Work Package-2: Incorporate Municipal Energy Services 3
1.3. Scope of Work Package 2 3
1.4. Outcomes of Work Package 2 7
2. Work Plan for capturing energy consumption in delivering the municipal services 8
2.1. Water Supply 9
2.1.1. Source 9
2.1.2. Water Treatment Plant 11
2.1.3. Water Distribution Stations 12
2.1.4. Distribution network 13
2.1.5. Building level 13
2.2. Waste Water Management 16
2.2.1. Collection and conveyance 16
2.2.2. Sewage Pumping Stations 17
2.2.3. Sewage Treatment Plant 18
2.3. Storm Water Management 19
2.4. Lighting in Public spaces 21
2.5. Current Status and Way forward for outcome-1 22
3. Framework for capturing energy consumption in municipal services 23
3.1. Review of Case studies pertaining to the Existing Information Systems 24
3.1.1. Information system capturing long term data sets and covering larger geographic areas: 24
3.1.2. Information systems capturing data sets through one time study: 26
3.1.3. Information system capturing long term data sets and covering smaller geographic areas: 27
3.2. Information system in Ahmedabad 28
3.3. Current Status and way forward for outcome-2 29
4. Synthesis and Conclusion 30
References 34
Appendix A Existing Information Systems in Ahmedabad 36
Appendix B Water Supply Network for Ahmedabad 37
Appendix C Sewerage Network for Ahmedabad 38

List of Figures

Figure 1: Schematic representation of the iNUMBER project 2
Figure 2: Overview of the work package 2 8
Figure 3: Current status and flow of work with respect to outcome-1 23
Figure 4: Existing Information systems in Ahmedabad 29
Figure 5: Current status and flow of work in outcome-2 30
Figure 6: Snapshots of the PAS data sets 32
Figure 7: Synthesis of the work package-2 33

List of Tables

Table 1: Initiatives undertaken by governing bodies in India towards monitoring the municipal energy services; a review 4
Table 2: Inferences from the review of Government Initiatives 7
Table 3: Level of services- Water sector, Ahmedabad 9
Table 4: Source of water for Ahmedabad City 10
Table 5: Required datasets for the City Energy Model: Source, Water 10
Table 6: Water Treatment Plants in Ahmedabad 11
Table 7: Required datasets for the City Energy Model: Water Treatment Plant 11
Table 8: Required datasets for the City Energy Model: Water Distribution Stations 12
Table 9: Required datasets for the City Energy Model: Booster pumps 13
Table 10: Required datasets for the City Energy Model: Building level 14
Table 11: Sources for the required data sets for City Energy Model: Water Sector 15
Table 12: Level of services- Waste Water sector, Ahmedabad 16
Table 13: Required datasets for the City Energy Model: Sewage Pumping Stations 17
Table 14: Capacities of Sewage Treatment Plants in Ahmedabad 18
Table 15: Required datasets for the City Energy Model: Sewage Treatment Plants 18
Table 16: Source of data pertaining to Waste Water sector 19
Table 17: Required datasets for the City Energy Model: Storm Water Pumping Stations. 20
Table 18: Source of data pertaining to Storm Water sector 21
Table 19: Types and numbers of street lights in Ahmedabad 21
Table 20: Required datasets for the City Energy Model: Lighting in Public Spaces 22

Acronyms

iNUMBER	iNtegrated Urban Model for Built Environment Energy Research
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
SCADA	Supervisory Control and Data Acquisition
TRACE	Tool for Rapid Assessment of City Energy

Abbreviations

EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
ULB	Urban Local Body
BIM	Building Information Modeling
WP	Work Package
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
BEE	Bureau of Energy Efficiency
GoI	Government of India
MuDSM	Municipal Demand Side Management
IGEA	Investment Grade Energy Audit
MEEP	Municipal Energy Efficiency Program
MoHUA	Ministry of Housing and Urban Affairs
PSU	Public Sector Undertakings
SLNP	Street Light National Program
KWh	kilo Watt hour
AMC	Ahmedabad Municipal Corporation
EE Cell	Energy Efficiency Cell
SMC	Surat Municipal Corporation
LPCD	Liter per Capita per Day
MLD	Million Liters per Day
CFL	Compact Fluorescent Light
LED	light-Emitting Diode
AMTS	Ahmedabad Municipal Transport Service
BRTS	Bus Rapid Transit System
IRDB	International Bank for Reconstruction and Development
IDB	Inter-American Development Bank
JBIC	Japan Bank for International Cooperation
EMWIS	Euro Mediterranean Water Information System
AWRIS	Australian Water Resources Information System
NAWC	National Association for Water Companies
ACEEE	American Council for an Energy-Efficient Economy
ESMAP	Energy Sector Management Assistance Program

This page is intentionally left blank.

Executive Summary:

iNUMBER is an Indo-UK collaborative research project that was co-created to address the Newton research topic: “Integration of information, communication and renewable energy technologies at building, community and city level interventions”. The project aims to address this research topic by developing a data-driven Intelligent Urban Model for Built Environment and Energy Research (iNUMBER). The primary focus of this tool is to support the Indian Municipalities to understand the variations in energy demand and thereby assist in providing clean and sustainable energy services to its citizens. iNUMBER being a four-year collaborative research project (2017-2021), Ahmedabad has been selected as the primary case city for the research. Further, the project could be extended by considering other cities as well.

The key objective of the project is to develop a City Energy Model that includes the 3D building stock and the municipal services energy model. The project aims to achieve the same by linking the existing and new data sets and testing the validity of the developed model for a range of scenarios in accordance with different data availabilities. To achieve this overarching objective, the project has been sorted into 3 work packages (WP) as mentioned below,

1. WP1: Create 3D Building Stock Model
2. WP2: Incorporate Municipal Energy Services
3. WP3: Improving Data Granularity

This executive summary provides a brief account of the activities carried out under the WP2: Incorporate Municipal Energy Services. This WP focuses on the activities of stakeholder organizations and institutions with a primary focus on Urban Local Bodies (ULBs). There are two major outcomes under the work package 2. The first outcome is, ‘Feeder for City Energy Model’. This includes the integration of the energy data pertaining to the municipal services such as water supply, wastewater management, stormwater management and the lighting in public spaces into the City Energy Model. The second outcome is, ‘Developing a framework for capturing energy consumption in delivering the municipal services’. This focusses to develop a Municipal services information system for Ahmedabad city to evaluate the municipal services based on their energy consumptions. Further, the framework will be tested by considering other cities as well.

Under outcome-1, the report provides a brief overview of the municipal services in the context of the Ahmedabad city. Further, the report also demonstrates a work plan for identifying and gathering the energy data pertaining to these above mentioned municipal services for incorporating the same into the City Energy Model.

Under outcome-2, the report comprises the documentation of a literature review of the information systems with respect to municipal services by considering the case studies from India and abroad.

Further, the report also provides details regarding the existing data collection methods followed by Ahmedabad Municipal Corporation and the current usages of the collected data sets in the decision making processes.

The integration of the outcomes from all 3 work packages will assist in understanding the energy demand of the entire city. Through a fourth work package, the activities under iNUMBER will further be integrated with other projects, related research in India, and across the world. Further, this integrated approach will develop new areas of inquiry related to future building stock and municipal services in India.

1. Introduction

Cities have often been described as the engines of economic growth (Colenbrander, 2016). Currently, 55% of the world's population is residing in the urban areas. This proportion is expected to stretch to 68% by 2050 (United Nation, 2018). As per new data sets launched by United Nations, it is observed that the overall shift in the human residences from rural to urban areas, combined with the overall growth of the world's population could add around 2.5 billion more people to urban areas by 2050. It is expected that, nearly 90% of this increase in the urban population would be accounted by Asian and African countries alone.

As the urban population increases, the demand for the basic amenities and living comforts will also increase. Thus, it is very important to plan and allow the urbanization to attain in a sustainable manner. In order to attain this, it becomes very necessary for the cities to develop and provide required amenities towards meeting the future demand of its citizens. One of the primary aspects that need to be accounted with the process of urbanization is the provision of the secure energy for the better health and comfort of the citizens.

As the urban population increases, the city's demand for the clean energy will also increase. Thus, with the changing lifestyle and growing cities, it becomes very important to understand the energy demand of the city and identify more efficient methods of utilizing available resources in catering the demands. This can be achieved by assessing and understanding the variations incurring in the energy demands of the city. These variations can only be studied by constant observation and analyses of the data sets specific to the respective services. Thus, the tools capturing variations in the demand for the energy over the time and space will serve the greater cause in understanding the trends, rationalizing the energy demands and thereby assist in planning and attaining a sustainable energy services for the cities.

iNUMBER focusses on developing one such tool for assessing and understanding the variation in energy demand of the city over time and space. iNUMBER is an iNtegrated Urban Model for Built Environment Energy Research. The research program aims at developing a City Energy Model to help in planning a secure energy supply for the urban population. Further, the tool will support the urban energy management process and assist municipalities and local partners for developing a data driven intelligent urban model for assessing the built environment energy and the municipal planning.

1.1. About iNUMBER

'iNtegrated Urban Model for Built Environment Energy Research (iNUMBER)' is a four-year collaborative research project between India and United Kingdom to help cities reduce their energy demand and improve their electricity and water services. Funded by the Newton-Bhabha Fund, iNUMBER is jointly supported by the UK Engineering and Physical Sciences Research Council

(EPSRC), and Economic and Social Research Council (ESRC) in partnership with the Government of India's Department of Science and Technology. The main objective of iNUMBER is to work towards reducing greenhouse gas emissions, stabilizing the electricity grid, and help the ULBs in rationalizing and planning the city's energy demands thereby, assisting in provision of secure and sustainable energy services. The tasks under the project are to develop a new model of building & municipal energy demand, grounded in appropriate empirical data and applicable to reducing energy demand in a wide range of different contexts and with varying data availability.

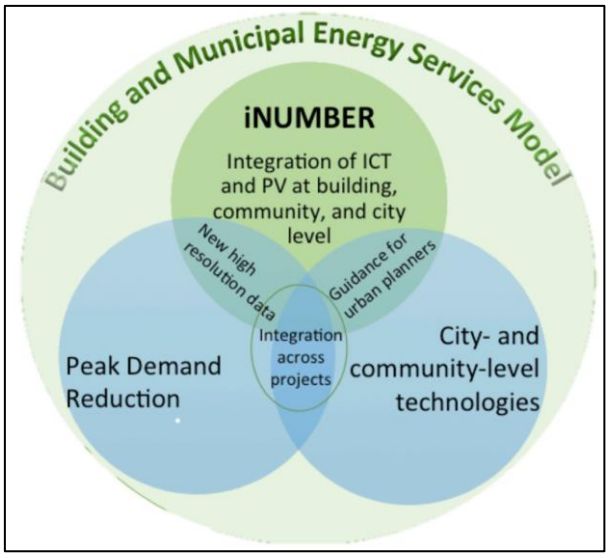


Figure 1: Schematic representation of the iNUMBER project

iNUMBER was co-created from the India-UK workshop to address the India-UK Newton research topic, "Integration of information, communication and renewable energy technologies at building, community and city level interventions" by developing a data- driven intelligent urban model for built environment energy research and municipal planning. It supports Indian municipalities and local partners by diagnosing urban energy problems, testing solutions, verifying progress and improving policy through state of art monitoring, data science and analytics. It will also meet interrelated elements of the other two topics, "peak demand reduction" by contributing new high resolution data city and community technologies by providing guidance to urban planners.

The iNUMBER project is systematically sorted into 3 work packages (WP) and are classified as described below,

1. Work Package 1: Create a 3D Building Stock Model

The WP1 aims at identifying and analysing various approaches suitable for capturing the urban environment using advanced aerial survey technologies and develop a 3D Building stock model. WP1 incorporates existing geographical and administrative datasets available at the city level and integrates the information with the developed 3D Building Model. Finally, WP1 in association with partners investigates techniques to scale up Building Information Modelling (BIM) based energy simulations to

develop a viable City Energy Model, thereby allowing municipalities to effectively optimize their current and future energy demands.

2. Work Package 2: Incorporate Municipal Energy Services

The WP2 primarily focusses on assessing the energy consumption in delivering the municipal services. The energy data sets obtained with regard to the municipal services feeds into the City Energy Model. Further, the work package also focusses on developing a framework for evaluating the municipal services with respect to their energy consumption.

3. Work Package 3: Improving Data Granularity

The WP3 primarily focusses on gathering intense datasets at dwelling unit level and common amenities at community level pertaining to the energy consumptions, indoor environment parameters and thermal comfort conditions. The data sets collected in this work package regarding the energy consumption will act as feeder for the City Energy Model, thereby assisting in improving the data granularity of the model.

The integration of the 3 work packages will assist in understanding the energy demand of the entire city. Through a fourth impact work package, the activities under iNUMBER will be integrated with other projects, related research in India, and across the world. Further, the integrated approaches incorporated in each of these work packages will help in answering additional questions and develop new areas of inquiry related to the future building stock and municipal services in India.

1.2. Work Package-2: Incorporate Municipal Energy Services

The WP2 aims at incorporating the energy consumptions in the delivery of the municipal services into the City Energy Model. Further, the work package also focusses on comprising the activities of the stakeholder organizations and associated institutions with the primary focus on ULBs.

The integration of all the municipal energy data sets and the understandings pertaining to the concerned stakeholder interaction and decision making processes will supplement in developing a framework for the ULB services tool. This framework will be helpful for the ULBs in evaluating the municipal services with respect to their energy consumptions. Thereby, the tool will assist the concerned decision makers in rationalizing their further advances towards better management of the system.

1.3. Scope of Work Package 2

As described earlier, the work package 2 primarily focusses on assessing the variations in the energy demand pertaining to the delivery of the municipal services. This is not the first attempt in India which is focusing on monitoring the energy consumptions pertaining to the municipal services. There have been many past efforts in India at the central level, state level and ULB level which aimed to mandate the ULBs to monitor their energy consumption in delivering the municipal services. Further, there

have also been many initiatives towards enhancing the operating efficiencies of the systems associated with the municipal services. The *Table 1* represents the learning from the review of such past initiatives undertaken by the governing bodies in India.

Table 1: Initiatives undertaken by governing bodies in India towards monitoring the municipal energy services; a review

Initiatives Undertaken	*Coverage of the Initiative*	*Key highlights*
JnNURM (2007-2014)	National level: (65 cities)	There have been many reforms brought at the state and the city level (Government of India. Ministry of Urban Development, 2009). The reforms included, ➢ To mandate the monitoring of the energy consumption in municipal services through regular energy audits. ➢ To mandate water audits for monitoring the losses.
AMRUT (2015-2020)	National Level: (434 cities)	The reforms under the mission mandate ULBs for optimization and conservation of energy in the Municipal services. The reforms also mandate water audits for monitoring the losses (Government of India. Ministry of Urban Development, 2009)
BEE (2002)	National Level	BEE is a statutory body set up by Ministry of Power (GoI) for bringing up programs for enhancing energy efficient sustainable practices and creating awareness among the cities pertaining to energy efficiency and energy conservation. (Ministry of Power, n.d.)
Municipal Demand Side Management (MuDSM) Program (2007-2012)	National Level: (175 ULBs)	The program was set up in 11th five year plan intending to enhance the overall efficiency of the ULBs thereby reducing the energy consumption in the municipal services. ➢ Situational surveys were conducted in the selected ULBs for assessing the existing status of the water pumping stations, sewage pumping stations, street lightings and buildings. ➢ Detailed project reports were prepared by ULBs based on situational surveys for undertaking an Investment Grade Energy Audit (IGEA). ➢ 12th five year plan focused on selecting sample ULBs and implementing the projects on ground. As the Gujarat state has already shown considerable efforts in

		the energy conservation and related projects, the state was considered among lower priority. Thus, Ahmedabad was not observed in the selected cities for the program. (Ministry of Power, n.d.)
Municipal Energy Efficiency Program (MEEP)	National Level: (All cities above 1 Lakh population)	MEEP is a central government initiative undertaken in association with MoHUA and Energy Efficiency Service Limited (PSU under Ministry of Power). ➢ MEEP majorly focused on retrofitting the inefficient municipality pump sets in water pumping stations and sewage pumping stations in 500 AMRUT cities. ➢ The program also aimed at replacing the inefficient pumps in the pumping stations of 100 selected cities under smart city mission.(Energy Efficiency Services Limited, n.d.)
Street Light National Programme (SLNP) (2015)	National Level	The SLNP was launched by central government towards replacing the conventional lights with the energy efficient lighting. The major objectives of the program includes, ➢ Replacing over 305Cr street lights across the country. ➢ Reducing energy consumption in street lighting and thereby assisting the distribution companies in managing the peak demands. The program estimated an overall annual energy saving of 9000 million KWh and an annual cost reduction of Rs. 5500 Cr for the ULBs.(Ministry of Electronics and Information Technology, n.d.)
Supervisory Control and Data Acquisition (2014-2019)	ULB Level	Under the SCADA initiative, the energy meters and flow meters will be installed in the systems associated with water supply and wastewater management. These devices will monitor and collect data sets pertaining to the flow rate, energy consumption and qualitative data sets such as pH, turbidity, chlorine level, etc. Ahmedabad Municipal Corporation (AMC) has installed the SCADA system for the water supply and waste water sector. These devices gather the data sets pertaining to water sector with a granularity of 15 minutes interval and the data sets

		pertaining to the waste water sector with the granularity of 1 hour interval. Further, as a part of Pan city proposal under the smart city mission, some of the cities that are selected under the mission have also proposed to install Supervisory Control and Data Acquisition (SCADA) system.
Energy Efficiency Cell (EE Cell)	ULB level (Surat, Ahmedabad)	Surat Municipal Corporation has set up EE Cell in 2001 with the aim of delivering basic services for their citizens at an optimum cost in an energy efficient manner. Under the supervision of this cell, the SMC conducted an energy audit for around 34 services that are having a contract demand of more than 75kwh Further, the similar cell has been replicated and incorporated by the (AMC) Ahmedabad Municipal Corporation. The main objective of the cell remained to reduce the energy consumption without depleting the performance of the system. (Ahmedabad Municipal Corporation, n.d.-c)

The study of the previous efforts by governing bodies suggests that there have been many initiatives that either mandate or promote the local bodies to monitor the municipal energy consumption. But, it is observed that most of these initiatives are insisting ULBs to monitor their municipal energy on an annual basis or biennial basis. Thus, the data sets collected by the ULBs under these initiatives represent only the existing situations and cannot be used for any major analyses.

Further, it is also observed that the most of the initiatives that focus on improving the municipal energy efficiency are majorly aiming to capture only the energy perspective of efficiency. These initiatives do not focus on the resource perspective of the services. The *Table 2* represents the inferences observed from the review of the initiatives by the governing bodies.

Table 2: Inferences from the review of Government Initiatives

Initiatives	*Initiatives towards monitoring Energy*	*Initiatives towards monitoring both Energy and Resource*	*Granularity of data captured*
National Missions		AMRUT	Annual or Biennial
		JnNURM	Annual or Biennial
National Programs	MuDSM		One time
	MEEP		One time
	NSLP		One time
ULB Level initiatives		SCADA	Hourly basis
	EE Cell		Monthly basis

The variations in the energy demand of the municipal services and the efficiency of the system involved in municipal services can be better understood with the real time datasets pertaining to the same. Such system will help in monitoring of the energy consumption and the variations occurring across the different time period, different seasons and space. As most of these previous initiatives by the governing bodies do not focus on monitoring both energy and the resource aspects of the services, the datasets gathered during these initiatives will not help to greater extent in understanding the correlation between the municipal services and their energy consumptions. Thus, the WP2 of iNUMBER project intends to focus towards developing one such tool that assist ULBs in understanding and managing the variations in the energy demand with respect to the municipal services and assist them in better management and planning of the operations with respect to the same.

Ahmedabad has been selected as the primary case city for the project. Further, project will be scaled up by considering different cities as well.

1.4. Outcomes of Work Package 2

The major outcomes of the work package includes,

1) Feeder for the City Energy Model:

This focuses on capturing the energy consumption in the delivery of municipal services such as water supply, waste water management, storm water management and the lighting in public spaces. Further, the data pertaining to the same is integrated into the City Energy Model.

2) Developing a framework for capturing energy consumption in delivering the municipal services:

This focusses on developing a Municipal services information system for the Ahmedabad city. This framework will help in evaluating the municipal services with respect to their energy consumptions. Further, the framework will be tested by considering other cities as well.

The outcome-1 and outcome-2 of the work package are complementary to one another. The work pertaining to both the outcomes will be happening in synchronous to one another. The *Figure 2* will provide a brief overview about the work flow with respect to the two outcomes of the work package 2.

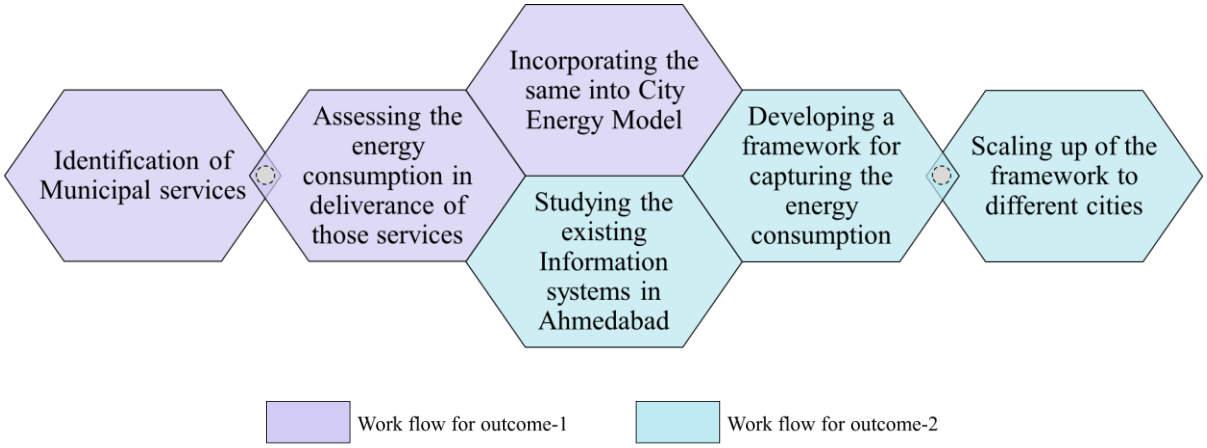


Figure 2: Overview of the work package 2

The *Figure 2* highlights the work flow with regard to the two outcomes of work package 2. Further, it also signifies the way the two outcomes are complementing each other towards achieving the larger goal of the project.

The energy consumption in the delivery of the municipal services is captured integrated in the City Energy Model. The understanding with respect to the energy consumptions in the municipal services and the study of the existing information systems in Ahmedabad will assist in developing the framework for evaluating the municipal services with respect to their energy consumptions. Further, this framework will be scaled up to different cities by identifying the variable parameters.

2. Work Plan for capturing energy consumption in delivering the municipal services

The municipal services offered by the municipalities that accounts for the majority of its revenue expenditure pertaining to electrical energy are listed below.

a) Water Supply
b) Wastewater management
c) Storm Water management
d) Lighting in the public places

These municipal services are considered for the study as a part of WP2. The details pertaining to each of these above mentioned services are explained in the context of Ahmedabad city.

2.1. Water Supply

Looking at the overview of the water sector in Ahmedabad (*Table 3*), it is clearly evident that the city is performing fairly well in terms of the coverage of network, quantity and quality of the supply.

Table 3: Level of services- Water sector, Ahmedabad

Indicator	*Status*
Coverage of water supply connections	97%
Per capita supply of water	134.2 LPCD
Quality of water supplied	98.2%
Extent of non- revenue water	23.7%
Cost recovery in water supply service	59.9%
Efficiency in collection of water supply- related charges	60.8%

Upon further understanding of the levels of water supply service, it is observed that there are certain technical and financial inefficiencies associated with the sector such as, the extent of non-revenue water, cost recovery in water supply services and efficiency in the collection of service related charges. These inefficiencies are not only affecting the supply standards of the service, but also accounting for a leap in the revenue expenditures linked with the sector. The assessment of past 10 years budgets of the Ahmedabad Municipal Corporation suggests that on an average, every year 51% (Approx. Rs.112.2 Cr) of the total revenue expenditure pertaining to the water sector is being spent only on the electricity charges. Thus, the reduction in the same would reduce a considerable amount of burden on the municipal corporation. In order to achieve the same, it is important to understand the value chain associated with the water sector in the context of Ahmedabad.

2.1.1. Source

Ahmedabad is majorly dependent on the surface water source as 75% of the total water supplied is obtained by the same. The rest 25% of the water is obtained through the ground water sources. Overall Ahmedabad city has 1840 MLD of fresh water available combining all the sources. The *Table 4* represents the different water sources and their quantities in MLD (Ahmedabad Municipal Corporation, n.d.-b).

Table 4: Source of water for Ahmedabad City

Type of Source	*Source*	*Quantity (MLD)*
Surface Water Sources	Narmada main Canal	330
	Intake wells	495
	Dholka branch Canal	275
	Sabarmati river	70
	Shedhi branch Canal	200
Ground Water Sources	French wells	170
	Municipal Bore wells	300

The water from the surface water sources gets treated in the water treatment plants and then gets supplied to the consumers through the distribution stations. Whereas, the ground water extracted from French wells and municipal bore wells undergo only chlorination at the distribution stations before getting supplied to the consumers. The conveyance of the surface water to the water treatment plant occurs through gravity flow and thus it does not consume any electricity for the same. Thus, at the source, electrical energy is consumed only at the French wells (7 numbers) and municipal bore wells (Approx. 400 in number). The components that consume energy and the data required pertaining to the same for the current study is represented in the *Table 5*.

Table 5: Required datasets for the City Energy Model: Source, Water

Value chain	*Components or operations that consume electricity*	*Scale of the amenity*	*Data required to feed into the city energy model*
Source	Deep well extractors at French wells	City Level	➢ Total number of pumps ➢ Total daily runtime of the pumps ➢ Time of operation of the pumps ➢ Total electric units consumed/pump/day ➢ Total electric units consumed per month ➢ Sanctioned load ➢ Maximum energy demand recorded in a month
	Deep well extractors at municipal bore wells		

The SCADA devices have been installed by AMC for the French wells. Thus, the required data sets pertaining to the French wells can be directly obtained by SCADA system. But, the municipal bore wells are not installed with any SCADA devices. Thus, the energy data pertaining to the municipal bore wells can be obtained by installing suitable energy meters. The energy meters can be installed by selecting suitable samples of the municipal bore wells so that it represents the all the bore wells that are spatially located across the city.

2.1.2. Water Treatment Plant

The surface water extracted from different sources will be treated before supplying to the end users. There are 3 Water treatment plants in Ahmedabad that account for a total capacity of 1200MLD. Currently, in Ahmedabad, 1080 million litres of water gets treated every day and supplied into the distribution network. The individual capacities of the treatment plants are represented in the *Table 6* (Ahmedabad Municipal Corporation, n.d.-b).

Table 6: Water Treatment Plants in Ahmedabad

Treatment Plant	*Capacity (MLD)*
Kotarpur Water Treatment Plant	650
Jaspur Water Treatment Plant	275
Raska Water Treatment Plant	200

Apart from the above mentioned treatment plants, there is Dudeshwar water works (82MLD capacity). Currently, it is only used as a storage reservoir wherein the treated water gets chlorinated and supplied into the distribution network.

The operation and maintenance of the water treatment plants has been outsourced to a private contractor. Ahmedabad Municipal Corporation supervises the operations and also pays the electricity charges of the treatment plants. The components and operations involved in the water treatment plants and the data required pertaining to the same for the current study is represented in the *Table 7*.

Table 7: Required datasets for the City Energy Model: Water Treatment Plant

Value chain	*Components or operations that consume electricity*	*Scale of the amenity*	*Data required to feed into the city energy model*
Water Treatment Plant	Chemical Operations (disinfection and clarification) Physical processes (Filtration and sedimentation) Booster pumps	City Level	➢ Total number of pumps ➢ Total daily runtime of the pumps ➢ Time of operation of the pumps ➢ Total electric units consumed/pump/day ➢ Total electric units consumed per month ➢ Sanctioned load ➢ Maximum energy demand recorded in a month

SCADA devices have been installed by AMC to measure the flow rate and the energy consumptions in the operations at treatment plants. These devices measure the data sets pertaining to the electrical parameters at the granularity of 15 minutes interval. Thus, the required data sets pertaining to the treatment plants can be obtained directly from the SCADA system.

2.1.3. Water Distribution Stations

There are 187 water distribution stations that are spatially located across the Ahmedabad. The water treated from the 3 water treatment plants gets supplied to the consumers through these distribution stations. The water distribution stations will also have the chlorination plants. The water obtained through the treatment plants and the bore wells is chlorinated in the chlorination plant and then it is pumped into the distribution network.

The operation and maintenance of the water distribution stations are mostly outsourced to the private contractors. Out of 187 WDS, 163 are being outsourced and the rest 24 WDS are being operated and maintained by the AMC. In case of WDS that are outsourced to the private contractors, the AMC supervises the operations and also pays the electricity bills pertaining to the same.

The components and operations at water distribution stations that consume electricity and data required pertaining to the same with respect to the current study is represented in the *Table 8*.

Table 8: Required datasets for the City Energy Model: Water Distribution Stations

Value chain	*Components or operations that consume electricity*	*Scale of the amenity*	*Data required to feed into the city energy model*
Water Distribution Station	Water distribution (Horizontal and vertical pumps)	Zone / Ward Level	➢ Total number of pumps ➢ Total daily runtime of the pumps ➢ Time of operation of the pumps ➢ Total electric units consumed/pump/day ➢ Total electric units consumed per month ➢ Sanctioned load ➢ Maximum energy demand recorded in a month
	Chlorination Plant		

The SCADA devices are installed at the distribution stations to monitor the flow rate and energy consumption in the operations. The devices measure the energy and flow related details pertaining to the pumps located at the distributions. The data sets are collected at the granularity of 15 minutes interval. Looking at the coverage of the SCADA network coverage at the WDS level, it is observed that out of 187 WDS, the SCADA devices are installed in 148 WDS. Thus, the required data sets can be obtained by SCADA for the 148 distribution stations only. For the remaining 39 distribution

stations, the data can either be extrapolated by considering the data sets of the other distribution stations or suitable energy metres can be installed for the same and can be monitored as well.

2.1.4. Distribution network

The water supplied from the distribution stations reaches the end users through this distribution network. The total length of the water supply network in Ahmedabad comprises to around 4015 km. The water supplied in the distribution network should be maintained at certain pressure. Thus, the booster pumps are used at certain points in the network to maintain the optimum pressure for the water throughout the length of the network. There are 3 booster pumps present at different points in the entire water supply network of Ahmedabad. The data sets required pertaining to the booster pumps used in the water distribution network is represented in the *Table 9*.

Table 9: Required datasets for the City Energy Model: Booster pumps

Value chain	*Components or operations that consume electricity*	*Scale of the amenity*	*Data required to feed into the city energy model*
Distribution Network	Booster pumps in distribution network (3 pumps in entire network)	City Level	➢ Total number of pumps ➢ Total daily runtime of the pumps ➢ Time of operation of the pumps ➢ Total electric units consumed/ pump/ day ➢ Total electric units consumed per month ➢ Sanctioned Load ➢ Maximum energy demand recorded in a month

The data pertaining to the booster pumps in the water supply network is not covered in the SCADA network. Thus, the details pertaining to the same can be monitored and gathered by installing suitable energy meters.

2.1.5. Building level

The water supplied by the Ahmedabad municipal corporation is generally stored in the underground tanks at the building level and society level. Further, the stored water is pumped into the overhead tank considering their usage and conveniences. In this case, the energy is consumed at the building level or the society level.

It is the responsibility of end users to collect the water supplied by Municipal Corporation and avail the same at the dwelling unit level. The energy required for the same is borne by the end users residing the particular building. The energy consumption in the same varies with the typology of the building

and the population residing in the building. Thus, in order to assess the same, suitable sample size should be selected such that the selected samples represent the pattern of the entire city.

Further, the suitable energy meters should be installed in the selected samples buildings and the energy data should be monitored. The datasets required for assessing the energy consumption at the building level is represented in the *Table 10*.

Table 10: Required datasets for the City Energy Model: Building level

Value chain	*Components or operations that consume electricity*	*Scale of the amenity*	*Data required to feed into the city energy model*
Building level	Submersible pumps	Building level	➢ Total number of pumps ➢ Total daily runtime of the pumps ➢ Time of operation of the pumps ➢ Total electric units consumed/pump/day ➢ Total electric units consumed per month

Further, the total number of municipal water supply connections that are present in the city should also be considered in deciding the sample sizes pertaining to the assessment of energy consumption at the building level.

The summary of the data sets required pertaining to water sector to feed into the city energy model is represented in the *Table 11*. Further, the table will also represent the sources for obtaining the required datasets. Cells in green shade represent the data sets that are readily available and the cells in red shade represent the data sets that need to be generated by installing suitable devices.

Table 11: Sources for the required data sets for City Energy Model: Water Sector

<table>
<tr><td rowspan="2">Value chain</td><td colspan="2">Data available with AMC</td><td rowspan="2">Data that need to be measured</td></tr>
<tr><td>Data from Water-operations department</td><td>Data from SCADA</td></tr>
<tr><td rowspan="5">Source, Water Treatment Plants and Water distribution Stations</td><td rowspan="3">Sanctioned Load</td><td>Total number of pumps</td><td rowspan="5">Energy data pertaining to the municipal bore wells</td></tr>
<tr><td>Total daily runtime of the pumps</td></tr>
<tr><td>Time of operation of the pumps</td></tr>
<tr><td rowspan="2">Max. demand of the month</td><td>Total electric units consumed/pump/day</td></tr>
<tr><td>Total electric units consumed per month</td></tr>
<tr><td rowspan="4">Booster Pumps in the Network (3 pumps in the entire network)</td><td rowspan="4"></td><td rowspan="4"></td><td>Total daily runtime of the pumps</td></tr>
<tr><td>Time of operation of the pumps</td></tr>
<tr><td>Total electric units consumed/pump/day</td></tr>
<tr><td>Total electric units consumed per month</td></tr>
<tr><td rowspan="4">Building Level</td><td rowspan="4"></td><td rowspan="4"></td><td>Total daily runtime of the pumps</td></tr>
<tr><td>Time of operation of the pumps</td></tr>
<tr><td>Total electric units consumed/pump/day</td></tr>
<tr><td>Total electric units consumed per month</td></tr>
</table>

Readily available data

Data to be measured

2.2. Waste Water Management

The waste water management being one of the obligatory functions of the urban local body, it is their responsibility to provide their citizens with the safe services pertaining to the conveyance and treatment of the same. The waste water management includes collection of the sewage, conveyance of the collected sewage, treatment, reuse and disposal. Looking at the overview of the waste water sector in the Ahmedabad city, it is observed that the city has network coverage of 93.2% with a collection efficiency of the network being 96.3%.

Table 12: Level of services- Waste Water sector, Ahmedabad

Indicator	*Status*
Coverage of waste water network services	93.2%
Collection efficiency of wastewater network	96.3%
Adequacy of waste water treatment capacity	96.3%
Extent of reuse and recycling of wastewater	0.7%
Extent of cost recovery in wastewater management	57.3%

Further, looking at the extent of cost recovery in the waste water management it is observed that the municipal corporation is recovering only 57.3% of the total cost spent in the waste water sector. The low percentage of cost recovery can either be due to low revenue income generated from the sector or because of the high revenue expenditure incurred in the operations. Upon analysing the past 10 years budget of Ahmedabad Municipal Corporation, it is observed that on an average every year around 25% (Approx. Rs. 22.4 Cr) of the total revenue expenditure pertaining to the waste water sector is being spent on the electricity charges. The electricity expense stands as second major cost head in the expenditure after the salary expenditures.

Thus, in order to understand the details pertaining to the energy consumptions in the wastewater sector, it is important to understand the overview of the sector in the context of the city.

2.2.1. Collection and conveyance

Ahmedabad is mostly dependent on the centralised sewage network. Overall 880 Million litres of sewage is generated every day in the Ahmedabad city. The city has a 2500km long network to collect and transmit the sewage till the treatment plant. Further, considering the length of the network and the topography of the city, it is difficult to convey the entire collected sewage through gravity flow. Thus, the network has booster pumps that are used in maintaining the required pressure in the network to ease the flow of the sewage. But, these pumps are used only during the cases of chocking in the sewage network. Further, as the incidents of chocking are not very frequent considering the terrain of Ahmedabad, the municipal corporation does not own the booster pumps. In cases for addressing such issues with respect to chocking, the municipal corporation will outsource the work to the private party.

Thus, majority of the sewage collected by the centralized network will get conveyed to the sewage pumping stations through gravity flow only. Thus, no electric energy is consumed with respect to this service.

2.2.2. Sewage Pumping Stations

The sewage collected by the centralized conveyance system reaches the pumping stations. The sewage pumping station pumps the sewage to the treatment plants. There are 51 Sewage pumping stations present in Ahmedabad that are spatially spread across the city. 40 out of these 51 sewage pumping stations are monitored by SCADA system. There are 3 types of sewage pumping stations based on their capacities and operational hierarchies namely, Terminal pumping stations, main pumping stations and normal pumping stations.

There are 25 normal sewage pumping stations that collect the sewage from different conveyance lines and pump it to the main pumping stations. There are 5 main pumping stations that collect the pump the sewage into the terminal pumping stations. There are 10 terminal pumping stations that pump the sewage to the sewage treatment plant. Further, the operation and maintenance of all the sewage pumping stations is outsources to different private contractors. AMC supervises the operations of these pumping stations and also pays the electricity charges of the same.

The *Table 13* represents the data sets required pertaining for assessing the energy consumption in the sewage pumping stations.

Table 13: Required datasets for the City Energy Model: Sewage Pumping Stations

Value chain	*Components or operations that consume electricity*	*Scale of the amenity*	*Data required to feed into the city energy model*
Sewage pumping stations	Pumping of sewage (Horizontal and vertical pumps)	Zone/ ward Level	➢ Total number of pumps ➢ Total daily runtime of the pumps ➢ Time of operation of the pumps ➢ Total electric units consumed/ pump/ day ➢ Total electric units consumed per month ➢ Sanctioned load ➢ Maximum energy demand recorded in a month

Most of the data sets mentioned in the *Table 13* are currently being monitored and collected by SCADA. Thus, the required datasets pertaining to the sewage pumping stations can be directly obtained by the SCADA system.

2.2.3. Sewage Treatment Plant

The sewage collected through the entire centralized sewage network reaches the sewage treatment plant. There are 9 sewage treatment plants in Ahmedabad. Different technologies have been adopted in the treatment of sewage in these sewage treatment plants. 5 treatment plants operate on the basis of Activated Sludge Process (ASP) technology, 2 treatment plants operate on the basis of up flow Anaerobic Sludge Blanket (UASB) technology and the remaining 2 treatment plants operate on the basis of lagoon technology. The *Table 14* represents the locations and capacities of the sewage treatment plants in Ahmedabad (Ahmedabad Municipal Corporation, 2017).

Table 14: Capacities of Sewage Treatment Plants in Ahmedabad

Location of sewage treatment plant	*Number of sewage treatment plant*	*Capacities of the sewage treatment plant (MLD)*			
Vasna	4	240	126	35	76
Pirana	4	180	60	106	182
Vinzole	1	70			

Combining all the sewage treatment plants available in Ahmedabad, the city has a total capacity to treat around 1075 million litres of sewage every day. Further, the operation and maintenance of the sewage treatment plants is outsourced to the private contractors. AMC supervises the operations pertaining to the same and also pays the electricity charges with respect to the same.

The *Table 15* represents the data sets required pertaining for assessing the energy consumption in the sewage treatment plants.

Table 15: Required datasets for the City Energy Model: Sewage Treatment Plants

Value chain	*Components or operations that consume electricity*	*Scale of the amenity*	*Data required to feed into the city energy model*
Sewage Treatment Plant	Pumping systems (Horizontal and vertical pumps)	City Level	➢ Total number of pumps ➢ Total daily runtime of the pumps ➢ Time of operation of the pumps ➢ Total electric units consumed/ pump/ day ➢ Total electric units consumed per month ➢ Sanctioned load ➢ Maximum energy demand recorded in a month
	Aerators, agitators, blowers, etc		

Most of the data sets mentioned in the *Table 15* are currently being monitored and collected by SCADA. Thus, the required datasets pertaining to the sewage treatment plants can be directly obtained by the SCADA system.

The summary of the data sets required pertaining to water sector to feed into the city energy model is represented in the *Table 16*. Further, the table will also represent the sources for obtaining the required datasets. Cells in green shade represent the data sets that are readily available and the cells in red shade represent the data sets that need to be generated by installing suitable devices.

Table 16: Source of data pertaining to Waste Water sector

Value chain	*Data available with AMC*		*Data that need to be measured*
	Data from Drainage department	*Data from SCADA*	
Sewage Pumping Stations	Sanctioned load	Total number of pumps	
		Total daily runtime of the pumps	
		Time of operation of the pumps	
	Maximum energy demand recorded in a month	Total electric units consumed/ pump/ day	
		Total electric units consumed per month	
Sewage Treatment Plant	Sanctioned load		Total number of pumps
			Total daily runtime of the pumps
			Time of operation of the pumps
	Maximum energy demand recorded in a month		Total electric units consumed/ pump/ day
			Total electric units consumed per month

Readily available data

Data to be measured

2.3. Storm Water Management

The Ahmedabad being a city in the semi aired region receives 782mm of average rainfall every year. On an average, every year the city experiences around 33 rainy days. Looking at the overview of the storm water management in Ahmedabad, only 55% of the city is covered with the network of storm water drains. Further, in order to reduce the issues of water logging during the peak rainy days, the municipal corporation has set up storm water pumping stations. There are 48 storm water pumping

stations in Ahmedabad that are spread spatially across the city. The storm water pumping stations will operate only during the monsoon season. The operations of the storm water pumping stations are monitored at the central monsoon control room.

As the city does not have 100% coverage of the storm water network, at certain places the storm water is aligned to flow through the sewerage network. The storm water flowing through the sewerage network will be pumped to the sewage treatment plant for further treatment before getting disposed. The unadulterated storm water will directly be pumped by the storm water pumping stations to the nearby water bodies.

Prior to monsoon season, the Ahmedabad Municipal Corporation takes up the pre monsoon cleaning action plan. This action plan includes the cleaning of the catch pits, desilting of the storm water drains. The tasks pertaining to the pre-monsoon cleaning action plan is outsourced private contractor. Further, the operation and maintenance of the storm water pumping stations is also outsourced to the private contractors. The data required in understanding the energy consumption in the operation of the storm water pumping stations is represented in the *Table 17*.

Table 17: Required datasets for the City Energy Model: Storm Water Pumping Stations.

Value chain	*Components or operations that consume electricity*	*Scale of the amenity*	*Data required to feed into the city energy model*
Storm water pumping stations	Horizontal and vertical pumps	City Level	➢ Total number of pumps ➢ Total daily runtime of the pumps ➢ Time of operation of the pumps ➢ Total electric units consumed/ pump/ day ➢ Total electric units consumed per month ➢ Sanctioned load ➢ Maximum energy demand recorded in a month

The storm water pumping stations are not installed with any SCADA devices for monitoring and data acquisition. Thus, any data pertaining to the energy consumptions in the storm water pumping stations can be obtained by installing suitable energy meters. The sources of the required data sets pertaining to the storm water sector are represented in the *Table 18*.

Table 18: Source of data pertaining to Storm Water sector

Value chain	*Data from Drainage department*	*Data that need to be measured*
Storm water pumping stations	*Sanctioned load*	Total number of pumps
		Total daily runtime of the pumps
	Maximum energy demand recorded in a month	Time of operation of the pumps
		Total electric units consumed/ pump/ day
		Total electric units consumed per month

Readily available data

Data to be measured

2.4. Lighting in Public spaces

The Ahmedabad Municipal Corporation has provided the service of lighting the public spaces with the responsibility of providing safety, improving the aesthetics and enhancing the ease of accessibility during the night time. Ahmedabad Municipal Corporation is responsible for offering the services pertaining to the street lights and the lighting at the parks and gardens. The lighting of the BRTS bus stops is the responsibility of a special purpose vehicle, Ahmedabad Janmarg ltd. Further, the lighting of the recreational spaces such as, Sabarmati riverfront and kankaria lakefront is the responsibility of the respective SPVs.

Lights department of Ahmedabad Municipal Corporation is responsible for installing, operating and maintaining the street lights in Ahmedabad. The different types of lights that are installed by the AMC and the number of such lights are represented in *Table 19*. (Ahmedabad Municipal Corporation, n.d.-c)

Table 19: Types and numbers of street lights in Ahmedabad

Types of street lights	*Number of lights*
Clear lamps	06
Tube Lights	38900
CFL	16800
28W: T-5 tube lights	9900
Mercury	3980
Sodium lights	61450
High must	245
LED lights	5500

The details pertaining to the type of data sets required for understanding the energy consumption in lighting the public spaces is represented in the *Table 20*

Table 20: Required datasets for the City Energy Model: Lighting in Public Spaces

Sector	*Scale of the amenity*	*Data required to feed into the city energy model*
Street lighting	City Level	➢ Number of street lights. ➢ Time of operation of the lights ➢ Total run time of the street lights ➢ The electric units consumed per month.
Lighting of parks and gardens	City level	➢ Number of lights in parks and gardens ➢ Time of operation of the lights ➢ Total run time of the lights ➢ Total electric units consumed per month
Lighting of AMTS and BRTS stops	City level	➢ Types of lights used in AMTS and BRTS stops ➢ Time of operation of the lights ➢ Total runtime of the lights ➢ Total electric units consumed per month
Lighting in the recreational spaces	City level	➢ Types of lights used in AMTS and BRTS stops ➢ Time of operation of the lights ➢ Total runtime of the lights ➢ Total electric units consumed per month

The data sets required pertaining to the street lights can be obtained by the lights department of Ahmedabad Municipal Corporation. Further, the data pertaining to the lighting of parks and gardens can be obtained by the gardens department of Ahmedabad Municipal Corporation. Further, the data pertaining to the BRTS and recreational spaces can be obtained by the respective SPVs.

2.5. Current Status and Way forward for outcome-1

As explained in the earlier chapter, the outcome-1 of the work package 2 focusses on integrating the energy data sets pertaining to municipal services into the city energy model. The data sets required with respect to each of the municipal services is identified. Further, the source for obtaining the required data sets and the data gaps with respect to the same are also recognized.

Ahmedabad Municipal Corporation has installed the Supervisory Control and Data Acquisition (SCADA) system for the water supply and waste water sector. The flow rate and the energy consumptions pertaining to the water and waste water sector are monitored and reported by the SCADA devices. These devices gather the data sets pertaining to water sector with a granularity of 15

minutes interval and the data sets pertaining to the waste water sector with the granularity of 1 hour interval.

The SCADA system was installed by AMC in 2015 and was operationalized since 2016. Though the system does not cover all the components of the water and waste water sector, it covers 90% of the services with respect to the same. The samples of the raw datasets reported by SCADA systems pertaining to the water and waste water sectors have been obtained from the concerned departments of Ahmedabad Municipal Corporation.

It is necessary to consider and analyze the long term energy datasets pertaining to the municipal services for understanding the trends and variations in the energy demands of the same. Further, the data sets pertaining to the municipal services might be varying from one year to another, thus the data of one year might not be the representative of all the actual data sets. Thus, the energy data pertaining to the identified municipal services will be obtained for over 3 years (from January 2017 till December 2019) of time period for assessing and assimilating the variations in their energy demands. These analyzed data sets will further be used in developing the City Energy Model. The Figure 3**Error! Reference source not found.** represents the current status and flow of work with respect to the outcome-1 of work package.

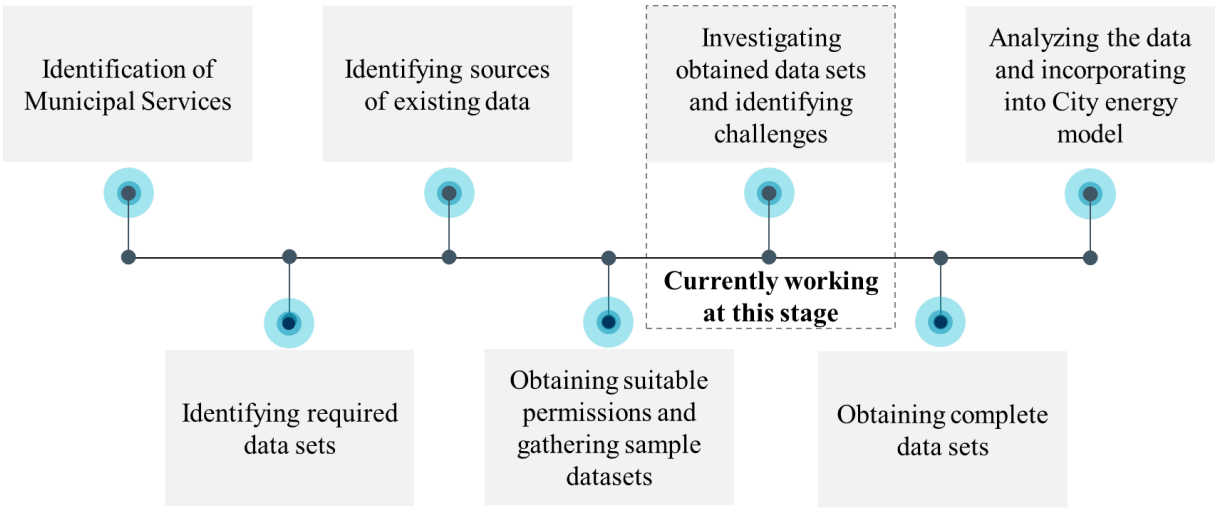


Figure 3: Current status and flow of work with respect to outcome-1

3. Framework for capturing energy consumption in municipal services

As explained earlier, the work package 2 of iNUMBER mainly focusses on incorporating the municipal energy services into the city energy model. Further, the work package also aims at developing a municipal services information system for the ULBs which assists the decision makers in rationalizing their improvement measures. The information system would basically be a framework

that helps in evaluating the municipal services with respect to their energy consumptions. This will help the ULBs in assessing the energy demand related to the delivery of the municipal services.

This is not the first effort towards developing such information system for municipal services. There have been many such efforts in the past where the information systems are developed and being utilized by many countries as an integrated system for organizing and analysing the past and existing data sets for assessing the trends for the related services. Such selected efforts of India and other countries towards capturing and assessing data sets at the national level, state level and city level pertaining to the municipal services have been studied in align with the criteria as mentioned,

- Objectives of information system
- Scale/ coverage of the information system
- Year of establishment and the size of the existing data sets in the information system
- Type of data sets that are collected in the information system
- Beneficiaries of the information system

The learning gathered from the case studies are further incorporated in context of the existing research.

3.1. Review of Case studies pertaining to the Existing Information Systems

The case studies of information systems studied were classified based on the scale or coverage of the information system and size of the data sets available with the information system. The classifications are as represented below,

3.1.1. Information system capturing long term data sets and covering larger geographic areas:

These are periodic efforts for gathering, storing, updating and assessing the series of data sets pertaining to the sector. Such systems help in understanding the past trends pertaining to the service and will also help in making service specific decisions. The system generally covers the large geographical boundaries and will generally help in maintaining data with respect to the broader aspects related to the service value chain such as coverage of the services at the urban scale, watershed data, Aquifer related datasets, etc., The major user groups of the system includes the decision makers and policy makers at the state, national and international levels. The details pertaining to some of the case studies reviewed with respect to this type of information systems are briefly described below.

3.1.1.1. The Brazilian SNIS: National information system on water, sanitation and solid waste management

The national level information system of Brazil covering the water and sanitation was established in 1995; later in 2002 the solid waste management was included in the framework (Montenegro, 2005). The information system was set up with an objective of contributing to the planning and development of the public polices and developing rationales in prioritizing the allocation of the public resources. Further, the information system also aims at assessing the performance of the service providers and

setting the benchmarks for improving the delivery of the services. The information system also helps in maintaining the transparency regarding the data with respect to service provisions among the general public, media, politicians, service providers, NGOs, etc.

The SNIS being the national level information system, it comprises the municipality level data for the entire urban coverage of the nation. The information system comprises of the data regarding the water and sanitation services including the information pertaining to the operational, managerial, financial and quality of the services. The data gathered through the information system is available through a tailored software package. The package will not only provide the raw data to the user groups but also includes an automated consistency analysis of the available data sets.

The major user groups of this information system include the federal, state and municipal governments, water supply and sanitation utilities, regulatory agencies, service providers in water and sanitation sectors and the educational and research institutions. The information system is also been utilized by the international development institutions like IRDB, IDB, JBIC, etc.

3.1.1.2. Euro Mediterranean water information system (EMWIS)

The Euro Mediterranean water information system is an initiative undertaken in partnership with the euro Mediterranean countries for sharing the information and knowledge among the Euro Mediterranean partnered countries. This system includes exchanging of information among the 27 EU membered states and 16 Mediterranean partnered countries. The main objective of this information system is to initiate active participation of the partnered countries towards sharing of the information and experiences related to the best practices at the local, regional and national level among the partnered countries. Further, the EMWIS provides easy access to the institutions and people that are involved in the management of the water services. The EMWIS also helps in providing training materials, administration and documentation of the data related to water management and thereby also assists in the research and development in the sector.

The Euro Mediterranean Water Information System maintains and displays data related to the referential datasets such as Hydrological networks data (Watersheds, aquifers, rivers, lakes, etc.). The EMWIS also provides data models and reference lists of the generic conceptual data models developed. The data and information from this system is being utilized by the policy and decision makers and officials of concerned departments for improving the services in the water sector. Further, the data is also utilized by the research and academic institutions for related studies. The National information system includes all the stakeholders involved in the management of water and this there will be many sub systems that is accessible only for concerned departments. Thus the information system has a hierarchy of data sets and the accessibility and sharing of the same happens only with concerned departments among concerned stakeholders only.

3.1.1.3. Australian Water Resources Information System (AWRIS)

The Australian Water Resources Information System collects and represents the data from over 200 organizations across the nation to represent and report data relating to the water availability, conditions and usage in a nationally consistent way. The water regulations in 2008 mandated certain agencies to collect certain set of specified water data for the Bureau of Meteorology. The Bureau would provide the public with the quality data, reports and forecasts. Further, the data was made standardized and was made available to all the stake holders such as managers, planners and policy makers for improving the decision making and service delivery in the water sector.

The AWRIS will merge the existing data sets with that of the previous data trends and provides the readymade trend observations that are suiting the usage of its user groups and stakeholders involved in management of the water services. The main objectives of the Bureau was to capture the real time data regarding the quantity of water stored, quantity of water available in the aquifer, quality of the water and the information related to the water supply services, water trading, etc. The major user groups of the information system are the stakeholders involved in management of water services. Further, the information system is also made available for the public of the nation. (Bureau of Meteorology, n.d.)

3.1.2. Information systems capturing data sets through one time study:

These are the studies undertaken by organizations/ renowned agencies working in the related aspects of the sector. These are mostly one time study done on the basis of the past data sets. These studies will majorly focus on assessing the existing situations. These studies cover only certain aspects of the value chain; geographical coverage varies depending on the level of the study. The case studies pertaining to this type of information systems are described further,

3.1.2.1. Survey of Energy Usage by water companies in America under NAWC

The survey was conducted by ACEEE in 2015 for understanding the energy consumption in the delivery of the water services. The survey was conducted among 100 water and waste water service companies that are registered under the National Association for Water Companies. The major objective of the survey was to assess the energy usage in the water processes such as Source and conveyance system, treatment plants and distribution stations. The survey results were represented as the mean, minimum, maximum and total energy consumption in each segment of the value chain in the consumption of water. Further, the survey results also represent the energy intensity (kWh/ million gallons) and the mean, minimum and maximum value of the same considering all the service providers. (Young, 2015)

Further, observing the energy consumption values in delivering the water and wastewater services, the study also focused on understanding the components/ factors that affects the energy intensity. These

observations would help service providers in improving the energy efficiency in delivering the services. The report also compares the results obtained from the service providers with the IAWWA's report, wherein the standards suggest the range of energy intensity of the entire water system. Based on this comparison the service providers can compare their efficiencies and observe the variations from the standards.

3.1.2.2. Tool for Rapid Assessment of City Energy (TRACE)

Energy Sector Management Assessment Program (ESMAP) developed the Tool for Rapid Assessment of City Energy (TRACE) in 2008. The tool was designed to give the city authorities a quick and easy way to assess the city's energy consumption and identify the cost effective measures for reducing the consumption in the municipal services such as lighting, water, waste water, solid waste management, building, power and heating. (ESMAP, 2013)

The TRACE has been supporting 80 cities across the world in understanding the cross sectorial challenges pertaining to energy consumptions and developing the energy efficient strategies for the same. There are certain set of indicators in the tool that helps the city officials in identifying the potential areas in the municipal services for reducing and conserving energy. After identifying these potential areas, the tool further assists in developing the energy efficient strategies for those areas through different set of indicators. Recently, the tool has been upgraded and it currently incorporates around 100 in built recommendations for energy efficient interventions. Further, upon obtaining the financial details for the cities from the concerned municipal officials, the tool will also assist in understanding the cost benefit assessments with respect to the recommended intervention. The municipal officials and other decision makers of the concerned services are the major beneficiaries of this Tool for Rapid Assessment of City Energy.

3.1.3. Information system capturing long term data sets and covering smaller geographic areas:

These are the periodic efforts of gathering and assessing the data sets pertaining to the specific services. But, in this case the system captures data for the smaller geographical boundaries. The SCADA system installed by the ULBs for obtaining the sector specific datasets is considered under this type of information systems. The Supervisory Control and Data Acquisition (SCADA) System are generally installed at the city level or the local administrative levels. These systems will help in real time monitoring of the operations in the delivery of the services. These systems will help in keeping the continuous audit and maintaining the real time data sets pertaining to the operations involved in the delivery of the services. Generally these systems are implemented at the ULB level, society levels, community level for helping in maintaining the efficiency, displays and process the procured data for taking up smarter decisions and for communicating the system issues to help in mitigating the down

time. Some of the case studies pertaining to this type of information system are briefed further. The case studies pertaining to this type of information systems are described further,

3.1.3.1. Supervisory Control and Data Acquisition System (SCADA), Ahmedabad and Surat

SCADA acts as the city level information system for monitoring the delivery of the services with respect to the water and waste water sectors. Further, the system also measures the energy consumption in the delivery of these services. These energy details and the details pertaining to the resource can be made available at the regular intervals of the granularity of minute's interval, daily basis, monthly basis and annual scale as well. These details help in obtaining the trends related to the energy consumption by each of the components in the regular operations. Further, this will also help in optimizes the deployment of the man power by enhancing the remote monitoring and controlling of the operations. The observations and outcomes of the system will also help in identifying the priority concerned areas and rationalizing the budget accordingly.

The Ahmedabad and Surat municipal corporation of Gujarat also have taken similar initiatives. The SCADA system in Surat was set up 2007 during the setting up of new water treatment plant. In case of Ahmedabad, the SCADA system was set in 2014. Both in Ahmedabad and Surat the monitoring system is being set for water and waste water systems.(Ahmedabad Municipal Corporation, n.d.-a)

3.2. Information system in Ahmedabad

There have been many initiatives undertaken by the Ahmedabad Municipal Corporation for gathering and maintaining the data sets pertaining to the municipal services. The Ahmedabad Municipal Corporation had established the Energy Efficiency Cell in 2008. The EE Cell has taken up many initiatives post JnNURM towards creating and managing the data base pertaining to these municipal energy services. Further, the cell has also taken up initiatives towards using the gathered data base towards rationalizing the decision making processes. Few of the major initiatives undertaken by EE cell include the monitoring of the energy consumptions by gathering the energy bills which further lead to rationalizing of the electric tariff of the concerned electric suppliers. Further, the cell has also taken up conservation measures such as demand side management, Power Factor improvement and replacement of inefficient systems by conducting and analysing the outcomes of the energy audits.

As the EE cell captures and maintains the data sets at the granularity of the monthly scale or annual scale, it is difficult to understand minor trends and address the issues aligned with the same. Apart from the EE cell, the energy data pertaining to the amenities associated with the municipal services such as Water distribution stations, sewage pumping stations, etc., were also captured by traditional methods such as data log books. In this case the operator records the reading of energy meters and flow meters at 1 hour intervals. As the reliability of the data is poor and is maintained in hard copies it is very difficult to draw analyses using the same.

Further, in order to understand the concern and address the issue pertaining to monitoring the delivery of the municipal services, Ahmedabad Municipal Corporation established Supervisory Control and Data Acquisition (SCADA) System. The SCADA monitory systems have been installed in 2014 for the water and waste water services. The energy meters and flow meters installed at the individual pump level helps in monitoring the performances of the systems at the lower granularity. The Figure 4 represents the brief summary regarding the existing information systems in Ahmedabad.

Service	*Value chain*	*SCADA (Automated)*				*Energy Efficiency Cell (Manual)*			
		Granumarity of data	*Type of data available*			*Granumarity of data*	*Type of data available*		
			Quantative data	*Qualitative data*	*Energy data*		*Quantative data*	*Qualitative data*	*Energy data*
Water supply	Source	15 minutes							
	Water Treatment Plant	15 minutes				1 month			
	Water Distribution Station*	15 minutes				1 Month			
Waste Water management	Sewage Pumping Stations	1 hour				1 Month			
	Sewage Treatment Plant	1 hour				1 Month			
Storm Water management	Storm water pumping stations					1 Month			
Lighting in Public places	Street lighting					1 Month			
	Lighting in parks and gardens					1 Month			
	Lighting in recreational places								
	Lighting in AMRTS and BRTS								

Required data completely getting captured

Required data partially getting captured

Required data not getting captured

Figure 4: Existing Information systems in Ahmedabad

The type of data that are currently getting captured in the existing information systems in Ahmedabad are classified as Quantitative data (quantity of resource), Qualitative data (quality of resource) and energy data (energy consumption details). Further, colour codes have been assigned to represent whether or not the particular type of data sets is getting captured with respect to each value chain of the services. The detailed description with respect to the type of data getting captured, usage of the captured data and the missing data for developing the city energy model is represented and attached in Appendix A.

3.3. Current Status and way forward for outcome-2

As explained in earlier chapters, the outcome-2 of work package 2 aims at developing the framework for capturing the energy consumption in the delivery of the municipal services. In order to achieve the aim, currently some of the existing information systems across different countries have been studied. Further, the information systems currently available in Ahmedabad have also been studied for understanding the type and granularity of the data getting captured and the current usage of the data. The energy consumption in the delivery of the municipal services which will be captured as a part of outcome-1 will the framework will further be co-relations with different variable parameters within the city to develop the desired framework for the city of Ahmedabad. This framework will further be scaled up to different cities by identifying the variable parameters that represents the contexts of

different cities. The *Figure 5* represents the current status and the flow of work with respect to outcome-2 of the work package.

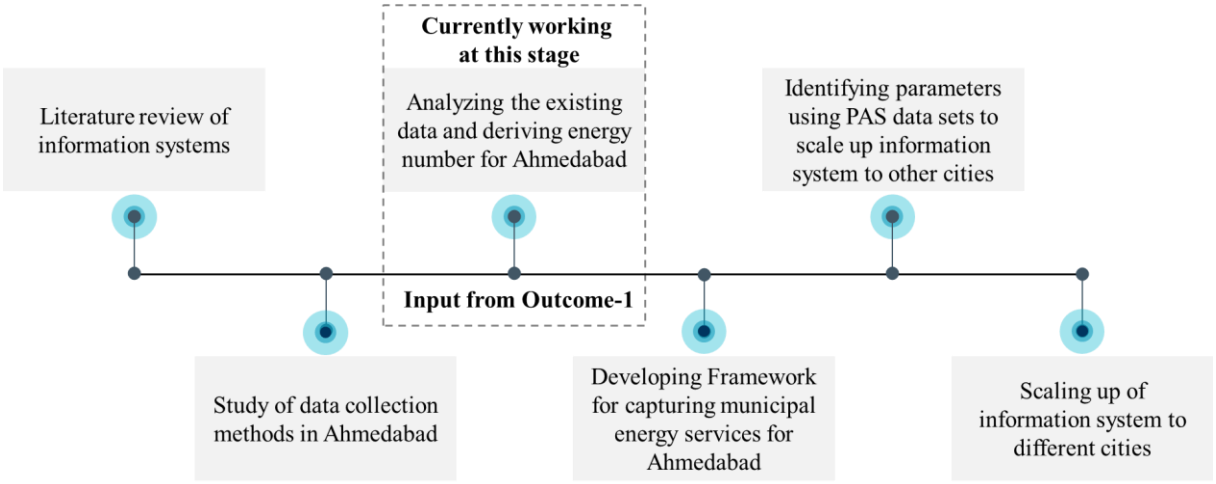


Figure 5: Current status and flow of work in outcome-2

4. Synthesis and Conclusion

The required datasets for assessing the energy consumption in the delivery of the municipal services has been identified. Further, the source of required data sets has been identified and the challenges associated with the available data sets have been studied by obtaining sample data from the concerned authorities. Upon obtaining the complete data sets available with the municipal corporation with respect to the municipal services and identifying the alternative methodologies (such as, conducting sample surveys and installing energy meters for monitoring energy consumptions) for fulfilling the data gaps the energy consumption in the delivery of the municipal services can be estimated. The estimated energy number for the municipal services will be incorporated into the City Energy Model.

Studying the correlation of the estimated energy number for the municipal services with the variable parameters in context of the Ahmedabad city such as, (1) age of the network across the city, (2) Operating hours of the system, (3) land use pattern associated with the services, etc.., a framework will be developed for evaluating the municipal services with respect to their energy consumptions.

The data sets pertaining to the municipal services for Indian municipalities available with the Performance Assessment System (PAS) will be understood and the will be effectively utilized in scaling up of the framework developed for Ahmedabad city to different cities. The PAS data sets for the Indian municipalities have 3 types of data sets,

1. General Information: This includes general data pertaining to the city and its water services such as area of the city, Population of the city, Population density of the city and details regarding the municipal budget associated with the services.

2. Key Performance Indicators: This includes details pertaining to the network coverage of the water services, Adequacy of the services, Efficiency of the services and the equity of the service.
3. Local Action Indicators: This include the details pertaining to the operations associated with the municipal services, technical aspects related to the water services and the financial details associated with the municipal services.

$e = f(GI, KPI, LAI)$

e: Energy consumption in delivering the municipal services
GI: General information from the PAS data sets
KPI: Key Performance Indicator from the PAS data sets
LAI: Local Action Indicators from the PAS data sets

As represented in the above equation, the energy consumption in delivering the municipal services is the function of the different parameters. The indicators from PAS required in scaling up of the framework for different cities have been identified and classified as below,

1. Indicators required for assessing energy consumption
   Eg: Unit electricity cost of water production, Unit electricity cost for collection and disposal of waste water, etc.
2. Indicators required for deriving sub parameters in assessing energy consumption
   Eg: Extent of Non-Revenue Water, Average pressure of water in the network, etc.,
3. Indicators required for classifying the city characteristics
   Eg: Per capita supply of water, Coverage of water distribution network

In total 49 indicators have been identified from the PAS data sets. Further, the data required for the municipals services pertaining to these identified 49 indicators have been obtained from PAS for 171 cities of Gujarat and 395 cities of Maharashtra.

The Figure 6 represents the snapshots of the data sets obtained from PAS pertaining to the identified municipal services.

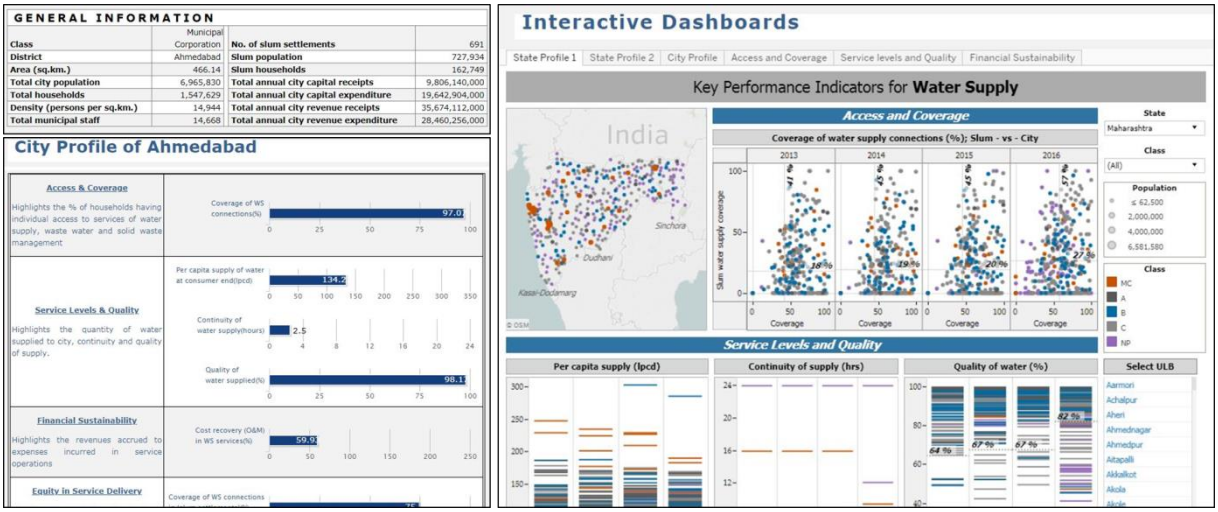


Figure 6: Snapshots of the PAS data sets

The study of correlation between the estimated energy numbers for the water services with the variable parameters identified from PAS data sets will help in scaling up of the developed framework for different cities. This framework will act as an Energy Water nexus for assisting the ULBs for evaluating their municipal services with respect to their energy consumptions. The Figure 7 represents the synthesis of the Work Package by providing a holistic preview of the stages involved in WP2 towards developing the Energy Water Nexus.

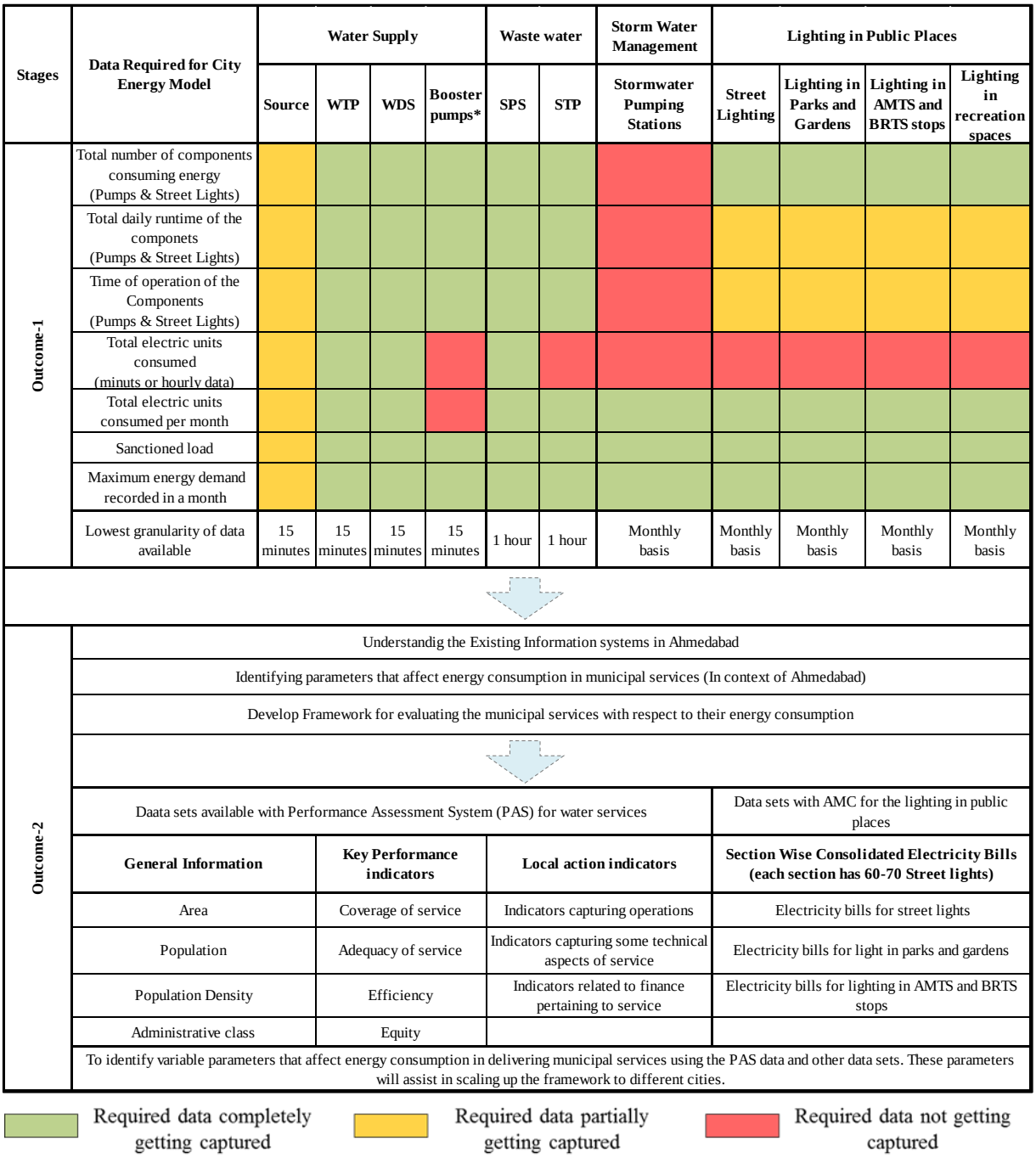


Figure 7: Synthesis of the work package-2

References

Ahmedabad Municipal Corporation. (n.d.-a). *SCADA Ahmedabad*.

Ahmedabad Municipal Corporation. (n.d.-b). Source of Water. Retrieved from https://ahmedabadcity.gov.in/portal/jsp/Static_pages/water_project.jsp

Ahmedabad Municipal Corporation. (n.d.-c). Street Lights. Retrieved January 27, 2019, from https://ahmedabadcity.gov.in/portal/jsp/Static_pages/light_dept.jsp

Ahmedabad Municipal Corporation. (2017). *Sewage Treatment Plants*.

Bureau of Meteorology, A. G. (n.d.). Australian Water Resources Information System (AWRIS), 1–2.

Colenbrander, S. (2016). Cities as engines of economic growth: The case for providing basic infrastructure and services in urban areas, (October). Retrieved from http://pubs.iied.org/pdfs/10801IIED.pdf

Energy Efficiency Services Limited. (n.d.). Energy Efficiency Services Limited.

ESMAP. (2013). *TRACE Tool for Rapid Assessment of City Energy*. Retrieved from https://goo.gl/wXE4Kx

Government of India. Ministry of Urban Development. (2009). Compendium of Primers for undertaking reforms at ULB Level for the scheme of urban infrastructure development in Sattellite Towns around seven million plus cities.

Ministry of Electronics and Information Technology, G. of I. (n.d.). Vikaspedia. Retrieved January 27, 2019, from http://vikaspedia.in/energy/policy-support/energy-efficiency/street-light-national-programme

Ministry of Power, G. of I. (n.d.). Bureau of Energy Efficiency. Retrieved January 27, 2019, from https://www.beeindia.gov.in/content/about-us

Montenegro, M. (2005). *The Brazilian SNIS : the National Information System on Water, Sanitation and Solid Waste*.

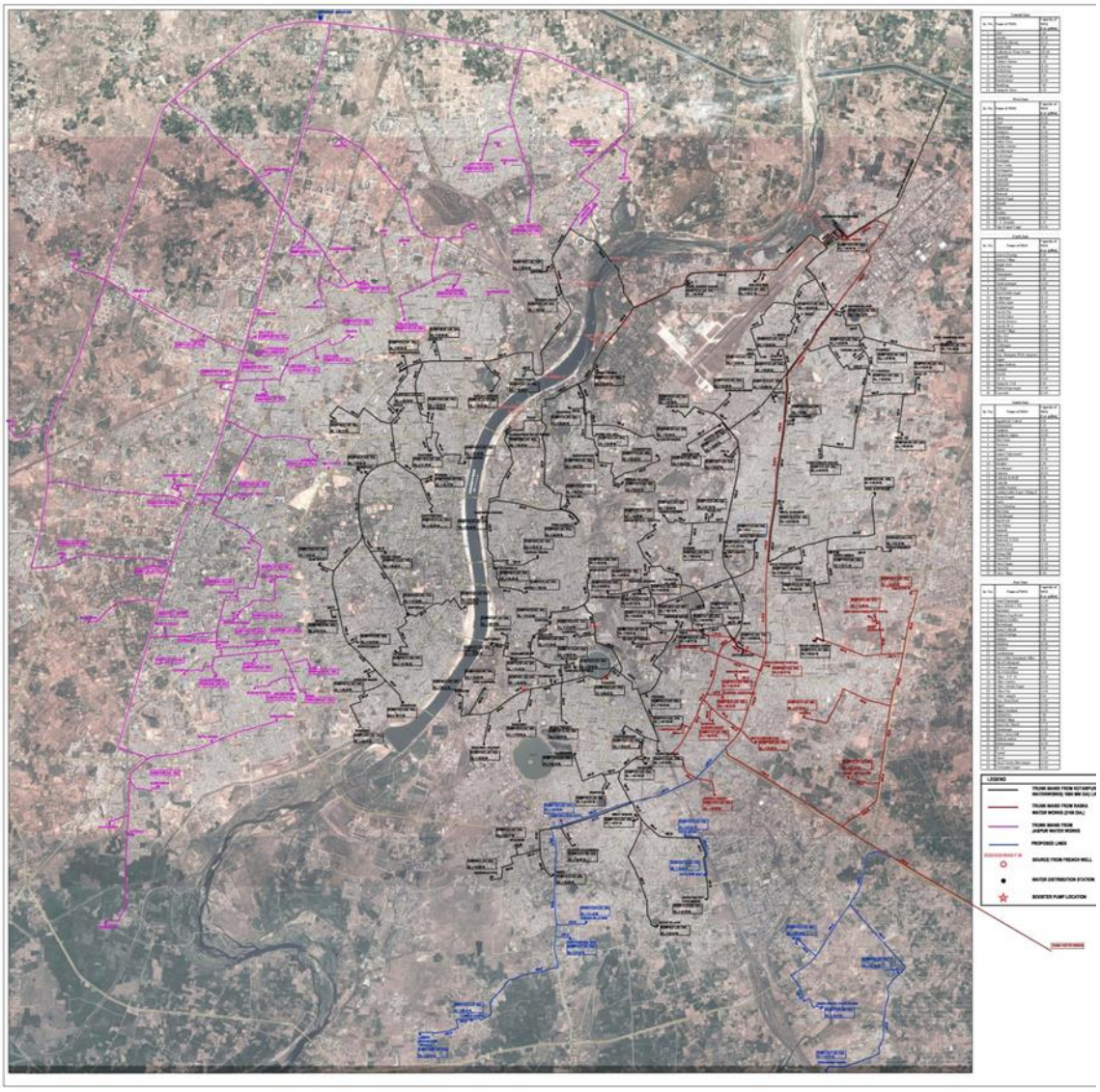
United Nation. (2018). 68% of the world population projected to live in urban areas by 2050. Retrieved January 26, 2019, from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

Young, R. (2015). A Survey of Energy Use in Water Companies. *American Council for an Energy Efficiency Economy (ACEEE)*, (June).

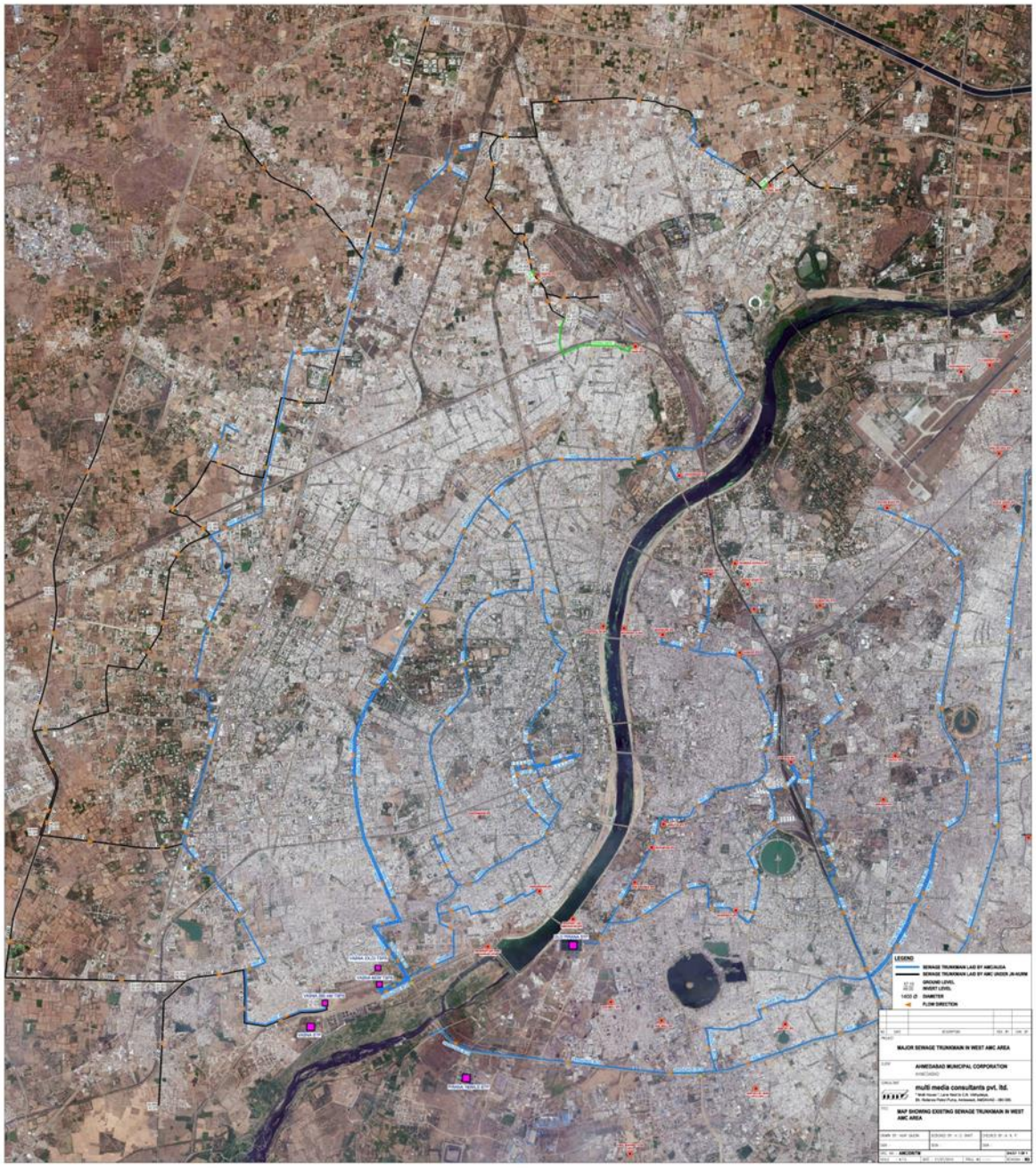
Appendix A Existing Information Systems in Ahmedabad

Components or operations that consume electricity	Data Collectors	Mode of data capture	Data reporting methods	Granularity of collected data	Fields of data available: Data on quantity of water (Unit)	Fields of data available: Data on quality of water (Unit)	Current User group and Current usage: Monitoring	Current User group and Current usage: Repairs and maintainance	Current User group and Current usage: Complaint redressal	Missing data for developing the City energy model
Deep well extractors at french wells	SCADA: Chetas control systems pvt ltd (Coverage: 6 French wells)	Automated	Daily pump report	15 minutes	Pump parameters (Voltage, Current, Frequency, PF)		Water operations department			Energy consumed in municipal borewells situated at WDS.
					Runtime of the pump		Water operations department	Water productions department		
					Time of operation of the pump			Water productions department		
					Electrical units consumed (kWh)		Water operations department			
			Daily report	15 minutes	Number of pumps operating	Turbidity (NTU)	Water productions department			
					Total inlet and total supply (m3)					
					Pressure (PSI)					
Deep well extractors at municipal bore wells			Monthly report	daily basis	Total supply (m3)	Turbidity (NTU)	Water productions department			
					Runtime of the pump		Water operations department	Water productions department		
					Electrical units consumed (kWh)		Water operations department			
					Electrical units consumed per m3 (kWh/m3)		Water operations department			
			Zonal report	15 minutes	Total supply (m3)	Turbidity (NTU)	Water productions department			
					Pressure (PSI)					
					Electrical units consumed (kWh)					
	Light department	Manual	Energy bills	Monthly	Electrical units consumed (kWh)		Energy Efficiency Cell			
					Sanctioned load					
					Max. demand recorded					
Chemical Operations (disinfection and clarification)	SCADA: Chetas control system Pvt Ltd. Coverage: 3 WTP	Automated	Daily pump report	15 minutes	Pump parameters (Voltage, Current, Frequency, PF)		Water operations department		Water productions department	
					Electrical units consumed (kWh)		Water operations department			
					Pressure (kg/cm2)			Water productions department		
Physical processes (Filtration and sedimentation)			Daily Report	15 minutes	Total inlet and total supply (m3)	Chlorine (PPM)	Water productions department			
					Sump level (m)					
					Pressure (PSI)					
			Zonal report	15 minutes	Total inlet and total supply (MLD)		Water productions department			
Booster pumps	Lights department	Manual	Energy bills	Monthly basis	Electrical units consumed (kWh)		Energy Efficiency Cell			
					Sanctioned load					
					Max. demand recorded					
Distribution pumps (Horizontal and vertical pumps)	SCADA: Chetas control system Pvt Ltd. Coverage: 148 WDS	Automated	Daily Report	15 minutes	Total inlet and total supply (m3)	Turbidity (NTU)	Water operations department	Water projects department	Ward and zonal level officers. (Asst. Engineers)	• Energy consumed in chlorination plant. • Data for 39 WDS that are not covered in SCADA
					Header pressure (PSI)	Chlorine (PPM)			Ward and zonal level officers. (Asst. Engineers)	
					Sump level (m)	pH		Water projects department	Ward and zonal level officers (Asst. Engineers)	
Chlorination Plants			Daily pump report	15 minutes	Pump parameters (Voltage, Current, Frequency, PF)		Ward and Zonal level officers (Asst. Engineer, Technical Supervisor)	Ward and Zonal level officers (Asst. Engineer, Technical Supervisor)	Ward and Zonal level officers (Asst. Engineer, Technical Supervisor)	
					Runtime of the pump					
					Time of operation of the pump					
					Electrical units consumed (kWh)					
			Monthly report	daily basis	Total inlet and total supply (m3)		Water operations department		Ward and Zonal level officers (Asst. Engineer, Technical Supervisor)	
					Runtime of the pump					
					Electrical units consumed (kWh)					
					Electrical units consumed per m3 (kWh/m3)					
			Zonal report	daily basis	Sump level (m)		Water operations department, Zonal level officers (Addl. City Engineers)			
					Total inlet and total supply (m3)					
					Header pressure (PSI)					
					Electrical units consumed (kWh)					
	Lights department, AMC Coverage: 187 WDS	Manual	Energy bills	Monthly basis	Electrical units consumed (kWh)		Energy Efficiency Cell			
					Sanctioned load					
					Max. demand recorded					
Deep well extractors (# bore wells are present)	Pump Operator	Manual	Daily log book	Hourly basis	Inlet and outlet flow (m3/hr)		Pump operators	Pump operators		
					Time of operation of the pump					
					Daily run time of the pump					
					Pressure (PSI)					
					Level of water in underground tank and overhead tank (m)					
					Pump specifications (age, capacity, designed efficiency)					

Appendix B Water Supply Network for Ahmedabad



Appendix C Sewerage Network for Ahmedabad



CEPT UNIVERSITY

Kasturbhai Lalbhai Campus,
University Road,
Ahmedabad - 380009, Gujarat, India
www.cept.ac.in/carbse

www.inumber.org